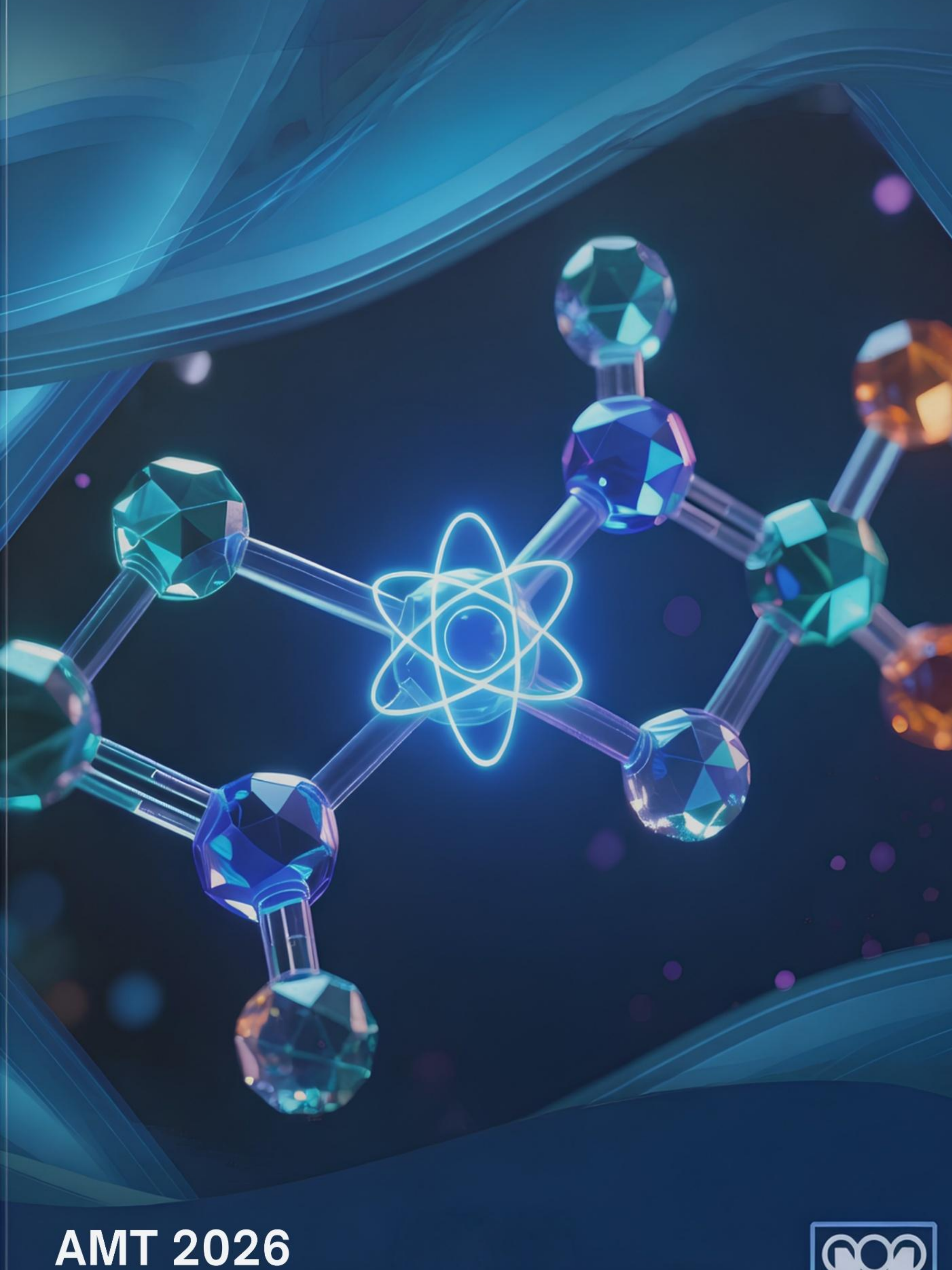

AMT 2026

ADVANCED MATERIALS AND TECHNOLOGIES
JUNE 14TH - 17TH, ŁÓDŹ, POLAND

This book contains the abstracts submitted by the Advanced Materials and Technologies Conference (AMT 2026) participants.

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ISBN: 978-83-979985-2-0

Kraków, 2026

Dear Colleagues, Distinguished Guests,
and Friends of Materials Science,

It is our great pleasure to welcome you to the 22nd International Conference on Advanced Materials and Technologies (AMT'2026), held in Łódź, Poland, 14-17 June 2026.

For more than two decades, the AMT Conference has served as a unique platform for the exchange of scientific knowledge, presentation of technological achievements, and development of cooperation between academia, research institutes, and industry. Throughout its history, the conference has brought together researchers representing diverse areas of materials science and engineering, reflecting the dynamic evolution of this discipline and its growing importance for modern society, economy, and technological development.

The choice of Łódź as the host city of the 22nd edition is particularly meaningful. Łódź is a city whose history has been closely intertwined with materials and manufacturing technologies for nearly two centuries. Known as the "Polish Manchester", it became one of the most important textile and industrial centers in Europe during the nineteenth century. The city's remarkable industrial heritage laid the foundations for generations of engineers, scientists, and entrepreneurs who transformed traditional textile production into advanced technologies and modern materials research.

Today, Łódź is recognized not only for its textile heritage but also as one of Poland's leading centers of materials science and engineering. The city is home to internationally recognized research institutions, universities, and industrial partners actively contributing to advances in materials science and engineering. Research teams based in Łódź contribute to the development of innovative technologies for the automotive, aerospace, energy, and defence sectors, particularly in the areas of advanced materials processing, thermo-chemical treatments, surface engineering, functional coatings, technical textiles, polymer materials, biomaterials, and sustainable manufacturing. In particular, the long-standing scientific traditions of the Lodz University of Technology and its materials-oriented faculties have played an important role in shaping the national and international position of Polish materials engineering. This combination of historical industrial traditions and modern scientific excellence makes Łódź a natural venue for discussions on the future of materials science and engineering.

The scientific programme of AMT'2026 reflects the broad spectrum of contemporary materials research, encompassing advanced and functional materials, nanotechnology, renewable energy technologies, optical and electronic materials, biomaterials, additive manufacturing, artificial intelligence in materials science, advanced composites, surface engineering, and many other rapidly developing fields. The conference also provides an opportunity to strengthen collaboration between science, industry, and public institutions, emphasizing the strategic role of materials engineering in addressing global technological, environmental, energy, and security-related challenges.

This year's edition holds special significance as it coincides with the celebration of the 70th birthday of Professor Natalia Sobczak, Corresponding Member and Vice-President of the Polish Academy of Sciences. Her outstanding scientific achievements, international recognition, and long-standing commitment to the development of materials science have inspired generations of researchers in Poland and abroad. We are honored to celebrate this important jubilee during AMT'2026 together with her colleagues, collaborators, students, and friends from the international scientific community.

We would like to express our sincere gratitude to all authors, invited speakers, members of the Scientific and Organizing Committees, sponsors, partners, and participants for their contribution to the success of this conference.

We are confident that AMT'2026 will provide an inspiring environment for scientific discussion, exchange of ideas, establishment of new collaborations, and the creation of future innovations that will shape the development of materials science and engineering in the years to come.

On behalf of the Organizing Committee,

Conference Chair

President of the Polish Society for Materials Science

Organizing Institutions

Lodz University of Technology

Institute of Metallurgy and Materials Science
Polish Academy of Sciences

PTM
POLISH MATERIALS SCIENCE SOCIETY

Organizing Committee

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Sara Bednarska (Lodz University of Technology)

Scientific Committee

Chairman: Prof. Jarosław Mizera - Warsaw University of Technology, Poland, President of Polish Materials Science Society

International Scientific Committee - Invited Speakers:

Prof. Natalia Sobczak - Polish Academy of Sciences, Poland
Prof. Mietek Jaroniec – Kent State University, USA
Prof. Blaž Likozar – National Institute of Chemistry, Slovenia
Prof. Ludovic Noels – University of Liège, Belgium
Prof. Joaquín Silvestre-Albero – University of Alicante, Spain
Dr Diego Martinez Martinez – Luxembourg Institute of Science and Technology, Luxembourg
Dr Juan Carlos Sanchez-Lopez – CSIC, Institute of Materials Science of Seville, Spain

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Prof. Piotr Bała – AGH University of Krakow, Poland
Prof. Jolanta Baranowska – West Pomeranian University of Technology in Szczecin, Poland
Dr hab. Marcin Barburski, Prof. Lodz University of Technology – Lodz University of Technology, Poland
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Prof. Katarzyna Braszczyńska-Malik – Czestochowa University of Technology, Poland
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Prof. Tomasz Czujko – Military University of Technology, Poland
Prof. Krzysztof Czupryński – Military University of Technology, Poland
Dr hab. Grzegorz Dercz, Prof. UŚ – University of Silesia, Poland
Dr hab. Agata Dudek, Prof. Czestochowa University of Technology – Czestochowa University of Technology, Poland
Prof. Mirosława El Fray – West Pomeranian University of Technology in Szczecin, Poland

LAUDATION

Prof. Natalia Sobczak

Corresponding Member of the Polish Academy of Sciences

Vice-President of the Polish Academy of Sciences

Professor Natalia Sobczak was born on 21 April 1956 in Dzhambul, Kazakhstan. She grew up alongside her elder sister, with whom she maintains a warm, unbreakable bond to this day. At the age of just sixteen, she began her studies at the Leningrad Polytechnic Institute – now Peter the Great St. Petersburg Polytechnic University, where she met Jerzy Sobczak, the man who would become the love of her life and her husband.

That love came at a price. In the Soviet Union, marriage to a foreign national was regarded as an act of disloyalty to the state. For over two years, she was unable to leave the USSR, while her husband remained in Poland with their young daughter. She endured that separation and never allowed it to break her. When she was finally free to leave, she brought with her a determination that would become the hallmark of her life and work.

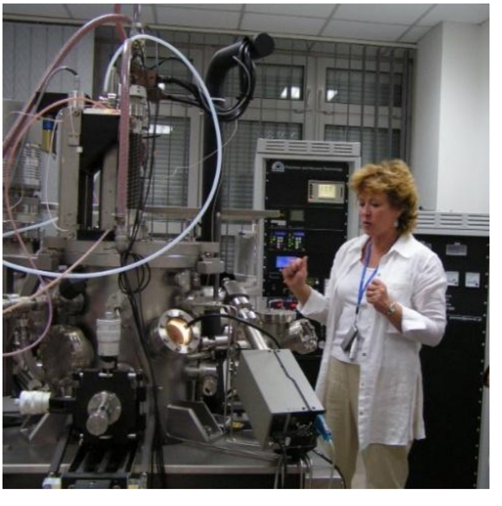
Together with her husband, she raised two remarkable daughters. The elder daughter, holding a doctorate in political sciences, works in European institutions. The younger, a doctor of medical sciences with an additional degree in biotechnology, found her true calling working with children as a paediatrician and neonatologist. Professor Sobczak is immensely proud of her three wonderful grandchildren – ambitious and equally hungry for knowledge.

There are scientists who study the world. And there are those who build the tools through which science is able to move forward.

Professor Natalia Sobczak belongs to the second, rarer category.

And in her case – to an even rarer one: she has created not only the tools, but an entire school of science that uses those tools to make discoveries.

She obtained her Master's and Doctoral degrees at the Leningrad Polytechnic in 1978 and 1984, respectively. In 1985 she joined the Foundry Research Institute in Kraków, where over 34 years she established the world's first Centre for High-Temperature Research dedicated to the methodology and practice of liquid metal engineering. She completed her habilitation at the Institute of Metallurgy and Materials Science Polish Academy of Sciences (IMMS PAS) in 2005 and received the title of Professor in 2012.



Since 2019 she has led the Laboratory of Theory of Metallurgical Processes at IMMS PAS, while also collaborating with the Liquid Metal Engineering Laboratory co-founded by IMMS PAS and the Faculty of Foundry Engineering at AGH University of Kraków – a place that continues and develops her vision of research into the secrets of metals in the liquid state.

Her domain is a world that most people perceive merely as the glow of molten metal. Professor Sobczak has asked the fundamental questions:

What happens to a metal at high temperature when it comes into contact with another substance? When does it wet? When does it repel? When does it react and why?

The answers to these questions determine the safety of nuclear reactors, the durability of aircraft turbine blades, and the biocompatibility of medical implants.

When the tools were lacking — she built them herself. She designed and constructed six unique experimental platforms, each protected by a patent, with no commercial equivalent anywhere in the world. One of them received the First Prize of the Polish Ministry of Industry in the "Polish Product of the Future" competition; another was awarded the Gold Medal at the Poznan International Trade Fair. Data obtained on her apparatus have been incorporated into the Smithsonian/NASA Astrophysics Data System and are recognised as *reference data* on a global scale.

Japan holds a special place in her scientific journey. A grant from the *Japan Society for the Promotion of Science* in 2000 opened the doors of Hokkaido University to her. Even before her habilitation, she won a competitive appointment as *visiting professor* at the *Joining and Welding Research Institute* at Osaka University – one of the world's foremost centres for research on high-temperature wettability and materials joining. She collaborated with Professors Nogi, Fujii and Matsumoto, resulting in joint publications and a year-long research contract funded by the NEDO agency. Japan – its culture of precision, beauty and focused attention – has remained close to her heart ever since. Her office in the Palace of Culture and Science is filled with keepsakes from that time, and Japanese fans – masterworks of traditional craft – are a particular love of hers.

Japan is but one chapter in her international map of activity. A postdoctoral fellowship at the *University of Wisconsin-Milwaukee*, research at *Lawrence Berkeley National Laboratory*, collaboration with CNR in Italy, IFW Dresden, *NASA Glenn Research Center*, the *University of Central Florida*, partnerships with the Bulgarian and Ukrainian Academies of Sciences, a project with the European Space Agency (ESA), membership of the Steering Committee of the HORIZON2020 AMADEUS project, grants from the Polish-American Maria Skłodowska-Curie Foundation and the United Nations.

She is a co-founder of the International Committee on *High Temperature Capillarity* (since 1994), Chair of the Working Group on *Cast Metal Matrix Composites* in the *World Foundry Organization* (since 2001), twice a Representative of Poland on the *FEMS Executive Committee*, and a member of the editorial boards of four Springer journals. Thanks to her, Poland is a full and recognised participant in the global community of liquid metal research.

Professor Sobczak's record includes: over 400 publications, 19 patents, more than 4,100 citations, an h-index of 31, annual inclusion in the World's Top 2% Scientists list, 38 awards and distinctions – among them the *FOSECO Golden Cup Award*, awards from the *American Vacuum Society* and *ASM International*, the Scientific Award of the Fourth Division of Technical Sciences of the Polish Academy of Sciences, and gold medals from numerous exhibitions and trade fairs. She is a recipient of the Knight's Cross of the Order of Polonia Restituta.

Since 2022 – Corresponding Member of the Polish Academy of Sciences.

Since 2023 – Vice-President and Member of the Presidium of the Polish Academy of Sciences.

Since 2024 – Member of the Polish Academy of Engineering.

She chairs the National Committee for Cooperation with the *Scholars at Risk* Network, defending scientists persecuted for their work. This speaks volumes about her: that science is for her not merely a profession, but a value worth protecting.

Professor Natalia Sobczak has shown that one can come to Poland from the outside and become one of the pillars of its science; that one can build a laboratory from scratch and have its data cited by researchers from NASA and Japan; that one can be, at one and the same time, an experimentalist, an instrument builder, a methodological authority and a mentor to generations of scientists.

And above all – that one can work with such energy and passion that seventy years of life feel like forty.

Today we celebrate – because there is every reason to.

Because Professor Sobczak deserves it.

Because we, who have the privilege of working alongside her, want to say this clearly and aloud.

And Professor Sobczak – as always – will say just one thing:

"Ms Joanna, let's get to work!"

And she will be right. Because our work continues.

Laudation delivered by:

Joanna Wojewoda-Budka, DSc, PhD,

Director of the Institute of Metallurgy and Materials Science

Polish Academy of Sciences

ADVANCED MATERIALS AND TECHNOLOGIES CONFERENCE 2026 PROGRAMME

Sunday, June 14, 2026	
16:00-20:00	Conference Registration
16:30-18:30	**Committee on Materials Engineering and Metallurgy of the Polish Academy of Sciences Meeting (Damask Hall)**
19:00-21:00	**Welcome Dinner**

Monday, June 15, 2026	
begins at 8:00	Conference Registration
8:00-9:00	**Breakfast**
9:00-9:15	**Official Opening Ceremony** **Welcome Address by the Rector of Lodz University of Technology** **(Satin Hall 1 and 2)**
9:15-10:00	**Plenary Lecture** **(Satin Hall 1 and 2)**
10:00-10:30	**Coffee Break**

10^{30}-12^{40}	**Thematic Session 1** **Advanced and Functional Materials – High Entropy Alloys and Advanced Metallic Systems** **(Satin Hall 1 and 2)**	**Thematic Session 2** **Heat Treatment and Surface Engineering** **(Silk Hall)**	**Thematic Session 3** **Optical and Electronic Materials** **(Cotton Hall)**
13^{00}-14^{00}	**Lunch**		
14^{00}-15^{40}	**Thematic Session 4** **Functional Materials and Advanced Metallic Systems** **(Satin Hall 1 and 2)**	**Thematic Session 5** **Advanced Surface Engineering and Functional Coatings** **(Silk Hall)**	**Thematic Session 6** **Materials Design sand Advanced Characterization Methods** **(Cotton Hall)**
15^{40}-16^{00}	**Coffee Break**		
16^{00}-18^{20}	**Thematic Session 7** **Additive Manufacturing and 3D Printing** **(Satin Hall 1 and 2)**	**Thematic Session 8** **Nanomaterials and Nanotechnology in Materials Science** **(Silk Hall)**	**Thematic Session 9** **Heat Treatment, Mechanical Behaviour and Structural Materials** **(Cotton Hall)**
20^{00}-21^{00}	**Concert by Andrzej Nestorowicz**		
21^{00}-00^{00}	**Gala Dinner Celebrating the 70th Birthday of Professor Natalia Sobczak**		

Tuesday, June 16, 2026			
8^{00}-9^{00}	Breakfast		
9^{00}-9^{45}	Plenary Lecture (Satin Hall 1 and 2)		
9^{45}-10^{00}	Coffee Break		
10^{00}-12^{10}	Thematic Session 10 Functional Biomaterials and Biomedical Engineering (Satin Hall 1 and 2)	Thematic Session 11 AI and Computational Strategies in Materials Science (Silk Hall)	Thematic Session 12 Materials for Renewable Energy and Low-Carbon Technologies (Cotton Hall)
13^{00}-14^{00}	Lunch		
14^{00}-15^{40}	Thematic Session 13 Surface Engineering and Thin Films (Satin Hall 1 and 2)	Thematic Session 14 Advanced Joining and Manufacturing Technologies (Silk Hall)	Thematic Session 15 Functional Metallic Materials and Structural Performance (Cotton Hall)
15^{40}-16^{00}	Coffee Break		
15^{50}-16^{50}	Polish Materials Science Society Meeting (Damask Hall)		
17^{00}-19^{00}	Cultural Tour		
20^{00}-21^{00}	Concert by the Folk Band “Bigiel Banda”		
21^{00}-00^{00}	Dinner		

Wednesday, June 17, 2026			
8^{00}-9^{00}	**Breakfast**		
9^{00}-11^{00}	**Poster Session (*)**		
9^{00}-13^{20}	**Young Researchers Zone** **supported by OPUS project**		
9^{00}-11^{10}	**Thematic Session 16** **Functional Biomaterials and Biomedical Engineering** **(Satin Hall 1)**	**Thematic Session 17** **AI and Computational Strategies in Materials Science** **(Satin Hall 2)**	**Young Researchers Zone** **supported by OPUS project** **(Cotton Hall 1 + 2)**
11^{10}-11^{30}	**Coffee Break**		
11^{30}-13^{20}	**Young Researchers Zone** **supported by OPUS project** **Students scientific association stands exhibition**		
11^{30}-13^{20}	**Thematic Session 18 NOMATEN** **Computational Materials for Nuclear Applications** **(Satin Hall 2)**	**Science-Industry Strategic Debate** **"Advanced Materials for Defence and Security"** **(held in Polish)** **(Satin Hall 1)**	**Young Researchers Zone** **supported by OPUS project** **(Cotton Hall 1 +2)**

13^{20}-13^{30}	**Closing Ceremony with Best Poster Awards (Satin Hall 1 and 2)**
13^{30}-14^{30}	**Lunch**

(*) **Poster dimensions:** 70 cm (width) × 100 cm (height). We kindly ask all presenters to mount their posters before the beginning of the poster session. The poster area will be accessible from **8:00 a.m.** 2. Please ensure that your poster is displayed in advance to facilitate the smooth running of the session.

ADVANCED MATERIALS AND TECHNOLOGIES CONFERENCE 2026
DETAILED PROGRAMME

Sunday, June 14, 2026	
16^{00}-20^{00}	Conference Registration
16^{30}-18^{30}	**Committee on Materials Engineering and Metallurgy of the Polish Academy of Sciences Meeting** **(Damask Hall)**
19^{00}-21^{00}	**Welcome Dinner**

Monday, June 15, 2026	
begins at 8^{00}	Conference Registration
8^{00}-9^{00}	**Breakfast**
9^{00}-9^{15}	**<u>Official Opening Ceremony</u>** **Welcome Address by the Rector of Lodz University of Technology** **Professor Krzysztof Jóźwik** **(Satin Hall 1 and 2)**
9^{15}-10^{00}	**<u>Plenary Lecture</u>:** **Professor Natalia Sobczak** **Synergy of Surface Engineering and Liquid Metal Engineering** **Session Chairs:** **Prof. Halina Garbacz** **Prof. Krzysztof Czupryński** **Prof. Jan Kusiński** **Prof. Paweł Zięba** **(Satin Hall 1 and 2)**
10^{00}-10^{30}	**Coffee Break**

10³⁰-12⁴⁰	**Thematic Session 1** **Advanced and Functional Materials – High Entropy Alloys and Advanced Metallic Systems** **Session Chairs:** **Prof. Joaquín Silvestre-Albero** **Prof. Piotr Bała** **Prof. Marek Kozicki** **(Satin Hall 1 and 2)**	**Thematic Session 2** **Heat Treatment and Surface Engineering** **Session Chairs:** **Prof. Dariusz Kata** **Prof. Katarzyna Major-Gabryś** **Prof. Jacek Sawicki** **(Silk Hall)**	**Thematic Session 3** **Optical and Electronic Materials** **Session Chairs:** **Prof. Grzegorz Golański** **Prof. Tomasz Rzychoń** **Prof. Juan Carlos Sanchez-Lopez** **(Cotton Hall)**
10³⁰-11⁰⁰	**Krzysztof Wieczerzak** Mapping the compositional hyperspace of refractory high-entropy alloys using high-throughput synthesis and machine learning	**Invited Lecture:** **Professor Diego Martinez Martinez** Protective coatings on flexible organic substrates	**Jarosław Myśliwiec** Multiphase Organic Molecular Systems for Light Amplification
11⁰⁰-11²⁰	**Anna Czech** Multi Scale Analysis of Refractory Materials Modified with Rhenium for Laser Powder Bed Fusion	**Witold Chromiński** Early stages of precipitation in AlMgSi alloy modified with minor Ag additions	**Zbigniew Mitura** Detailed structural characterization of epitaxial perovskite multilayers carried out with the help of computer modelling
11²⁰-11⁴⁰	**Tomasz Koziel** Glass-forming ability of Cu-Zr-Al alloys with near-equiatomic Cu and Zr concentrations	**Radosław Swadźba** Synthesis and High Temperature Oxidation of Nanolaminate MAX Phase Coatings by Closed Hollow Cathode PVD	**Anna Szeremeta** Electrical properties of doped barium calcium titanate
11⁴⁰-12⁰⁰	**Wiktoria Michalik** Development of Al-TiNbZr Metal-Metal Composites by Mechanical Milling and Long-Term Sintering	**Grzegorz Płaczek** Degradation Analysis of Vacuum Furnace Components in Low-Pressure Carburizing (LPC) Processes	**Nina Tarnowicz-Staniak** Linear and Third-Order Nonlinear Optical Properties of Au and AuPd Nanorods and Their

	Izabella Laszko Influence of reinforcement size and content on the properties of Ti-Ti6Al4V metal-metal composites		Application in Photocatalysis
12^{00}-12^{20}	**Márk Windisch** Investigation and structuring of laser-deposited dual-phase high-entropy alloy coatings	**Agnieszka Sasiela** Effects of Water Vapor on High-Temperature Oxidation of Uncoated and Aluminide-Coated René N5 Nickel Superalloy at 1000 - 1200 °C	**Andrzej Żak** Electron beam induced phase transitions in liquid crystals
12^{20}-12^{40}	**Julia Zając** Effect of Molybdenum Addition on Microstructural Evolution and Phase Formation in Arc-Melted Zr-Nb-Mo Alloys	**Toheed Khan** Laser surface remelting on degradation of Ti-6Al-3V alloy	**Marta Prześniak-Welenc** Controlled crystallization and defect engineering in vanadium oxide bronzes: toward tunable structure–function relationships
13^{00}-14^{00}	**Lunch**		
14^{00}-15^{40}	**Thematic Session 4** **Functional Materials and Advanced Metallic Systems** **Session Chairs:** **Prof. Małgorzata Lewandowska** **Prof. Katarzyna Braszczyńska-Malik** **Prof. Jarosław Myśliwiec** **(Satin Hall 1 and 2)**	**Thematic Session 5** **Advanced Surface Engineering and Functional Coatings** **Session Chairs:** **Prof. Diego Martinez Martinez** **Prof. Adam Zieliński** **Prof. Marek Polański** **(Silk Hall)**	**Thematic Session 6** **Materials Design sand Advanced Characterization Methods** **Session Chairs:** **Prof. Mirosława El Fray** **Prof. Jarosław Bieniaś** **Prof. Krzysztof Pałka** **(Cotton Hall)**

14^{00}-14^{20}	**Piotr Bała** Effect of process parameters on the microstructure and mechanical properties in L-PBF processed hot-work tool steels	**Hanna Szebesczyk** Rapid synthesis and screening of Al-Mg-Zr libraries: Exceptional strength in aluminum alloys	**Karolina Rudziarczyk-Jagoda** Dental implant personalization in the era of Dentistry 4.0: From numerical optimization to green additive manufacturing
14^{20}-14^{40}	**Katarzyna Młynarek-Żak** The influence of electrodeposition parameters on structure, morphology, adhesion and corrosion resistance of CoFeNi medium-entropy alloy coatings	**Andrzej Nowotnik** Thermal Barrier Coatings with Polymer-Derived SiAlOC Bond Coats for Ti48Al2Cr2Nb Alloys Deposited by EB-PVD Using Hollow Cathode Plasma	**Łukasz Borgul** Can Simulations Replace Some Experiments? Ansys in Materials Research
14^{40}-15^{00}	**Amna Sadiq** Development of injectable photo-responsive furan based biomaterials	**Kacper Kij** Towards quantitative SIMS: High-throughput investigation of matrix effects in multicomponent alloys	**Mateusz Tarsała** Analysis of the effects of degradation of the structure and mechanical properties of boiler installation elements made of 10H2M steel after long-term operation
15^{00}-15^{20}	**Aleksandra Fiołek** The influence of electrophoretic deposition conditions on the microstructure and properties of chitosan/totarol coatings on titanium substrates	**Agnieszka Krawczyńska** The impact of microstructure refinement on the antibacterial activity of lead-free brass	**Min Wu** Interaction of Plasma Ions with Solid Materials: Challenges and Lessons Learned

15^{20}-15^{40}	**Krzysztof Sielicki** The impact of aluminum on microstructure evolution in nanostructured copper-aluminum alloys during high hydrostatic and atmospheric pressure annealing	**Zuzanna Zając** Hydrogenated and Nitrogenated Carbon Coatings for Durable and Hemocompatible Blood-Contacting Surfaces	**Tomasz Goryczka** Microstructure and Phase Evolution of Mechanically Milled Ni–Mn–Ga Magnetic Shape Memory Alloy
15^{40}-16^{00}	**Coffee Break**		
16^{00}-18^{20}	**Thematic Session 7** **Additive Manufacturing and 3D Printing** **Session Chairs:** **Prof. Mateusz Kozioł** **Prof. Maciej Motyka** **Prof. Leszek Roman Jaroszewicz** **(Satin Hall 1 and 2)**	**Thematic Session 8** **Nanomaterials and Nanotechnology in Materials Science** **Session Chairs:** **Prof. Beata Leszczyńska-Madej** **Prof. Wojciech Stępniowski Prof. Bogusław Mendala** **(Silk Hall)**	**Thematic Session 9** **Heat Treatment, Mechanical Behaviour and Structural Materials** **Session Chairs:** **Prof. Maria Sozańska** **Prof. Stanisław Roskosz** **Prof. Tomasz Goryczka** **(Cotton Hall)**
16^{00}-16^{20}	**Hubert Przygucki** Early-Stage Yield Surface Evolution in LENS-Manufactured Inconel 625: A Combined Multiaxial Testing and 3D EBSD Study	**Piotr Bazarnik** Modern hybrid nanomaterials fabricated by high-pressure torsion technique	**Adam Grajcar** High-temperature deformation behavior and softening phenomena in advanced Cu- and Mo-alloyed medium-Mn steels

16^{20}-16^{40}	**Michał Stróżyk** Additive Manufacturing of Magnesium Alloy WE43 for Biomedical Applications	**Martyna Pokojska** Correlative SEM Techniques in Microstructure and Mechanical Properties Analysis — Case Studies. SEM-AFM, FIB, TOF-SIMS and Elemental Mapping	**Adam Skowronek** Microstructure–Property Relationships in Q&P Medium-Mn Steels Processed in Continuous Annealing Regimes
16^{40}-17^{00}	**Bartłomiej Wysocki** Design, Casting, and Additive Manufacturing of Titanium-Rhenium Alloys	**Małgorzata Norek** Porous anodic alumina – synthesis, properties, and applications	**Joanna Wojewoda-Budka** When aluminium meets oxide at high temperature – reaction-driven wetting
17^{00}-17^{20}	**Hubert Pasiowiec** Improving microstructural homogeneity in Iconel625/CoCrMo gradient materials additively manufactured by laser powder bed fusion with laser beam remelting	**Artur Kozera** Investigation of the phenomenon of silver segregation on the surface of zinc oxide coatings	**Firew Kassaye** Analysis of the deformation behavior and fracture mechanism of advanced high-strength medium-Mn steels under conditions of static tensile tests
17^{20}-17^{40}	**Beata Dubiel** Multiscale microstructural characterization of a compositional gradient Inconel 625/CoCrMo material additively manufactured by laser powder bed fusion	**Filip Kapuściński** The development of Cu-Mo nanomultilayers for thermal management in modern electronics	**Anna Wojtacha** Effect of hot deformation and isothermal holding parameters on microstructure evolution of 3Mn bainitic-austenitic steel for forgings

17^{40}-18^{00}	**Izabela Mierzejewska** From Thermal History to Properties in Direct Energy Deposition	**Agnieszka Tomala** From 2D Transition Metal Dichalcogenides to MXenes: Bridging Nanolubricant Design Rules with Next-Generation Bioactive Implant Surfaces	**Aleksandra Kozłowska** Morphological details of fine-dispersed retained austenite stabilized by C partitioning in plastically deformed and undeformed multiphase medium-Mn steels with Cu and Mo additions
18^{00}-18^{20}	**Marcin Barburski** 3D printing as a shaping base for textile composites in custom-made orthoses	**Marek Polański** Room-temperature synthesis of metal hydrides via self-shearing reactive milling	**Janusz Krawczyk** Results of the Small Punch Test for the validation of metallic materials properties
20^{00}-21^{00}	**Concert by Andrzej Nestorowicz**		
21^{00}-00^{00}	**Gala Dinner Celebrating the 70th Birthday of Professor Natalia Sobczak**		

Tuesday, June 16, 2026			
8^{00}-9^{00}	**Breakfast**		
9^{00}-9^{45}	**Plenary Lecture:** **Professor Juan Carlos Sanchez-Lopez** **Integrated Design of Nanostructured Coatings** **Session Chairs:** **Prof. Natalia Sobczak** **Prof. Jarosław Mizera** **Prof. Ludovic Noels** **(Satin Hall 1 and 2)**		
9^{45}-10^{00}	**Coffee Break**		
10^{00}-12^{10}	**Thematic Session 10** **Functional Biomaterials and Biomedical Engineering** **Session Chairs:** **Prof. Anna Boczkowska** **Prof. Agnieszka Sobczak-Kupiec** **Prof. Krzysztof Mroczka** **(Satin Hall 1 and 2)**	**Thematic Session 11** **AI and Computational Strategies in Materials Science** **Session Chairs:** **Prof. Maciej Zubko** **Prof. Tadeusz Burczyński** **Prof. Piotr Kulinowski** **(Silk Hall)**	**Thematic Session 12** **Materials for Renewable Energy and Low-Carbon Technologies** **Session Chairs:** **Prof. Marek Polański** **Prof. Paweł Pichniarczyk** **Prof. Blaž Likozar** **(Cotton Hall)**
10^{00}-10^{30}	**<u>Invited Lecture:</u>** **Professor Mirosława El Fray** Development of functional biomaterials featuring photo- and thermo-responsiveness	**<u>Invited Lecture:</u>** **Professor Joaquin Silvestre-Albero** Structural Flexibility in Porous Materials upon an External Stimulus	**<u>Invited Lecture:</u>** **Professor Blaž Likozar** Catalysis by Design: Modelling-based Process Optimisation for Hydrogen, CO_2 and Bio-based Composites Manufacturing

10^{30}-10^{50}	**Lekshmi Gopakumari Satheesh Chandran** NIR-Responsive Cu-Doped ZIF-8 Coatings on Laser-Textured Ti-6Al-4V for Targeted Antimicrobial Action Against MRSA	**Dorota Wilk-Kołodziejczyk** Analysis and comparison of selected machine learning methods in prediction the thermal fatigue strength of materials	**Jędrzej Piątek** Selective recovery of critical materials from end-of-life batteries
10^{50}-11^{10}	**Łukasz Maj** Antibacterial coatings deposited with micro-arc oxidation on hydrostatically extruded titanium dedicated for biomedical applications	**Adam Janek** Prediction System Architecture for the Influence of Initial Defects on Damage Propagation in Impact-loaded Hybrid Structures	**Ewa Wierzbicka** Engineering Nanostructured TiO_2 for Efficient Solar-Driven Hydrogen Evolution
11^{10}-11^{30}	**Dorota Bociaga** 3D-Printed Metal Implants – The Influence of Plasma-Assisted Post-Processing on Cleaning Efficiency and Biological Response	**Konrad Perzyński** Multiscale fracture analysis of thin films and coatings based on molecular and continuum modelling approaches	**Maria Gazda** Role of the microstructure of ceramic proton and mixed conductors
11^{30}-11^{50}	**Agata Sotniczuk** Degradation of titanium biomedical materials under simulated inflammatory conditions	**Antoni Wadowski** Machine Learning Interatomic Potentials for Metallic Glasses: CuZrAl case study	**Łukasz Cieniek** Engineering LaCeO3 Perovskite Thin Films: From Controlled Fabrication to Catalytic Efficiency

11:50-12:10	**Wiktor Bednarczyk** Development of fine-grained biomedical zinc alloys: processing challenges and microstructural stabilization	**Karol Pietrak** Inverse identification of constituent properties in conductive composite materials: percolation in carbon ceramics	**Zeinelabedin A. Mohamed** Dual-Spectral Design of Porous Anodic Alumina for Tunable Colored Passive Radiative Cooling
13:00-14:00	**Lunch**		
14:00-15:40	**Thematic Session 13** **Surface Engineering and Thin Films** **Session Chairs:** **Prof. Katarzyna Jodko-Piórecka** **Prof. Tomasz Kozieł** **Prof. Marcin Barburski** **(Satin Hall 1 and 2)**	**Thematic Session 14** **Advanced Joining and Manufacturing Technologies** **Session Chairs:** **Prof. Tomasz Czujko** **Prof. Janusz Mikuła** **Prof. Cezary Gozdecki** **(Silk Hall)**	**Thematic Session 15** **Functional Metallic Materials and Structural Performance** **Session Chairs:** **Prof. Grzegorz Golański** **Prof. Andrzej Żak** **Prof. Jerzy Łabaj** **(Cotton Hall)**
14:00-14:20	**Maria Kanczewska** Effect of deposition temperature on the microstructure of W-Cr thin-film material libraries	**Krzysztof Mroczka** The use of a manual welding laser to fabricate braze-welded joints	**Krzysztof Dzwoniarski** Lightweight Strength: The Science of High-Performance Fibers in Personal Defense Systems
14:20-14:40	**Iwona Jóźwik** High-temperature XRD and Cr-ion implantation studies of Cr and Cr/Al coated Zircaloy-4 for nuclear applications	**Mateusz Kopyściański** Impact of Friction Stir Processing on the Microstructural Evolution and Cavitation Erosion Performance of AlSi9Mg Aluminum Alloy	**Daria Pałgan** HPT processed Cu-Mo nanocomposites as an interlayer for active brazing in thermal management systems

14^{40}-15^{00}	**Agata Niemczyk** Deposition of EVA-based composite coatings by Pulsed Electron Beam method	**Anil Kunwar** Mapping Laser-Microstructure Interactions in Metals, Compounds and Multicomponent Alloys through Concept Graph and Vectorless RAG Techniques	**Hanna Myalska-Głowacka** Micropillar compression study of a titanium coating matrix reinforced with Ti–TiC satellite particles deposited by cold spray
15^{00}-15^{20}	**Sylwia Golba** Adhesion Characteristics of Polypyrrole Coatings Modified with Bulky Organic Dopants	**Olha Khshanovska** Probing Liquid Alloy Nanoparticle Composition Using Plasmon EELS in a TEM	**Agnieszka Lewczyńska** Influence of the substrate's topography on chitosan/bioglass coatings deposited on titanium alloy Ti-13Nb-13Zr
15^{20}-15^{40}	**Agnieszka Radziszewska** Effect of laser interference heating on amorphous Fe-based ribbons	**Izabela Kalemba-Rec** Role of tool geometry in AA5xxx–AA7xxx friction stir welded joints: microstructure and properties	**Laura Ząbek** Effect of air plasma exposure on Al_2O_3/Cu composites
15^{40}-16^{00}	**Coffee Break**		
15^{50}-16^{50}	**Polish Materials Science Society Meeting (Damask Hall)**		
17^{00}-19^{00}	**Cultural Tour**		
20^{00}-21^{00}	**Concert by the Folk Band "Bigiel Banda"**		
21^{00}-00^{00}	**Dinner**		

Wednesday, June 17, 2026			
8^{00}-9^{00}	**Breakfast**		
9^{00}-11^{00}	**Poster Session (*)** **Session Chairs:** **Prof. Jolanta Baranowska** **Prof. Agata Dudek** **Prof. Jarosław Piątkowski** **Prof. Stanisław Jóźwiak** **Prof. Paweł Jóźwik** **Prof. Henryk Noga** **Dr hab. Maciej Szczerba**		
9^{00}-13^{20}	**Young Researchers Zone** **supported by OPUS project** **Session Chairs:** **Prof. Joanna Paciorek-Sadowska** **Prof. Katarzyna Grabowska** **Prof. Dawid Stawski**		
9^{00}-11^{10}	**Thematic Session 16** **Functional Biomaterials and Biomedical Engineering** **Session Chair:** **Prof. Paweł Zięba** **(Satin Hall 1)**	**Thematic Session 17** **AI and Computational Strategies in Materials Science** **Session Chair:** **Prof. Magdalena Gawęda** **(Satin Hall 2)**	**Young Researchers Zone** **supported by OPUS project** **Session Chairs:** **Prof. Joanna Paciorek-Sadowska** **Prof. Katarzyna Grabowska** **Prof. Dawid Stawski** **(Cotton Hall 1 and 2)**

9^{00}-9^{30}	**<u>Invited Lecture:</u>** **Professor Leszek A. Dobrzański** Materials and Technological Design of Dental Implants and Prosthetic Restorations in the Context of the Industry Integrated Idea 5.0 and the 6×E Principles of Expectations as a Paradigm of Materials Engineering	**<u>Invited Lecture:</u>** **Professor Pavel Souček** Designing High-Entropy Refractory-Metal-Based Nitride Coatings through Plasma Kinetics and Thermodynamics	**Katarzyna Wybrzak** Limitations and Perspectives of Numerical Analysis of TPMS Structures in the Context of Energy Absorption
9^{30}-9^{50}	**Joanna Kacprzyńska Gołacka** PVD Antibacterial Coatings: Challenges, Perspectives and Opportunities	**Agata Zaborowska** Radiation-induced defect evolution and high-temperature stability of a Co-free FCC FeCrMnNiAl high-entropy alloy	**Dominik Knozowski** Nano-structured porouse Co3O4 thin film: oustanding material for oxygen evolution reaction
9^{50}-10^{10}	**Samih Haj Ibrahim** TWIP/TRIP effects in metastable beta titanium alloys	**Małgorzata Frelek-Kozak** Microstructural evolution of a novel Co-Free High Entropy Alloy under high-temperature ion irradiation	**Norbert Banaś** Lightweighting of gears using TPMS lattices and neural networks
10^{10}-10^{30}	**Łukasz Banaś/Tomasz Wlazło** Boost your competitiveness! Use a batch production system with a digital twin	**Tomasz Stasiak** Comparison of microstructure, mechanical properties and irradiation resistance of Inconel 617 produced by additive manufacturing vs traditional methods	**Mateusz Szydłowski** Performance of an Inclined Additively Manufactured Aluminium Heat Pipe with Internal Grooves

10^{30}-10^{50}	**Krzysztof Pajor** Effect of cooling rate on microstructure and properties of as-cast alloys synthesized via the suction casting process	**Marcin Brykała** Thermal Properties of Cr/CrAl Coatings for Advanced Accident Tolerant Fuel Systems	**Alan Marciniak** Green Synthesis of Graphene Quantum Dots: From Fruit Waste to Optoelectronic Applications.
10^{50}-11^{10}	**Piotr Ledwig** Plasma induced surface degradation and microstructural evolution of LPBF manufactured CuCrZr Alloy		**Mikołaj Kądzik** Effect of Glow Discharge Cleaning on Tribological Performance of Magnetron Sputtered MoS_2(Ti) Coatings on Anodized 6061 T6 Aluminum
11^{10}-11^{30}	**Coffee Break**		
11^{30}-13^{20}	**Young Researchers Zone** **supported by OPUS project** **Students scientific association stands exhibition**		
11^{30}-13^{20}	**Thematic Session 18 NOMATEN** **Computational Materials for Nuclear Applications** **Session Chair: Javier Dominguez** **(Satin Hall 2)**	**Science-Industry Strategic Debate** **"Advanced Materials for Defence and Security"** **(held in Polish)** **Debate Chair: Prof. Łukasz Kaczmarek** **(Satin Hall 1)**	**Young Researchers Zone** **supported by OPUS project** **Session Chairs:** **Prof. Joanna Paciorek-Sadowska** **Prof. Katarzyna Grabowska** **Prof. Dawid Stawski** **(Cotton Hall 1 and 2)**

11^{30}-12^{00}	<u>**Invited Lecture:**</u> **Professor Ludovic Noels** Data-driven multi-scale simulations of composite materials failure	**Panelists:** • **Adam Pustelnik,** First Deputy Mayor of the City of Łódź • **PhD Eng. Maciej Korecki,** Vice President, Business Segment Vacuum Heat Treatment Furnaces, Seco/Warwick Group • **Professor Marcin Struszczyk,** Acting Director, Professor of the Institute of Security Technologies, MORATEX • **Professor Stanisław Jóźwiak** Military University of Technology, Faculty of Advanced Technologies And Chemistry • **PhD Eng. Michał Borkowski** Technology Development Specialist, Hitachi Energy • **Mateusz Kurmanow** R&D Director of UNIFEQ EUROPE	**Barbara Bołtryk** Clothing for people with sensory issues
12^{00}-12^{20}	**Tymofii Khvan** Correlating ion and neutron damage effects in ferritic steels via FEM-based nanoindentation modeling		**Adam Roślak** Termomechanical properties of epoxy resin composites containing carbon nanofillers
12^{20}-12^{40}	**Karol Frydrych** Searching nuclear-relevant HEAs using combined evolutionary algorithm and CALPHAD approach		**Krzysztof Sergot** **SKN Nano** Functionalized acrylic hydrogels as next-generation sorption platforms
12^{40}-13^{00}	**Yulin Li** Phase Stability Criterions of Cobalt-Free High Entropy Materials		**Zuzanna Niemiec** **SKN Włókno** Sustainable Fashion Design through Textile Upcycling
13^{00}-13^{20}	**Axel E. Poisvert** Short range order analysis for a comprehensive description of complex processes in medium and high entropy alloys		**Jakub Dobrysiak** **Lodz Solar Team** Impact of the Ventilation System on the Aerodynamics of the Eagle Three Solar Car
13^{20}-13^{30}	**Closing Ceremony with Best Poster Awards (Satin Hall 1 and 2)**		
13^{30}-14^{30}	**Lunch**		

(*) **Poster dimensions:** 70 cm (width) × 100 cm (height).

We kindly ask all presenters to mount their posters before the beginning of the poster session. The poster area will be accessible from **8:00 a.m.**2 Please ensure that your poster is displayed in advance to facilitate the smooth running of the session.

Synergy of Surface Engineering and Liquid Metal Engineering for Reliable Testing and Innovative Processing of Advanced Materials

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Abstract

Surfaces and interfaces govern some of the most complex phenomena in materials science, a truth famously captured by Wolfgang Pauli in his remark: “God made the bulk; surfaces were invented by the devil.” This complexity is especially evident in studies of liquid metals interacting with solids at high temperatures, where subtle variations in surface chemistry, contamination, oxidation, or physical non uniformity can strongly affect wetting behavior, interfacial reactions, and thermophysical property measurements.

The lecture discusses how the synergy of surface engineering and liquid metal engineering enables the generation of FAIR, reproducible, and physically meaningful data. Building on decades of research on high temperature wettability, interfacial phenomena, and measurement methodologies, the presentation highlights the critical role of surface condition, interfacial chemistry, and experimental design in interpreting wetting, spreading, dissolution, and reactivity. Studies on the “mystery” of molten metals show how dynamic surface transformations and hidden reactions can obscure intrinsic material behavior and lead to deviations in contact angles, interfacial energies, and reaction kinetics. To address these challenges, the lecture discusses improved procedures and diagnostic strategies, e.g. refined sessile drop method, testing conditions, in situ monitoring, advanced imaging.

Particular attention is given to wetting-interface structure-bonding relationships in metal-ceramic systems. Case studies show how integrated surface and liquid metal engineering enable innovative processing routes, including high temperature joining or liquid metal assisted fabrication of advanced materials. In this sense, progress in the field allows to revisit Pauli’s remark in a modern light: “God made the bulk; surfaces were invented by the devil - yet scientists have built the knowledge to turn this complexity into reliable testing and advanced materials processing.”

Keywords: liquid-metal engineering, high-temperature measurements, FAIR data

Acknowledgements

The research was partially supported by the National Science Centre, Poland, under the OPUS 21 project no. 2021/41/B/ST5/02787 for the years 2022–2026.

Mapping the Compositional Hyperspace of Refractory High-Entropy Alloys Using High-Throughput Synthesis and Machine Learning

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Abstract

The growing demand for metallic materials that maintain high strength, corrosion resistance, and microstructural stability at elevated temperatures increasingly exceeds the capabilities of conventional Ni-based superalloys. Refractory complex concentrated alloys (RCCAs) have therefore emerged as promising candidates for extreme-environment applications due to their high melting temperatures, strong solid-solution strengthening, and enhanced phase stability associated with high configurational entropy.

In this work, we present a systematic, data-driven exploration of the compositional hyperspace of RCCAs in the Cr–Mo–Nb–Ta–V–W system using high-throughput materials science. A combinatorial thin-film materials library was synthesized by physical vapor deposition on a silicon substrate, generating continuous compositional gradients with elemental concentrations ranging from 30 to 45 at.%. At a compositional resolution of 1 at.%, the library represents approximately 35,000 distinct alloy compositions, a scale unattainable within a reasonable timeframe using conventional synthesis routes.

High-throughput characterization was employed to establish structure–composition–property relationships across the library. Chemical compositions were determined by X-ray fluorescence, while phase constitution and lattice parameters were extracted from X-ray diffraction data using Le Bail full-profile analysis. Mechanical properties were evaluated via high-throughput nanoindentation. The resulting multidimensional dataset was used to train an artificial neural network capable of predicting mechanical properties beyond the experimentally sampled compositional space, providing an efficient pathway for accelerated discovery and optimization of refractory alloys for high-temperature applications.

Keywords: refractory complex concentrated alloys (RCCAs), high-throughput materials science, combinatorial materials libraries, machine learning, high-temperature materials

Multi Scale Analysis of Refractory Materials Modified with Rhenium for Laser Powder Bed Fusion

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Abstract

Refractory metals such as W and Mo are increasingly important for applications operating under extreme conditions. Their high melting point, density and brittleness make them attractive yet difficult to process using conventional methods. Additive manufacturing offers a way to improve material efficiency but producing high-quality parts from these metals remains challenging.
To address these needs, drawing on the rhenium effect, we proposed modifying W and Mo with Re additions. The objective of this study was to perform a comprehensive characterization of W–Re and Mo–Re (modified with 4%, 8% and 12% of Re) powders intended for Laser Powder Bed Fusion processing. Initially, Re was introduced as a layer onto non-spherical powder particles. The Re layer had varying thicknesses depending on the Re content. Detailed microstructural and chemical composition analysis of the modified powders, and in particular of the rhenium layers, was performed using transmission electron microscopy (TEM) techniques. After modification process, the powders were subjected to a spheroidization process to prepare them for processed via LPBF to obtain bulk materials. As a result Re was incorporated into the W and Mo structures, forming stable phases with these materials. In the case of Mo modification, Re was distributed homogeneously throughout the powder grain structure, whereas in the case of W, slight segregation and increased Re content at the grain boundaries were visible. The effect of Re addition on the mechanical properties of powders was determined by nano-indentation studies. Subsequently, first LPBF solid samples were produced and evaluated through tensile tests, using appropriately designed sample geometries. Printouts for corrosion tests are also being prepared. This type of complex functional and structural testing will allow to describe the material and select its composition to obtain optimal product for specific applications.

Keywords: refractory materials, additive manufacturing, SEM, TEM

Acknowledgements

This work has been performed within the project: „Preparation and multi-scale characterization of materials from high-melting metals produced in the LPBF technology" DWD/7/0210/2023.

Glass-Forming Ability of Cu-Zr-Al Alloys with Near-Equiatomic Cu and Zr Concentrations

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Abstract

Glass-forming ability (GFA) describes the tendency of an alloy to form a glassy structure upon solidification. The most fundamental GFA indicator is the critical cooling rate (Rc), defined as the minimum rate required to suppress crystallization during solidification. However, since Rc is difficult to determine experimentally, GFA is commonly evaluated using the critical diameter (Dc), defined as the maximum sample diameter that remains fully amorphous, i.e., without detectable Bragg peaks in X-ray diffraction (XRD). In addition, GFA can be assessed using thermal indicators derived from characteristic temperatures, such as the glass transition, onset of crystallization, solidus and/or liquidus temperatures, obtained from thermal analysis of phase transformations conducted at a constant heating rate.

Cu-Zr-based alloys are widely recognized as promising metallic glass-forming systems due to their favorable thermodynamic and kinetic properties. In particular, the strongly negative heat of mixing between Cu and Zr promotes chemical short-range order and suppresses long-range atomic diffusion, which significantly enhances the glass-forming ability (GFA). The addition of aluminum further improves GFA by increasing atomic size mismatch and chemical complexity, thereby stabilizing the amorphous structure against crystallization.

In this study, three alloys with nominal compositions $Cu_{48}Zr_{45}Al_7$ $Cu_{46.5}Zr_{46.5}Al_7$ and $Cu_{45}Zr_{48}Al_7$ were synthesized by arc melting high-purity elements under a protective atmosphere, followed by suction casting into copper molds. Their critical diameters were determined based on XRD analysis, supported by scanning electron microscopy observations. Thermal behavior was investigated by differential thermal analysis (DTA) at a heating rate of 20 K/min. With increasing Zr content, the critical diameter increases, reaching 9 mm for $Cu_{45}Zr_{48}Al_7$.

Keywords: glass forming ability, metallic glasses, suction casting

Development of Al-TiNbZr Metal-Metal Composites by Mechanical Milling and Long-Term Sintering

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Abstract

Based on aluminium and titanium corrosion resistance and also great mechanical properties, this study focuses on metal-metal composites with aluminium matrix and varying contents of TiNbZr reinforcing particles. The influence of the reinforcing fraction and sintering time on the development of the resulting intermetallic phases is examined in particular. The reinforcing particles were synthesized using powder metallurgy through a process of high-energy ball milling in a planetary ball mill. The reinforcing phase powders were prepared from Ti, Nb, and Zr powders with varying Nb and Zr contents, which influenced both the phase quantity and morphology of the obtained TiNbZr particles. Aluminium matrix composites reinforced with flake-like particles were fabricated by powder metallurgy and sintered at 500°C for 24 and 100h to evaluate the effect of sintering time on microstructure. X-ray diffraction analysis performed on the materials after sintering revealed the presence of intermetallic phases such as Al3Zr, AlZr3, Al3Zr4 and Al3Ti, which corresponds to the results of Distribution Maps of Elements, during which diffusion changes could be observed at the interfaces between the matrix and the reinforcing phase. Optical microscopy imaging and SEM analysis revealed increased porosity in the samples after 24h of sintering, and also revealed the presence of flake-like particles, with characteristic parallel bands particularly noticeable in composites with a reinforcing fraction content ranging 20-40% by weight, resulting from high-energy milling. Mechanical tests showed that materials sintered for 100h exhibit increased indentation hardness and indentation modulus values for the flake-like reinforcing particles and for the matrix. This is primarily due to improved element diffusion during longer sintering periods, leading to a reduction in the number of pores within the structure.

Keywords: composite, owder metallurgy, Ti-Nb-Zr

Influence of Reinforcement Size and Content on the Properties of Ti-Ti6Al4V Metal-Metal Composites

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Abstract

Metal-matrix composites and titanium alloys are studied for orthopedic and dental applications due to their high specific strength, corrosion resistance and biocompatibility. Ti6Al4V alloy and commercially pure titanium are widely used biomaterials. Their combination in metal-metal composite systems may provide a balance between performance and cost-effectiveness. In this work, metal-metal composites were fabricated by powder metallurgy followed by vacuum sintering at 900°C for 12 h. Commercially pure titanium was used as the matrix and Ti6Al4V particles as reinforcing phase. The influence of reinforcement particle size (~45 μm and ~450 μm) and reinforcement content (20 wt.% and 40 wt.%) on the microstructure and selected properties was investigated. X-Ray Diffraction analysis revealed peak broadening, lattice parameter changes and diffraction effects consistent with an increased contribution of the β-phase after sintering. These effects were pronounced in composites reinforced with coarser particles. Microstructural observations and elemental distribution maps confirmed diffusion-bonded interfaces and local interdiffusion between the matrix and reinforcement. Local chemical and mechanical heterogeneities were still observed. Increasing reinforcement content increased porosity. Composites reinforced with smaller particles exhibited a more homogeneous microstructure, whereas materials with larger particles showed higher indentation modulus. The Ti6Al4V reinforcement exhibited a lamellar α+β microstructure with a hardness gradient toward the particle-matrix interface. Moreover, a gradual increase in lamellar spacing was observed toward the interfacial diffusion regions, indicating localized thermal and compositional effects associated with diffusion processes during sintering. The results show that reinforcement particle size and content strongly influence diffusion-driven microstructural evolution and local mechanical heterogeneity in Ti-based metal-metal composites.

Keywords: titanium-based composites, metal-metal composites, Ti6Al4V particle reinforcement, powder metallurgy, diffusion-bonded interfaces, interfacial diffusion, biomedical titanium alloys

Investigation and Structuring of Laser-Deposited Dual-Phase High-Entropy Alloy Coatings

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Abstract

High-entropy alloys (HEAs) are a promising materials for advanced surface engineering. In our work, a near-HEA coating was built on 316L stainless steel using a mixture of Inconel 625, chromium and molybdenum powders by laser metal deposition. The resulting coating exhibited a dual-phase microstructure consisting of a face-centered cubic (FCC) and a highly distorted tetragonal phases. These phases appeared in a periodic nanoscale network in the deposited coating. Due to these phases and their spatial ordering, the hardness of the produced HEA coating ranged from 550 to 700 HV. An additional ultrafast pulsed laser surface treatment step was then performed on the polished coating. During this surface treatment, laser-induced periodic surface structures (LIPSS) formed. Electron microscopy examination revealed well-defined periodic features on the micro- and nanoscale, while cross-sectional observations confirmed the preservation of the underlying dual-phase microstructure in the structured regions. These results demonstrate the potential of combining laser metal deposition and femtosecond laser structuring to fabricate mechanically enhanced micro- and nanostructured near-HEA coatings.

Keywords: HEA, LMD, LIPSS, femtosecond laser surface treatment

Microstructural Evolution and Phase Stability of Zr–Nb–Mo Alloys Induced by Nb and Mo Additions

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Abstract

Zirconium-based alloys are considered promising materials for advanced applications, medicine being one of the most interesting among them. Controlling phase stability and microstructure in Zr–Nb–Mo alloys is an essential starting point for tailoring their properties.
In this work, the effect of varying niobium and molybdenum content on the microstructure and phase stability of Zr–Nb–Mo alloys produced by arc melting is investigated.
Microstructural characterization was performed using optical microscopy (OM) and scanning electron microscopy (SEM) combined with energy-dispersive spectroscopy (EDS). Phase composition was analyzed using X-ray diffraction (XRD). Selected samples underwent chemical composition analysis.
The results indicate that molybdenum addition leads to grain refinement, modifies the distribution of alloying elements, and promotes the formation of additional phases. In contrast, the influence of niobium content within the investigated range appears to be less significant, suggesting that Mo plays a dominant role in controlling the studied properties of alloys.

Keywords: zirconium alloys, arc melting, microstructure

Engineering and Performance of Protective Coatings on Flexible Organic Substrates

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Abstract

Traditionally, the development of protective coatings has been oriented towards the enhancement of lifetime of rigid substrates, such as steel or metallic alloys. In comparison, little attention has been given to flexible substrates, such as rubber or cork. These substrates are very challenging to coat, for several reasons; first of all, they are 'dirty' substrates to work with, while they are sensitive to chemicals typically used for cleaning prior to coating deposition. Second, they are damaged when heated to relatively low temperatures, which constraints the operational deposition conditions. Finally, their surface is rough (and very complex in case of cork), and an efficient surface polishing is very difficult.

In this work, two examples of successful protection of organic flexible substrates will be presented. In the first case, carbonaceous coatings were deposited by plasma-assisted vapor deposition to improve the tribological performance of rubbers. In the second case, reactive magnetron sputtering was used to coat cork and recycled rubbers with metal oxide films to prevent damage and color change induced by UV radiation from sunlight. Different practical aspects related to these examples will be described, such as the tailoring of surface microstructure, the measurement of coating adhesion, or the methods used for the evaluation of the properties and performance of the coated substrates.

Keywords: rubber, cork, DLC, ZnO, TiO2, flexible substrates, protection

Early Stages of Precipitation in AlMgSi Alloy Modified with Minor Ag Additions

Witold Chromiński[1,*], Wei Shao[1], Michał Misiak[1], Grzegorz Cieślak[1], Michał Kanios[1], Fan Sun[2], Jan Wróbel[1], Małgorzata Lewandowska[1]

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Abstract

Early stages of precipitation in AlMgSiAg alloy has been studied by means of direct visualization of clusters and precipitates via TEM/STEM, indirect methods like resistivity measurements and DSC as well as combined cluster expansion and Monte Carlo simulation approaches. It has been revealed that Ag addition significantly alter the local chemical ordering of solutes which directly lead towards nucleation and growth of strengthening precipitates. Since silver atoms feature strong binding energy with vacancies and Mg, solid state diffusion processes typical for AlMgSi series are changed. Instead of continuous supply of solutes to nuclei which enable its growth, the clusters with limited number of atoms are being formed . Then, they transform keeping the number of atoms involved which set the density of strengthening precipitates unchanged through the whole process. This mechanism is in contrary to classical theory which assume continuous nucleation and growth. This complementary study provides the direct insight into decomposition of supersaturated solid solution supported with electrical and thermal characteristics which are directly linked to the process, As the atomic interactions cannot be determined experimentally, theoretical approach involving determination of binding energies and thermodynamic database for phase stability have been used for justification of the results.

Keywords: aluminum alloys, precipitation strengthening, electron microscopy, local chemical ordering

Synthesis and High Temperature Oxidation of Nanolaminate MAX Phase Coatings by Closed Hollow Cathode PVD

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Abstract

MAX-phase materials are promising candidates for protective coatings in high-temperature environments due to their combination of metallic and ceramic properties. These nanolayered compounds, with general formula Mn+1AXn (M = early transition metal, A = group 13–16 element, X = C and/or N), exhibit excellent thermal stability and oxidation resistance. Ti_2AlC and Cr_2AlC are particularly attractive, forming dense, adherent α-Al_2O_3 scales during high-temperature exposure that protect against oxidation.

In this study, Ti_2AlC coatings over 30 µm thick were deposited on TiAl 48-2-2 substrates using closed hollow cathode PVD (CHC-PVD) at 770 °C, achieving deposition rates of 8–9 µm/h. Cr_2AlC coatings were synthesized at 550 °C with thicknesses over 20 µm. X-ray diffraction, including high-temperature measurements, confirmed fully crystalline MAX phases. Ti_2AlC coatings consisted mainly of Ti_2AlC with minor Ti_3AlC_2. High-resolution TEM showed strong preferential orientation of (002) basal planes parallel to the growth direction, with local misorientations at V-shaped grains. Heat treatment at 800 °C for 2 h in vacuum showed no phase changes, confirming thermal stability.

Cyclic oxidation tests at 850 °C for 300 cycles revealed degradation starting at defects such as voids and weld regions, which acted as fast diffusion paths. This caused localized Al depletion, TiO_2 formation, and breakaway oxidation due to Al_2O_3 scale disruption. Cr_2AlC coatings were also evaluated at 850 °C in dry air and water vapor. These results clarify oxidation mechanisms and confirm the potential of CHC-PVD MAX-phase coatings for high-temperature applications.

Keywords: coatings, TiAl, MAX phases, oxidation, PVD, TEM

Degradation Analysis of Vacuum Furnace Components in Low-Pressure Carburizing (LPC) Processes

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Abstract

Low-Pressure Carburizing (LPC) is currently an established technology in heat treatment, offering significant advantages over traditional carburizing methods. Seco/Warwick has developed a unique solution use ceramic insulation instead of graphite, which enables hot-chamber unload at the austenitizing temperature. Despite the numerous benefits of the LPC technology in this variant, the aggressive processing conditions — high temperatures (up to 1050°C) and reactive atmospheres — can accelerate the degradation of components within the furnace chamber. The study evaluates the degradation degree of critical construction materials: Kanthal APM alloy, used for the heating elements, and Inconel 601, utilized for the protecting the heating system. The research methodology involved high-precision mass change measurements, chemical composition analysis, and detailed microstructural characterization. To identify morphological and structural changes, both optical microscopy (LOM) and scanning electron microscopy (SEM) were employed. The results revealed a clear difference in material resistance: while Inconel 601 underwent substantial degradation due to intensive carburization, the Kanthal APM alloy maintained full structural stability, showing no signs of wear.

Keywords: LPC, vacuum furnace, Kanthal APM, Inconel 601, material degradation, SEM analysis

Effects of Water Vapor on High-Temperature Oxidation of Uncoated and Aluminide-Coated René N5 Nickel Superalloy at 1000 - 1200 °C

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Abstract

The aviation industry is currently focused on reducing CO2 and NOX emissions and its harmful impact on the environment. As a result, a shift towards alternative fuels is observed. Hydrogen is considered as a promising future fuel. The use of hydrogen fuel increases water vapor concentration inside the engine, as it is a product of hydrogen combustion. This will affect the oxidation of engine components made of nickel superalloys. There are gaps in understanding how water vapor affects degradation mechanisms in nickel superalloys such as René N5. The aim of this study was to investigate the effect of water vapor on the high-temperature oxidation of the nickel superalloy René N5, both uncoated and with an aluminide coating. The effects were analyzed using electron microscopy (SEM, STEM) thermogravimetric analysis (TGA) and X-ray diffraction (XRD). Differences were observed between specimens oxidized at 1000 °C in air and in 10 % water vapor. The oxide scale formed in 10% water vapor was thicker and exhibited a more complex microstructure and chemical composition. Spinel phase NiAl2O4 and nickel oxide were present in the oxide scale after oxidation in 10% water vapor, but not after oxidation in air. René N5 specimens with an aluminide coating were oxidized for 24 hours. The effect of water vapor was observed only at 1000 °C and 1100 °C. At 1200 °C, only the effect of high temperature was observed. As in uncoated specimens, the oxide scale exhibited a more complex microstructure and chemical composition. Nickel oxide appeared in the oxide scale only after oxidation in water vapor atmosphere. Based on these results, it is expected that the more complex oxide scale microstructure and chemical composition will affect the lifespan of the coating in long-term oxidation processes.

Keywords: high-temperature oxidation, nickel superalloys, water vapor oxidation, coatings

Effect of Laser Surface Remelting on Degradation of Ti-6Al-3V Alloy

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Abstract

Cavitation erosion leads to progressive material degradation and premature failure of components in hydraulic systems, resulting in increased maintenance costs and reduced system efficiency. To address this issue, various coating techniques have been applied to improve the cavitation erosion resistance. In this study, Laser Surface Remelting (LSR) was employed to modify the surface of Ti6Al3V alloy. Different laser parameters (900 W and 1200 W at 5, 10, and 15 Hz) were applied. The results showed that the melted layer depth ranged from 69 μm to 96 μm and the heat-affected zone ranged from 57 μm to 69 μm, depending on the selected parameters. The heat-affected zone exhibited a hardness increase of 25–27% compared to the untreated alloy and 6–11% higher than the melted layer. Microstructural analysis revealed the formation of α′-Widmanstätten plate structures with an a'-acicular martensite/basketweave structure in the melted layer and acicular α′-martensite with β-phase grains in the HAZ. X-ray diffraction analysis further confirmed a phase transformation along with a shift in peak positions toward higher angles. This indicates a reduction in lattice parameters and the development of compressive residual stresses. Ultrasonic cavitation tests demonstrated that LSR-treated samples exhibited a 50% longer incubation period and 3 to 4.6 times lower mass loss compared to untreated material. The highest cavitation erosion resistance was achieved for the sample treated at 900 W and 5 Hz despite relatively lower surface hardness. Additionally, a novel Grey Scale Mapping methodology was introduced, enabling effective determination of the deformation period associated with initial pit formation. Overall, the findings demonstrate that LSR is a promising alternative to conventional heat treatment and coating methods, offering deeper surface modification, improved cavitation resistance, and enhanced durability without altering the base material composition.

Keywords: laser surface remelting, titanium alloy, ultrasonics cavitation

Multiphase Organic Molecular Systems for Light Amplification

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Abstract

In the last few years, the sources of directional, coherent, and powerful White Light Emission (WLE) have been extensively studied due to their many possible applications in optoelectronics, imaging, and lighting. Future directions for research include the development of the WLE sources for the novel concept of fully wireless technology of data transmission entitled Light Fidelity (Li-Fi). The combination of different color-emitting laser dyes, together with compatible materials with targeted optical properties, can lead to the construction of different white lasers (WL), which is still a very novel topic. In the last few years, since the discovery of the first WL (2015), a rapid evolution of scientific interest from the topic of white fluorescence to white lasing has been noticed.

The aim of this work is to present these advanced devices, fabricated using organic dyes, liquid-crystalline systems, or a multifunctional phase-separated polymer matrix containing liquid crystals, ionic liquids, and multiple organic chromophores. Precise color tuning can be achieved by applying external DC electric fields or by increasing the delivered energy density (e.g., via higher-intensity optical or electrical pumping) [1-4].

Keywords: organic lasers, organic photonics, liquid crystals, luminecent dyes, ranom lasing, DFB lasers

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Detailed Structural Characterization of Epitaxial Perovskite Multilayers Carried out with the Help of Computer Modelling

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Abstract

The application of pulsed laser deposition for the fabrication of different types of high-quality heterostructures composed of oxide perovskites is first briefly demonstrated. Next, the preparation of periodic multilayers consisting of lanthanum strontium manganite (LSMO) and barium titanate (BTO) is discussed. Although such systems are often referred to as superlattices, it has recently been suggested that the term superstructures is more appropriate, therefore, this terminology is adopted in the present work. High-quality samples were fabricated and subsequently characterized using a number of complementary techniques. The results obtained from reflection high-energy electron diffraction (RHEED), scanning electron microscopy (SEM), electron backscatter diffraction (EBSD), and X-ray diffraction (XRD) are presented. It should be emphasized that advanced computer modelling was employed, enabling a more precise analysis of the experimental data. In particular, RHEED patterns were processed using 2D computer graphics software. The analysis of EBSD patterns was supported by simulations performed within the framework of dynamical diffraction theory. XRD diffractograms were interpreted using Monte Carlo calculations based on a statistical model [1] of the superstructure. Finally, a more general discussion on how to verify the epitaxial growth of other types of superstructures is presented. In particular, methods for obtaining information on the arrangement of atoms along the direction perpendicular to the growth direction are described.

Keywords: oxide perovskites, PLD, computer modelling

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Electrical Properties of Doped Barium Calcium Titanate

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Abstract

The BaTiO3 is a classic ferroelectric perovskite-type material investigated in literature for over 75 years. This compound has many applications because of its dielectric, ferroelectric, and piezoelectric features [1].
Our work focuses on ferroelectric features of (Ba0.83Ca0.17)TiO3 (BCT) and shows the differences in electrical properties of these ceramics sintered by the solid-state reaction method. The BCT ceramics exhibits a high magnitude of permittivity and increased sensitivity of ferroelectric-paraelectric phase transition on applied hydrostatic pressure, which is essential from an application point of view [2]. Moreover, we show the characterization of the structure and chemistry of a sintered BCT and ceramics doped with the same amount of Sr, Mn, Cr, and Mg ions using several techniques: X-ray diffraction, scanning electron microscopy, and electrical impedance measured over a wide temperature and frequency ranges. Based on the distribution of relaxation times estimated according to the Tikhonov regularization method, we show the occurrence of mixed order disorder and displacive components in the discontinuous phase transition. Local structural disorder corresponding with dipoles created by oxygen vacancies was confirmed. Introduced disorder enabled recognition of the relaxor features of dipolar-glass-like behavior in BCT doped by Mg ions ceramics [3].

Keywords: ceramics, perovskite, dielectric, ferroelectric

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Linear and Third-Order Nonlinear Optical Properties of Au and AuPd Nanorods and Their Application in Photocatalysis

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Abstract

Gold nanorods (AuNRs) are one of the most popular examples of anisotropic plasmonic nanoparticles. Due to their unique interactions with light and, thus, generation of the so-called plasmon-related phenomena [1], AuNRs have found applications in various fields. If modified with a second metal, such as palladium or platinum, the as-obtained bimetallic nanostructures exhibit an even broader scope of application, including potential roles as antimicrobial agents or components of novel materials for catalysis, bioimaging, and sensing.
We would like to discuss the photocatalytic properties of AuNRs and AuPdNRs, starting with their proper stabilization for light-driven processes. Here, we propose cellulose nanofibers (CNFs) as a robust scaffold for the immobilization of AuPdNRs [2]. The functionality of the obtained composite material is evaluated in a bioinspired photocatalytic regeneration of cofactor molecules, coupled with the dehydrogenation of sodium formate under visible light. The promising role of CNFs in the formation of hybrid, photocatalytically active materials is further discussed by presenting a novel plasmonic-photochromic formulation, showcasing how the optical properties of AuNRs can be used to gain indirect control over the photoswitching of the photochromic component in an on-off manner[3]. Finally, future perspectives for AuNRs and AuPdNRs are discussed, based on their third-order nonlinear optical properties measured over a broad spectral range (500-1500 nm) using the Z-scan technique with a femtosecond laser source [4].

Keywords: photocatalysis, plasmonics, nanoparticles, hybrid materials, nonlinear optics

Acknowledgements

N. Tarnowicz-Staniak acknowledges financial support from project no. 2021/41/N/ST5/04470 funded by Narodowe Centrum Nauki.

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Electron Beam Induced Phase Transitions in Liquid Crystals

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Abstract

The ability to manipulate liquid crystal (LC) phases with sub-micrometer precision is a cornerstone of future adaptive photonic devices. We present a novel approach using liquid-phase scanning transmission electron microscopy (LP-STEM) to both image and induce phase transitions in nanoconfined 4′-octyl-4-cyanobiphenyl (8CB) [1]. Our research represents the first direct visualization of phase transitions in liquid crystals performed using transmission electron microscopy and liquid-cell sample encapsulation. Our experiment not only allows for the characterization of phase transitions at an unprecedented level of resolution but also validates the hypothesis that the electron beam can serve as a "thermal stylus," capable of driving reversible SmA-N-I phase sequences through controlled energy dissipation. By tuning the electron dose rate, we directly influence the kinetics of these transitions, capturing the real-time formation of disclinations and nanoscale ordering. Moreover, we confirmed that the electron beam interaction mechanism is predominantly thermal. Crucially, our findings highlight significant deviations in thermal properties between nanoconfined and bulk LCs—a discovery with profound implications for the design of LC-based nanocomposites. This work marks the first detailed application of liquid-phase electron microscopy to LC physics, paving the way for maskless, electron-beam patterning of soft functional materials.

Keywords: liquid cell electron microscopy, soft matter, beam heating, topological defects, confinement effects, cyanobiphenyls

Acknowledgements

The research was funded by the Ministry of Science and Higher Education (Poland) under grant no. PN/01/0121/2022 from the Perły Nauki program and supported by the National Science Centre (Poland) Sonata Bis grant no. 2025/58/E/ST11/00225..

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Controlled Crystallization and Defect Engineering in Vanadium Oxide Bronzes: Toward Tunable Structure–Function Relationships

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Abstract

Vanadium oxide bronzes (AxVyOz) are layered materials in which functional properties arise from the interplay between crystal structure, interlayer chemistry, and vanadium mixed valence states. However, their rational design is limited by strong coupling among these parameters, hindering independent control of material functionality.

In this work, I introduce a design strategy for vanadium bronzes based on controlled crystallization and defect engineering, enabling partially independent tuning of structural and functional parameters. This approach is realized through the Liquid-Phase Exfoliation–Ion Exchange (LPE-IonEx) method, which provides access to low-temperature synthesis pathways with precise control over phase composition, morphology, and interlayer chemistry. Importantly, this method enables access to structural regimes not attainable via conventional hydrothermal synthesis.

I demonstrate that the functional behaviour of vanadium bronzes is governed by the interplay between microstructure, interlayer environment, and the V4+/V5+ ratio, which together control charge transport, redox activity, and surface reactivity.

By tuning these parameters, the engineered materials exhibit enhanced performance in electrochemical energy storage and visible-light-driven photocatalysis. In particular, defect-engineered KV3O8 systems display rapid visible-light photocatalytic response, directly linking controlled defect formation to functional performance.

This work advances a unified structure–property–function framework for vanadium bronzes. It demonstrates that controlled crystallization combined with defect engineering constitutes a powerful strategy for the rational design of advanced functional oxide materials.

Keywords: vanadium oxide bronzes, Defect engineering, liquid-phase exfoliation, interlayer chemistry, visible-light photocatalysis, alkali-ion batteries

Effect of Process Parameters on the Microstructure and Mechanical Properties in L-PBF Processed Hot-Work Tool Steels

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Abstract

This work explores advanced capabilities of Laser Powder Bed Fusion (L-PBF) in processing tool steels (H11, H13 and maraging steel MS1). Process parameters were optimized to achieve high-quality prints, followed by detailed microstructural and mechanical characterization, including the effects of heat treatment.

A key innovation is the controlled introduction of nitrogen from the processing atmosphere into the melt pool. By tailoring laser parameters and melt pool dynamics, nitrogen uptake can be regulated, enabling the in-situ formation of strengthening nitrides and carbonitrides.

The study demonstrates that gas atmospheres in AM can be actively used as a tool for local material modification, rather than just a protective environment. This concept introduces a new paradigm in additive manufacturing: spatially controlled strengthening during fabrication, offering significant potential for next-generation engineered materials.

Keywords: additive manufacturing, L-PBF, hot-work tool steels, microstructure, process parameters

The Influence of Electrodeposition Parameters on Structure, Morphology, Adhesion and Corrosion Resistance of CoFeNi Medium-Entropy Alloy Coatings

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Abstract

Electrodeposition is a method of producing coatings that has a number of advantages like low cost, scalability, low-temperature conditions, the possibility of using a wide range of electrolytes and substrate materials with complex shapes [1]. This method has been successfully applied in the production of binary alloy coatings, including Co-Ni, Co-Fe, Fe-Ni, which are mainly used in electronics [2,3]. The aim of this work was to evaluate the influence of electrodeposition parameters like current (0.5, 0.6 and 0.7 A) and duration (20, 30 and 40 min) on structure, morphology, adhesion to the copper substrate and corrosion resistance of medium-entropy CoFeNi coatings. Based on the X-ray diffraction phase analysis, a dual-phase structure (FCC + BCC) was identified for the coatings deposited for 30 min with a current of 0.5 and 0.6 A. For the remaining parameters, a single-phase structure (FCC) was found. All studied coatings were characterized by a granular morphology, and it was additionally observed that larger agglomerates were formed for longer electrodeposition duration. Adhesion tests carried out using the scratch-test method indicated that the highest values of average critical forces were obtained for coatings produced with a current of 0.5 A, and the lowest for 0.7 A. The best corrosion resistance in 3.5% NaCl solution was obtained for the coating deposited with a current of 0.5 A for 40 min due to the highest polarization resistance and the lowest corrosion current density. The coating produced with a current of 0.7 A for 20 min indicated the worst corrosion resistance.

Keywords: electrodeposition, medium-entropy alloy coatings, structure, morphology, adhesion, corrosion resistance

Acknowledgements

The work was supported by the National Science Centre of Poland under research project no. 2024/08/X/ST11/01775.

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Development of Injectable Photo-Responsive Furan Based Biomaterials

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Abstract

The most pressing need in bone fracture repair is improving the healing of complex fractures, especially in aging populations and patients with medical complications. In this context, the development of photocurable organic-inorganic composites that combine suitable mechanical performance with structural similarity to bone is of great interest. In the this work, a furan-based photocurable composite system was developed to obtain composite formulations for potential bone-related application. Therefore, a furan-vegetable oil based macromonomer was synthesized and subsequently methacrylated to obtain a UV-curable resin matrix. Composite formulations were prepared by adding HAp at varying loadings. The chemical structure was characterized by IR spectroscopy, and mechanical testing was performed to assess the effect of HAp on the composite's performance and their suitability for bone substitute applications. Structural characterization confirmed the successful synthesis of the furan-based methacrylated macromonomer and the formation of the photocurable network after UV exposure. The incorporation of HAp enabled the preparation of composite systems with tunable composition and enhanced functionality for bone-mimicking applications. Mechanical testing demonstrated that the addition of HAp affected the mechanical response of the photocured composites. These findings suggest that the developed furan-based composite system is a promising candidate for further investigation as a bone repair material.

Keywords: organic/inorganic composite, furan based material, biomaterial

Acknowledgements

This work has been supported by research project Preludium Bis4 from the Polish National Science Center "New composite biomaterials prepared by photocrosslinking", UMO-2022/47/O/ST5/01653.

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The Influence of Electrophoretic Deposition Conditions on the Microstructure and Properties of Chitosan/Totarol Coatings on Titanium Substrates

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Abstract

The main objective of this work was to determine the electrophoretic deposition (EPD) conditions of chitosan/totarol coatings on titanium substrates and the influence of the process conditions on the microstructure and selected properties of coatings, especially their antibacterial performance. To prepare the coating deposition solution, totarol was dissolved at a concentration of 0.8 g/l or 1.6 g/l in ethanol heated to 60 °C, and then mixed with a previously prepared aqueous chitosan solution at a concentration of 2 g/l. The coatings deposited at a voltage of 10 V and a time of 300 s were found to be homogeneous, regardless of the totarol concentration in solution. SEM observations showed a compact and homogeneous morphology of the coatings, without cracks or voids, with evenly distributed fine totarol particles in the chitosan matrix. TEM observations of the coating in the cross-section showed the presence of uniformly distributed totarol agglomerates, elongated parallel to the substrate. The coating thickness was in the range of 290-320 nm. Adhesion tests showed significant differences depending on the totarol concentration in the solution. According to the ASTM standard, the obtained adhesion classes were 4B (high adhesion) and 1B (low adhesion) for coatings with totarol concentrations of 1.6 g/l and 0.8 g/l, respectively. Regardless of the totarol concentration, the coatings showed almost identical surface topography and based on roughness parameters could be classified as smooth. The coated titanium were characterized by moderate hydrophilic properties, with contact angles of approximately 78°. The results of microbiological tests showed moderate to strong antibacterial activity of coated titanium against S. aureus under short-term exposure conditions and exceptionally high effectiveness in inhibiting biofilm formation.

Keywords: antibacterial coatings, electrophoretic deposition, microstructure, titanium alloy

The Impact of Aluminum on Microstructure Evolution in Nanostructured Copper-Aluminum Alloys During High Hydrostatic and Atmospheric Pressure Annealing

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Abstract

Copper-aluminum alloys are widely used in advanced engineering applications due to their favorable combination of strength, conductivity, and thermal stability. However, conventional processing routes often produce coarse-grained microstructures that limit their mechanical performance.

In this study, a CuAl–5 at.% alloy was processed using high-pressure torsion (HPT) to obtain a nanostructured material. HPT-processing was followed by annealing under either atmospheric pressure (Conventional Annealing - CA) or high hydrostatic pressure (High Hydrostatic Pressure Annealing - HPA), with the aim of optimizing the strength - ductility balance and improving thermal stability. Microstructural observations and analysis of produced samples using scanning electron microscopy, transmission electron microscopy and electron beam scattered diffraction were performed. Additionally, their mechanical properties were evaluated in microhardness measurements and tensile tests. HPT processing resulted in significant grain refinement to an average size of 90 nm and increased microhardness from 59 HV0.2 (initial state) to 219 HV0.2 (HPT-processed). Subsequent annealing revealed distinct differences between the impact of both heat treatments on the microstructure evolution. While CA led to a substantial reduction in microhardness and a pronounced grain growth, HPA effectively suppressed grain coarsening, preserving a finer microstructure across all investigated temperatures. Microhardness and tensile test results revealed that HPA-processing enabled improving the mechanical properties of investigated samples. This work provides new insights into the mechanisms governing microstructural evolution in severely deformed and HPA-processed copper-aluminum alloys.

Keywords: copper–aluminum alloys, high-pressure torsion (HPT), high hydrostatic pressure annealing (HPA), microstructure evolution, mechanical properties

Acknowledgements

This research was financially supported by the National Science Centre (NCN) (POLAND, project no. 2021/03/Y/ST5/00253).

Rapid Synthesis and Screening of Al-Mg-Zr Libraries: Exceptional Strength in Aluminum Alloys

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Abstract

One of the main challenges facing materials engineering is the development of sustainable, high-strength light alloys for transportation and aviation. To address this demand, high-throughput synthesis and characterization methods were used in this work to explore aluminum-based alloys from the Al–Mg–Zr system.
A material library with a composition of 56–97 wt.% Al, 2–40 wt.% Mg, and up to 12 wt.% Zr was produced using direct current magnetron sputtering. Analysis of the chemical composition using energy dispersive spectrometry, the crystal structure using X-ray diffraction, and the mechanical properties using nanoindentation allowed for rapid screening of the alloys.
All alloys were found to have a solid solution structure with an FCC lattice originating from aluminum. A correlation was observed between decreasing excess configurational entropy and an increase in crystallite size. Mechanical strength increased with increasing entropy, reaching a maximum in the alloys most enriched in zirconium. Hardness exceeding 5 GPa, according to Tabor's relationship, corresponds to a yield strength above 1700 MPa, which significantly exceeds the values typical for conventional aluminum alloys (200–600 MPa).
The study confirms the effectiveness of high-throughput methods in the rapid screening of alloys. The results indicate the potential of the Al–Mg–Zr system for the production of ultralight materials with exceptional strength.

Keywords: thin films, magnetron sputtering, high-throughput characterization, mechanical properties, aluminum alloys

Thermal Barrier Coatings with Polymer-Derived SiAlOC Bond Coats for Ti48Al2Cr2Nb Alloys Deposited by EB-PVD Using Hollow Cathode Plasma

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Abstract

Gamma titanium aluminides, particularly the Ti48Al2Cr2Nb (4822) alloy, are considered promising candidates for replacing conventional Ni-based superalloys in aerospace applications due to their low density and high specific strength at elevated temperatures. However, their limited oxidation and corrosion resistance requires the development of effective protective coating systems. Thermal Barrier Coatings (TBCs) are commonly used to improve high-temperature performance of structural materials, yet the application of conventional metallic bond coats such as MCrAlY or Pt-based layers on TiAl alloys is problematic due to interdiffusion and the formation of brittle intermetallic phases at the coating–substrate interface.

In this work, polymer-derived ceramic coatings (PDC) from the SiAlOC system were explored as a bond coat for TBC systems deposited on the Ti48Al2Cr2Nb alloy. SiAlOC glasses belong to the group of PDCs, known for high thermal stability, corrosion resistance and tunable properties obtained through controlled sol-gel synthesis. SiAlOC coatings were deposited by dip-coating, followed by drying in air at 70°C for one week and pyrolysis in argon at 800°C/30min to convert the precursor into a ceramic layer. Subsequently, YSZ top coats were deposited using the EB-PVD.

The influence of hollow cathode (HC) plasma during EB-PVD deposition was investigated. The results showed that HC plasma enabled the formation of columnar YSZ coatings at substrate temperatures up to about 200°C lower than those typically required for EB-PVD deposition. The coating systems were characterized using XRD, Raman confocal imaging, TEM, SEM and optical microscopy, while chemical composition was analyzed using EDS and EPMA.

Corrosion tests were carried out under isothermal conditions at 750 and 900°C for up to 800 h. The results demonstrated good resistance to simulated corrosion conditions at 750 °C, whereas exposure at 900 °C resulted in accelerated degradation of the coating system.

Keywords: polymer-derived ceramic, thermal barrier coatings, EB-PVD, coatings, corrosion, oxidation

Towards Quantitative SIMS: High-Throughput Investigation of Matrix Effects in Multicomponent Alloys

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Abstract

Focused Ion Beam Time-of-Flight Secondary Ion Mass Spectrometry (FIB-ToF-SIMS) is a highly sensitive surface analysis technique enabling simultaneous detection of all elements with lateral resolution below 50 nm. However, its quantitative applicability is limited by the matrix effect, i.e., the strong dependence of secondary ion yield on the chemical environment. This work systematically investigates the matrix effect in Cu–Ag–Zr, Cu–Ag, Cu–Zr, and Ag–Zr systems using combinatorial thin-film material libraries fabricated by magnetron co-sputtering. A comparison of high-power impulse magnetron sputtering (HiPIMS) and direct current magnetron sputtering (DCMS) deposition revealed significantly lower oxygen contamination (4–8 at.% vs. 20–33 at.%) and higher film density for HiPIMS, which was therefore selected for further studies. Chemical composition and thickness were determined by X-ray fluorescence (XRF), while phase formation was analyzed by X-ray diffraction (XRD). FIB-ToF-SIMS measurements focused on $^{63}Cu^{+}$, $^{107}Ag^{+}$, and $^{90}Zr^{+}$ signals. To account for variations in sputtering yield, the useful yield parameter was introduced. The results revealed strong, nonlinear dependencies of useful yield on composition. In the Cu–Zr system, Zr signal enhancement and Cu suppression were observed at high Zr content, while minor Cu additions to Zr significantly increased Cu yield. In the Ag–Zr system, both elements exhibited enhanced signals near equiatomic compositions. The study confirms the complexity of the matrix effect and highlights the limitations of quantitative SIMS analysis in multicomponent systems. Although material libraries enabled high-throughput data acquisition, further densification of compositional sampling is required to establish reliable calibration strategies.

Keywords: FIB-ToF-SIMS, thin films, magnetron sputtering, high-throughput characterization, material libraries

The Impact of Microstructure Refinement on the Antibacterial Activity of Lead-Free Brass

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Abstract

Preventing infections in healthcare facilities is of prime importance. Brasses are more promising for replacing austenitic steels in healthcare facilities than copper due to their higher strength. One way to improve the antibacterial properties of metals and their alloys, though not well understood, is to design their microstructures. It was shown that nanostructuring, due to increased grain boundary density, dislocation density, and vacancy concentration, can enhance copper ion release and, as a result, improve the antibacterial properties of copper-containing materials.

In this study, the nanostructured CuZn20Si3P was produced using severe plastic deformation. Afterward, its antibacterial properties were verified in adhesion and biofilm formation experiments using the Staphylococcus aureus ATCC 25923 strain. The microstructures and bacteria-substrate interfaces were characterized using fluorescence microscopy, scanning electron microscopy, focused ion beam and high-resolution scanning transmission electron microscopy. High-pressure torsion processing of CuZn20Si3P led to nanostructurization and did not impact the phase composition. The grain size had little effect on the passive film thickness and the oxidation product type. The fluorescence intensity of bacterial cells was greater for annealed than nanostructured samples.

The antibacterial properties of CuZn21Si3P can be enhanced by severe plastic deformation.

Keywords: lead-free brass, scanning transmission electron microscopy, high pressure

Acknowledgements

The work was funded by the National Science Centre in Poland under the project "Sonata bis 11", UMO-2021/42/E/ST5/00118.

Hydrogenated and Nitrogenated Carbon Coatings for Durable and Hemocompatible Blood- Contacting Surfaces

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Abstract

Mechanical circulatory support (MCS) systems are increasingly used in the treatment of advanced heart failure, with ventricular assist devices (VADs) representing a standard solution in adults. In pediatric applications, however, the development of safe and effective short-term support devices remains limited due to anatomical constraints, distinct hemodynamic conditions, and increased susceptibility to device-related complications. A critical challenge is the optimization of blood-contacting surfaces to ensure both hemocompatibility and mechanical durability. Amorphous carbon coatings modified with hydrogen and nitrogen were developed using physical vapor deposition (PVD) by magnetron sputtering and investigated as advanced surface materials for blood-contacting applications. The study focused on understanding how these modifications influence the physicochemical, mechanical, and biological performance of the coatings. Characterization included evaluation of surface wettability, surface free energy, tribological properties, and residual stress. Biological response was assessed in vitro through LDH cytotoxicity, cell adhesion under dynamic conditions using a radial flow chamber, and protein adsorption from human whole blood and fetal bovine serum (FBS), providing insight into blood–material interactions. Nitrogen incorporation increased surface polarity and compressive residual stress, whereas hydrogen addition reduced internal stress and improved coating durability. Hydrogenated coatings exhibited the lowest cytotoxicity and reduced cell adhesion under flow conditions, indicating improved hemocompatibility while maintaining favorable mechanical stability. These findings indicate that hydrogenated amorphous carbon coatings provide a balanced set of surface and functional properties relevant for applications requiring enhanced hemocompatibility and durability.

Acknowledgements

This work was supported by the National Centre for Research and Development as part of the project M-ERA.NET3/2023/98/KIDmicroBLOODpump/2024 “Miniaturization of impeller pump as minimal invasive implanted mechanical heart assist for children & teenagers - KIDmicroBLOODpump”.

Dental Implant Personalization in the Era of Dentistry 4.0: From Numerical Optimization to Green Additive Manufacturing

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Abstract

The rapid evolution of Dentistry 4.0 has revolutionized the approach to patient-specific treatment, shifting the focus towards highly personalized and biomechanically optimized medical devices. This study explores the integrated workflow of developing advanced dental scaffolds, combining computational intelligence with sustainable production methods.

The primary objective of this work is to present personalized scaffolds that meet specific anatomical and mechanical requirements. The first stage of the research involves the application of Finite Element Analysis (FEA) to evaluate stress distribution and structural integrity. In this context, numerical optimization allows for the design of structures capable of withstanding physiological loads while simultaneously promoting bone tissue regeneration.

In alignment with the principles of the green economy and low-carbon technologies, additive manufacturing (AM) was employed as a sustainable alternative to traditional subtractive methods. Incremental methods enable a significant reduction in material waste and the production of complex geometries. The experimental part of the study focuses on analyzing the impact of the strategies applied during the additive manufacturing process on the structural quality of the scaffolds.

The integration of numerical simulations and additive manufacturing enables the production of high-quality dental implants that are both clinically effective and environmentally responsible. Such an approach aligns with the modern model of sustainable medical engineering, setting the direction for the development of personalized dentistry of the future.

Keywords: additive manufacturing, titanium alloys, implant-scaffold, finite elements analysis, dentistry 4.0, implantology, digital dentistry, dental engineering, sustainable manufacturing

Acknowledgements

The paper was developed in connection with the "DOKTORAT WDROŻENIOWY 2024" Project number DWD/8/0372/2024. The project is co-financed from the Polish state budget. This publication was co-financed by project no. FESL.10.25-IZ.01-07E7/23.

Analysis of the Effects of Degradation of the Structure and Mechanical Properties of Boiler Installation Elements Made of 10H2M Steel After Long-Term Operation

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Abstract

This paper analyzes the effects of structural degradation caused by mechanical excitation in the form of cyclic loading in boiler system components made of 10H2M steel operated for 280,000 h at a temperature of 540 °C and an internal pressure of 2.9 MPa. The comparative analysis covers the material in as-received and after exploitation condition. Microhardness measurements and fatigue tests at stress amplitudes of ensuring quasistatic loading conditions of 400 MPa, low-cycle loading conditions 370 MPa, and high-cycle conditions 320 ÷ 350 MPa were used to assess the changes. Using metallographic techniques, including light microscopy, scanning electron microscopy (SEM), X-ray diffraction (XRD), and chemical composition analysis (EDS), changes in the microstructure of the exploited material were observed and compared with changes occurring in the as-received steel. The paper also presents calculation methods based on the Massing hypothesis and the Halford-Marrow relationship, which were used to determine the energy density of plastic deformation absorption as a parameter influencing the service life of the tested construction material.

Keywords: material fatigue, 10H2M, structural degradation, long-term exploitation

Interaction of Plasma Ions with Solid Materials: Challenges and Lessons Learned

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Abstract

It is widely known that Focused ion beam (FIB) technology has employed gallium ions for more than five decades, whereas plasma-based ion sources for FIB applications have only emerged over the past 15 years. This presentation will focus on the interactions of various ion species with a broad range of solid materials, including conventional gallium ions generated from liquid metal ion sources (LMIS) and novel plasma ions—such as xenon, oxygen, argon, and nitrogen—produced by inductively coupled plasma (ICP) sources. The effects of ion–solid interactions will be discussed, together with the underlying physical mechanisms. Key challenges associated with the utilisation of different ion species, as well as important insights gained from experimental investigations, will also be presented.

In addition, the presentation will provide an overview of recent advances in FIB technology from both hardware and software perspectives. Particular emphasis will be placed on emerging applications of focused plasma ion beam (PFIB) systems, including distinguished use cases involving oxygen and argon ion beams. The requirements for the fabrication of damage-free transmission electron microscopy (TEM) lamellae will be highlighted, and the best practices for achieving high-quality specimen preparation will be shared. At last, the need of cryogenic workflow for beam sensitive materials will be also discussed.

Keywords: focused ion beam (FIB), plasma FIB, TEM

Microstructure and Phase Evolution of Mechanically Milled Ni–Mn–Ga Magnetic Shape Memory Alloy

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Abstract

The subject of the study was a Ni–Mn–Ga alloy with a chemical composition deviating from stoichiometry, belonging to the group of magnetic shape memory alloys based on the Heusler-type A_2BC structure. Deviation from stoichiometry alters the valence-electron concentration (e/a), which affects the characteristics of the martensitic transformation and the sequence of phase transformations between the parent phase and martensite. In the polycrystalline state, these alloys exhibit high brittleness, which significantly hinders their processing. To overcome this limitation, the brittleness of the material was utilized as an advantage in powder production by applying a fragmentation approach to melt-spun ribbons.

An alloy with a nominal chemical composition of Ni49.9Mn25.1Ga25.0 (wt.%) was produced and cast into ribbon. It was subsequently used as the feedstock for milling in a vibratory mill. The milling time (15, 30, and 60 minutes) was used as a process variable. The powders were characterized for morphology, particle size distribution, and phase composition using transmission electron microscopy (TEM), scanning electron microscopy (SEM), X-ray diffraction (XRD), and a particle size analyzer.

The milling resulted in the fragmentation of the material into particles with diverse morphologies, including both near-spherical and platelet-like forms. With increasing milling time, the average particle size decreased from approximately 60 µm to 43 µm.

Phase analysis showed that at room temperature, the parent phase with an $L2_1$-type structure was present. Increasing the milling time led to a reduction in crystallite size and an increase in internal stresses, which was reflected in the broadening of diffraction peaks and the appearance of reflections corresponding to a disordered fcc-type phase. After 60 minutes of milling, a change in phase fraction was observed, with the fcc phase becoming dominant, while only a small amount of the parent phase remained.

Keywords: Ni–Mn–Ga alloys, magnetic shape memory, mechanical milling, microstructure, phase evolution

Early-Stage Yield Surface Evolution in LENS-Manufactured Inconel 625: A Combined Multiaxial Testing and 3D EBSD Study

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Abstract

This study investigates the evolution of the yield surface in Laser Engineered Net Shaping (LENS) manufactured Inconel 625 with a particular focus on early-stage deformation behavior. Tubular specimens were subjected to multiaxial loading to experimentally determine yield surfaces at initial plastic offsets and following controlled pre-deformation up to approximately 1% plastic strain. Three-dimensional electron backscatter diffraction (3D EBSD) was employed to characterize the as-built microstructure and its evolution during early plastic deformation, capturing grain morphology, crystallographic texture, and local misorientation development. The initial yield surface exhibited near-symmetric tensile–compressive behavior with moderate anisotropy, consistent with the additively manufactured microstructure. Progressive pre-deformation resulted in measurable changes in the shape and orientation of the yield surface, indicating the onset of plastic-induced anisotropy. Correlations between yield surface evolution and microstructural features revealed by 3D EBSD highlight the role of grain-scale deformation heterogeneity and texture in governing the early plastic response of LENS-fabricated Inconel 625.

Keywords: additive manufacturing, LENS, yield surface, deformation, superalloy, inconel, multiaxial, EBSD, pre-deformation, anisotropy

Additive Manufacturing of Magnesium Alloy WE43 for Biomedical Applications

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Abstract

Magnesium (Mg) and Mg-based alloys have been considered promising materials for biomedical device applications such as resorbable implants or stents, due to their biodegradability, biocompatibility and mechanical properties comparable to human bone [1,2]. Their inherent properties could potentially solve limitations of conventional temporary mechanical supports (steel, Ti or CoCr alloys) through elimination of removal surgery and reduction of stress shielding effects. Furthermore, much emphasis is currently put on the development of personalised medical devices through additive manufacturing techniques. Such advanced applications necessitate precise control over corrosion of the implant [3]. In this work, Mg alloy WE43 has been successfully additively manufactured via selective laser melting (SLM) and characterised using SEM, TEM, XRD, nanoindentation and electrochemical testing. The presentation will discuss aspects of 3D-printing parameters optimization, ion implantation and production of Mg-based metal matrix composites (MMC) for biomedical applications.

Keywords: Mg alloys, additive manufacturing, metal matrix composites (MMC), corrosion, biomedical

Acknowledgements

This work received funding from the National Science Center, Poland, through the MINIATURA 9 scheme, grant no. 2025/09/X/ST11/00921. The research was also supported through the initiative of the Ministry of Science and Higher Education 'Support for the activities of Centers of Excellence established in Poland under the Horizon 2020 program' under agreement No. MEiN/2023/DIR/3795.

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Design, Casting, and Additive Manufacturing of Titanium-Rhenium Alloys for Aerospace Applications

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Abstract

The increasing demand for lightweight materials in air, land, and sea transportation arises from the need to reduce costs associated with fuel consumption and greenhouse gas emissions, which contribute to worldwide climate change. Our research focuses on ab initio designing, casting, atomization, and Laser Beam Powder Bed Fusion (PBF-LB) processing of new titanium alloys. For example, by adding rhenium to these alloys, we aim to enhance their properties, making them suitable for high-temperature and aggressive environments.
According to existing research, rhenium is a versatile element that limits diffusion processes and significantly inhibits oxidation of titanium alloys. Titanium-rhenium (Ti-Re)alloys are important for modern lightweight materials required in high-temperature applications. The market lacks effective solutions due to the low melting points of aluminum and magnesium alloys and the limited structural stability and oxidation resistance of the titanium alloys available today. Nickel, currently used in high-temperature applications, is a few times more expensive and has an almost twice higher density, leading directly to fuel consumption.
In our research, we developed a Ti-Al-Si-Re alloy using ab initio methods, which was later cast in an arc-melting system and atomized by gas atomization. Furthermore, we processed fabricated powder in the PBF-LB process using an Aconity GmbH device, varying the many process parameters (laser power, scanning speed, scanning strategy, etc.) and substrate heating temperatures from room temperature (RT) to 700°C. Our alloy demonstrates a strength at 625°C that exceeds Inconel 625. In addition, other results concerning porosity, phase composition, and mechanical testing at elevated temperatures indicate a promising potential for utilizing Ti-Re alloys in new sections of jet engines.

Keywords: additive manufacturing, PBF-LB/M, titanium-rhenium, design, mechanical properties

Improving Microstructural Homogeneity in Inconel625/CoCrMo Gradient Materials Additively Manufactured by Laser Powder Bed Fusion with Laser Beam Remelting

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Abstract

Layer-by-layer manufacturing in Laser Powder Bed Fusion (LPBF) enables the fabrication of complex multi-material components by joining dissimilar alloys, thereby overcoming the limitations of traditional joining methods. This flexibility stems from the ability to control the mixing ratios of alloys in gradient zones, which helps avoid unfavorable compositions that cause formation of brittle intermetallic phases. However, in-situ powder mixing often results in abrupt step gradients or compositional variations at the zone interfaces. Therefore, this study aims to optimize LPBF process parameters to achieve Inconel 625/CoCrMo gradient material with limited local fluctuations in chemical composition.

Inconel 625/CoCrMo gradient material, compositionally graded along the build direction was prepared using the AYAS 120 LM 3D printer equipped with two powder tanks mounted above the recoating system. Gradient samples were printed starting from pure Inconel 625 through two gradient zones with Inconel 625 and CoCrMo powder in-situ mixing ratios 1:2 and 2:1 wt.%, respectively, and ending with pure CoCrMo. A single-scan and remelting strategy was applied. Microstructural analysis revealed that the remelting scan allows for a reduction in the number of inhomogeneities caused by local segregation of alloys in particular gradient zones and limits the fluctuation of chemical composition at their interfaces. For both single-scan and remelting strategy the porosity of gradient samples was similar and close to 0.1%. However, the remelting strategy resulted in one order of magnitude reduction in crack density, decreasing from 1.1 – 1.2 × 10-4 to 3.2 – 6.5 × 10-5 µm-1.

It was determined that although the remelting scan extends the 3D printing time, it allows to produce reliable gradient materials with smooth compositional transition and a limited number of defects.

Keywords: LPBF, gradient, Inconel 625/CoCrMo, remelting

Acknowledgements

This work was supported by the National Science Centre, Poland, under grant agreement no. UMO-2024/55/B/ST11/00729.

Multiscale Microstructural Characterization of a Compositional Gradient Inconel 625/CoCrMo Material Additively Manufactured by Laser Powder Bed Fusion

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Abstract

Combining various laser powder bed fusion (LPBF) process parameters and chemical composition alterations by mixing Inconel 625 with CoCrMo alloy powders offers new opportunities to manufacturing Inconel 625/CoCrMo gradient materials for high temperature and aggressive environment application.
This study focuses on characterization of differences in microstructure, chemical and phase composition in gradient material consisting of Inconel 625 and CoCrMo connected by two zones with Inconel 625 and CoCrMo mixing ratios of 1:2 and 2:1 (wt.%). The set of gradient material variants was prepared using the AYAS 120 LM 3D printer equipped with two powder feeders, enabling composition control through variable powder mixing in successive gradient zones. Microstructural analysis was performed using SEM combined with EBSD and EDS microanalysis, TEM, STEM-EDS, and simultaneous STEM imaging and electron nanodiffraction by 4D STEM. The results were correlated with the chemical composition and hardness profiles across the gradient.
EDS microanalysis showed that the chemical composition profiles across the gradient exhibit a stepwise character, which is associated with local compositional inhomogeneities resulting from incomplete mixing of the Inconel 625 and CoCrMo molten alloys. Electron microscopy analysis revealed systematic changes in grain morphology and orientation, cellular structure, formation of precipitates of carbides, intermetallic phases, and the ε phase (resulting from $\gamma \rightarrow \varepsilon$ martensitic transformation) with increasing CoCrMo content across the gradient. Hardness increased with increasing CoCrMo fraction, indicating a strong dependence on the local chemical composition.
The results show how the compositional gradient affects microstructure and hardness of the individual zones along the Inconel 625/CoCrMo gradient material.

Keywords: Inconel 625, CoCrMo, gradient material, additive manufacturing, electron microscopy

Acknowledgements

This work was supported by the National Science Centre, Poland, under grant agreement no. UMO-2024/55/B/ST11/00729.

From Thermal History to Properties: Experimental and Numerical Studies of Micrometallurgical Processes in Direct Energy Deposition Additive Manufacturing

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Abstract

Additive manufacturing (AM) involves layer-by-layer material deposition to produce fully functional components. The thermal history during processing strongly affects microstructure evolution, mechanical properties, and residual stress development. These characteristics depend on process parameters and local thermal conditions. Improper parameter selection may lead to excessive residual stresses, distortion, cracking, reduced corrosion resistance, and non-uniform material performance. Therefore, understanding and controlling thermal history is essential for obtaining reliable component properties.

This work investigates the relationship between thermal history, microstructure evolution, mechanical properties, and residual stresses in Direct Energy Deposition (DED) manufactured components. The study evaluates the possibility of predicting these characteristics using temperature measurements acquired during processing. Initial experiments performed with a custom thermal imaging system revealed significant challenges related to temperature acquisition and data processing, leading to discrepancies between measured and expected results. Experimental observations were therefore correlated with numerical simulations.

The developed numerical model enables faster parameter selection to achieve the desired microstructure while minimizing residual stresses. Model validation was performed using temperature measurements and substrate displacement recorded during manufacturing. Temperature evolution was monitored with thermocouples and pyrometers, whereas displacement was measured using Digital Image Correlation. Good agreement between simulations and experiments was achieved.

The results demonstrate that additively manufactured components cannot be considered fully homogeneous at the macroscopic scale. Local thermal variations produce measurable differences in microstructure, mechanical response, and residual stress distribution, which should be considered in process optimization.

Keywords: additive manufacturing, direct energy deposition, thermal history, numerical simulations

3D Printing as a Shaping Base for Textile Composites in Custom-Made Orthoses

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Abstract

Studies demonstrate the functional implementation of personalized ortheses manufacturing through a novel composite material, which integrates a 3D-printed internal structure with external unidirectional glass fiber and braided carbon fiber reinforcement.

Keywords: 3D printing, textile composites, custom-made orthoses

Acknowledgements

The MicroWeave-TEX Project is co-funded by the European Union's Erasmus+ programme under reference number 2025-1-ES01-KA220-HED-000356411.

Modern Hybrid Nanomaterials Fabricated by High-Pressure Torsion Technique

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Abstract

Nanostructured alloys attract significant interest due to their exceptional combinations of properties unattainable in conventional coarse-grained materials. High-Pressure Torsion (HPT) provides unique opportunities for synthesizing hybrid materials through severe plastic deformation under extreme pressure and shear strain. This approach is particularly attractive for immiscible metallic systems, where conventional thermodynamic processing fails due to positive enthalpy of mixing and limited mutual solubility.

This work investigates the fabrication of nanostructured multilayer composites based on immiscible systems, including Cu–Ta and Cu–Fe, processed by HPT under an applied pressure of 6.0 GPa using various numbers of revolutions. Selected miscible systems such as Cu–Al and Ti–Al were also examined for comparison. Microstructural evolution and phase formation were analyzed using X-ray diffraction, electron microscopy (SEM/TEM), energy-dispersive spectroscopy, microhardness measurements and tensile testing.

Microstructural observations revealed intense mechanical mixing leading to vortex-like structures and progressive fragmentation of initial layers, resulting in homogeneous nanoscale dispersion with increasing strain. Despite thermodynamic immiscibility, forced intermixing and localized solid-state diffusion were observed in selected regions. The processed composites exhibited significant strengthening, with mechanical properties improved by approximately 200–600% compared to the initial materials. The results demonstrate that HPT enables the synthesis of non-equilibrium nanostructured composites from immiscible metals, opening new pathways for designing advanced high-performance materials.

Keywords: HPT, nanometals, immiscible systems

Porous Anodic Alumina – Synthesis, Properties, and Applications

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Abstract

Porous anodic alumina (PAA) is a well-known nanostructured material valued for its unique architecture and versatile fabrication possibilities. It is produced by the electrochemical oxidation of aluminum, leading to the self-organized formation of highly ordered nanoporous structures. Under appropriate anodization conditions, PAA develops a hexagonal close-packed pore arrangement. However, such self-ordering occurs only within narrow processing windows determined mainly by the applied voltage and electrolyte type.

Despite extensive research, the mechanisms responsible for pore ordering are still not fully understood, and the fabrication of PAA with large interpore distances ($D_c > 380$ nm) remains challenging. In this seminar, the fundamental mechanisms governing PAA formation will be briefly discussed, together with recent approaches enabling the synthesis of PAA with enlarged pore spacing.

By applying pulse anodization techniques, PAA can also be engineered into functional photonic materials with strong potential for sensing applications. Because pore geometry can be precisely tuned by electrochemical parameters such as voltage or current, this approach enables the fabrication of one-dimensional photonic crystals in which the effective refractive index is modulated along the PAA thickness. Carefully designed pulse sequences allow the production of gradient-index and step-index optical filters with photonic stop bands spanning the visible to the mid-infrared spectral range.

In addition, PAA serves as an excellent template for the synthesis of functional nanomaterials with well-defined geometrical parameters. As an example, the luminescent properties of ZnO/TiO_2, ZnO/HfO_2, and ZnO/ZrO_2 core–shell hybrid nanotubes with shell thicknesses between 9 and 40 nm will be presented.

Keywords: porous materials, photonic structures, template-assisted synthesis, atomic layer deposition

Investigation of the Phenomenon of Silver Segregation on the Surface of Zinc Oxide Coatings

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Abstract

Metal oxide coatings doped with metals have found widespread application in medicine due to their biocidal properties. One of the most commonly used dopants for such coatings is silver, which exhibits a broad spectrum of antimicrobial activity. However, during the deposition of silver-doped oxide coatings using the magnetron sputtering method, an undesirable phenomenon of metal segregation on the surface of ceramic coating may occur. In this study, the effect of deposition time on the amount of metallic silver present on the coating surface was investigated. Silver-doped metal oxide coatings were deposited using the High Power Impulse Magnetron Sputtering (HiPIMS) method with varying process durations of 5, 20, 40 and 60 minutes. The surface morphology was examined using scanning electron microscopy (SEM), while their chemical composition was analysed by energy-dispersive X-ray spectroscopy (EDS). Phase analysis was carried out using X-ray diffraction (XRD). The results indicate that as the deposition time increases, the number of silver areas on the coating surface also increases.

Keywords: Zinc oxide, silver, magnetron sputtering, coatings

The Development of Cu-Mo Nanomultilayers for Thermal Management in Modern Electronics

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Abstract

Miniaturization of electronics, together with increasing demands for computing performance and power density, significantly amplifies the importance of thermal management. Some estimates suggest that up to 50% of all failures originate from overheating or thermally induced microcracking. The latter is primarily associated with the mismatch in coefficients of thermal expansion (CTE) at material interfaces, for example, between copper interconnects (CTE ≈ 14 ppm/K) and silicon wafers (CTE ≈ 2.5 ppm/K).

One of the most promising approaches to tailoring the thermal properties of electronic circuits is the use of Cu-Mo composites. It has been demonstrated that combining highly conductive copper with thermally stable molybdenum yields materials that retain good thermal conductivity while exhibiting a significantly reduced CTE.

In this work, we investigate the potential of nanomultilayered Cu-Mo thin films (NMLs) for thermal management applications with a total thickness of approximately 200 nm, consisting of up to 20 alternating Cu and Mo layers. The samples were fabricated using a DC magnetron sputtering, enabling the production of high-purity NMLs with controlled thickness. Comprehensive characterization - including HR-SEM, XRF, and XRD analyses, combined with electrical resistivity measurements and supported by Fuchs - Sondheimer (FS) and Mayadas-Shatzkes (MS) electron transport models - provided insights into the relationship between NMLs structure and electrical conductivity. Furthermore, using the Wiedemann-Franz law, we estimated the thermal conductivity of the fabricated materials.

The investigations confirmed a significant effect of grain size and individual layer thickness on the electrical and thermal conductivity of NMLs. The results are in agreement with values predicted by FS+MS models. The study provides in-depth knowledge and practical guidelines for the future design of nanomaterials with tailored thermal properties controlled by architecture and microstructure.

Keywords: thermal management, Cu-Mo, nanocomposites, nanolaminates

From 2D Transition Metal Dichalcogenides to MXenes: Bridging Nanolubricant Design Rules with Next-Generation Bioactive Implant Surfaces

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Abstract

Two-dimensional (2D) nanomaterials with layered crystal structures — transition metal dichalcogenides (TMDs), their oxide precursors (TMOs) and, more recently, MXenes — offer a unique combination of easy interlayer shear, tribofilm-forming ability and tuneable surface chemistry that makes them attractive for advanced tribological applications. In our earlier systematic studies on MoS_2, WS_2, MoO_3 and WO_3 nanoparticles as lubricant additives, we established mechanistic design rules governing synergy and antagonism between 2D nanoparticles and conventional additive packages (ZDDP, EP, dispersants) under varying contact geometries, loads and temperatures. A key finding was the concept of adaptive oxide precursors — TMO nanostructures that undergo in-situ tribochemical sulphurisation to form lubricious MoS_2/WS_2-like tribofilms.

Building on this framework, the present work extends the adaptive-surface concept to $Ti_3C_2T_x$ MXene coatings deposited into femtosecond-laser-textured cavities on powder-metallurgy Ti/HAp gradient composites developed for load-bearing orthopaedic implants. We investigate how MXene architecture, laser texture geometry and the physiological environment (SBF, Ringer's solution) jointly control fretting wear, tribofilm evolution and surface degradation at the implant–bone interface. Preliminary results demonstrate that synergy between laser-induced micro-reservoirs and MXene nanosheets yields significantly enhanced wear resistance compared to untextured or uncoated references, while maintaining favourable cytocompatibility and osteoconductivity. The findings confirm that the rational nanolubricant design methodology — mapping structure–tribofilm–performance relationships across 2D material families — is transferable from industrial tribology to the biotribological domain

Keywords: 2D materials, MXene, $Ti_3C_2T_x$, transition metal dichalcogenides, laser surface texturing, biotribology, Ti/HAp composites, tribofilm, fretting wear

Acknowledgements

This research is funded by the National Science Centre, Poland (OPUS LAP, UMO-2022/47/I/ST8/01778) within the bilateral NCN–FWF programme.

Room-Temperature Synthesis of Metal Hydrides via Self-Shearing Reactive Milling

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Abstract

Self-shearing reactive milling (SSRM) is emerging as a highly efficient approach for the synthesis of metal hydrides under mild conditions. The process relies on intensive mixing of hydrogen-absorbing materials in a hydrogen atmosphere without grinding media, where particle–particle interactions activate surfaces and initiate solid–gas reactions. In this work, a generalized study of SSRM applied to various material classes is presented, including titanium and its alloys, NiTi-based alloys (Nitinol), Mg_2Ni intermetallics, and selected transition metals. Under appropriate conditions, all investigated materials undergo hydrogenation at room temperature, forming stoichiometric or near-stoichiometric hydride phases. The reaction mechanism is governed by the removal of surface oxide layers and continuous exposure of fresh, highly reactive surfaces generated during mixing. In many cases, once initiated, hydrogenation proceeds spontaneously without further mechanical input. The kinetics and susceptibility to hydrogenation strongly depend on the material type and stability of formed hydride. Phase analysis using X-ray diffraction (XRD) and thermogravimetric measurements confirm the formation of hydride phases such as TiH_2 and disordered high temperature polymorph of Mg_2NiH_4. Microstructural observations indicate that, in selected cases, the original particle morphology can be preserved despite the reaction.

The SSRM approach offers significant advantages over conventional reactive milling, including the elimination of grinding media, reduced contamination, and the ability to perform synthesis at room temperature. These features improve energy efficiency and provide new opportunities for scalable production of hydride materials, including spherical powders suitable for advanced manufacturing technologies such as additive manufacturing.

Keywords: hydrogen storage, hydrides, reactive milling, titanium alloys, mechanical synthesis

High-Temperature Deformation Behavior and Softening Phenomena in Advanced Cu- and Mo-Alloyed Medium-Mn Steels

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Abstract

The work focuses on high-temperature deformation behavior and softening phenomena in three advanced medium-Mn steels alloyed with increased additions of Cu and Mo as elements occurring more often in steel scrap especially from electric vehicles. Axisymmetric samples of 10 mm in diameter and 12 mm in height were subjected to continuous compression tests in a temperature range of 900-1100°C at different strain rates of 0.05, 0.5 and 5 s^{-1} and double-hit compression tests at 900 and 1100°C with interval times from 1 to 60s using the Gleeble 3800 thermomechanical simulator. Flow stresses values and softening kinetics of austenite were determined based on the hot deformation curves. The deformation conditions and chemical composition (the additions of Cu and Mo) affected the hot deformation response and recrystallization kinetics. Moreover, a comparison analysis of prior austenite grain size was performed among the three alloys using different methods (reconstruction analysis using EBSD, chemical etching, thermal etching). Final conclusions were drawn concerning the effect and tolerance of Cu and Mo on the hot deformation behavior and softening phenomena in advanced group of high-strength steels for automotive applications.

Keywords: medium-Mn steel, high deformation behavior, dynamic recovery, static recrystallization, prior austenite grain size

Acknowledgements

The study was funded by National Science Centre, Poland under the OPUS call in the Weave programme, grant no. 2021/43/I/ST5/02658 and by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – 504849602.

Microstructure–Property Relationships in Q&P Medium-Mn Steels Processed in Continuous Annealing Regimes

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Abstract

Final mechanical properties of structural elements in the automotive industry are often determined in a sheet steel during heat treatment. The heat treatment process of steel coils may be performed using either batch or continuous annealing. A significant drawback of batch annealing is the long processing time and the non-uniform mechanical properties along the coiled steel sheet. In continuous annealing, a single sheet thickness is heat-treated at a time, which shortens production time significantly and enables the use of advanced thermal cycles, leading to multi-phase or two-phase microstructures.
Recent advancements in automotive steels (AHSS) have led to the development of medium-Mn steels, which may represent an evolutionary step in the automotive steel industry. In this study, a systematic heat treatment optimization process was performed for Q&P (Quenching and Partitioning) cycles on steel with a composition of 0.17% C, 4.7% Mn, 1.6% Al, 0.2% Si, and 0.2% Mo to achieve the highest possible strength-plasticity product. A wide range of heat treatment parameters was analyzed, allowing for additional identification of conditions that ensure either maximum strength or plasticity.
The heating and cooling rates, along with the energy-saving annealing time of maximum 120 s, were selected to enable the heat treatment process using industrially available continuous annealing production lines. The research covered a dilatometric analysis of the material and an investigation of the influence of heat treatment parameters on the thermal stability of austenite (Ms temperature).
For a promising range of process parameters, heat treatment was performed on subsize tensile samples using a dilatometer. The maximum UTS × TEl of 29 GPa% was obtained for a sample with a yield strength (YS) of 850 MPa.

Keywords: medium-Mn, retained austenite, AHSS

Acknowledgements

This research was funded in whole or in part by National Science Center (Poland) through the grant no. 2023/49/N/ST11/02907.

When Aluminium Meets Oxide – Reaction-Driven Wetting

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Abstract

High-temperature wetting and reactivity of liquid Al, Al–Cu, and Ni-bearing alloys with Y_2O_3, ZnO, CoO, NiO, and SiO_2 reveal a landscape governed by the thermodynamic stability of the parent oxide. At one extreme, the Al/Y_2O_3 system departs entirely from the Al_2O_3-forming paradigm: the reaction product region extends ~1 mm and is organised into three zones — fine YAG ($Al_5Y_3O_{12}$) near the drop, coarse YAP ($AlYO_3$) in the intermediate zone, and a C4-type YAP/Al_2Y network at the substrate — with the phase sequence governed by progressive yttrium enrichment of the melt. For oxides reduced more readily, α-Al_2O_3 is the primary product, yet its morphology is strongly modulated by volumetric mismatch. In Al/ZnO the exceptional mismatch (~40%) yields coarse crystals and persistent non-wetting ($\theta = 100–107°$) for all orientations; under short contact times the interface instead consists of two epitaxial nanolayers — metastable Al_2O_3 (γ-, δ-, or λ-type, controlled by ZnO surface chemistry) and $ZnAl_2O_4$ spinel — with spinel consuming the alumina as interaction proceeds. The Al/CoO system provides a mechanistic window: at 700°C a corrugated C4-type zone forms with α-Al_2O_3 and Al_9Co_2, while at 1000°C a periodic laminate of α-Al_2O_3 and $Al_{13}Co_4$ develops, separated by a thin Co strip offering direct proof of the redox reaction at the advancing front. A comparably layered microstructure characterises Al/NiO: at 700°C two sublayers of α-Al_2O_3 and Al_3Ni form with Al_3Ni grading from coarse near the drop to nanoscale near the substrate; at 1273°C the same assembly is preserved independently of NiO orientation, with Al_3Ni precipitating in three distinct morphologies from the Al–Ni–O liquid upon cooling. Alloying with copper introduces further complexity: in Al–Cu/SiO_2, coarse α-Al_2O_3 near the drop gives way to a fine δ-Al_2O_3 matrix near the silica — consistent with Ostwald-step nucleation — while the large volumetric strain leaves its imprint as deformation twins in reactively formed silicon.

Keywords: reactive wetting, sessile drop method, liquid aluminium, metal–oxide interface, redox reaction, metastable alumina, C4 composites, interfacial microstructure

Acknowledgements

The research was supported by the Ministry of Science and Higher Education of Poland (Projects No. PBZ-KBN-114/T08/2004, N N507 272836, and Iuventus Plus No. IP2011061071), by the Foundation for Polish Science through the START programme for young researchers, and by the framework programme "Advanced Materials and Technologies for their Production" (POIG.01.01.02-00-015/09-00, task 5.5).

Sessile drop couples were produced thanks to the intense cooperation with Prof. Natalia Sobczak and her team at the Centre for High-Temperature Studies, Foundry Research Institute in Kraków.

Analysis of the Deformation Behavior and Fracture Mechanism of Advanced High-Strength Medium-Mn Steels Under Conditions of Static Tensile Tests

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Abstract

In this study, the deformation behavior and fracture mechanism of advanced high-strength medium-Mn steels under static tensile loading were investigated. Three steels were designed: the first steel (base) with a composition of 0.17C–4Mn–0.8Al–0.5Si (wt.%), the second steel contained 0.3Mo, and the third steel contained 1.0Cu. The optimal quenching and partitioning temperature and a suitable partitioning time window to promote more than 10% of retained austenite (RA) and carbide-free martensite (M) were analyzed using a high-resolution Bahr DIL805 dilatometer. Next, salt bath treatments were used to implement full-scale heat treatment conditions for tensile testing samples. Subsequently, after dilatometric and salt-bath processing, the evolution of RA fractions was quantitatively evaluated, demonstrating a strong dependence on partitioning temperature (PT) and time conditions. Higher RA fractions were obtained at PT 400 and 450°C for 600 s, reaching ~16-18.5% (dilatometry) and ~10-14% (salt bath), whereas lower PT (350°C) and longer time (400°C_1800 s) resulted in slightly reduced RA. Tensile test results showed that ultimate tensile strengths range from ~1200 to 1400 MPa and total elongation ranges from ~10 to 15%, depending on steel composition and heat treatment parameters. The better strength-ductility balance was obtained for partitioning at 400 °C for 600 s in all investigated steels. The Mo and Mo + Cu-added steels shift the response toward higher strength up to ~1400 MPa but slightly slower ductility, reflecting modified austenite stability and suppressed SIMT kinetics. Fractographic analysis of all QP-treated samples showed mixed ductile-brittle fracture behavior, varying with steel composition and processing parameters.

Keywords: medium-Mn steel, deformation behavior, quenching and partitioning process, tensile testing, static fracture mechanism

Acknowledgements

The study was funded by National Science Centre, Poland under the OPUS call in the Weave programme, grant no. 2021/43/I/ST5/02658 and by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – 504849602.

Effect of Hot Deformation and Isothermal Holding Parameters on Microstructure Evolution of 3Mn Bainitic-Austenitic Steel for Forgings

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Abstract

The aim of this study was to determine the effect of hot deformation and isothermal holding parameters on the microstructure evolution of 0.17C–3.1Mn–1Si–0.55Al–0.22Mo–0.034Ti–0.073V novel steel intended for forgings. Based on dilatometric and X-ray analyses, the most promising time–temperature parameters for stabilizing retained austenite were identified. Five-step compression tests were performed in the temperature range of 1100–980°C, followed by isothermal holding under various conditions, using a Gleeble thermomechanical simulator. Comprehensive microstructural analysis and X-ray diffraction measurements of retained austenite content were essential to achieving the aim of the study. The applied parameters resulted in a homogeneous, fine-lath microstructure consisting of bainitic ferrite, retained austenite (12–14 vol.%), and a small fraction of martensite. After isothermal holding below the Ms temperature, coalesced bainite was observed. The formation of ultrafine-grained microstructure was promoted by the presence of Ti and V microadditions.

Keywords: medium-Mn steel, bainitic steel, retained austenite, Gleeble simulation, forgings

Acknowledgements

The research leading to these results has received funding from National Centre for Research and Development, grant no. LIDER/16/0090/L-12/20/NCBR/2021.

Morphological Details of Fine-Dispersed Retained Austenite Stabilized by C Partitioning in Plastically Deformed and Undeformed Multiphase Medium-Mn Steels with Cu and Mo Additions

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Abstract

Quenching and Partitioning (Q&P) processing is the promising strategy of increasing the mechanical response of medium-Mn steels under various load types. The Q&P heat treatment consists of austenitization followed by quenching to a temperature between Ms and Mf to produce some fraction of martensite and then a heating step to a higher temperature is applied for C partitioning from the supersaturated martensitic laths into the austenite. Therefore, the Ms temperature of the C-enriched austenite is lower and some fraction of this phase can be stabilized to the room temperature. Metastable retained austenite RA present as thin layers between martensitic laths, enables an enhancement of the mechanical response of forgings during service conditions. On the other hand, the presence of blocky RA may deteriorate impact toughness and fatigue crack resistance. Therefore, the selection of time-temperature parameters for the Q&P processing should enable the formation of RA with the beneficial lath-like morphology.

In the present study, the microstructural evolution of undeformed and plastically-deformed medium-Mn steels (4 wt.% of Mn) containing Cu and/or Mo additions processed via the Q&P route was investigated. Plastic deformation at 900°C was applied using a dilatometer prior to the Q&P processing to investigate its effect on phase transformation kinetics, as well as the fraction and morphology of RA. Quenching in the temperature range of 270-290°C was employed to optimize the martensite-austenite fraction. Partitioning was subsequently performed at 400-450°C for 120-900s. The resulting microstructures were characterized using quantitative (XRD, EBSD) and qualitative (SEM, TEM) techniques. The final microstructures consist of low-C martensite and 10-15 vol.% of RA exhibiting a beneficial lath-type morphology. The differences between three steels and undeformed and plastically deformed samples are characterized in detail especially in terms of morphological details of RA.

Keywords: medium-Mn steel, retained austenite, plastic deformation, quenching and partitioning

Acknowledgements

The study was funded by National Science Centre, Poland under the OPUS call in the Weave programme, grant no. 2021/43/I/ST5/02658 and by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – 504849602

Results of the Small Punch Test for the Validation of Metallic Materials Properties

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Abstract

This paper presents an analysis of small punch test (SPT) results with regard to heterogeneity, anisotropy, microstructure, and macroscopic mechanical properties (e.g., static tensile testing) of metallic materials. The tests were conducted on steels, cast steel, nickel alloys, and zirconium. The research was primarily focused on validating materials for the power industry. However, the heterogeneity of materials across the sheet thickness was verified based on tests of DP600 steel, which is used in the automotive industry. The effect of microstructural degradation on SPT results was determined based on samples taken from materials that had been in long-term exploitation in power plant and from steel after long-term exposure to high temperatures. The tests for L21HMF cast steel focused on evaluating the material's anisotropy after exploitation. For P91 and S304H steels, the effect of microstructural changes resulting from long-term annealing on the properties evaluated using SPT was assessed. SPT tests were also performed on 13CrMo4-5 steel, Nimonic 75 nickel alloy, and technical zirconium. The standard evaluation of SPT results was supplemented with measurements of acoustic emission, hardness, and fractographic observations. The studies confirmed the suitability of the SPT method for evaluating the strength properties of materials. However, it was pointed out that the interpretation of the results must take into account the local nature of the measurement, which not only poses challenges regarding the macroscopic parameters of the material but also offers opportunities for a more comprehensive characterization of the material. With regard to specific materials and changes in their microstructure, it is necessary to introduce individual empirical corrections for the evaluation of macroscopic material properties using SPT.

Keywords: small punch test, creep-resistant steel, cast steel, nickel alloy, zirconium

Acknowledgements

The research was conducted as part of the 7th edition of the Implementation Doctorate Program of the Ministry of Science and Higher Education.

Integrated Design of Nanostructured Coatings: Interfaces, Architecture and Functional Surfaces

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Abstract

The long-term performance of components operating under friction, high temperatures, or aggressive environments does not depend solely on the intrinsic properties of a coating material, but rather on how the coating is designed as an integrated system. surface engineering based on nanostructured coatings provides a powerful toolbox to tailor functionality through controlled manipulation of interfaces, internal architectures, and surface reactions.

In this invited lecture, an integrated design approach for nanostructured coatings developed using PVD magnetron sputtering technologies will be presented, based on selected examples from our research group. The presentation will be organized around three main design levels. First, strategies to control the coating–substrate interface will be discussed, focusing on the use of interlayers, diffusion barriers, and compositional gradients to promote adhesion, mechanical compatibility, and thermal stability. Second, we will examine the internal architecture of the coating, showing how multilayer designs, nanocomposite concepts, and nanoscale doping can be used to tailor load-bearing capacity, oxidation resistance, and damage tolerance. Finally, we will focus on the top surface and the coating–environment interface, where the formation of tribolayers, passivation films, and adaptive surface layers plays a decisive role in governing friction, wear, environmental response, and surface-driven functionalities such as antibacterial behavior.

Throughout the lecture, these design strategies are supported by the analysis of process–structure–property–performance relationships using complementary spectroscopic, microscopic, and diffraction techniques. Representative examples include self-lubricating nanocomposites, oxidation-resistant CrAlN-based coatings, and Ag-doped or Ti-alloy coatings for biomechanical and biomedical applications, illustrating the versatility of the proposed design approach

Keywords: nanostructured coatings, surface engineering, PVD magnetron sputtering, interface engineering, functional surfaces

Development of Functional Biomaterials Featuring photo and Thermo-Responsiveness

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Abstract

The bone implant industry has expanded significantly and is projected to exceed 7 billion by 2027. The development of functional biomaterials that replicate the structural and mechanical characteristics of native bone while overcoming limitations of current implant materials (metals) remains critical. To address this, biodegradable polymer-ceramic composites have been developed as an alternative. These materials enable minimally invasive delivery via injection and rapid in situ curing upon UV exposure, forming mechanically stable implants with potential for gradual biodegradation.
Novel UV-responsive macromonomers were synthesized from dilinoleic diol and lactic acid, followed by formation of polypseudorotaxanes through complexation with α-cyclodextrin (α-CD). Composite formulations were prepared by incorporating N-isopropylacrylamide (NIPAM) and hydroxyapatite (HAp) at varying concentrations. Mechanical properties were evaluated by compressive testing, while cytocompatibility was assessed using MG-63 cells.
Formulations containing 0-60 wt.% HAp were evaluated for photocuring, rheology, mechanical performance, and cytocompatibility. Mechanical testing showed compressive strength of 10.65 MPa and modulus of 10.47 MPa, with elastic behavior at 19-20% strain. MG-63 studies showed 85% viability, confirming cytocompatibility.
The developed α-CD-complexed macromonomer composites exhibit UV and thermoresponsive behavior, tunable rheology, efficient photopolymerization, enhanced mechanical performance, and good cytocompatibility. HAp incorporation maintains mechanical and biological performance without compromising injectability and processability, supporting minimally invasive applications. These materials show strong potential as injectable, in situ dual-curable systems for bone tissue engineering.

Keywords: injectable implants, bone reconstruction, UV curing, thermo gelling

Acknowledgements

This work was supported by „New biomaterials based on supramolecular and thermosensitive polymer networks", UMO-2023/49/B/ST11/04005.

NIR-Responsive Cu-Doped ZIF-8 Coatings on Laser-Textured Ti-6Al-4V for Targeted Antimicrobial Action Against MRSA

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Abstract

Orthopedic implant infections caused by multidrug-resistant bacteria, particularly methicillin-resistant Staphylococcus aureus (MRSA), pose a persistent clinical challenge. Here, we present a multifunctional surface-engineering approach that combines laser-induced microtexturing of medical-grade Ti-6Al-4V alloys with near-infrared (NIR)-responsive copper-doped zeolitic imidazolate framework-8 (Cu/ZIF-8) coatings. Different surface patterns were made on the biomaterial using a Yb fiber laser. Using a one-pot solvothermal method, Cu/ZIF-8 was uniformly deposited on shark-skin and heart-shaped laser-textured surfaces, yielding well-defined polyhedral crystals confirmed by FE-SEM and successful Cu^{2+} incorporation validated by XPS. Under NIR irradiation, these coatings achieved over 90% reduction in both Gram-negative (Escherichia coli) and Gram-positive (S. aureus, including methicillin-sensitive (MSSA) and MRSA strains and clinical isolates) bacterial populations within 3 h, with sustained antibacterial effects up to 24 h. The enhanced efficacy arises from synergistic mechanisms: localized photothermal heating, accelerated Cu^{2+} release, and reactive oxygen species generation, which collectively disrupt bacterial membranes and induce oxidative stress. Importantly, cytocompatibility assays with Saos-2 osteoblast-like cells demonstrated preserved cell viability and metabolic activity over 14 days, indicating that antibacterial performance is achieved without compromising osteointegration. This work provides a strategic platform for NIR-activated, infection-resistant orthopedic coatings that combine topographical surface cues and smart Cu/ZIF-8 functionality to prevent MRSA-related implant infections.

Keywords: orthopedic implants, titanium alloys, antibacterial, photothermal, MRSA

Antibacterial Coatings Deposited with Micro-Arc Oxidation on Hydrostatically Extruded Titanium Dedicated for Biomedical Applications

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Abstract

Fabrication of antibacterial coatings containing silver nanoparticles (Ag-NPs) has been recognized as the effective way to limit the microbial activity on the surface of biomaterials. Although there is a number of ways to produce the Ag-doped coatings, one of the most promising is the micro-arc oxidation (MAO). The MAO method gained a considerable popularity in terms of producing antibacterial surfaces due to its simplicity in embedding proper elements into the coating's microstructure directly from the electrolyte, among them nanoparticles, in order to improve the functional properties such as antimicrobial performance.

In this work, the influence of Ag-NPs addition on microstructure, biocompatibility, antibacterial effect and tribological properties of MAO coatings produced on plastically deformed (multi-pass hydrostatically extruded) titanium was investigated. The Ag-doped coatings were fabricated with MAO method and phosphate-based electrolyte with suspended Ag-NPs.

The plan-view SEM and cross-sectional TEM investigations supported by phase and chemical analysis revealed a uniform distribution of the Ag-NPs on the upper coating's surface and their presence close to the porosity. The coatings with small Ag-NPs content present a good biocompatibility (L929 fibroblasts), however, a cytotoxic effect may occur for higher Ag concentrations (>1 g/l). Antimicrobial effect against E. coli, S. aureus and P. gingivalis visibly increases with Ag-NPs addition. The level of Ag ions release, confirmed with ICP-MS method, remains at a safe level for the human organism. Tribological tests, carried out in artificial saliva at 37°C with ball-on-disc regime (alumina ball used as a counterface) confirmed a positive effect of Ag-NPs on reduction of coefficient of friction and wear rate of the MAO coatings.

Keywords: micro-arc oxidation, titanium, Ag nanoparticles, antibacterial coatings

Acknowledgements

This research was financially supported by the National Centre for Research and Development of Poland, grant number LIDER13/0175/2022.

3D-Printed Metal Implants – The Influence of Plasma-Assisted Post-Processing on Cleaning Efficiency and Biological Response

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Abstract

DMP (Direct Metal Printing) technology enables the precise production of metal components with complex geometries, such as implants. Postprocessing is a key challenge, often ineffective in removing powder residue or causing significant volume and weight losses in the printed pieces. The aim of the study was to improve the quality of implants through oxygen and argon plasma cleaning, and to assess the effectiveness of particle removal and the impact of processing on the biological response using bone-forming cells.

The samples were printed using DMP technology from titanium alloy powder (LaserForm® Ti Gr23 A) with a particle diameter of up to 40 µm on a ProX DMP 320 3D printer. The samples were divided into two groups: 1) samples without sandblasting and 2) samples sandblasted after manufacturing. The sandblasting process was carried out using an abrasive in the form of glass microbeads with a diameter of 70–110 µm, delivered through a nozzle with a diameter of 8 mm and operating pressure of 6-8 bar. Samples from both groups were steam sterilized. The cleaning process of the prints was performed using the ion etching method with high-frequency plasma (RF PACVD). During the etching process, the samples are located directly on the electrode. The following analysis were conducted: imaging using scanning electron microscopy – surface topography and composition analysis (EDS), surface roughness, mass change analysis, in vitro assessment of the biological response in osteogenic cells.

The results showed that plasma cleaning is an effective method for cleaning and surface modification of metallic components manufactured from the Ti-6Al-4V alloy using the DMP technology. It enables effective cleaning without mass loss (and thus without weakening the designed printed structure and its mechanical properties), while simultaneously cleaning and developing the surface, activating it, and achieving a very good biological response of osteoblast-like osteogenic cells.

Keywords: ion eaching, custom-made implants, osseointegration, 3D bioprinting

Degradation of Titanium Biomedical Materials under Simulated Inflammatory Conditions

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Abstract

Standard evaluation of biomedical titanium corrosion resistance is performed in typical biological solutions such as physiological saline (0.9% NaCl) or phosphate-buffered saline (PBS). However, these solutions omit complexity of the human body environment, for example the presence of reactive oxygen species generated by immune cells during inflammatory reactions. Here, we present the inflammatory corrosion behavior of commercially available titanium biomaterials, as well as that of novel, experimental alloys fabricated in the Ti-Mo system. First, the results of standard electrochemical and ion release tests in the inflammatory fluid are discussed together with post-exposure microscopy nanometric oxide film analysis by TEM observations of FIB-prepared specimens. This approach provides and insight into the extent of metal dissolution and oxide growth after a given exposure time in inflammatory fluid. To investigate the kinetics of dissolution under controlled electrochemical conditions, atomic emission spectroelectrochemistry (AESEC) was employed. Overall, the results obtained allowed us to propose pathways for suppressing the degradation of titanium biomaterials under simulated inflammatory conditions.

Keywords: titanium, biomaterials, degradation, corrosion

Acknowledgements

This research was funded by National Science Centre, Poland under Sonatina 7 grant (2023/48/C/ST11/00085).

Development of Fine-Grained Biomedical Zinc Alloys: Processing Challenges and Microstructural Stabilization

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Abstract

Zinc alloys are promising candidates for load-bearing, biodegradable medical implants. However, they require significant improvements in strength and thermal stability. While grain refinement typically strengthens materials, ultrafine-grained zinc alloys can exhibit an inverse Hall-Petch effect, leading to material softening driven by grain boundary-mediated deformation.

To overcome this, current investigations focus on complex chemical compositions coupled with rapid solidification (RS) techniques. Incorporating multiple alloying elements mitigates chemical segregation and yields uniformly distributed nanometric intermetallic phases. For example, rapidly solidified Zn–0.33Li–0.44Mn–0.45Mg alloy exhibits ultrafine grains stabilized by Mg2Zn11 precipitates. These precipitates stabilize grain boundaries, preventing coarsening during thermal exposure. This microstructural control yields exceptional properties, including YS exceeding 390 MPa and UTS above 500 MPa.

Translating these achievements into realistic production requires moving beyond laboratory-scale severe plastic deformation towards scalable pathways like melt spinning combined with hot extrusion. Developing a novel Zn-Ag-Cu-Mn-Mg-Ca-Zr system presents distinct metallurgical challenges. Completely dissolving intermetallic phases containing Ca and Zr demands massive superheating prior to melt spinning. The resulting RS ribbons are then consolidated via hot extrusion, offering an industrially viable method to tailor the microstructure and limit grain boundary mobility.

This presentation synthesizes recent advancements in zinc alloy processing, highlighting how the correlation of microstructural features with advanced micromechanical analysis paves the way for optimized, high-strength Zn alloys in critical bioresorbable applications. Additionally, unusual difficulties encountered with the LiZn4 phase identification and false-positive cytotoxicity evaluations will be discussed.

Keywords: zinc alloy, electron microscopy, mechanical properties, plastic processing

Acknowledgements

This research was funded in whole or in part by National Science Centre, Poland, under Grant UMO- 2023/51/D/ST11/00486 "High-strength complex zinc alloys with an enhanced thermal stability for biodegradable implant application.

Analysis and Comparison of Selected Machine Learning Methods in Prediction the Thermal Fatigue Strength of Materials

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Abstract

The research problem addressed in this thesis is the development and comparison of machine learning models and the analysis of their potential application in testing the thermal fatigue strength of materials. A particular challenge is working with a very limited dataset, which significantly increases the risk of overfitting—a situation in which the model adapts fully to the training data while achieving very poor results on the test set, ultimately rendering it useless for potential implementation in a production environment.

Keywords: componthermal fatigue, boosting algorithms, Gaussian processes, strength of materials, small datasets, SHAP

Prediction System Architecture for the Influence of Initial Defects on Damage Propagation in Impact-loaded Hybrid Structures

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Abstract

Fibre-metal laminates (FMLs) are hybrid structures that combine fibre-reinforced composite layers, which offer significant in-plane properties, with metal layers that ensure out-of-plane performance. However, the metal–composite interface, which is an adhesive bond, is the weakest part of the structure and is particularly vulnerable to out-of-plane loading. Because of the complex structural response to impact loading and the complex interaction between defects and the structure, it is important to assess the influence and significance of defects within the structure. Therefore, a proposal for a predictive system has been developed, aiming to estimate the likely progression of damage in the laminate, particularly when delamination occurs at the layer interface. This approach relies on both quantitative and qualitative analyses, including visual and ultrasonic inspections of impact-induced delaminations in FML structures with simulated delaminations. The system aims to identify the direction of damage progression and the likely expansion of the damaged area caused by delamination, thereby enhancing understanding of the mechanical behaviour of fibre-metal laminates.

Keywords: artificial intelligence, effect of defect, fibre-metal laminates, impact damage, predictive system

Multiscale Fracture Analysis of Thin Films and Coatings Based on Molecular and Continuum Modelling Approaches

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Abstract

Titanium nitride (TiN) thin films are widely used in demanding applications such as implantology due to their high biocompatibility and mechanical strength. However, their columnar nanostructure, formed during PLD and PVD deposition processes, increases their susceptibility to crack initiation and propagation under mechanical loading. To better understand these mechanisms, this work proposes a multiscale numerical framework with a strong emphasis on Molecular Dynamics (MD) simulations, supported by experimental characterization and continuum FE modelling.

At the nanoscale, MD simulations enable detailed analysis of atomic-scale processes such as defect evolution, decohesion and crack initiation within TiN and at film–substrate interfaces. These simulations provide direct conection to macroscopic fracture parameters, including traction–separation relationships and interfacial strength, which are transferred to higher-scale models.

The continuum-scale modelling is based on the digital material representation concept, integrated with cohesive zone (CZ) and the XFEM models. Parameters determined on the basis of MD ensure that the continuum parameters remains physically reasonable, while allowing for a replication of the columnar morphology and local inhomogeneities. Thin films deposited on different substrates are characterized using nanoindentation and electron microscopy to determine mechanical properties for the simulation purposes.

By combining atomistic insights with experimentally calibrated continuum simulations, the proposed framework enables predictions of cracking and delamination in complex TiN thin-film systems across multiple length scales.

Keywords: thin films, coatings, molecular dynamics, cohesive zone, extended finite element method, digital materials representation

Acknowledgements

This research was funded in part by National Science Centre, Poland grant no. 2024/53/B/ST8/00808. We gratefully acknowledge Polish high-performance computing infrastructure PLGrid (HPC Center: ACK Cyfronet AGH) for providing computer facilities and support within computational grant no. PLG/2025/018413.

Machine Learning Interatomic Potentials for Metallic Glasses: CuZrAl Case Study

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Abstract

Interatomic potentials are a cornerstone of atomistic simulations, enabling the exploration of structure–property relationships in complex materials. However, for metallic glasses, their intrinsically disordered atomic structure and vast compositional space make the development of accurate, transferable potentials particularly challenging. In this work, we present an efficient computational strategy for constructing machine learning interatomic potentials (MLIPs) tailored to metallic glasses, demonstrated on the Cu–Zr–Al system.
Our approach integrates a physically motivated Lennard-Jones surrogate model with advanced sampling techniques, specifically swap Monte Carlo, to generate representative amorphous configurations spanning an exceptionally wide range of thermodynamic states. These configurations are subsequently refined using single-point Density Functional Theory (DFT) calculations, significantly reducing the need for extensive ab initio datasets while preserving high accuracy. The MLIP trained on this dataset accurately reproduces structural, dynamical, energetic, and mechanical properties, achieving performance comparable to established semi-empirical methods such as the Embedded Atom Method, while offering improved flexibility and transferability. Importantly, the proposed methodology addresses key bottlenecks in data generation and model generalization, paving the way for scalable and data-efficient ML-driven materials modeling. This work highlights how the integration of physics-based modeling, advanced sampling, and machine learning can accelerate the discovery and design of metallic glasses and other disordered materials, aligning with emerging AI-driven computational strategies in materials science.

Keywords: machine learning interatomic potentials, metallic glasses, CuZrAl alloys, atomistic simulations, density functional theory, Monte Carlo, materials informatics, AI in materials science

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Inverse Identification of Constituent Properties in Conductive Composite materials: Percolation in Carbon Ceramics

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Abstract

Electrically conductive ceramic–carbon composites are used in battery electrodes, EMI shielding, resistive heating, sensors etc. When sustainable biochar from biomass is the conductive filler, effective electrical conductivity is governed almost exclusively by percolation. Most studies report only the macroscopic conductivity and provide no information on the in-situ properties of the biochar phase after high-temperature sintering.This work develops an efficient 3D random resistor-network (RRN) model that permits interfacial effects. The model is embedded into an inverse identification framework combining a Gaussian Process (GPR) surrogate, Genetic Algorithm optimizer, and bootstrapping for uncertainty quantification. Experimental conductivity data from organoclay–biochar composites sintered at 850–1050 °C are used to retrieve electrical conductivity of biochar and apparent densities of both constituents.The analysis reveals a pronounced temperature dependence: biochar apparent conductivity rises sharply from 3.08 S/m to 44.25 S/m, ceramic matrix density decreases slightly from 1.86 g/cm^3 to 1.62 g/cm^3, and biochar apparent density increases from 0.38 g/cm^3 to 0.59 g/cm^3. The methodology enables true in-situ characterization of constituent properties and directly links them to manufacturing parameters — a clear advantage over conventional ex-situ techniques.By integrating RRN with machine-learning techniques (GPR surrogate and Genetic Algorithm), the framework overcomes the prohibitive computational cost of direct numerical methods (FEM/FVM) in high-contrast percolation problems while providing reliable uncertainty bounds. This practical, single-platform tool supports the design of low-emission, locally sourced functional ceramics and extends inverse modelling in effective transport of composites.Future work will focus on refining the conduction model, including effective-medium approximations, particle anisotropy, higher-order geometries, and segregation effects.

Keywords: inverse problems, effective electrical conductivity, carbon ceramics, biochar, Gaussian Process Regression, percolation, sustainable composites

Selective Recovery of Critical Materials from End-of-life Batteries

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Abstract

End-of-life batteries are increasing rapidly worldwide, posing significant risks to both the natural environment and human health. At the same time, they represent an important secondary source of critical raw materials such as lithium, cobalt, nickel, and manganese. Despite growing awareness and increasingly stringent regulations, conventional battery recycling technologies remain limited by high process costs and insufficient sustainability.

This presentation reports our recent findings on novel processes for the recovery of valuable metals from a range of waste battery types. The proposed approaches demonstrate high selectivity toward target elements while maintaining flexibility with respect to varying feedstock compositions. These characteristics highlight their potential suitability for industrial implementation and their contribution to more efficient and sustainable battery recycling pathways.

Keywords: battery recycling, e-wastes, energy storage, reuse of materials

Engineering Nanostructured TiO_2 for Efficient Solar-Driven Hydrogen Evolution

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Abstract

The European Green Deal aims to achieve climate neutrality by 2050, requiring a rapid transition from fossil fuels to alternative energy carriers. Hydrogen is regarded as one of the most promising options due to its carbon-neutral character, as its reaction with oxygen produces only water. Therefore, the development of sustainable technologies for renewable hydrogen production is of high scientific and technological relevance.

One environmentally friendly route to hydrogen generation relies on photoactive materials capable of splitting water under solar illumination. Since the pioneering work of Fujishima and Honda in 1972, titanium dioxide (TiO_2) has remained a benchmark material for photocatalysis (PC) and photoelectrocatalysis (PEC). However, despite decades of research, the efficiency of TiO_2-based systems is still insufficient for large-scale application, making further material optimization necessary.

TiO_2 can be fabricated in various nanostructured forms, including nanopowders and anodically formed nanotube or nanoporous arrays, providing a significantly increased surface area. Nanostructuring enhances PC/PEC performance and enables further functionalization. Common strategies include coupling TiO_2 with noble-metal cocatalysts such as Pt, Ag, or Au, as well as noble-metal-free approaches like semiconductor sensitization or self-doping. This contribution demonstrates how rational modification of nanostructured TiO_2 improves PC and PEC water-splitting efficiency by promoting effective charge-carrier separation.

Keywords: hydrogen evolution, TiO_2, photocatalysis, photoelectrocatalysis

Role of the Microstructure of Ceramic Proton and Mixed Conductors

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Abstract

Microstructure influences the properties of many materials. So far, the surface and interfaces in semiconductors, metals, and their junctions have been studied intensively, resulting in unprecedented progress in electronic technologies. Also, in ionic- and mixed ionic-electronic conducting materials, it has generally been agreed that grain boundaries are critical to device performance. Many attempts have been made to improve grain-boundary characteristics, though aligning interfaces in bulk proton-conducting oxides has not yet been reported.

In this work, we present the results of the templated-grain-growth ceramic processing route of the $Ba(Zr,Ce,Y)O_{3-\delta}$. This process is driven by the difference in surface free energy between the template and the matrix grains during processing. Because of that, the matrix grains should be fine, while the template crystals should be relatively large and have anisomeric shapes. Barium titanate [1] and $BaZr_{0.1}Ce_{0.7}Y0.1Yb_{0.1}O_{3-\delta}$ [2] templates were manufactured using molten-salt synthesis. The former took the form of nanorods, while the latter were rectangular plates. Further sintering of the template crystals with fine-grained barium cerate-zirconate ceramic powder resulted in compact ceramics with varying degrees of grain orientation.

Keywords: proton-conducting ceramics, microstructure, grain boundaries, aligning

Acknowledgements

The research was financially supported by the National Science Centre (NCN) in Poland within the project 2024/55/B/ST11/01911.

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Engineering $LaCeO_3$ Perovskite Thin Films: From Controlled Fabrication to Catalytic Efficiency

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Abstract

This research project investigates the fabrication of thin lanthanum cerate (LaCeO3) perovskite films using Pulsed Laser Deposition (PLD) to develop high-quality functional materials for advanced catalytic applications, specifically focusing on gas sensing and photocatalysis in both liquid and gaseous phases.The methodology utilizes a dual-track approach for target preparation, employing two complementary techniques: sol-gel synthesis and reactive milling. Following deposition, a comprehensive structural and morphological characterization of the films was conducted. Analytical techniques included X-ray Diffraction (XRD) for phase identification, Atomic Force Microscopy (AFM) for topographical analysis, and Scanning Electron Microscopy (SEM) for surface morphology. Additionally, the internal microstructure was examined via cross-sectional Transmission Electron Microscopy (TEM).This systematic characterization enabled the optimization of laser ablation parameters and the identification of films with superior structural integrity for subsequent catalytic performance testing. The findings demonstrate that precise control over deposition conditions allows for the modulation of the films' morphology and surface development. Ultimately, the study confirms that tailoring these microstructural features is critical to enhancing the functional and catalytic efficiency of LaCeO3 perovskite thin films.

Keywords: PLD, perovskite LaCeO3, functional thin films, catalytic properties

Dual-Spectral Design of Porous Anodic Alumina for Tunable Colored Passive Radiative Cooling

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Abstract

Passive radiative cooling requires materials that simultaneously achieve high mid-infrared (MIR) emissivity within the atmospheric transparency window (8–13 um) and minimal solar absorption, all while ensuring scalable fabrication. Porous anodic alumina (PAA) is a promising dielectric platform due to its intrinsic phonon-mediated infrared emission and electrochemically tunable nanostructure. However, achieving independent control of the visible photonic response and MIR emissivity within a single PAA architecture remains a significant challenge.

In this work, we demonstrate dual-spectral control of PAA photonic structures integrated on aluminum (Al) substrates using charge-controlled sinusoidal pulse anodization (SPA). Periodic modulation of the anodization voltage produces well-defined photonic stop bands (PSBs) in the visible range, enabling tunable structural coloration. Crucially, this is achieved while preserving an average MIR emissivity of up to 0.99 within the 8–13 um window. Thermal performance analysis reveals that the colored PAA architectures achieve a significant sub-ambient temperature reduction of 8.3 K and a cooling power of 82.01 W/m² (at hc = 6 W m⁻² K⁻¹). Systematic pore widening induces a progressive blue shift of the PSB, revealing distinct mechanisms governing spectral position and coherence, while MIR emissivity remains robust as confirmed by constant-voltage reference samples.

Furthermore, investigating the role of the Al substrate demonstrates how interfacial impedance matching governs the efficiency of infrared thermal emission. These results establish anodic alumina as a scalable, multifunctional platform for independently engineered optical and thermal functions, paving the way for the development of aesthetic, color-designed radiative cooling surfaces.

Keywords: passive radiative cooling, porous anodic alumina, sinusoidal pulse anodization, photonic stop bands, structural coloration, mid-infrared emissivity, dual-spectral control

Effect of Deposition Temperature on the Microstructure of W-Cr Thin-Film Material Libraries

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Abstract

Refractory alloys are essential materials for extreme-environment applications such as aerospace technologies, nuclear energy systems, and high-temperature industrial processes, where performance is governed by microstructural stability. Conventional bulk alloy development is time-consuming and costly, motivating the use of thin-film material libraries as a high-throughput approach for alloy discovery. By incorporating continuous compositional gradients on a single substrate, these libraries enable rapid assessment of phase stability and structure-property relationships. A major challenge lies in transferring thin-film results to bulk materials, as Physical Vapor Deposition (PVD) produces alloys in different thermodynamic and kinetic states compared with bulk processing routes such as arc melting or powder metallurgy. These differences influence grain size, phase formation, and microstructural evolution. This work focuses on understanding microstructural control in high-melting-point alloys through systematic variation of substrate temperature during deposition. Compositionally graded thin-film libraries are employed to study the response of alloy compositions to changes in deposition temperature. Tungsten-chromium (W-Cr) is chosen as a model system because of its extremely high melting point, excellent oxidation resistance above 20% chromium, and relevance to fusion energy and high-temperature coating applications. The findings provide insight into linking thin-film behavior to bulk alloy design with controlled microstructures.

Keywords: refractory alloys, thin-film material libraries, W-Cr alloys, magnetron sputtering, microstructural evolution, Substrate temperature effects

High-Temperature XRD and Cr-ion Implantation Studies of Cr and Cr/Al Coated Zircaloy-4 for Nuclear Applications

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Abstract

Following the Fukushima Daiichi disaster, global research efforts intensified around the development of Accident Tolerant Fuel (ATF) systems1. These new types of nuclear fuel cladding materials are designed to prevent the oxidation of zirconium during severe incidents like a Loss of Coolant Accident (LOCA), reduce cladding degradation and lower the amount of heat released during emergency core cooling (ECC) procedures. Zirconium alloy cladding with a protective chromium (Cr) coating is considered one of the promising candidates, largely due to its relatively short timeline for deployment in nuclear power plants2.

In this work, structural and thermal studies of a Cr and Cr/Al-coated zirconium alloy are presented. Furthermore, coated samples have been implanted with Cr ions at ambient temperature, 350°C and 600°C, simulating different reactor operation conditions. High temperature X-ray diffraction (HTXRD) in vacuum over a temperature range from RT to 1100°C, revealed the temperatures corresponding to the formation of oxide phases, which are >200°C and >600°C for the uncoated and Cr-coated samples, respectively. SEM and TEM characterisation of the sub-surface in Cr-coated specimen after HT-XRD revealed Fe segregation, formation of Zr(Fe,Cr)2 Laves phase and nano-bubbles at the former Cr/Z4 interface. Moreover, TEM results of Cr-ion implanted Cr and Cr/Al coatings are presented, comparing dislocation density in ion-implanted zone.

Keywords: ATF, irradiation damage, TEM

Acknowledgements

This study has been financed via National Centre for Research and Development project POLKOR/1/ATFCladding/2/2023.

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Deposition of EVA-based Composite Coatings by Pulsed Electron Beam Method

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Abstract

Polymer-based composite coatings offer an effective route to tailor surface functionality while preserving the bulk properties of the substrate. Among solvent-free deposition methods, pulsed electron deposition (PED) is particularly attractive due to its broad compatibility with complex target materials and its ability to provide precise control over coating growth. In this study, PED is used to fabricate ethylene–vinyl acetate (EVA)-based composite coatings from targets containing 2 wt% carbon nanotubes (CNTs) or halloysite nanotubes (HNTs), selected as model conductive and non-conductive tubular fillers, respectively. Depositions are performed under various N2 background pressures, corresponding to different electron beam power conditions.

The results show that the nature of the filler strongly influences both ablation behavior and the morphology of the resulting coatings. Neat EVA produces smooth and continuous films, whereas EVA/HNT coatings exhibit surfaces densely populated with spherical particulates whose size distribution and number density vary systematically with process pressure. In contrast, EVA/CNT coatings develop a markedly different, three-dimensional architecture composed of nanotube agglomerates, with their surface coverage decreasing as the pressure increases. This trend indicates that conductive fillers promote a different transfer pathway and suggests more efficient selective filler transfer at higher beam power.

A particularly important aspect of the study is the application of AFM-IR, which enables chemical identification at the nanoscale. AFM-IR reveals localized absorption bands characteristic of HNTs within individual surface features. This provides direct evidence that halloysite is transferred during PED and clarifies how it is incorporated into the polymer coating.

The findings reveal the critical influence of filler properties on ablation dynamics and identify PED as an effective method for tailoring polymer-based composite coatings.

Keywords: pulsed electron beam deposition, EVA, composite coatings

Adhesion Characteristics of Polypyrrole Coatings Modified with Bulky Organic Dopants

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Abstract

Abrasion resistance is a key parameter determining the functional performance of polypyrrole coatings deposited on electrode substrates in biomedical applications, charge storage systems, and anticorrosion protection. The mechanical stability of such coatings directly affects their durability, structural integrity, and operational reliability. In the study, the abrasion resistance of polypyrrole coatings was evaluated using tribological testing in a ball-on-disc configuration with a tribometer. The results revealed significant differences in wear resistance between the analyzed sample variants, confirming the strong influence of composition and surface modification on the tribological properties of the materials.
Analysis of friction coefficient curves enabled clear identification of coating failure points for most variants. Morphological observations of wear tracks and profilometric analyses indicated that the dominant wear mechanism was abrasive - adhesive in nature. The wear scars were relatively shallow but wide, which is characteristic of soft, conductive polymer coatings. Furthermore, the average volumetric wear of heparin-modified samples was lower compared to unmodified samples, demonstrating the beneficial effect of surface functionalization on tribological performance. These findings highlight the importance of composition and structural design in optimizing the wear resistance of polymer coatings for advanced functional applications.

Keywords: polypyrrole, electrodeposition, abrasion resistance, large organic dopant, heparin

Effect of Laser Interference Heating on Amorphous Fe-based Ribbons

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Abstract

Intensive research is currently being conducted into technologies that make it possible to produce materials with properties practically unattainable for conventional crystalline alloys. A special place among such materials is occupied by iron-based amorphous glasses in the form of ribbons, whose structure is characterized by the absence of long-range atomic ordering. This type of configuration is obtained primarily by very rapid cooling of the molten alloy, which effectively suppresses both nucleation and growth of crystalline phases. As a result, a material with an amorphous structure is formed, exhibiting favourable soft magnetic properties. At the same time, appropriate heat treatment can enable partial crystallization of metallic glasses, thereby improving their properties, including both magnetic and mechanical ones. Thus, precise, induced crystallization of the amorphous matrix leading to the formation of a nanocrystalline phase makes it possible to significantly increase resistance to brittle fracture while simultaneously maintaining, and often even enhancing, the soft magnetic properties of the ribbons. In this work, the effect of surface laser heating (SLH) on amorphous Fe-based alloy ribbons was investigated. Scanning (SEM) and transmission electron microscopy were used to study structural changes. New insight into the devitrification of the amorphous ribbon structure was provided, and an enhanced response of the ribbons in terms of their soft magnetic properties was demonstrated by means of the Magneto-Optic Kerr Effect (MOKE) measurements. These studies have shown that SLH can be a clean (no need for chemical cooling media), efficient, and single-stage process.

Keywords: laser interference heating, amorphous Fe-based alloys, ribbons, thermal processing, microstructural modification

Acknowledgements

The work was co-financed by Faculty of Metals Engineering and Industrial Computer Science and as part of the Excellence Initiative – Research University AGH University of Krakow project, no. 417379. Thanks for help with laser processing of ribbons to Mr. Jakub Turbak.

The Use of a Manual Welding Laser to Fabricate Braze-Welded Joints

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Abstract

This paper will focus on brazing galvanized steel using a manual welding laser. The research focused on macro- and microstructures as well as mechanical properties. Significant difficulties were encountered in achieving complete filling of the space between butt-jointed 1.5 mm thick sheets. Selecting appropriate parameters and brazing both sides of the sheet ultimately enabled the creation of a complete joint. The braze joint can have a highly diverse microstructure, largely determined by process parameters and the extent to which the joined material (steel) melts. The extent of damage to the zinc layer was also examined. The mechanical properties in terms of tensile strength of the (full) joint are better than those of the brazed material.

Keywords: braze-welding, laser welding, galvanized steel

Impact of Friction Stir Processing on the Microstructural Evolution and Cavitation Erosion Performance of AlSi9Mg Aluminum Alloy

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Abstract

This study investigates the influence of friction stir processing (FSP) on the microstructure, mechanical properties, corrosion resistance, and cavitation erosion behaviour of cast AlSi9Mg alloy. Optical and scanning electron microscopy revealed that FSP transformed the coarse dendritic as-cast structure into a refined, equiaxed microstructure with uniformly distributed silicon and intermetallic particles. The process eliminated casting porosity and produced a fully dynamically recrystallized stir zone with a high fraction of high-angle grain boundaries.

These microstructural modifications led to significant improvements in mechanical performance. Yield strength, ultimate tensile strength, and microhardness increased as a result of grain refinement strengthening described by the Hall–Petch relationship and the uniform dispersion of hard phases that impede dislocation motion. Electrochemical tests indicated enhanced corrosion resistance of the FSP-treated alloy, evidenced by a shift toward more positive corrosion potentials and lower corrosion current density. This improvement is attributed to the refined and homogeneous structure, which reduces susceptibility to localized corrosion.

Cavitation erosion experiments demonstrated that the ground FSP surface exhibited the lowest mass loss and erosion rate. Increased hardness and reduced surface roughness limited bubble nucleation and pit formation, improving resistance to cavitation damage. In contrast, the rough as-cast surface showed more severe early-stage degradation. Overall, the combined effects of grain refinement, strengthening, and surface smoothing achieved through FSP significantly enhance the durability of AlSi9Mg alloy in aggressive operating environments.

Keywords: FSP, cavitation, corrosion, microstructure

Mapping Laser-Microstructure Interactions in Metals, Compounds and Multicomponent Alloys through Concept Graph and Vectorless RAG Techniques

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Abstract

The optimization of laser processing for multicomponent alloys, intermetallics, and pure metals requires the proper understanding of the complex multi-scale process-structure-property relationships. This work presents a unified physics-informed framework integrating qualitative concept discovery with quantitative extraction. The methodology includes Concept Graph analysis and a Hierarchical Vectorless Retrieval-Augmented Generation (RAG) systems for efficient knowledge discovery. Domain-specific concepts are extracted from abstracts using LLMs; alloy notations and laser parameters are normalized to build hybrid co-occurrence and semantic similarity graphs. GraphSAGE embeddings, trained via contrastive learning guided by shortest-path distances, identify emerging research directions through semantic novelty, predicted property enhancement, and experimental feasibility. Concurrently, the vectorless RAG system analyzes full publications without embedding overhead using multi-stage heuristic retrieval, regex-based quantitative parsing, and hierarchical document trees. The framework extracts more than 200 physical parameters, including laser power, volumetric energy density, stacking fault energy, yield strength, and phase-field variables. A three-tier summarization engine and unified physical quantity classifier link extracted values to material systems (HEAs, AlSiMgZr, TiB2 composites). Advanced visualization generates sunburst hierarchies, chord diagrams, and knowledge networks; statistical robustness is ensured via bootstrap confidence intervals, modularity analysis, and permutation testing. This framework bridges hypothesis generation with data-driven validation, enabling efficient literature navigation, microstructure evolution prediction, and physics-informed digital twins for next-generation laser additive manufacturing.

Keywords: laser additive manufacturing, multicomponent alloys, concept graph, vectorless RAG, process-structure-property relationships, physics-informed machine learning, microstructure evolution

Acknowledgements

This work was supported by the National Science Centre, Poland (UMO-2021/42/E/ST5/00339).

Probing Liquid Alloy Nanoparticle Composition Using Plasmon EELS in a TEM

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Abstract

Mapping the composition of liquid binary alloy nanoparticles in TEM at elevated temperatures remains a major experimental challenge. Conventional analytical techniques such as EDX require high electron doses and are often impractical under in situ heating conditions. In this work, we address this challenge using low-loss electron energy loss spectroscopy (EELS) to determine the composition of a liquid binary alloy nanoparticle at relatively low electron doses. As a model system, we investigate a 53 nm Sn-Ge Janus nanoparticle heated in TEM from a temperature of 250 to 750 °C. Low-loss EELS spectral images were acquired at 50 °C intervals during heating, enabling determination of temperature-dependent shifts of both volume and surface plasmon peak positions across the nanoparticle.

To quantitatively relate plasmon energy shifts to alloy composition, we employed the free-electron Drude model combined with the Zen's law. The composition of the liquid Sn-Ge alloy, determined from the temperature dependence of the volume and surface plasmon energies in the Sn-rich region, showed good agreement with independent EDX measurements and with the liquidus line of the Sn-Ge phase diagram, confirming the reliability of the approach. In contrast, the Ge-rich region developed a thin liquid shell over a solid core, enabling temperature-controlled tuning of its surface plasmon resonance from 9.75 to 10.25 eV (≈121-127 nm, deep-UV range).

Keywords: nanoparticles, phase transformations, electron energy loss spectroscopy, alloys, transmission electron microscopy

Acknowledgements

This research was supported by the National Science Centre, Poland, under project no. 2021/43/B/ST5/00320.

Role of Tool Geometry in AA5xxx–AA7xxx Friction Stir Welded Joints: Microstructure and Properties

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Abstract

Friction stir welding (FSW) is a solid-state joining process. The geometry of the FSW tool has a crucial influence on plasticised material flow in the stir zone and on the amount of heat generated, which directly determines the microstructure and properties of the joints. In particular, the pin profile plays a key role in controlling deformation and material mixing conditions.

This work investigates the effect of pin geometry on the microstructure, mechanical properties, and corrosion resistance of AA5083–AA7075 friction stir welded joints. Three pin geometries were analysed: a threaded tapered, Whorl, and Triflute. Optimal process parameters and joint configuration resulted in defect-free welds.

Microstructural analysis revealed clear differences in stir zone morphology depending on tool geometry. In all joints, a fine-grained structure formed due to dynamic recrystallization and a banded structure resulting from material mixing was observed. Microstucture analyses showed alternating bands of both base alloys, while additional mixed-composition bands were identified in the Triflute joint. Texture analysis indicated also possible occurrence of static recrystallization, particularly for Whorl and Triflute pins.

Mechanical properties and microstructure were strongly dependent on deformation intensity and heat input. The most pronounced grain refinement and highest tensile strength were achieved using the Triflute pin, attributed to higher deformation intensity and favourable thermomechanical conditions. The Whorl pin promoted more uniform mixing but resulted in reduced strength. The highest corrosion resistance was obtained for Whorl and Triflute joints.

In conclusion, pin geometry is a key factor controlling the microstructure, mechanical properties, and corrosion resistance of AA5083–AA7075 FSW joints, and its optimisation enables improved joint performance.

Keywords: friction stir welding, tool design, dissimilar aluminum alloys, microstructure, properties

Acknowledgements

This work was supported by the statutory research funds (no. 16.16.110.663) of the AGH University of Krakow.

HPT Processed Cu-Mo Nanocomposites as an Interlayer for Active Brazing in Thermal Management Systems

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Abstract

Effective thermal removal is a challenging issue in many industrial applications, including high-power electronics, electrical vehicles, structural components and many others. It is limited by the lack of materials that simultaneously offer high thermal conductivity and proper coefficient of thermal expansion (CTE). Cu-Mo composites exhibit promising thermal properties which makes them suitable for such applications. However, in addition to proper thermal properties, good bondability with other system components is also required.

In the present work, a successful attempt has been made to join nanostructured Cu-Mo composites with metal (Cu) and ceramic (SiC) materials, using active brazing with CuSil-ABA active alloy. For this purpose, nano-grained Cu-Mo composites with thickness of ~0.5 mm were produced by high pressure torsion (HPT) with 200 turns from commercially available Cu-Mo laminates (1.1 mm thick). The nano-grained Cu-Mo composite (with the grain size of 30 and 20 nm for Cu and Mo, respectively) acted as an interlayer between a Cu substrate and a SiC, with the active braze alloy placed at the interfaces to enable bonding during active brazing at ~850°C. Good interfacial bonding was achieved with both Cu and SiC without any cracks or delamination. Mechanical testing revealed that the joints without the interlayer failed at ~60 MPa within the braze, while the use of a Cu-Mo interlayer increased shear strength to ~140 MPa and shifted fracture to the SiC substrate. In addition, active brazing affected the microstructure, causing coarsening of both Cu grains (to ~100 nm) and Mo particle (to ~80 nm), which is expected to be beneficial for thermal conductivity. These results demonstrate that nano-grained Cu-Mo composites are effective interlayers for active brazing, offering improved mechanical reliability. The developed approach is promising for such applications as heat sinks or electrode assemblies operating under high thermal and electrical loads.

Keywords: Cu-Mo nanocomposites, high pressure torsion, joining, active brazing

Micropillar Compression Study of a Titanium Coating Matrix Reinforced with Ti–TiC Satellite Particles Deposited by Cold Spray

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Abstract

Titanium and its alloys exhibit relatively low wear resistance, which often leads to galling and increased wear rates. One effective approach to improve their performance is the incorporation of a hard secondary phase, forming a metal matrix composite that can be applied either in bulk form or as a coating. In this study, pure titanium powder was blended with Ti–TiC satellite particles and deposited using cold spray. The deposition process was carried out at two temperatures: 900°C and 1100°C. The coatings were characterized using scanning electron microscopy (SEM), hardness measurements, and phase analysis by X-ray diffraction (XRD). Micropillar compression tests were performed to investigate the local mechanical response and deformation behaviour of the titanium matrix. In addition, the in-flight particle velocity was calculated, and its influence on the resulting microstructure was analysed, with particular emphasis on the deformation of the titanium matrix.

Keywords: titanium, titanium carbide, cold spray, satelliting, metal-ceramic

Influence of the Substrate's Topography on the Chitosan/Bioglass Coatings Deposited on Titanium Alloy Ti-13Nb-13Zr

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Abstract

Among the various surface treatments used in implantology, bioactive coatings are also employed. Their role can focus on enhancing mechanical properties (particularly wear resistance) as well as improving biological response. Electrophoretically deposited chitosan/bioactive glass coatings have great potential due to their beneficial bioactivity, biocompatibility, and corrosion resistance in the human body's environment. Nevertheless, they also exhibit low adhesion to the titanium substrate. Therefore, various approaches are investigated. Among these are surface pretreatments, such as shot peening and chemical etching. These methods can increase coating adhesion; however, they may also influence surface topography. Because the chemical composition, roughness, and wettability of the substrate affect biological response and implant acceptance, it is crucial to investigate how the substrate influences the coating's topography and, in turn, its bioactivity.

In this work, chitosan/bioglass coatings were electrophoretically deposited onto the biomedical titanium alloy Ti-13Nb-13Zr, which was subjected to various surface treatments (mechanical and chemical). The influence of the initial modifications on the coatings' adhesion, topography, wettability, and bioactivity was investigated.

Keywords: titanium, bioactive coatings, electrophoretic deposition, biomaterials

Acknowledgements

This research was supported financially by the National Science Centre, Poland, under the grant OPUS 23 (2022/45/B/ST5/03398).

Effect of Air Plasma Exposure on Surface Degradation and Microstructure Evolution of Al2O3/Cu Composites

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Abstract

Degradation of copper plasma torch electrodes determines its service lifetime, particularly in application for waste treatment using reactive air or steam plasma. To improve their performance, the Al2O3/Cu composites, combining the excellent electrical and thermal conductivity with microstructural stability and strength at high temperature are examined. The aim of this study is the investigation of the effect of air plasma exposure time on surface degradation and microstructure evolution of Al2O3/Cu composites.
Three grades of Al2O3/Cu composites (C3/30, C3/80 and C3/11-M) delivered by CEP - Compound Extrusion Products GmbH, Germany, were examined. Samples were exposed to air plasma for 1 and 8 h in the test facility BaCon at TU Freiberg, Germany. Surface morphology, microstructure and chemical and phase composition were examined using LM, XRD, SEM, EBSD and EDS.
The LM and SEM surface analysis shows that after 1 h of air plasma exposure the brittle and spalling oxide scale formed on every composite. The XRD analysis revealed that the scale consists mainly of CuO with minor amounts of Cu2O. The oxide scale retained on the largest surface area of C3/11-M, showing its higher adhesion. After 8h of plasma exposure the scale residues were thicker and spallation was enhanced. SEM and EBSD analysis showed that plasma exposure induced grain growth in the subsurface area of C3/30 and C3/80, while the microstructure of C3/11-M seems to be unchanged.
It was determined that surface degradation under air plasma occurs mainly due to oxidation. With prolongation of plasma exposure the scale growths and its spallation is more intense. The C3/11-M composite exhibits the highest scale adherence and microstructural stability, thus demonstrating enhanced resistance to air plasma-induced degradation.

Keywords: Al2O3/Cu composites, plasma exposure, microstructure

Acknowledgements

The study was performed within the M-ERA.NET project ArcAMAT. The research was funded by the National Science Centre, Poland, grant no Nr DEC-2023/05/Y/ST11/00236.

Materials and Technological Design of Dental Implants and Prosthetic Restorations in the Context of the Industry Integrated Idea 5.0 and the 6×E Principles of Expectations as a Paradigm of Materials Engineering

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Abstract

The civilizational progress has been inseparably linked with the development of materials currently designed in accordance with the 6×E principle of expectations, which constitutes a paradigm of materials engineering and is supported by modelling based on the digital twin idea (DTI) at the Materials 4.0/5.0 level. The unquestionable progress in manufacturing is associated with the Industry 4.0/5.0 model, which, however, is inadequate. The Author's Industry Integrated Idea 3×I 4.0/5.0 model covers two planes—technological and consumption—through products that connect people from two groups: producers and consumers. The horizontal factors of industrial transformation include materials, cyber-physical factors, ecology, and economics, which determine the market attractiveness of every product.

The design and production centre of dental prosthetic restorations requires the application of the 3×I 4.0/5.0 assumptions encompassed by the models of Dentistry 4.0/5.0 and Materials 4.0/5.0. Metallographic and mechanical test results of dental prosthetic restorations are presented, as well as porous or surface-textured Author's implant-scaffolds manufactured from Ti alloys using selective laser sintering, and surface layers such as Al_2O_3 or TiO_2 deposited by atomic layer deposition. These layers prevent the diffusion of metal atoms from the substrate of prosthetic restorations into the ceramic veneering layer or stimulate the proliferation of human osteoblasts on the surface and inside the pores of Ti alloy implant-scaffolds. The Author's model of liquid-phase-assisted sintering is presented, ensuring complete minimization of technological pores, guaranteeing up to a 2.5-fold increase in the mechanical properties of the product, and minimizing waste in accordance with the 10×R butterfly model of circular practices.

An integral part of the lecture is the premiere presentation of the Author's book "Engineering Materials with the Fundamentals of Material Processing Technologies".

Keywords: paradigm of materials engineering 6xE, Industry Integrated Idea 3×I 4.0/5.0, 10×R butterfly model of circular practices, design and production centre of dental prosthetic restorations and implant scaffolds, book premiere presentation

PVD Antibacterial Coatings: Challenges, Perspectives and Opportunities

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Abstract

The intensified globalization means a wider spread of various pathogenic microorganisms. At the same time, there is a growing demand for infection control across various sectors of the economy. This phenomenon causing growing interest in area of new material solutions which limit pathogen transmission. Recent scientific achievement in nanocomposite materials and the rapid development of thin-film deposition technologies have opened up new possibilities for designing surfaces with antibacterial properties. This paper presents the results of own research on new developments in antibacterial coatings produced by high power impuls magnetron sputtering (HiPIMS), which can reduce microbial transmission in water filtration processes and public spaces. The review composite antibacterial coatings based on metal oxides and metals, focusing on the challenges and opportunities presented by the generation of these materials was made. Particular attention is focused to ensuring multifunctionality and improving long-term stability.

Keywords: composite coatings, bactericidal properties, multifunctionality, long-term stability, magnetron sputtering, HiPIMS

TWIP/TRIP Effects in Metastable Beta Titanium Alloys

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Abstract

This study presents the processing, microstructural characterization, and mechanical response of metastable titanium-based alloys produced by arc melting, with particular emphasis on deformation mechanisms such as TWIP and TRIP. TWIP (TWinning Induced Plasticity) refers to plastic deformation mediated by mechanical twinning, whereas TRIP (TRansformation Induced Plasticity) is associated with stress-induced phase transformations, typically to martensitic products. The aim of this study was to investigate the relationship between microstructure evolution, phase constitution, and mechanical behavior during deformation, as well as to assess the potential of these alloys for applications requiring high strength, ductility, strain hardening, and damage tolerance.

The Ti32Nb and Ti12Mo alloys were fabricated in a laboratory-scale arc furnace and subsequently examined in the as-cast condition as well as after uniaxial tensile deformation. The tensile results confirmed a favorable combination of strength and ductility, characteristic of metastable titanium alloys exhibiting TWIP/TRIP-like behavior. The stress–strain response showed extended work-hardening, which is consistent with progressive microstructural rearrangement during deformation. Overall, the combined use of arc melting, microscopy, tensile testing, and XRD provided a coherent description of the structure–property relationships in the investigated titanium alloys. The present findings highlight these alloys' potential as powder feedstock for additive manufacturing, with arc-melted ingots serving as precursors processed via ultrasonic atomization into powders evaluated for key AM properties.

Keywords: twinnind induced plasticity, transformation induced plasticity, metastable beta titanium alloys, AM powders

Effect of Cooling Rate on Microstructure and Properties of as-Cast Alloys synthesised via the Suction Casting Process

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Abstract

Casting conditions play a crucial role in determining the microstructure and mechanical properties of alloys. One of the most important parameters is the cooling rate during solidification. In the suction casting process, the alloy is melted using an electric arc and subsequently injected into a copper mould due to the pressure difference between the main chamber and the reservoir vacuum. This enables rapid filling of the mould cavity, reducing casting defects and improving structural homogeneity. In addition, the copper mould's high thermal conductivity promotes efficient heat extraction, resulting in relatively high cooling rates. Several factors influence the cooling rate during the casting process, primarily by affecting heat transfer between the alloy and the mould. One of the most important parameters is the mould temperature. Both the casting size and the temperature of the mould cooling system can significantly modify the cooling rate, ranging from approximately 1×10^1 to 5×10^2 °C s^{-1}.
The present work investigates the influence of cooling rate on the microstructure and selected properties of multicomponent alloys including heat-resistant metal-matrix-composites produced by the suction casting.

Keywords: suction casting, solidification, cooling rate, mechanical properties

Acknowledgements

The authors gratefully acknowledge the funding by National Center for Research and Development, Poland, under grant LIDER XIII – Development of the manufacturing and deposition technology of metal-ceramic nanocomposite coatings for the structural reconstruction of heat-resistant nickel-based superalloys (Project no. 0036/L-13/2022).

Plasma Induced Surface Degradation and Microstructural Evolution of LPBF Manufactured CuCrZr Alloy

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Abstract

Copper-chromium-zirconium (CuCrZr) alloys produced via Laser Powder Bed Fusion (LPBF) are of significant interest for applications requiring high thermal conductivity and mechanical strength in harsh environments as plasma. This study investigates the surface degradation and near surface microstructural evolution of LPBF-manufactured CuCrZr alloy exposed to air, N2 and CO2 plasma. The LPBF process parameters were optimized with 200 W laser power and heated platform up to 200 °C. The optimization resulted in a low porosity of approximately 1%, consisting of lack of fusion pores. The as-built samples were subjected to a heat treatment: solution annealing at 1000 °C for 1 hour, followed by aging at 480 °C for 6 hours.

The microstructure was comprehensively characterized using SEM, TEM, and STEM combined with EDS. In the as-built condition, a cellular structure, characterized by the segregation of Cr and Zr to the cell walls was observed. After heat treatment, numerous nanometer-sized Cr precipitates and Zr oxides formed along cell walls.

The heat-treated samples were exposed to N2, CO2, and air plasma for 1 hour in the test facility BaCon at TU Bergakademie Freiberg. The exposure led to the formation of Cu oxide layers and the appearance of numerous splatters caused by the redeposition of droplets from electrode material. The thickest oxide scale was observed on samples exposed to the air plasma, whereas in the N2 plasma the thinnest scale was formed. Furthermore, TEM and STEM-EDS investigations revealed that the plasma interaction significantly affected the near-surface layer, resulting in severe grain refinement. These findings provide valuable insights into the microstructural stability and degradation mechanisms of additively manufactured CuCrZr components subjected to plasma exposure.

Keywords: laser powder bed fusion, CuCrZr, plasma degradation, microstructure characterization

Acknowledgements

The study was performed within the M-ERA.NET project ArcAMAT. The research was funded by the National Science Centre, Poland, grant no Nr DEC-2023/05/Y/ST11/00236.

Designing High-Entropy Refractory-Metal-Based Nitride Coatings through Plasma Kinetics and Thermodynamics

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Abstract

High-entropy nitride coatings are widely considered a breakthrough concept for next-generation protective materials, promising exceptional hardness, thermal stability, and resistance to extreme environments. Yet a fundamental question remains. Is configurational entropy truly the governing factor, or do chemistry, defects, and growth conditions play a more decisive role?

In this talk, we present a complex view on the design of multicomponent nitride coatings synthesised by magnetron sputtering, with particular emphasis on High Power Impulse Magnetron Sputtering (HiPIMS). The highly ionised plasmas generated in HiPIMS can fundamentally alter thin-film growth, enabling dense microstructures, tailored defect populations, and access to metastable phases far from equilibrium.

Using refractory Cr–Hf–Mo–Ta–W–N coatings as a model system, we demonstrate that coating performance emerges from a complex interplay between plasma conditions, elemental interactions, and defect chemistry. While entropy contributes to phase formation, it is the control of nitrogen vacancies, element-specific effects, and ion-driven growth processes that ultimately dictate mechanical properties and thermal stability.

Thermal exposure to extreme temperatures reveals that stability is not universal, but highly sensitive to composition and defect evolution. These findings challenge the conventional "entropy stabilisation" paradigm and instead point towards a more general design strategy based on the whole Gibbs free energy.

Keywords: high entropy ceramics, thin films, magnetron sputtering, refractory metals

Comparison of Microstructure, Mechanical Properties and Irradiation Resistance of Inconel 617 Produced by Additive Manufacturing vs Traditional Methods

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Abstract

Inconel 617 is a solution-strengthened nickel-based alloy, which is commonly used in industrial applications. Inconel 617 exhibits very good high-temperature strength and creep resistance. Therefore, the material can find application for components exposed to a harsh environment in Generation IV nuclear reactors. In addition, Inconel 617 was qualified by the American Society of Mechanical Engineers (ASME) as a structural material, primarily for heat exchangers in Generation IV nuclear reactors. The preparation of components from Inconel 617 is quite complicated due to significant work hardening. Thus, the preparation of Inconel 617 using additive manufacturing techniques could be a solution. However, the irradiation and creep resistance of Inconel 617 should be studied. In this study, we investigated both Inconel 617 prepared using traditional metallurgical methods and using additive manufacturing. The microstructure of samples produced by different additive manufacturing techniques, such as the directed energy deposition technique (powder or wire feedstock), powder bed fusion, or arc welding. The observations revealed significant differences in grain size and distribution, and the type of carbide precipitates. These factors significantly impacted mechanical properties, which were evaluated using hardness measurements and tensile testing from room temperature up to 800 °C. Moreover, creep tests were carried out on the selected samples. In addition, the samples were ion implanted to evaluate irradiation resistance. This study investigated mechanical and irradiation resistance properties, which are crucial for the application of Inconel 617 alloy in nuclear installations.

Keywords: Inconel 617, additive manufacturing, irradiation resistance, high temperature properties

Acknowledgements

The authors acknowledge the support of the EU OFFERR CreepAlloy project. The project was partially supported by NCBiR grant ATF Cladding, grant agreement DWM/POLKOR/2/2024.

Thermal Properties of Cr/CrAl Coatings for Advanced Accident Tolerant Fuel Systems

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Abstract

The concept of Accident Tolerant Fuel (ATF) gained particular importance following the Fukushima Daiichi nuclear accident. Its primary objective is to enhance the safety of nuclear fuel under severe accident conditions. This approach involves both modifications to the fuel composition and the application of protective coatings on zirconium alloy claddings. In Loss-of-Coolant Accident (LOCA) scenarios, rapid oxidation of zirconium in steam leads to the formation of ZrO_2 and intensive hydrogen generation, posing a significant threat to reactor core integrity. The application of Cr or Cr-Al coatings aims to slow down oxidation kinetics, reduce hydrogen production, and improve the thermal stability of cladding at temperatures reaching 1000–1100°C. However, a critical aspect of their implementation is a thorough understanding of their thermal properties, which directly affect heat transfer under both normal operating conditions and transient states. The aim of this study was to determine the key thermal parameters of Cr and Cr-Al coatings, including the coefficient of thermal expansion, specific heat capacity, thermal diffusivity, and thermal conductivity. The investigations were carried out using simultaneous thermal analysis (STA), high-temperature dilatometry, the laser flash analysis (LFA) and thermoreflectance (NanoTR) method. The obtained results provide essential data for assessing coating performance under both operational and accident conditions in nuclear reactors.

Keywords: Cr/Cr-Al coatings, thermal properties, coating thermal stability, Accident Tolerant Fuel (ATF)

Data-Driven Multi-Scale Simulations of Composite Materials Failure

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Abstract

Because of their inherent computational cost, multi-scale simulations of composite materials are unpractical for complex non-linear material responses.
Data-driven approaches offer the opportunity to address this bottleneck by training surrogate models from a synthetic dataset built using offline simulations. Once trained, the surrogate can substitute the micro-scale BVP resolution of a multi-scale simulation while reducing the computation time. In this work we compare two surrogate models in the case of complex non-linear material responses of composite materials, including failure prediction.
A neural-networks (NNWs) offer a potential of reducing the computation time by more than 5 orders of magnitude. In particular, recurrent neural networks (RNNs) were shown to be efficient and accurate in approximating the history-dependent homogenized stress-strain relationships. However, they have no possibility of extrapolating responses and thus require a large dataset for their training.
A physics informed alternative is the deep material network (DMN) approach which consists in a network of parametrized mechanistic building blocks. During the training process, the DMN "learns" the micro-structure topology from elasticity data. Once trained, the DMN is able to predict nonlinear responses, including for unseen material responses and loading conditions, in a thermodynamically consistent way, ensuring extrapolation capabilities. The DMN is now extended to damage simulations for material failure analysis.

Keywords: data-driven, multi-scale, composites, damage

Acknowledgements

This project has received funding from the European Union's Horizon Europe Framework Programme under grant agreement No. 101056682 for the project "DIgital DEsign strategies to certify and mAnufacture Robust cOmposite sTructures (DIDEAROT)". The contents of this publication are the sole responsibility of ULiege and do not necessarily reflect the opinion of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

Phase Stability Criterions of Cobalt-Free High Entropy Materials

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Abstract

Cobalt-free high-entropy alloys (HEAs) are promising structural materials for nuclear reactor systems due to their excellent properties under high doses of radiation. The extremely high hardness and brittleness of the intermetallic (IM) phase in HEAs have a significant effect on their performance. Consequently, the importance of comprehending the stability of the IM phases is becoming increasingly evident. In this study, the formation rules of IM phases in Co-free HEAs were proposed based on calculations of widely used semi-empirical parameters. Both Co-free refractory HEAs (RHEAs) and regular HEAs that mainly contain 3d transition metals were considered. The semi-empirical parameters include electronegativity difference (ΔX), valence electron concentration (VEC), enthalpy of mixing (ΔHmix) and atomic size difference (δ). In addition, the recent surge in interest in high-entropy oxides (HEOs) as a novel class of ceramic materials can be attributed to the remarkable performance enhancements caused by both the complexity of chemical composition and simplicity of structure. The extensive range of components presents challenges to the implementation of HEOs, rendering it difficult to predict the phase structure prior to the final synthesis. Herein, semi-empirical methods were also utilized to determine the phase stability of rock salt, spinel, perovskite and fluorite structures.

Keywords: high-entropy materials, composition design

High-Resolution X-ray Diffraction Imaging of Crystal Lattice Misorientation in Ni-Based Single Crystal Superalloys

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Abstract

Ni-based single-crystal superalloys are key materials for turbine blades operating under severe thermo-mechanical conditions in aero-engines and gas turbines. Their excellent creep resistance is mainly associated with optimized γ/γ′ microstructure and alloy chemistry, while the elimination of high-angle grain boundaries and crystallographic orientation control further enhance high-temperature performance. However, local crystal lattice misorientation, subgrains and residual stress fields may affect structural integrity and long-term performance.

In this work, high-resolution X-ray diffraction imaging was applied to evaluate the spatial distribution of crystal lattice misorientation in CMSX-4 single-crystal superalloy specimens. The investigated material was directionally solidified at different withdrawal rates.

The proposed approach enables visualization of local lattice misorientation over large areas with micrometre-scale spatial resolution. During stepwise rocking around the Bragg position, lattice regions with slightly different orientations diffracted the X-ray beam at specific angular positions and were recorded by a 2D detector. The resulting misorientation maps revealed a clear relationship between dendritic microstructure and local crystallographic defects. Although increasing withdrawal rate refined the dendritic arrangement, the overall range of internal misorientation remained comparable. Localized misoriented regions were mainly associated with dendrite cores, secondary dendrite arms and structural defects inherited from solidification.

The results demonstrate that high-resolution X-ray diffraction imaging is a powerful non-destructive tool for analysing crystal quality, dendrite-related misorientation and residual stress distributions in single-crystal superalloys. The method may support optimization of directional solidification parameters and provide valuable information for assessing the structural reliability of turbine blade materials.

Keywords: Ni-based superalloys, single crystals, lattice misorientation, X-ray diffraction, crystal quality

Surface Nitriding of Titanium and Its Alloys Powder Particles Via Self-Shearing Reactive Milling for Use as a Feedstock in Additive Manufacturing

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Abstract

While titanium and its alloys are favoured in the medical and aerospace industries for their excellent strength-to-density ratio and superior corrosion resistance, they suffer from inherent surface softness and chemical reactivity. Enhancing these materials with titanium nitride (TiN) coatings is a common strategy to boost their surface hardness, wear resistance and overall durability. Traditional TiN deposition techniques often necessitate elevated temperatures or harsh processing conditions, typically restricting their use to bulk solid substrates. Consequently, there is a growing need for alternative synthesis methods that can operate under milder parameters, specifically those tailored for the surface modification of powder materials.
This study introduces a pioneering approach to surface nitriding using a novel self-shearing reactive milling process conducted under 50 bar of nitrogen. Unlike traditional methods, this innovative technique enables the synthesis of a brittle TiN nanolayer (~500 nm) on Ti, Ti6Al4V, and Ti-5553 spherical powders at ambient temperature without the need for any grinding media. While XRD patterns confirmed the presence of the TiN phase in Ti6Al4V after 10 hours, Raman spectroscopy revealed characteristic TiN spectra from the very early stages of this unique mechanical treatment. Most significantly, the original spherical morphology remains entirely untouched, establishing these powders as a revolutionary, ready-to-use feedstock for the additive manufacturing of functionally graded biomaterials.

Keywords: nitride, reactive milling, self-shearing, functionally graded biomaterials

Effect of Partial Pressure in the Saturation Segments on the Alloy's Chemical Composition and the Kinetics of the Low-Pressure Carburizing Process

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Abstract

The study presents results of research on the effect of changes in chemical composition in the surface layer on the kinetics of the carburizing process at reduced pressure — an aspect of vacuum carburizing that, to the authors' knowledge, has not been systematically investigated before. The 16MnCr5, 17CrNiMo7, and 18CrNi8 alloys were subjected to vacuum carburizing in four variants, with each variant using a different partial pressure in the boost/diffusion segments: 30, 50, and 100Pa. A hybrid process was also conducted, in which the pressure was first reduced to 5Pa and then raised to 100Pa using an inert gas. Glow discharge emission spectroscopy showed that reduced pressure in the holding segments changes the manganese concentration in the surface layer by up to 80%, affecting carbon activity in the austenite and the diffusion coefficient. These changes are detectable at a depth of 0.1mm from the surface — in the presented study this corresponds to 25% of the assumed effective carburized layer thickness. For 16MnCr5, the effective layer thickness increased by 18% relative to the designed value. For 17CrNiMo7 and 18CrNi8, no such deviation was found, despite a comparable change in manganese concentration in the surface layer.

Keywords: carburizing, vacuum, manganese volatilization

Surface-Driven Engineering of Mn/($PdTe_2$, Bi_2Te_3) Interfaces for Spintronic Applications

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Abstract

Topological materials combined with magnetic elements offer a promising route toward low-power spintronics. This work explores Mn-deposited $PdTe_2$ and Bi_2Te_3 – a topological superconducting semimetal and a 3D topological insulator, respectively – to reveal how interfacial Mn modifies their electronic and magnetic properties.

Using molecular beam epitaxy, Mn layers of varying thickness were grown on single-crystalline Bi_2Te_3 and $PdTe_2$. The electronic structure and surface chemistry were probed by X-ray photoelectron spectroscopy (XPS), soft X-ray angle-resolved photoelectron spectroscopy (SX-ARPES), and X-ray absorption spectroscopy (XAS) at the PHELIX beamline (SOLARIS synchrotron).

SX-ARPES (55, 70, 100 eV) revealed significant band structure modifications upon Mn deposition. XPS confirmed Te–Mn bond formation and metallic Bi segregation, along with subtle chemical changes in both tellurides. Depth-resolved XPS (200–1000 eV) mapped the layered composition, while XAS in total and partial electron yield modes captured surface-sensitive electronic and magnetic interactions.

These results demonstrate that Mn-modified telluride junctions enable controlled tuning of electronic and magnetic properties, paving the way for advanced spintronic and low-power memory devices.

Keywords: topological insulators, spintronics, Mn-modified tellurides, synchrotron radiation, interface engineering

Acknowledgements

This project was financed by the National Science Centre, Poland, under research project „Badanie struktury elektronowej i reaktywności powierzchniowej w materiałach hybrydowych na bazie wybranych tellurków”DEC-2023/07/X/ST3/01487.

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Tailoring Surface Topography and Phase Composition of Ti–Au Alloys for Optimized PVD Thin Film Performance

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Abstract

Titanium-gold alloys have recently attracted increasing attention as advanced functional materials due to their unique combination of high strength, corrosion resistance, and potential biocompatibility. However, their application as substrates for physical vapor deposition (PVD) coatings remains insufficiently explored, particularly in the context of surface engineering strategies that enable precise control over coating performance. This study investigates the tailoring of surface topography and phase composition of Ti-Au alloys to optimize the nucleation, growth, and functional properties of laser treated PVD thin films.
PVD coatings were deposited onto the engineered substrates, and their microstructural evolution, adhesion strength, and mechanical performance were evaluated. Particular attention was given to the influence of surface roughness, phase heterogeneity, and interfacial characteristics on coating nucleation density and growth mechanisms. The results demonstrate that both topographical features and phase composition play a critical role in governing coating-substrate interactions, ultimately affecting coating integrity and performance. These modifications were characterized using scanning electron microscopy, and surface roughness analysis to establish correlations between processing conditions and resulting surface states. The findings highlight the importance of integrated surface engineering approaches in designing high-performance coated systems. By coupling laser-induced surface modification with PVD deposition, it is possible to achieve enhanced coating adhesion and tailored functional properties. This work provides a framework for the rational design of Ti–Au-based hybrid systems for advanced engineering and biomedical applications.

Keywords: TiAu, laser treatment, PVD, biocompatibility

Microstructural Evolution of Zinc-Based Alloys After Deformation: The Role of Alloying and Surface Modification

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Abstract

Interest in zinc alloys as bioabsorbable metals has gradually increased since it was discovered that pure zinc has an optimal corrosion rate for bioabsorbable cardiovascular stents. One of the main disadvantages of pure zinc is its insufficient mechanical properties. A wide range of potential zinc alloy systems was considered, mainly binary and ternary alloys. One of the most examined alloying elements is Mg. The presence of an intermetallic phase prevents the recrystallization process in Zn-Mg alloys. However, the higher Mg2Zn11 content is not beneficial for the material's ductility or the uniformity of its corrosion properties. Thus, some modifications to Zn-Mg alloys are needed. For the proposed investigation, the ZnMgMn ternary alloys were chosen.

Materials for investigation were prepared by gravity casting in an argon atmosphere from pure zinc with various Mg and Mn contents (0.1-0.5% wt. for both) and then deformed by hot and hydrostatic extrusion. The deformed material was investigated using XRD (X-ray Diffraction), SEM (scanning electron microscopy), and TEM (transmission electron microscopy). Mechanical properties, including static tensile tests and microhardness measurements, were analyzed. Furthermore, the alloys were subjected to plasma immersion ion implantation (PIII) using oxygen to form an oxide layer. The microstructure of those layers was characterized, and the impact of PIII parameters on the substrate was studied.

Alloying with Mg and Mn improves the mechanical properties of zinc-based alloys. Additionally, hydrostatic extrusion is advantageous for enhancing the plasticity of those alloys. Modulating the contents of both alloying elements and deformation process parameters influences the final properties and enables meeting the demands. The PIII process can form different oxide layers on the surface. However, PIII process parameters must be carefully selected to ensure the stability of the substrate microstructure at elevated process temperatures.

Keywords: bioabsorbable zinc, plastic deformation, EBSD

Acknowledgements

This work was supported by the National Science Centre Polish UMO-2023/51/B/ST11/02814.

Influence of Aluminum Surface Treatment on Mode I Interfacial Fracture Behavior of Fiber Metal Laminates

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Abstract

Fibre metal laminates (FMLs) are a type of hybrid material combining metal layers with fibre-reinforced polymer composites. They offer an attractive combination of low density, high fatigue resistance and good impact performance. However, their overall mechanical behaviour is strongly influenced by the integrity of the metal–composite interface, which in turn depends on the surface condition of the metallic component.

This study aimed to comprehensively assess the influence of various aluminium surface modification methods on the strength of metal–composite joints in peel tests and to provide an in-depth analysis of failure mechanisms, with a particular focus on the metal–composite interface. Mechanical, chemical and electrochemical treatments were applied to modify the surface characteristics of the aluminium, such as roughness, morphology and physicochemical properties, to enhance adhesion and stress transfer between the components. Additionally, the impact of applying primer and sol-gel intermediate layers was examined. Laminates were made of unidirectional carbon-epoxy prepreg with high strength carbon fibres and of aluminium alloy 2024-T3. T-peel test was conducted according to ASTM-D1876 standard.

The results showed that the highest delamination resistance was observed for laminates with chromic acid anodized aluminum with primer and etching with sol–gel treatment. While the lowest resistance was recorded for sulfuric acid anodizing with primer. Aluminium surface modification method significantly affects failure mechanisms. Chemical or electrochemical treatment exhibited predominantly cohesive failure within the composite, indicating enhanced interfacial bonding. In contrast, application of mechanical methods resulted in mixed failure modes involving both interfacial debonding and composite damage. These findings emphasise the importance of effective surface engineering to enhance the delamination resistance and overall performance of fibre metal laminates.

Keywords: surface modifcation, adhesion, failure analysis, fibre metal laminates

Interfacial Engineering of Oil-Water Systems with Carbon Nanostructures for Sustainable Applications

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Abstract

Pristine carbon nanostructures are emerging as sustainable alternatives to conventional surfactants, offering unique amphipathic properties that enable efficient stabilization of emulsions. We demonstrate that pristine graphene flakes possess a true amphipathic nature, arising from their hydrophobic basal planes and hydrophilic edges. Through a combination of wet-chemistry testing, microscopy, and advanced computational methods, we show that this duality allows graphene flakes to form ultrastable water/oil emulsions, with their stabilizing strength governed by the edge-to-surface ratio and tunable via the oil-to-water ratio. These features position graphene as a robust next-generation stabilizer, functional even under extreme conditions such as high pressure, elevated temperature, and saline environments. Complementarily, short and thin pristine carbon nanotubes (CNTs) are revealed as fully recyclable one-dimensional surfactants. Their amphipathicity originates from hydrophilic open ends, limited oxygen-functionalized or vacancy domains, and hydrophobic sidewalls and caps. Experimental and theoretical studies confirm that these structural features enable CNTs to stabilize water-in-oil emulsions effectively. Importantly, their emulsifying strength depends on nanotube size, defect density, and phase ratios, and can be harnessed in practical applications such as paintable, flexible conductive coatings. Together, these findings establish a unifying framework for understanding the amphipathic behavior of pristine carbon nanostructures - from two-dimensional graphene flakes to one-dimensional CNTs - highlighting their potential to revolutionize advanced emulsion technologies with recyclable, green, and high-performance stabilizers.

Keywords: carbon nanotubes, graphene, activated carbon, Pickering emulsions

Phase Composition of AM50 Alloy with Si Addition

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Abstract

Recently, materials from the Mg-Si system have also been intensively studied due to a number of properties offered by the main structural component of these materials, i.e. the Mg2Si phase, such as high melting point, low density, a relatively low coefficient of thermal expansion, high hardness, and a relatively high Young's modulus. It should also be noted that due to the properties of the Mg2Si phase, materials from the Mg-Si system can also be called in situ composites (especially those with higher levels of silicon), in which the reinforced phase (Mg2Si) is formed inside the matrix.

The effects of 4 wt.% of silicon on the microstructure and mechanical properties of AM50 magnesium alloys fabricated by the casting method were presented. New AM50-Si material was gravity cast into a metal mould under the same conditions for comparison. Analyses of the alloys' microstructures were carried out by light microscopy (with differential interface contrast), scanning electron microscopy (with an energy dispersive X-ray spectrometer), as well as X-ray diffraction (XRD). In as-cast conditions, fabricated material was composed of α-Mg solid solution, alpha+gamma eutectic (where gamma is Al12Mg17), Al8Mn5 intermetallic phases and discontinuous gamma precipitates. The AM50-Si material also consisted of the Mg2Si phase. This structural constituent appeared in the form of primary crystals with regular polygonal morphology and an alpha+Mg2Si eutectic in the form of "Chinese script". In the microstructure of the AM50-Si material, the Mn3SiAl9 ternary phase was also identified. The detailed analyses revealed that the new ternary Mn3SiAl9 structural compound caused a reduction in the volume fraction of the Al8Mn5 phase but did not completely replace it. These two phases formed competitively.

Keywords: magnesium alloy, Si, microstructure

Role of Microstructural Constituents in the Liquation Cracking Mechanism of Cast-Ni-Based Superalloys

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Abstract

Ni-based superalloys are widely used in high-temperature applications such jet engines and gas turbines due to their excellent strength, creep resistance, and oxidation resistance. However, their complex chemical composition and multiphase microstructure result in susceptibility to liquation cracking during welding, particularly in the heat-affected zone. Understanding the mechanisms governing this phenomenon is essential for improving weldability and repair technologies of components. This study investigates the mechanism of liquation cracking in selected cast Ni-based superalloys, including IN738LC, C101, and René 77. Characterization of the pre-weld microstructure was performed using light microscopy, scanning and transmission electron microscopy, supported by thermodynamic simulations. These analyses enabled identification of key strengthening phases, including γ′ precipitates, carbides, and borides, and their morphology, distribution, and chemical composition. The results demonstrate that cracking is primarily governed by constitutional liquation occurring at precipitate/matrix interfaces. During rapid thermal cycles associated with welding, partial dissolution of these phases leads to local enrichment of alloying elements and the formation of low-melting eutectic liquid films. The susceptibility to cracking is strongly influenced by the type, size, and distribution of precipitates, as well as their interfacial characteristics and diffusion kinetics. Differences between the investigated superalloys highlight that not only γ′ content, but also the presence of carbides and borides, play a critical role in crack initiation. The findings provide new insight into the relationship between microstructure and weldability of Ni-based superalloys. A comprehensive understanding of liquation mechanisms enables more accurate prediction of cracking susceptibility and supports the development of improved repair and processing strategies for advanced aerospace materials.

Keywords: GTAW, superalloy, microstructure, constitutional liquation

Acknowledgements

The authors gratefully acknowledge the funding by National Centre for Research and Development, Poland, under grant LIDER XIII 0147/L-13/2022 (Development of a technology for

the regeneration of precise castings of nickel superalloys intended for use in the aviation industry).

Thermal Stability and Microstructural Evaluation of Cr and Cr/Al Coated Zirconium Claddings under LOCA Conditions

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Abstract

The safe operation of nuclear reactors depends on fuel systems capable of withstanding both normal conditions and severe accident scenarios. One of the most critical events is a loss of coolant accident (LOCA), during which cooling of the reactor core is reduced. This can lead to a rapid increase in zirconium-based cladding temperature, accelerated oxidation, hydrogen generation, and loss of mechanical integrity, highlighting the need to improve fuel system resilience.

To address these challenges, accident-tolerant fuel (ATF) concepts have been developed. ATF aims to enhance fuel and cladding performance by improving oxidation resistance, reducing hydrogen production, and maintaining structural stability at high temperatures. Among the proposed solutions, protective coatings such as chromium (Cr) and chromium/aluminum (Cr/Al) applied to zirconium alloys have gained significant attention. These coatings act as diffusion barriers and oxidation-resistant layers, slowing degradation processes during LOCA and increasing safety margins.

This study focused on determining key thermal parameters of Cr- and Cr/Al-coated claddings and evaluating their behavior under simulated LOCA conditions. Thermal stability was assessed using non-isothermal heating in air and steam atmospheres with Simultaneous Thermal Analysis (STA). The effect of pre-oxidation on thermal stability kinetics was also examined. Furthermore, light microscopy and scanning electron microscopy (SEM) observations of the claddings were performed after LOCA simulations to analyze microstructural changes. These investigations enabled a preliminary assessment of Cr and Cr/Al coatings as protective solutions for zirconium-based cladding.

Keywords: thermal stability, LOCA, accident-tolerant fue, cladding

Acknowledgements

The project was financed by the National Center for Research and Development (NCBiR) and the Korea Institute of Energy Technology Evaluation and Planning (KETEP) as part of the ATF Cladding project, based on grant agreement DWM/POLKOR/2/2024 (part implemented in Poland).

Electroless Nickel-Phosphorus Coatings for Optical Components

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Abstract

The presented work envolves around research dedicated to electroless deposition of nickel-phosphorus (Ni-P) alloy coatings for applications in optics, such as mirrors in space telescopes or nanosatellites. The developed coating has been applied to the optical components of a constellation of observation nanosatellites operating in Low Earth Orbit (LEO).
The alloy Ni-P coatings were deposited on a 6061-T6 aluminum substrate using the chemical reduction method. Coatings were deposited using varying concentrations of complexing agents, reducing agent and stabilizer in bath at a temperature of 85 °C.
Structure, composition and mechanical properties along with morphology and thickness of obtained coatings were investigated to determine influence of applied conditions. For this purpose, variety of techniques, i.e., X-ray diffraction, scanning electron microscopy equipped with an energy-dispersive X-ray spectrometer, X-ray fluorescence spectrometry, Vickers hardness or scratch test method were utilized.
Changes in concentrations of complexing agents, reducing agent and stabilizer in the bath were determined to influence coating thickness, composition, structure, etc.

Keywords: nickel-phosphorus coatings, electroless deposition, telescope mirrors, nanosatellite

Metallic Core–Shell Microparticles for Heterogeneous, Composite and Functionally Graded Materials

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Abstract

Porous and heterogeneous metallic materials with controlled internal architecture represent a promising direction in the development of advanced biomaterials and functional engineering materials. Core-shell systems enable simultaneous tailoring of surface and bulk properties. This study presents the fabrication and characterization of metallic core-shell microparticles produced using 316L stainless steel, Ti6Al4V alloy, titanium Grade 5, and aluminum as core materials, while tantalum was applied as the shell-forming material due to its excellent biocompatibility and corrosion resistance.

The microparticles were synthesized by mechanical alloying involving surface activation and mechanically driven shell formation. The influence of key technological parameters, including milling speed, milling time, Ta content, and the core-to-shell material ratio, was investigated. The results showed that processing conditions strongly affect the efficiency of core-shell formation, particle morphology, and particle size distribution.

Microparticles with sizes ranging from approximately 50 µm to 150 µm were successfully obtained. Laser diffraction analysis confirmed the significant influence of mechanical alloying parameters on powder homogenization. Microstructural observations revealed the formation of continuous or partially developed Ta shells depending on the core material and milling intensity. The obtained microparticles are intended for the fabrication of heterogeneous and functionally graded composite materials for biomedical, veterinary, and structural applications. Following consolidation and sintering, multi-zone structures with locally differentiated phase composition, porosity, and mechanical properties are expected, enabling the design of materials with tailored stiffness and corrosion resistance.

Keywords: core–shell microparticles, mechanical alloying, tantalum coating, functionally graded materials, heterogeneous materials, powder metallurgy, metallic biomaterials, diffusion processes, composite materials, particle size distribution

Acknowledgements

This work was supported by the Polish National Science Centre (Narodowe Centrum Nauki, NCN) under the research project OPUS-27, no. UMO-2024/53/B/ST11/00431. Conference participation was supported by the GreenMat project, co-funded by the European Union under the program "European Funds for Silesia 2021-2027".

AI-Driven Design of Al–Cu–Fe–Ni–Ti Alloys: Effect of Composition on Structure and Properties

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Abstract

High-entropy alloys (HEAs) are an emerging class of materials characterized by multi-component compositions and high configurational entropy, offering outstanding mechanical, chemical, and thermal properties. However, designing them remains very challenging due to the large compositional space and limited availability of thermodynamic data. Additionally, configurational entropy alone is not always a reliable predictor of phase stability, which complicates the development of effective design strategies. This work introduces a modular, uncertainty-aware machine-learning-based computational framework to accelerate the discovery of new HEAs [1]. This methodology combines physics-informed models, probabilistic approaches, and design heuristics, allowing efficient exploration of high-dimensional compositional spaces. The framework's predictive performance is validated experimentally using an Al–Cu–Fe–Ni–Ti system. From an initial set of 2.4 million candidate compositions, 91 high-confidence alloys were identified. Selected alloys were synthesized by induction melting and analyzed through X-ray diffraction (XRD), scanning electron microscopy (SEM), and differential scanning calorimetry (DSC) to confirm their microstructure, crystal structure, and thermal properties. Furthermore, hardness and magnetic measurements were performed to assess the alloys' applicability. The results show that this platform enables fast, scalable, and interpretable HEA design while explicitly considering predictive uncertainty. This approach provides a strong basis for the rapid discovery and improvement of advanced engineering materials.

Keywords: computational alloy design, multi-component alloys, thermodynamic modeling, phase composition, microstructure, DSC measurements, mechanical properties, magnetic properties

Acknowledgements

This work was funded by the Institute of Metallurgy and Materials Science of the Polish Academy of Sciences as part of a statutory task Z-10/2026, titled "Integrated thermodynamic modeling and experimental validation of high- and medium-entropy alloys for advanced materials design."

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Fabrication of Austenitic ODS Steels with TiB_2 Addition: Effect Mechanical Alloying Time on Microstructure and Mechanical Properties

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Abstract

Oxide Dispersion Strengthened (ODS) steels are advanced materials known for their exceptional high-temperature strength, good corrosion resistance, and excellent stability under irradiation. These properties make them suitable for use in harsh environments, such as nuclear reactors or aerospace applications. ODS steels achieve these properties through the dispersion of fine, stable oxide particles, which act as barriers to dislocation movement, improving mechanical performance. Besides the most common Y_2O_3, which provides dispersion strengthening and enhances creep resistance, elements such as Ti can form stable Ti–Y–O, further refining oxide distribution and improving thermal stability. TiB_2 has been proposed as a strengthening phase due to its high thermal stability and mechanical properties.
The study aimed to analyze the influence of TiB_2 on the microstructure and mechanical properties of austenitic ODS steel. 316L stainless steel and 1 wt.% TiB_2 powders were subjected to mechanical alloying for 5, 10 and 50 h and consolidated using pulse plasma sintering. The microstructure was examined by scanning electron microscopy, while mechanical properties were evaluated by tensile tests and microhardness.
The results showed that milling time significantly affected grain size. Longer alloying led to coarser particles due to agglomeration, promoting a bimodal microstructure after sintering. TiB_2 was located between fine and coarse grains. Depending on their fraction, the mechanical properties varied. The results confirm the effect of ceramic addition on mechanical performance, as shown by strength and microhardness.

Keywords: oxide dispersion strengthened steels (ODS steels), mechanical alloying, pulse plasma sintering (PPS)

Acknowledgements

This research is funded by the National Science Centre, Poland under the OPUS call in the Weave programme (project No. 2021/43/I/ST8/01018).

TiB_2-Modified 316L Steel: Correlation Between Reinforcement Concentration, Corrosion Resistance, and Mechanical Properties

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Abstract

Oxide Dispersion Strengthened (ODS) steels with TiB_2 addition combine the benefits of fine oxide particles and hard ceramic reinforcements to enhance mechanical and thermal performance. The dispersed TiB_2 particles contribute to improved hardness, wear resistance, and high-temperature strength due to their high melting point and excellent stability. Additionally, TiB_2 can act as a grain refiner and barrier to dislocation motion, further enhancing the creep resistance and structural integrity of the steel. This makes TiB_2-reinforced ODS steels promising candidates for advanced structural applications in extreme environments such as nuclear reactors and aerospace systems.
In this study, an attempt was made to characterize the properties of the manufactured materials (316L + TiB2). The design was aimed to obtain an ODS steel with an austenitic matrix, through the formation of in situ Ti-oxides. We produced composites with 316L as a matrix with the addition of 1,3 and 5 wt.% of TiB2. Powder precursors were mechanically alloyed for 5 h, and consolidated using pulse plasma sintering (PPS). The relationship between microstructure and corrosion as well as mechanical properties was evaluated. The results of this work clearly show that the higher the concentration of TiB2, the higher the strength of the composites, but the elongation decreases.

Keywords: oxide dispersion strengthened (ODS) steels, corrosion resistance, mechanical properties

Acknowledgements

This research is funded by National Science Centre, Poland under the OPUS call in the Weave programme (project No. 2021/43/I/ST8/01018).

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Explainable and Supervised Learning models for Optimal Hydrogen Annealing Conditions for Defect-Engineered TiO_2 Photocatalysts

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Abstract

Optimizing hydrogen annealing conditions for TiO_2-based photocatalysts remains a complex task due to the nonlinear interplay between temperature, time, and defect formation mechanisms. In this work, we propose a data-driven approach to identify optimal hydrogen annealing windows for enhanced photocatalytic H_2 evolution using supervised machine learning. A structured dataset was constructed from digitized experimental data, including polymorph type (brookite, anatase, rutile), treatment temperature, duration, and atmosphere, along with the corresponding H_2 evolution rates and pressure.

Tree-based regression models, including Decision Trees, Random Forests, and XGBoost, were employed to capture nonlinear relationships and interactions between process parameters. Given the limited dataset size, model performance was evaluated using leave-one-out cross-validation. Additionally, a physics-inspired feature describing treatment severity was introduced to improve predictive capability.

The models successfully reproduced the characteristic non-monotonic behavior of photocatalytic activity, identifying an optimal treatment regime and hydrogenation times, beyond which performance deteriorates due to defect migration and phase transformations. Feature importance analysis highlights temperature and treatment duration as dominant factors, consistent with defect-driven activation mechanisms reported in the literature. This study demonstrates the potential of supervised learning as a tool for guiding defect engineering strategies in photocatalysis, providing a framework that can be extended to larger datasets and more complex material systems.

Keywords: photocatalysis, machine learning, hydrogen production, TiO_2

Advanced Materials and Low-Emission Manufacturing Technology of Dye-Sensitized Solar Cells

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Abstract

Dye-sensitized solar cells (DSSCs) are considered one of the more environmentally friendly photovoltaic technologies, among others due to the possibility of applying green manufacturing processes. Unlike conventional silicon solar cells, their fabrication requires significantly lower temperatures, which results in lower energy consumption and reduced CO_2 emissions during production. In addition, many active layers can be deposited using printing techniques such as screen printing or inkjet printing, which are less energy-intensive and help reduce technological waste.

This study presents the technology of dye-sensitized solar cells using materials including titanium dioxide and platinum nanoparticles. The surface topography of TiO_2 was analyzed using scanning electron microscopy (SEM). The electrical properties of the fabricated DSSCs were determined based on the measured current–voltage (I–V) characteristics. The porous structure of TiO_2 provides a very large active surface area of the photoelectrode, enabling proper adsorption of dye molecules and efficient absorption of solar radiation. Platinum nanoparticles used at the DSSC counter electrode increase the catalytic activity of the system by accelerating the reduction reaction of redox couples in the electrolyte.

Keywords: low-emission manufacturing technology, dye-sensitized solar cells, nanomaterial

Removing Sulphates From Water Using Self-Supporting Graphene Foams

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Abstract

The removal of sulphate ions from water is an important challenge in water treatment, especially when lightweight, porous and chemically active materials are required. In this study, self-supporting graphene foams were investigated as sorptive materials for sulphate removal from aqueous solutions. The foams were fabricated from a aqueous graphene oxide dispersion. After sonication, the dispersion was cast into a glass Petri dish and dried under vacuum at room temperature. The obtained graphene oxide structure was then exposed to hydrazine hydrate vapour at 30 °C. This treatment induced partial reduction of oxygen functional groups, cross-linking of graphene-based flakes through nitrogen-containing bonds, and gas evolution, which separated the graphene oxide planes and formed a porous, coherent and binder-free foam.
The resulting material consisted of multilayered graphene oxide and reduced graphene oxide flakes forming anisotropically arranged walls and an open lamellar pore system. Owing to its low density, open porosity and stable self-supporting architecture, the foam provides accessible internal surfaces for interaction with dissolved ions.
Sulphate concentration was determined by a gravimetric method based on the quantitative precipitation of sulphate ions as insoluble barium sulphate ($BaSO_4$). A barium sulphate reference solution and a solution collected after contact with graphene foam were analysed. Each 25 cm^3 sample was acidified with hydrochloric acid, boiled, treated with barium chloride solution, filtered, washed and calcined at 900 °C to constant mass. The reference solution contained 1412 mg/L sulphate ions, whereas the solution after sorption contained 396 mg/L. This corresponds to a sulphate removal efficiency of 71.9%. These results demonstrate that self-supporting graphene foams produced from graphene oxide can effectively reduce sulphate concentration in water and may be considered promising porous carbon sorbents for water treatment.

Keywords: graphene foam, graphene oxide, reduced graphene oxide, sulphate removal, water treatment, sorption

Laser Powder Bed Fusion of AZ91E–Ti6Al4V Hybrid Materials: Initial Insights into Thermophysical and Microstructural Behaviour

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Abstract

The increasing interest in lightweight structural materials for advanced engineering applications has intensified research on additively manufactured magnesium alloys and hybrid metallic systems. In the present work, novel LPBF-processed AZ91E-based materials reinforced with Ti6Al4V additions were investigated. Powder mixtures containing 5, 10, and 20 wt.% Ti6Al4V were successfully processed using the Laser Powder Bed Fusion (LPBF) technique. Preliminary investigations demonstrated that even the AZ91E–Ti6Al4V systems without further alloy modification exhibited highly interesting processing behavior and microstructural characteristics. Furthermore, the addition of Sc was found to noticeably improve the printability and stability of the LPBF process.

The study focused primarily on the thermophysical and microstructural characterization of the fabricated materials. Dilatometric investigations were performed in order to determine the coefficient of thermal expansion, identify possible phase transformations, and evaluate dilatational effects potentially associated with internal porosity and structural heterogeneity generated during LPBF processing. The obtained results revealed significant microstructural complexity related to the interaction between the magnesium matrix and Ti6Al4V particles, as well as clear effects of scandium addition on process stability and microstructural evolution.

The presented results constitute an initial contribution toward the development of novel LPBF-processed magnesium-based hybrid metallic systems with tailored thermophysical and microstructural properties.

Keywords: LPBF (Laser Powder Bed Fusion), magnesium alloys (AZ91E), Ti6Al4V reinforcement, hybrid metallic systems

Irradiation Damage in W and WTaCrV from Molecular Dynamics Simulations

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Abstract

Investigation of radiation damage on atomistic level is crucial for understanding its mechanisms and designing the ways it can be mitigated. Experimental observations, such as TEM, are the most reliable, but also the most expensive and time-consuming means of obtaining the information about the irradiation damage in materials. The alternative is to use a variety of modelling techniques, or their combination in a multi-scale modelling approach.
In this work, we used machine-learned interatomic potential in molecular dynamics (MD) simulations of collision cascades in pure tungsten and WTaCrV refractory high entropy alloy as a representation of neutron irradiation. These simulations allowed us to investigate the evolution and morphology of collision cascades as a function of primary knock-on atom (PKA) energy – kinetic energy transferred to the ion by the neutron – and identify the critical energy at which the cascades branch out.
Performing the subsequent analysis of the post-irradiation MD supercells, we have identified the defects induced by irradiation, which for single collision cascades are exclusively Frenkel pairs. Additionally, the distinguishing feature of MD simulations as compared to experiment, is that we can track all individual atoms in the lattice, and therefore – calculate the number of recombinations. Lastly, radial density distribution change from pristine and irradiated samples can be calculated, which shows the extent to which the atomic lattice changes, including the directly unaffected areas of the sample.
Even though MD simulations provide significant insight into the mechanisms of irradiation damage, they are not the final step in the multi-scale approach. The results of MD simulations, such as energy of cascade splitting, number of recombinations and the radial density distribution can be used to parametrize mesoscale models, which allow for much larger simulated sample sizes and larger time scales.

Keywords: tungsten, refractory HEA, molecular dynamics, collision cascades

Plasma-Deposited Nickel-Based Catalytic Thin Films for Carbon Dioxide Hydrogenation

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Abstract

The increasing concentration of CO_2 in the atmosphere has intensified research toward its catalytic conversion into fuels and chemical feedstocks. In this work, we developed conditions for fabrication of nickel-based catalytic thin films via plasma-enhanced chemical vapor deposition (PECVD), enabling precise and uniform deposition on structured supports such as fine meshes. The combination of catalytic films with such supports enhances mass and heat transfer in heterogeneous reactors, helping to overcome limitations associated with conventional powder catalysts.

Nickel-based thin films were deposited in an RF plasma reactor using nickel acetylacetonate as a precursor and argon as a carrier gas. The process was carried out at a discharge power of 60 W, with a precursor partial pressure of 0.02 Pa and a total pressure of approximately 4 Pa. The deposition time was 30 min.

Post-synthesis thermal treatment in air at 400 °C for 1, 2, and 4 h led to the formation of Ni(II) and Ni(III) species, with oxidized nickel accounting for more than 95 at% of the total nickel content. The treatment also influenced the carbon content originating from the acetylacetonate ligand. The film thickness was approximately 390 nm.

Catalytic performance was evaluated in CO_2 hydrogenation in a tubular reactor using an H_2/CO_2 ratio of 4:1 over a temperature range of 100-400 °C. The nickel-based thin films demonstrated promising activity, enabling CO_2 conversion to CH4 and CO. The best performance was observed for the catalyst thermally treated for 2 h, reaching 30% CO_2 conversion and 41% CH4 selectivity at 400 °C.

The results indicate that plasma-deposited nickel-based thin films constitute a promising catalyst for CO_2 conversion; however, further tuning of their composition and structure is needed to improve performance.

Keywords: CO_2, carbon dioxide hydrogenation, nickel-based thin films, plasma-enhanced chemical vapor deposition (PECVD), structured catalytic supports, catalytic thin films

Powłoka z Fazy S Jako Alternatywa dla Azotowania Gazowego

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Abstract

W pracy porównano wpływ azotowania gazowego oraz zastosowania powłoki z fazy S osadzanej metodą PVD na właściwości mechaniczne i tribologiczne czterech stali narzędziowych: 40CrMnNiMo8-6-4, 60CrMoV18-5, X50CrMoV5-2 oraz X38CrMoV5-3. Próbki wstępnie hartowane i odpuszczane w temp. 600 °C poddano dwóm różnym modyfikacjom powierzchni: azotowaniu gazowemu (575 °C, 6 h, potencjał azotowania Kn – 0,18, 0,79 lub 2,18) lub osadzaniu powłoki z fazy S metodą RMS w atmosferze Ar/N_2 (20 lub 40 %N2) lub Ar/N2/CH4 (20 %N2+ 20 %CH4) w temperaturze 200°C lub 400°C. Zbadano budowę fazową (XRD), grubość (LOM oraz SEM), twardość Vickersa (HV0,1) oraz szybkość zużycia metodą kulka–tarcza.

Po azotowaniu gazowym uzyskano warstwy dyfuzyjne azotu o grubości 80–200 µm, złożone z azotków γ'-Fe4N lub ε-Fe2–3N i γ'-Fe4N co zwiększyło twardość od 80 do 100 % w porównaniu do stali hartowanej. Najwyższą twardość uzyskano dla stali X38CrMoV5-3, ok. 1150 HV0,1. Najmniejsza zmierzona szybkość zużycia stali po azotowaniu wynosiła 2,2×10−6 mm3/N·m dla stali azotowanych przy potencjale Kn = 0,79 i była o rząd wielkości niższa w porównaniu do szybkości zużycia stali hartowanej, która wynosiła średnio 2,7×10−5 mm3/N·m.
Powłoki z fazy S miały grubość od 1,6 do 3,6 µm. Twardość stali z naniesioną powłoką z fazy S wynosiła maksymalnie ok. 1150 HV0,1 dla powłoki osadzanej w temperaturze 400 °C w atmosferze zawierającej 40 %N2, co było wartością porównywalną do stali po azotowaniu przy najwyższym potencjale Kn. Dla powłok osadzanych w temperaturze 400 °C obserwowano wytworzenie dyfuzyjnej warstwy azotu w podłożu. Wysoka twardość powłoki oraz fakt wytworzenia podparcia w postaci warstwy dyfuzyjnej w podłożu spowodował zmniejszenie szybkości zużycia dla stali z naniesioną powłoką z fazy S do 2,42 × 10−7 mm3/N·m.

Keywords: stale narzędziowe, azotowanie gazowe, powłoki z fazy S, twardość, zużycie tribologiczne

Insights into Barrier Properties of Fe-Doped Amorphous SiOC-Based Coatings for Nuclear-Reactor Applications

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Abstract

Silicon oxycarbide (SiOC) is a promising amorphous material for protective coatings intended for harsh nuclear-relevant environments, due to its thermal stability, chemical durability and potential resistance to irradiation-induced degradation. In this work, Fe-doped SiOC-based coatings were developed on AISI 316L stainless steel. The incorporation of iron into the polymer-derived coating is intended to enhance its barrier function during the high-temperature conversion of organosilicon precursors into amorphous ceramics. In particular, Fe modification is expected to limit the diffusion of substrate-derived elements during pyrolysis, thereby reducing expansion of interfacial oxide/spinel layer and improving coating continuity, adhesion and long-term protective performance.

The coatings were prepared from sol-gel-derived organosilicon precursors, deposited by dip-coating and pyrolysed in an inert argon atmosphere. Their morphology, thickness and interfacial quality were examined by electron microscopy, while phase composition and amorphicity were assessed using X-ray diffraction. Raman and FTIR spectroscopy were applied to evaluate the chemical structure of the SiOC network and the influence of Fe incorporation on polymer-to-ceramic transformation.

The obtained results provide insight into the relationship between Fe modification, interfacial stability and barrier properties of amorphous SiOC-based coatings. Particular attention is given to the suppression of substrate-element diffusion during thermal treatment, which is a critical factor for maintaining coating integrity under nuclear-relevant conditions. The study supports Fe-doped SiOC coatings as a promising platform for protective barriers for high-temperature and radiation-tolerant applications.

Keywords: SiOC, PDCs coatings, sol-gel, FTIR, Raman spectroscopy, electron microscopy

Acknowledgements

This research was funded by the National Science Centre, Poland, under the SONATINA 7 project no. 2023/48/C/ST11/00025.

Preliminary Studies on Textile Waste-Based Nonwovens for Acoustic Applications

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Abstract

Using waste to produce new materials supports a circular economy. It's estimated that approximately 5 million tons of textile waste are discarded globally each year, and only 1% is recycled. Mechanical recycling is the most common method, as it's the most economical and has the lowest environmental impact. However, mechanical recycling shortens and weakens fibers. It is therefore justified to process textile waste using technologies that enable the processing of raw materials with a diverse structure and into products where the strength aspect is not required.

The aim of the work is preliminary research on obtaining sound-absorbing nonwoven from mechanically recycled textile waste.

This work utilized mechanical textile recycling using a laboratory fiberizing machine. Cotton jeans were fiberized using the lowest possible number of cycles and the highest possible feed roller speed. To produce the nonwoven, the resulting recyclate, in the form of threads and fibers, was first carded on a roller carder with a saw cover, using two passes through the machine. Next, the resulting fleece, with its longitudinal fiber arrangement, was needled on a needle-punching machine. The sound absorption coefficient of the resulting nonwoven fabric was determined using an impedance tube, in the frequency range up to 6400 Hz, in accordance with the PN-EN ISO 10534-2 standard.

For high sound frequencies in the range of approximately 5000-6000 Hz, one layer of nonwoven approximately 2.5 mm thick and with an apparent density of 0.1 g/cm3 demonstrates sound absorption coefficient of 0.2-0.3, while two layers provide absorption of approximately 0.6, three layers provide absorption of approximately 0.8, and four or more layers provide absorption in the range of 0.9-1. The lower the sound frequency, the more nonwoven layers should be combined to increase sound absorption.

Research indicates the high potential for nonwovens made from textile waste as sound-absorbing materials.

Keywords: textile, acoustic applications

Beyond Electro-Fenton: Enhanced Treatment of Textile Wastewater via an Integrated Electro-Oxy-Fenton Process Using Low-Cost Electrode Materials

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Abstract

The study proposes a novel integrated Electro-Oxy-Fenton (EOF) process dedicated to the treatment of textile wastewater using low-cost and commercially available electrode materials. The research involved comprehensive electrochemical investigations aimed at evaluating the applicability of steel as a cathodic material for the oxygen reduction reaction. Three different steel grades were systematically examined to determine their electrocatalytic activity. Electrochemical analyses enabled identification of the optimal potential window ensuring maximized in situ H_2O_2 production. Complementary studies were additionally performed to identify an anodic material capable of controlled iron ion release required for sustaining Fenton-type reactions.

The treatment efficiency of the developed system was evaluated using Reactive Black 5 (RB5), a representative azo dye extensively applied in the textile industry. Particular attention was devoted to assessing the influence of pH, electrode composition, electrolyte type, and process configuration on the degradation kinetics, with emphasis placed on extending the applicability of Electro-Fenton-based systems.

To intensify oxidative degradation pathways, the EOF system was coupled with ozonation, leading to the development of an integrated process. The incorporation of ozone resulted in a pronounced synergistic enhancement of process performance, manifested by a substantial increase in the decolorization kinetic constant over a broad pH range. The observed enhancement was attributed to the simultaneous generation of highly reactive oxidative species through Fenton and ozone-mediated pathways, promoting more efficient degradation of the chromophoric structure.

The proposed integrated EOF process constitutes a promising, economically attractive, and scalable approach for textile wastewater treatment, particularly under operational conditions limiting the effectiveness of conventional Electro-Fenton systems.

Keywords: electrode materials, H_2O_2 electrogeneration, catalytic surfaces

Advanced Cu–C and Ni–C Coatings for Electronic Applications

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Abstract

The aim of this study was to develop technologies for producing functional composite coatings with enhanced thermal conductivity for electronic applications. As efficient heat dissipation is a key challenge in modern electronics, the research focused on innovative material and technological solutions enabling effective thermal management.

The study investigated next-generation metal–carbon composite coatings. Cu–C coatings were fabricated using electrochemical reduction, while Ni–C coatings were deposited by chemical (electroless) reduction. In selected systems, dispersed diamond particles were introduced to further improve the thermophysical properties of the coatings.

The deposited coatings were characterized in terms of morphology, microstructure, thickness, chemical composition, and surface roughness. Adhesion to the substrate was evaluated using scratch testing, and microhardness measurements were performed on metallographic cross-sections by the Knoop method. Additional experiments were conducted to assess the thermophysical properties of the coatings and their stability at elevated temperatures.

The functional performance of the coatings was verified in soldered joints on printed circuit boards using lead-free solders SnCu1 and SAC305. The investigations included solderability tests, wettability angle measurements, microscopic analysis of solder–coating interfaces, mechanical testing of joints, climatic resistance studies, and surface composition analysis using SEM/EDX and XRF techniques.

The results showed good solderability and strong adhesion at the solder–coating interface. For most composite coatings, wetting angles below 40° were obtained, suggesting that no technical issues are likely to occur during joint formation. Furthermore, the mechanical strength of the joints exceeded that of the solder itself. The developed coatings demonstrate strong potential for application in electronic systems requiring effective thermal management.

Keywords: composite coatings, carbon-based coatings, technological properties, electronic applications

Chemical Structure Changes During PED of Monosaccharide Coatings

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Abstract

Although Pulsed Electron Beam Deposition (PED) is increasingly regarded as a viable route for preparing organic thin films, little is known about how this process affects the chemical structure of small saccharide molecules. In this work, glucose monohydrate served as a model monosaccharide for examining PED-induced modifications in its structure and chemical composition.

Glucose monohydrate targets were prepared by cold pressing and deposited on silicon substrates in an argon atmosphere. The process parameters were varied in the ranges of 10–16 kV and 6–14 mTorr. The resulting coatings were examined by optical microscopy, AFM, XRD, and complementary spectroscopic techniques.

The deposited films showed strongly parameter-dependent morphology, with granular and bulky-like surface features. Lower gas pressure promoted the formation of sharper, taller, and more massive structures, indicating a strong influence of deposition conditions on film growth. XRD analysis demonstrated that, although the initial target was crystalline, the deposited coatings were predominantly amorphous.

IR and NMR results further suggest that the electron beam affects the chemical structure of the monosaccharide during deposition, with the extent of these modifications being strongly dependent on the applied process parameters.

Keywords: pulsed electron beam deposition, glucose, chemical structure, NMR

Acknowledgements

This research was funded by the National Science Centre, Poland, within project SONATA-19 (no. 2023/51/D/ST11/00263).

Thermodynamic Properties of the κ-Ag2Mg5 Phase

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Abstract

The Ag–Mg alloys exhibit a wide range of potential applications, spanning from advanced aerospace materials and energy technologies to biomedical uses [1]. This system has attracted considerable research interest due to the unique combination of the constituent elements' properties and the presence of various intermetallic phases. A comprehensive understanding of these intermetallic compounds, including their thermal stability and invariant reactions, is essential for the design of microstructures and, consequently, the resulting material properties [2]. Recent studies on the Ag–Mg phase diagram have refined its description following the discovery and crystallographic characterization of the κ-Ag_2Mg_5 phase [3]. This phase is one of the intermetallic phases that occur in the Mg-rich part of the equilibrium system. It crystallizes in a hexagonal system and forms as a result of a peritectoid reaction [4,5]. Due to the relatively recent discovery of this phase, studies on its thermodynamic properties reported in the literature have been limited to theoretical calculations. With this in mind, the primary objective of this study is to summarize the current knowledge on the κ phase and expand upon it by introducing results of enthalpy of formation measurements determined with the drop dissolution calorimetry technique. Moreover, this work is enriched by results obtained by DSC, SEM, and XRD methods.

Keywords: Ag-Mg alloys, enthalpy of formation, thermodynamic properties, calorimetric measurements

Acknowledgements

This work is supported by the National Science Centre, Poland, for the funding project no. 2021/43/O/ST8/01291 entitled "Thermodynamic properties and structure of Cu-Mg-Ti and Ag-Mg-Ti alloys and their potential to interact with hydrogen" in the years 2022–2027.

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Medium-Manganese Steels as Advanced Lightweight Materials for the Automotive Industry

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Abstract

The growing demand for lightweight structures in the automotive industry is closely related to global efforts aimed at reducing fuel consumption and CO_2 emissions. Medium-manganese steels represent an attractive alternative to aluminum alloys due to their lower production costs and improved recyclability. They also exhibit significant industrial implementation potential because of their compatibility with continuous annealing and thermomechanical rolling processes. Their excellent balance between strength and formability makes them suitable for the production of safety-critical automotive components, such as reinforcements, shock absorbers, and structural body parts. These steels typically contain from 3 to 12 wt.% Mn, which enables the stabilization of retained austenite and the activation of the TRIP effect during deformation.

This study analyzed the effect of intercritical annealing time on the microstructure, retained austenite stability, and mechanical properties of 0.17C–4Mn steel. It was found that extending the annealing time increased the fraction of retained austenite in the steel microstructure from approximately 13% to approximately 29%, which resulted from more intensive diffusion of carbon and manganese. Tensile tests revealed that samples subjected to short-time intercritical annealing were characterized by higher tensile strength (Rm = 1033 MPa), whereas the steel annealed for 300 min achieved greater ductility (A = 22%). X-ray diffraction analysis after deformation demonstrated an almost complete transformation of retained austenite in the short-time annealed sample, confirming the intensive activation of the TRIP effect. The obtained results indicate that appropriate selection of intercritical annealing parameters enables effective control of the relationship between strength, ductility, and austenite stability in medium-manganese steels intended for automotive applications.

Keywords: medium-manganese steels, AHSS, automotive industry, intercritical annealing, microstructure, mechanical properties

Dynamic Deformation Effects on Twinning and Plasticity Mechanisms in TWIP Steel

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Abstract

TWIP steels play a significant role in the automotive industry and other applications operating under severe loading conditions due to their exceptional combination of strength and ductility. In this study, the influence of strain rate on the deformation mechanisms in Fe–21Mn–2.5Al–0.4C (wt.%) steel was investigated. The primary objective was to establish the relationship between dislocation slip, deformation twinning, strain rate, and the temperature rise associated with the conversion of plastic work into heat during deformation.

Microstructural characterization was performed using light microscopy, electron microscopy, and synchrotron analysis. During dynamic tensile tests conducted at strain rates exceeding 170 s^{-1}, temperature evolution was monitored throughout successive stages of deformation, from the onset of strain localization to final fracture. A temperature increase of approximately 250 °C was recorded within the necking region immediately prior to cohesion loss.

The results revealed that increasing strain rate led to a reduction in the volume fraction of deformation twins, while the twins themselves became finer compared with those formed at lower strain rates. The findings contribute to a deeper understanding of the complex thermomechanical phenomena governing the deformation behavior of advanced TWIP steels under dynamic loading conditions.

Further investigations are currently ongoing, as very fine deformation twins may remain undetectable using the available EBSD techniques. In particular, the formation of nanotwins and their bundles presents significant challenges for quantitative characterization and for distinguishing them from mechanically induced twins.

Keywords: TWIP steel, dynamic deformation, twinning, strain rate sensitivity, thermomechanical behavior, nanotwins

Interaction Mechanisms and Wettability Behavior of Molten Al–7Si Alloy on Ti+C Compacted Substrate

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Abstract

Aluminium matrix composites reinforced with carbides such as TiC are of increasing interest due to their enhanced mechanical and thermal properties. In particular, in-situ synthesis enables the formation of fine, well-bonded reinforcement phases directly in the liquid metal.
The study investigates the high-temperature interaction between molten Al-7Si alloy and a Ti+C compacted substrate at 800°C under high vacuum conditions. The wettability of the couple was evaluated using the sessile drop method with non-contact heating and capillary purification procedure. It was observed that an initial non-wetting regime persisted for approximately 150 seconds, after which a reactive wetting stage ensued. During this stage, the apparent contact angle decreased to approximately 60°. The transition to reactive wetting was found to be significantly prolonged, with the quasi-steady state being reached after approximately 960 seconds. This finding indicates that reaction-controlled spreading is strongly influenced by silicon. SEM and TEM characterization revealed that interfacial reactions were dominated by the Al–Si–Ti system, leading to the formation of Ti(Al,Si)3 intermetallic and Si-enriched α-Ti particles. Localized TiC formation was also observed, associated with transient thermal effects at the interface. The results obtained demonstrate that silicon plays a key role in modifying interfacial reactions and wetting behavior, while surface oxides further influence high-temperature interactions. The mechanisms governing interaction during the high-temperature wettability test at the Al-7Si/Ti+C system are also discussed.

Keywords: wettability, sessile drop method, capillary purification procedure, microstructure, aluminium-matrix composite

Acknowledgements

This research was supported by the National Science Centre of Poland within OPUS 22 Project no. 2021/43/B/ST8/03271 in the years 2022–2026.

The Effect of Surface Modification Methods of Ti_6Al_7Nb Alloy on the Biological Response

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Abstract

The surface properties of implants determine the biological response by governing protein adsorption after implantation, which regulates cell recruitment, inflammatory processes, and osseointegration [1-2]. Controlled modification of surface topography, wettability, chemical composition, and surface energy offers a pathway for improving implant performance, yet systematic comparative studies remain scarce [3-5].

Five modification methods applied to Ti6Al7Nb alloy were compared: SF_6 plasma etching, O_2 plasma oxidation, electrochemical oxidation, DLC, and F-DLC coating deposition. Modified surfaces were characterized using SEM, optical profilometry and EDS analysis. Wettability, and surface free energy also were investigated. Biological response was assessed via the Live-Dead assay on Saos-2 cells.

Etching and electrochemical oxidation increased the roughness of the surface. All samples were of hydrophilic nature, with O_2 plasma treatment having the strongest effect on wettability. Saos-2 viability exceeded 90% across all variants; only F-DLC showed a slightly reduced response. The results confirm that diverse surface characteristics can be achieved while maintaining good cellular tolerance.

Keywords: biomaterials, titanium alloys, DLC coatings, plasma treatment, Saos-2 cells, osteointegration

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Evaluation of the Physicochemical and Degradation Properties of Semipermeable Polymeric Membranes Used as Regenerative Dressings

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Abstract

The dynamic development of biomaterials and biomedical engineering contributes to the rapid advancement of modern wound treatment methods, including advanced polymer-based wound dressing materials. Semipermeable polymeric membranes play a particularly important role in regenerative medicine due to their ability to selectively transport gases and fluids, enabling the maintenance of an optimal moist environment within the wound area while simultaneously limiting pathogen access and supporting regenerative processes.

The aim of this study was to analyze selected semipermeable polymeric membranes intended for wound dressing applications and to evaluate the influence of their structure and composition on properties relevant to regenerative medicine. Material characterization was performed using Fourier Transform Infrared Spectroscopy (FTIR), enabling the identification of functional groups and assessment of chemical composition, Scanning Electron Microscopy (SEM) for the analysis of surface morphology and structure, as well as Differential Scanning Calorimetry (DSC) to determine the thermal properties of the investigated systems.

Additionally, hydrolytic degradation studies were conducted to evaluate material stability and their potential behavior under biological environment conditions. The analysis of the obtained results enabled the assessment of relationships between structure, physicochemical properties, and degradation susceptibility of the investigated membranes. The obtained results indicate the potential of the analyzed materials as advanced wound dressings supporting the wound healing process and provide a basis for the further optimization of biomaterials intended for applications in regenerative medicine.

Keywords: semipermeable polymeric membranes, regenerative wound dressings, physicochemical characterization, hydrolytic degradation

Irradiation-Induced Defect Accumulation in WTaCrV Refractory High-Entropy Alloy and Pure Tungsten Under High-Temperature Helium Irradiation

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Abstract

The development of advanced nuclear reactors requires structural materials with high radiation resistance and thermal stability. In future fusion reactors, plasma-facing materials (PFMs) will operate under extreme conditions, including temperatures above 1000 K, high heat loads, and intense irradiation by neutrons and plasma particles. Although tungsten is currently the leading PFM candidate due to its excellent thermal properties, its application is limited by radiation-induced embrittlement and defect accumulation. Therefore, refractory high-entropy alloys (RHEAs) are being explored as alternative materials because of their high mechanical strength and enhanced irradiation tolerance.

This work investigates irradiation-induced defect formation in a novel quaternary WTaCrV RHEA compared with pure tungsten. The materials were fabricated by arc melting and heat-treated to obtain a homogeneous single-phase BCC solid solution. To simulate fusion reactor conditions, samples were irradiated with He ions at temperatures up to 1273 K. TEM observations revealed the formation of large dislocation loops in pure tungsten throughout the irradiation zone. In contrast, the WTaCrV alloy exhibited only fine nanometric loops localized near the peak damage region, indicating suppressed defect clustering and reduced irradiation-induced hardening.

To further study defect evolution, in-situ TEM irradiation experiments were conducted at the JANNuS-Orsay facility using 2 MeV W ions at 1073 K. The results demonstrated substantial differences in defect accumulation between the two materials. In pure tungsten, rapid defect diffusion promoted the growth of large extended dislocation loops, whereas in WTaCrV reduced defect mobility led to the formation of a high density of fine defects. These findings confirm the enhanced irradiation resistance of the WTaCrV RHEA and its potential application as a plasma-facing material for future fusion reactors.

Keywords: defect, refractory high-entropy alloy, high-temperature helium irradiation

Microstructure and High-Temperature Compressive Behavior of a Nb-Ti-Al-Cr Refractory Complex Concentrated Alloy Fabricated Via Mechanical Alloying and Sintering

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Abstract

This work investigates the development and characterization of high-temperature refractory complex concentrated alloys (RCCAs) within the Nb-Ti-Al-Cr system, fabricated via powder metallurgy. The fabrication route involved the mechanical alloying (MA) of elemental powders, followed by conventional sintering. This study aims to elucidate the effects of chemical composition and milling parameters on the microstructure, phase evolution, and mechanical properties of the synthesized alloys. High-purity Nb, Al, and Cr powders blended in two distinct atomic ratios were utilized as starting materials. Powder morphology, phase evolution, and chemical composition were evaluated using scanning electron microscopy (SEM), X-ray diffraction (XRD), and energy-dispersive X-ray spectroscopy (EDS), respectively. High-energy ball milling was performed for up to 120 cycles, and the consolidated green compacts were subsequently sintered at 1400°C. The microstructural features, microhardness, and compressive behavior of the sintered samples were investigated both at room temperature and at elevated temperatures (500°C and 800°C).

The results demonstrate that increasing the number of milling cycles promotes microstructural homogenization and eliminates the initial layered structures. Concurrently, Laves phases and Nb-/Ti-based solid solutions were formed during the milling process. The microstructure of the sintered alloys exhibited a multi-phase morphology with a heterogeneous elemental distribution. The microhardness of the consolidated alloys showed a significant increase compared to the raw constituent materials. Compression testing revealed typical brittle behavior at room temperature; however, at elevated temperatures, a reduction in yield strength was accompanied by a substantial increase in plastic deformation.

Keywords: complex concentrated alloys, mechanical alloying, powder metallurgy, microstructure, mechanical properties

Acknowledgements

A financial support from the National Science Centre, Poland , under Grant no. UMO-2021/43/B/ST5/01907 (OPUS 22), is gratefully acknowledged.

Structural and Electrochemical Characterization of Zinc Coatings Deposited on DC01 Steel by Electrogalvanizing

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Abstract

Corrosion resistance and improved physicochemical properties of steel components can be achieved through the deposition of zinc coatings on the surfaces of functional elements. This study presents the structural and electrochemical characterization of zinc layers obtained by electrogalvanizing in comparison with coatings produced by hot-dip galvanizing.
The effectiveness of the anticorrosion protection of galvanized steel depends on several galvanizing process parameters, including bath composition, temperature, and immersion time. This work describes and quantitatively evaluates the properties of zinc coatings deposited on DC01 steel as a function of coating thickness obtained at different current densities (1.7 and 2.5 A/dm^2) and varying galvanizing times.
The microstructure and chemical composition of the obtained zinc coatings were investigated using a SUPRA 35 scanning electron microscope (SEM) (Carl Zeiss, Jena, Germany) equipped with an UltraDry EDS detector (Thermo Scientific, Waltham, USA). X-ray measurements were performed using Grazing Incidence X-ray Diffraction (GIXRD) geometry with a PANalytical Empyrean diffractometer equipped with a copper anode X-ray tube, a PIXcel detector, and a 5-axis sample stage. Phase identification of the obtained diffraction patterns for the investigated incidence angles (0.25°, 0.5°, 1.0°, 1.5°, and 2.0°) was carried out using PANalytical HighScore Plus software integrated with the ICDD PDF5+ 2025 crystallographic database.
The effective thickness, morphology, homogeneity, chemical composition, elemental distribution, and corrosion resistance of the zinc coatings were compared and evaluated.

Keywords: electrogalvanizing, zinc coatings, corrosion resistance, GIXRD analysis

Microstructure and Properties of the 800HT Alloy After Long-Term Operation

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Abstract

Alloy 800HT is classified as an austenitic heat-resistant alloy and is widely used in applications such as chemical processing installations. A review of the literature indicates that most studies focus on new materials, whereas service-exposed materials are rarely investigated or are not analyzed at all. This creates technological challenges during maintenance and repair operations, for example welding. In the case of repairs of installations, it is essential to understand not only the properties of materials in the as-delivered (new) condition, but also the mechanisms of their degradation during long-term service and the kinetics of these degradation processes. The investigated materials had been operated for 25–30 years in an environment containing methane and steam at temperatures ranging from 500 °C to 700 °C.

The results revealed significant degradation within the near-surface layer of the service-exposed tubes, including chromium carbide precipitation, sigma phase formation, and localized brittle regions resulting from diffusion-induced aging and the presence of slip bands. Vickers hardness testing and grain size analysis were also performed.

The investigation of heat treatment effects confirmed that the solution annealing temperatures typically applied for microstructural restoration (approximately 1100 °C) are insufficient to achieve complete dissolution of precipitates in service-exposed material, particularly in regions containing slip bands and the σ phase. Furthermore, it was demonstrated that subsequent aging treatments at 850–900 °C intensify precipitation processes, which is detrimental to the restoration of the material's original ductility. TIG welding technology for in-use materials requires precise control of the input energy to limit the width of the HAZ and the risk of annealing stress cracking. Selected and verified welding process parameters enable the production of high-quality welds with stable, favorable operating properties.

Keywords: 800HT alloy, TIG, microstructure after long-term operation

Effect of Short-Term Annealing of Amorphous Metal Alloy Al87Y4Gd1Ni4Fe4 for 2 min at a Temperature Range (661-686)±1 K on Physical and Chemical Properties

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Abstract

The effects of short-term annealing in the temperature range of (661–686) ± 1 K on the structural, surface, mechanical, tribological, and electrochemical properties of the amorphous metal alloy Al87Y4Gd1Ni4Fe4 were investigated.

The object of the tests were AMAs alloys in the form of ribbons with a thickness and width of 20-25 µm and 3 mm, respectively, which were obtained at the G. V. Kurdyumov Institute for Metal Physics of the National Academy of Sciences of Ukraine (Kyiv) by melt spinning method in a helium atmosphere on a copper drum rotating at a speed of ~30 m/s. The melt was prepared from pure metals and binary compounds REAl3 (RE = Y, Gd). The purity of the starting metals was as follows: Al (99.999 wt.%), Ni (99.99 wt.%), Y (99.96 wt.%), Gd (99.96 wt.%) and Fe (99.99 wt. %).

Isothermal annealing was performed at certain temperatures with a heating rate of 20 K/min, determined from the DSC curves, which are characteristic of the origin (T1), growth (T2)and stable growth (T3) of crystals of the third stage of crystallization and are equal to 661±1, 667±1 and 686±1K, respectively. X-ray structural analysis showed that after 2 minutes of isothermal annealing at T1, nanocrystalline phases Al(X), Al8(Ni,Fe)4(Y,Gd)1 are formed, which are also fixed during annealing at T2, during annealing at T3, the phase Al19Ni5(Y,Gd)3 formed.

Scheme of phase transition in the temperature range with an annealing time of 2 min:

Am → Am′ + solid solution Al(X) + nano- Al8(Ni,Fe)4(Y,Gd)1
→solid solution Al(X) + nano- Al8(Ni,Fe)4(Y,Gd)1
→solid solution Al(X) + Al8Fe4(Y,Gd)1+nano- Al19Ni5(Y,Gd)3

After the tribological tests, the average area of the wear marks was assessed using a Surftest SJ-500 contact profilometer (Mitutoyo, Tokyo, Japan). It has been established that the friction coefficient decreases as a result of annealing at T1 and T2.

Keywords: amorphous metal alloy, heat treatment, crystallization, tribological properties

Effect of Slurry Cementation Parameters on the Microstructure and Oxidation Resistance of Silicide-Aluminide Coatings on Molybdenum

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Abstract

Protective silicide, silicide-aluminide and aluminide coatings were synthesized on molybdenum substrates using a proprietary slurry cementation process. The coatings were deposited at 800 and 1000 °C for durations ranging from 2 to 6 h using slurries with different Al/Si ratios. The cyclic oxidation resistance of the coatings was evaluated at 1000 °C. Detailed characterization of the coating surface and cross-sectional microstructure was performed using scanning electron microscopy (SEM), while chemical composition and phase constituents were analyzed by X-ray microanalysis (EDS) and X-ray diffraction (XRD), respectively.

The produced coatings exhibited a characteristic multilayer architecture. It was found that the slurry composition significantly affected the coating morphology, phase development, growth kinetics and oxidation performance of the silicide-aluminide systems. Among the investigated variants, the coatings obtained from slurry containing 50 wt.% Al and 50 wt.% Si demonstrated the highest oxidation resistance. During cyclic oxidation, microcracks generated within the coating were sealed by the formation of alumina, indicating a self-healing effect that contributed to improved protective properties.

Keywords: silicide-aluminide coatings, slurry method, molybdenum

High-Temperature Corrosion and Nitridation of Cr, Ni Alloy Steels in Ammonia at 575 °C for 1000 h

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Abstract

Four grades of alloy steel were used for heat resistance tests: one ferritic steel X3CrTi17 (1.4510) and three austenitic steel grades X10CrNi18-8 (1.4310), X1NiCrMoCuN25-20-5 (1.4539) and X12NiCrSi35-16 (1.4864). . The heat resistance tests were conducted in a nitriding atmosphere containing ammonia and its dissociation products. No external ammonia dissociator was used, nor were any diluent gases introduced. Nitriding was carried out in a vertical retort with a volume of approximately 90 liters, placed in a pit furnace. The nitriding process was performed at temperatures ranging from 550°C to 575°C, with the ammonia flow rate adjusted between 60 and 160 L/h to maintain an ammonia dissociation degree inside the retort within the range of 60–70%. A total of 100 nitriding processes were carried out, each lasting 10 hours. Changes in the structure were evaluated every 200 hours of the nitriding process. Sample surfaces were examined using scanning electron microscopy with X-ray microanalysis (SEM-EDS) and X-ray diffraction (XRD). After 1000 hours of nitriding, the samples that had undergone surface examinations were also tested on cross-sections. The conducted tests revealed a significant influence of chemical composition on the heat resistance of steels in a nitriding atmosphere. The depths of the nitrided layers ranged from approximately 0.1 mm to over 1 mm, depending on the steel grade. The greatest nitriding depths were observed for nickel-free steel, while the smallest were found for steel containing 35% nickel.

Keywords: nitradation, long time nitriding, heat resistance

Can Ascorbic Acid Serve as an Effective Reducing Agent in the Synthesis of Gold Nanoparticles Stabilized with PAMAM G2 Dendrimers — Advantages and Limitations?

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Abstract

Ascorbic acid plays an important role in the human body due to its antioxidant and anti-inflammatory properties, as well as its involvement in collagen synthesis, enzymatic regulation, and the biosynthesis of corticosteroids and selected neurotransmitters. Owing to these diverse functions, it is used both in the prevention and supportive treatment of several disorders and as a mild, non-toxic reducing agent in the synthesis of gold nanoparticles (AuNPs). In this study, a method for synthesizing AuNPs was developed using second-generation poly(amidoamine) dendrimers (PAMAM G2) with an ethylenediamine core as stabilizers and ascorbic acid as the reducing agent. The synthesis was carried out using two techniques: sonication and microwave irradiation. Colloidal systems were prepared at various PAMAM G2:chloroauric acid molar ratios (1:1–1:5). The presence of gold nanoparticles was confirmed by UV–Vis spectroscopy. Particle diameters and zeta potentials were determined using dynamic light scattering (DLS), while metallic core sizes were estimated via scanning transmission electron microscopy (STEM). Physicochemical analyses confirmed effective/well established nanoparticle nucleation and demonstrated that the AuNPs/PAMAM G2 colloids remained stable for up to three months.

The results indicate that the synthesized nanoparticles exhibit slightly higher cytotoxicity on human breast adenocarcinoma and osteosarcoma cell lines compared with citrate-reduced AuNPs/PAMAM G2, as evidenced by lower EC_{50} values. It should be noted, however, that ascorbic-acid-reduced nanoparticles are significantly smaller (≈10 nm) than those reduced with sodium citrate (≈20 nm). The development of a synthesis route employing ascorbic acid as the reducing agent enabled the preparation of monodisperse AuNPs/PAMAM G2 colloids using both the sonication and microwave-assisted methods. The microwave approach offers greater potential due to the substantial reduction in synthesis time.

Keywords: gold nanoparticles, PAMAM dendrimers, synthesis method, MTT test

From Thermal History to Properties: Experimental and Numerical Studies of Micrometallurgical Processes in Direct Energy Deposition Additive Manufacturing

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Abstract

Additive manufacturing (AM) involves layer-by-layer material deposition to produce fully functional components. The thermal history during processing strongly affects microstructure evolution, mechanical properties, and residual stress development. These characteristics depend on process parameters and local thermal conditions. Improper parameter selection may lead to excessive residual stresses, distortion, cracking, reduced corrosion resistance, and non-uniform material performance. Therefore, understanding and controlling thermal history is essential for obtaining reliable component properties.
This work investigates the relationship between thermal history, microstructure evolution, mechanical properties, and residual stresses in Direct Energy Deposition (DED) manufactured components. The study evaluates the possibility of predicting these characteristics using temperature measurements acquired during processing. Initial experiments performed with a custom thermal imaging system revealed significant challenges related to temperature acquisition and data processing, leading to discrepancies between measured and expected results. Experimental observations were therefore correlated with numerical simulations.
The developed numerical model enables faster parameter selection to achieve the desired microstructure while minimizing residual stresses. Model validation was performed using temperature measurements and substrate displacement recorded during manufacturing. Temperature evolution was monitored with thermocouples and pyrometers, whereas displacement was measured using Digital Image Correlation. Good agreement between simulations and experiments was achieved.
The results demonstrate that additively manufactured components cannot be considered fully homogeneous at the macroscopic scale. Local thermal variations produce measurable differences in microstructure, mechanical response, and residual stress distribution, which should be considered in process optimization.

Keywords: additive manufactoring, direct energy deposition, thermal history, numerical simulations

Multiscale Insight into Tribological Behaviour of IF-WS_2-Modified Anodic Al_2O_3 Coatings

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Abstract

This study presents a multiscale analysis of the tribological behaviour of anodic Al_2O_3 coatings modified with inorganic fullerene-like WS_2 (IF-WS_2). The chemical depth distribution of the modifier within the oxide coatings was characterised using GD-OES, providing insight into its incorporation and gradient profile. Tribological performance was evaluated by measuring friction coefficients and conducting scratch testing with a zirconia ball as the counterbody under defined loading conditions. The results demonstrate a clear relationship between the depth distribution of IF-WS_2, coating integrity, and frictional response. The combined chemical and tribological analyses allow identification of dominant wear and deformation mechanisms, highlighting the role of IF-WS_2 in enhancing tribological stability of anodic Al_2O_3 coatings.

Keywords: AAO coatings, IF-WS2 nanolubricant, tribological properties, GD-OES

Investigation of Ion Irradiation Effects on EPDM Cable Insulation for Nuclear Power Plant Applications

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Abstract

The primary objective of this study was to develop an elastomer based on ethylene-propylene-diene rubber (EPDM) containing inorganic fillers to enhance its resistance to ionizing radiation. The material, a sulfur-cured EPDM with polysulfidic crosslinks, is intended for use as cable insulation in radiation-exposed environments such as nuclear power plants, where ionizing radiation is one of the main factors responsible for insulation degradation. The mechanism of radiation interaction depends on the macromolecular structure of the elastomer. Ionizing radiation can induce chain scission of macromolecules, resulting in the formation of shorter radical-terminated fragments. Subsequent radical recombination leads to crosslinking, manifested as increased hardness, brittleness, and shrinkage of the material. To simulate the effects of ionizing radiation on cable insulation, the material was irradiated with He^{+} ion beams. Ion beam irradiation modifies the chemical and physical properties of elastomeric materials in a manner similar to gamma radiation, with inelastic ion–electron interactions providing a suitable analogue for studying radiation effects. Consequently, ion irradiation allows the simulation of radiation damage typically observed under nuclear reactor conditions. Characterization of the modified materials was performed using scanning electron microscopy (SEM), transmission electron microscopy (TEM), Raman spectroscopy, Fourier-transform infrared spectroscopy (FTIR). The analyses indicate that ion irradiation induces additional crosslinking accompanied by chain scission in the sulfur - cured EPDM, leading to increased stiffness and changes in the chemical structure of the insulation. The results provide valuable insights into the mechanisms of radiation interaction with elastomeric materials and contribute to the development of improved cable insulation systems for long-term operation in radiation-exposed environments, particularly in nuclear power applications.

Keywords: EPDM, ion irradiation, inorganic fillers

Experimental Models of Diffusion Nitrogen Saturation of Steel Blades

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Abstract

The concept of this work is aimed at developing an experimental model of multidirectional nitrogen diffusion into steel component with a complex geometric surfaces. This issue, successfully implemented in the gear industry, remains of great research interest due to the multiparametric nature of the nitriding process [1]. For example, J.Michalski et. al analyzed gas nitride layers on steel balls [2]. This work analyzes such layers formed on blades, assuming diffusion occurs "throughout" the products.

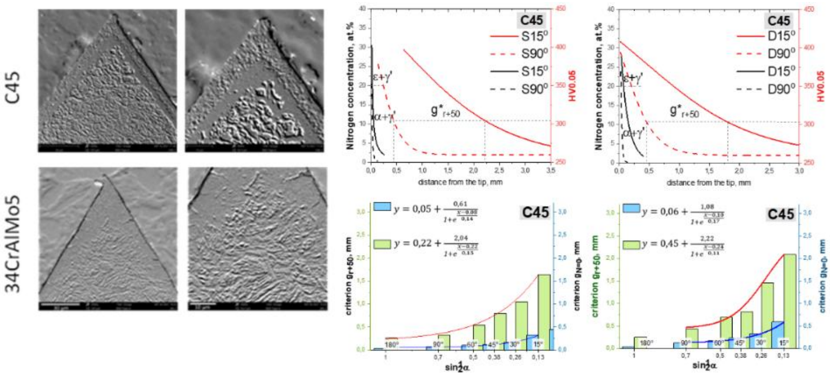

Fig.1. *Examples of microstructure, profiles of nitrogen concentration and hardness, mathematical models of gas nitrided steel blades (D- double-walled, S - conical)*

The more intense nitrogen saturation of the conical blade compared to double-walled blade samples was confirmed by the diffusion layer thicknesses determined using the gr + 50 and gN=0 criteria (Fig.1).

Keywords: nitrogen saturation, steel, experimental model

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Fully Bio-Based Furan Copolymesters: from Engineering Polymers to Thermoplastic Elastomers

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Abstract

Thermoplastic elastomers (TPEs) are a class of materials combining rubber-like elasticity with easy processability. However, the TPEs are still produced from petrochemical feedstocks. Increasing environmental concerns, fluctuations in oil prices and need to reduce CO_2 emissions highlight the importance of developing sustainable alternatives. 2,5-furandicarboxylic acid (FDCA), widely regarded as the bio-based counterpart of terephthalic acid, has attracted significant attention. FDCA offers the possibility of designing new polymers with variable properties while preserving the renewable origin.

As multiphase materials, TPEs display complex and highly variable behavior, and the correlation between their performance, chemical structure of segments, and the microstructure formed during processing remains an active field of research. Previous studies have shown that furan-based polyesters, especially poly(butylene furoate) (PBF), can effectively serve as rigid crystallizable segments. Different renewable flexible segments, including bio-PTMG, PEG, dimerized fatty acids, and PPO, have been investigated proving that differences in molecular architecture and segment length lead to substantial variations in the physical properties of the copolymers.

This study focuses on sustainable multiblock furan–ester copolymers of poly(butylene furanoate) (PBF) and poly(1,3-propanediol) (PO3G) (PBF-b-PO3G) with different rigid-to-flexible segment ratios. The applied polyol, Velvetol (WeylChem), is fully plant-based, recommended to polyurethanes. However, its low glass transition temperature, linear molecular structure, and availability in different molecular weights make it suitable as soft segment for copolymers. The obtained materials were analyzed in terms of their phase transitions, formed microstructure, as well as mechanical performance and elastic recovery. The fully – biobased copolyesters reveal varied performance of both engineering polymers and thermoplastic elastomers.

Keywords: sustainable polymers, furan polyesters, thermoplastic elastomers

Structure and Corrosion Behaviour of Novel Biodegradable Mg-Zn-Ca-Er Sintered Alloy

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Abstract

In this work, novel Mg-Zn-Ca-Er alloys were prepared to assess their application potential in the production of modern orthopedic implants. A spark plasma sintering (SPS) technique was used to produce samples from powders synthesized by mechanical alloying (MA). A high-energy ball mill was used in MA, with milling times of 20 and 30 hours. Sintering temperature of 583 K and holding time of 4 min were used. Their structure, containing amorphous and crystalline phases, i.e., solid solutions Mg i Zn and oMgZn2, Ca2Mg5Zn13 intermetallic phases, was identified by the X-ray method. The corrosion behavior of the plates was investigated by hydrogen evolution measurements, electrochemical polarization tests, and electrochemical impedance spectroscopy in Ringer's solution at 37°C. X-ray methods, i.e., diffraction analysis, photoelectron, and energy-dispersive spectroscopy, were used to characterize the corrosion products formed on the surface of the studied samples.

This study provides novel insights into sintered biodegradable Mg-Zn-Ca-Er alloys, corrosion behaviour, and the characteristics of corrosion products under simulated physiological conditions.

Keywords: Mg-Zn-Ca-Er alloy, spark plasma sintering - SPS, mechanical alloying - MA, corrosion

Preparation of ZnO Ceramics by Direct Coagulation Casting Method

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Abstract

Direct Coagulation Casting (DCC) is a method for forming ceramics from slips with a high solid phase concentration. Unlike gel casting, where the monomer introduced into the system polymerizes, there are fewer coagulating additives and they are removed more quickly, and post-sintering shrinkage is minimal. Other advantages of this method include the fact that the casting molds do not have to be made of plaster, but can be made of metal or polymer. The process also does not require the use of high pressures during the forming process or elevated temperatures. The main disadvantages of DCC are low strength in the raw state, the possibility of long coagulation times (few hours) and drying proces (even couple of days), and a tendency to crack, among other things, due to the formation of carbon dioxide during enzymatic decomposition. These issues limit its use in large-scale industrial applications. Furthermore, the use of salts as coagulants can lead to high viscosity and early mixing problems.
Gallic acid in a system with NaOH or TMAH and Tiron were used as dispersants, while gluconic acid lactone (GAL) was used as a coagulant. We studied ceramic suspensions containing 40-50 vol.% of ZnO with an average grain size of 0.490 um. The maximum share of each dispersant was 0.4 wt%. Above this value, unstable suspensions, which were characterized by, among other things, thixotropy, were obtained. Based on, inter alia, the results after drying and rheological studies of the solidification kinetics, we determined that the most optimal results were obtained for ceramic suspensions containing 0.3 wt.% of Tiron or 0.3 wt.% of gallic acid in a 1:2 molar ratio with TMAH/NaOH, with a coagulant content of 0.4% by weight. Samples with a higher content of fluidizer and coagulants solidified faster (after even 2-3 minutes) and also cracked during drying. In turn, the SEM images of samples after sintering at 925 ◦C (determined based on DIL measurements) also showed the presence of pores.

Keywords: ZnO ceramics, Direct Coagulation Casting, dense ceramics, rheological measurements, DIL measurements

Infrared Sauna Clothing: Impact of Selected Fabrics on Physiological Effects and User Comfort

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Abstract

Infrared (IR) sauna therapy has gained popularity due to its potential benefits, including improved circulation, detoxification, muscle recovery, and relaxation. IR sauna use without clothing allows optimal penetration of infrared waves into the skin, maximizing benefits; however, it often causes psychological discomfort for users. Studies addressing the influence of clothing or coverings on IR radiation penetration and therapeutic outcomes remain scarce.
This pilot study evaluated the effect of different white fabrics on IR transmission, selected physiological parameters, and user comfort during infrared sauna sessions.
Three healthy volunteers (1 woman, 2 men) participated in 20-minute IR sauna sessions under four conditions: naked, polyester towel, cotton towel, and polyethylene non-woven fabric. Before and after the sessions, participants were assessed using: thermal imaging camera (skin surface temperature distribution), blood oxygen saturation (SpO_2), skin pH and hydration level. Mid- and far- infrared (3 µm – 15 µm) wave transmission through the fabrics was also tested.
Infrared radiation penetration, assessed by direct wave transmission testing and supported by resulting skin surface temperature responses, was highest with the polyethylene non-woven fabric (closest to the naked condition), followed by polyester, and lowest with cotton. Blood oxygen saturation decreased least in the naked condition (remaining at 95%) and most with polyethylene clothing (decreasing to 92%). Skin pH shifted toward more alkaline values in all conditions. While polyethylene allowed excellent IR transmission, it was associated with significantly reduced user comfort due to poor breathability.
Polyethylene-based materials demonstrate promising IR permeability for sauna use. Developing advanced polyethylene fabrics with improved breathability could provide a comfortable alternative to IR sauna use without clothing. Further studies with larger samples and optimized materials are needed.

Keywords: infrared sauna clothing, user comfort

Fabrication of Porous Functionally Graded Titanium Materials via Powder Metallurgy Method

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Abstract

Titanium-based materials are widely utilized in advanced industrial applications due to their exceptional mechanical properties and corrosion resistance. However, expanding their utility by the design of Functionally Graded Materials with varying porosity. It is possible to fabricate components with optimized fluid permeability, customized thermal insulation, or targeted mechanical stress distribution. These advanced architectures are highly sought after in sectors such as medicine and implants, environmental engineering and catalytic substrates.
A critical aspect of the fabrication process is the mechanical milling stage, where controlling powder behavior is paramount to achieving the desired gradient properties. This research demonstrates that the introduction of minor elemental additions, such as tin (Sn), silver (Ag), or copper (Cu) in concentrations of approximately 2-3 wt.%, significantly influences particle agglomeration and synthesis dynamics.
The material characterization was conducted by evaluating the structural evolution of the metallic powders following the modified milling processes and analyzing the final sintered FGMs. Powder properties were assessed using a laser particle size analyzer to determine volume distribution and mean diameters. Scanning Electron Microscopy was employed to analyze the morphology of the powders and the microstructure of the sintered samples, while phase composition was determined via X-ray Diffraction. The results confirmed the successful formation of interconnected pore networks and a gradual transition in microhardness across the sample cross-sections. These findings demonstrate that the modified powder metallurgy route is a highly effective and versatile platform for engineering the next generation of porous, functionally graded titanium components with tailored mechanical and structural performance.

Keywords: titanium-based materials, powder metallurgy, functionally graded materials

Synthesis and Consolidation of Multicomponent Ni–Co–Mn–In–Fe–Cr Heusler Alloy Powders by Mechanical Alloying and Spark Plasma Sintering

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Abstract

Ni–Mn-based magnetic shape memory alloys (MSMAs) are functional materials exhibiting coupled magnetic and structural transformations, enabling magnetic-field-induced strain, magnetocaloric response, and shape memory effects. Due to their fast response and magnetic control, these materials are promising for actuators, sensors, and advanced cooling technologies. Ni–Co–Mn–In-Fe-Cr alloys have attracted structural and magnetic properties. However, fabricating multicomponent Heusler alloy powders for additive manufacturing remains challenging due to difficulties in controlling phase composition and structural homogeneity.
The aim of this work was to produce and characterize multicomponent Ni–Co–Mn–In–Fe–Cr Heusler alloy powders synthesized by mechanical alloying for potential application in additive manufacturing and functional composites. Mechanical alloying was performed using different milling times and ball-to-powder ratios (BPR) to investigate their influence on phase evolution and powder morphology.
Crystallization from the amorphous phase and structural transformations during heating were investigated using in situ X-ray diffraction (XRD). Structural and chemical characterization was additionally performed using scanning and transmission electron microscopy (SEM, TEM) and energy-dispersive spectroscopy (EDS). The obtained powders were consolidated by spark plasma sintering (SPS) at different temperatures.
The results showed that high-energy milling produced highly refined powders with a partial amorphous structure. In situ XRD revealed crystallization and formation of the Heusler-type $L2_1$ phase during heating. SPS consolidation produced dense materials with fine-grained microstructure composed mainly of the Heusler phase with γ-phase particles. Although the martensitic transformation was hindered in the as-sintered state, post-sintering heat treatment led to weak shape memory behavior, indicating potential for further optimization of processing parameters.

Keywords: magnetic shape memory alloys, heusler alloys, mechanical alloying, Ni–Co–Mn–In–Fe–Cr alloys, spark plasma sintering (SPS), additive manufacturing, powder metallurgy, phase transformations, In situ X-ray diffraction, functional materials

Microstructure and Bond Coating Properties under Cyclic Oxidation Conditions

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Abstract

The presented research results are the effect of the M-ERA.NET 3 Call 2022 project, financed in Poland by the National Centre for Research and Development - NCBR, entitled "Thermal Barrier Coatings for greener heat-to-power applications: understanding the limitations of hydrogen combustion conditions and a sustainable outlook", acronym TBC4H2. The study was conducted on a modern singlecrystalline Rene N5 alloy, used in aviation applications, on which platinum-modified diffusion aluminide coatings and Pt-ɣ/ɣ' as well as MCrAlY coatings were produced, sprayed using the APS plasma method, laser-LPA, and deposited using the PVD-CHC method. These coatings constitute interlayers for TBC ceramic coatings obtained using the SPS and EB-PVD methods. The resulting coatings and layers were subjected to cyclic oxidation at 1200°C in an air atmosphere on an automated test bench under laboratory conditions. The results of the oxidation kinetics of the samples obtained during 300 one-hour cycles are presented.

Keywords: superalloys, protective coatings, TBC, oxidation, cyclic oxidation test

Comparison of Properties of Alumina/MoS_2 and Titania/MoS_2 Low-Friction Coatings

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Abstract

Reducing the intensity of friction through lubrication is one of the most effective methods for increasing the durability of materials surfaces cooperating under frictional contact conditions. In certain operating environments, the use of conventional liquid lubricants encounters difficulties. A possible solution is the use of a solid lubricant (such as molybdenum disulfide) as a triboactive component in a coating with a non-triboactive matrix (e.g., oxide-based).

Within this study, the morphological structure characteristics and the anti-friction properties of nanocomposite TiO_2 and Al_2O_3 oxide coatings containing an addition of MoS_2, were compared. The coatings were produced using the sol–gel method via deposition of colloidal suspensions with dispersed MoS_2 particles.

It was demonstrated that it is possible to fabricate thin nanocomposite coatings containing molybdenum disulfide, which significantly reduce friction intensity of a metallic substrate. The effectiveness of this reduction depends on the amount, size, and spatial orientation of the triboactive MoS2 particles, as well as on the coating matrix material. It was found that dip-coating deposition may lead to a favorable alignment of MoS_2 platelets parallel to the substrate surface. It was also shown that coatings with an Al_2O_3 matrix containing a high fraction (10%) of molybdenum disulfide exhibited better wear durability and lower coefficients of friction compared to coatings with a TiO_2 matrix. The obtained results indicate the potential application of Al_2O_3/MoS_2 nanocomposite coatings for friction reduction on light metal alloy substrates.

Keywords: alumina, titania, coatings, low friction, MoS_2, sol-gel

Fabrication of Austenitic ODS Steels with TiB_2 Addition: Effect Mechanical Alloying Time on Microstructure and Mechanical Properties

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Abstract

Oxide Dispersion Strengthened (ODS) steels are advanced materials known for their exceptional high-temperature strength, good corrosion resistance, and excellent stability under irradiation. These properties make them suitable for use in harsh environments, such as nuclear reactors or aerospace applications. ODS steels achieve these properties through the dispersion of fine, stable oxide particles, which act as barriers to dislocation movement, improving mechanical performance. Besides the most common Y_2O_3, which provides dispersion strengthening and enhances creep resistance, elements such as Ti can form stable Ti–Y–O, further refining oxide distribution and improving thermal stability. TiB_2 has been proposed as a strengthening phase due to its high thermal stability and mechanical properties.
The study aimed to analyze the influence of TiB_2 on the microstructure and mechanical properties of austenitic ODS steel. 316L stainless steel and 1 wt.% TiB_2 powders were subjected to mechanical alloying for 5, 10 and 50 h and consolidated using pulse plasma sintering. The microstructure was examined by scanning electron microscopy, while mechanical properties were evaluated by tensile tests and microhardness.
The results showed that milling time significantly affected grain size. Longer alloying led to coarser particles due to agglomeration, promoting a bimodal microstructure after sintering. TiB_2 was located between fine and coarse grains. Depending on their fraction, the mechanical properties varied. The results confirm the effect of ceramic addition on mechanical performance, as shown by strength and microhardness.

Keywords: oxide dispersion strengthened steels (ODS steels), mechanical alloying, pulse plasma sintering (PPS)

Acknowledgements

This research is funded by the National Science Centre, Poland under the OPUS call in the Weave programme (project No. 2021/43/I/ST8/01018).

Degradation of SiC/SiC Composites in Terms of Their Application in Hot-Section Components of Aircraft Engines

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Abstract

Silicon carbide fiber–reinforced silicon carbide (SiC/SiC) ceramic matrix composites are considered key materials for next generation aircraft engine hot section components due to their low density, high temperature capability and improved damage tolerance compared to monolithic ceramics. However, their long term durability under combined thermomechanical loading and oxidative environments remains a critical challenge for safe engine application.

In this study, the degradation mechanisms of melt infiltrated SiC/SiC composites exposed to conditions relevant to aircraft engine operation, including high temperature oxidation, static thermal exposure and combined thermomechanical loading, were investigated. Microstructural evolution was analyzed using scanning electron microscopy coupled with EDS, complemented by phase and thermal analyses. Particular attention was paid to damage initiation and propagation, interphase degradation and oxidation related changes in matrix and fiber regions.

Obtained results demonstrate that degradation is strongly controlled by temperature depended processes rather than exposure time alone. Oxidation leads to progressive interphase consumption and changes in matrix chemistry, while thermomechanical loading promotes crack opening and accelerates oxygen ingress. Despite limited mass uptake under certain conditions, substantial microstructural degradation was observed, emphasizing the limitations of metrics based on changes in mass for lifetime assessment.

The findings provide insight into degradation pathways governing SiC/SiC composites in engine relevant environments and support the need for protective environmental barrier coatings and tailored testing methodologies for reliable hot section implementation.

Keywords: Ceramic Matrix Composites (CMC), SiC/SiC composites, creep, oxidation, aircraft engine

Microstructural Characterization and Functional Properties of Recycled 2xxx Series Aluminum Alloys

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Abstract

This study presents an analysis of the effect of scrap recycling on the microstructure, mechanical properties, and machinability of 2xxx series aluminum alloys (EN AW-2007 and EN AW-2017A). The research conducted includes a comprehensive assessment of the structural, mechanical, and technological properties of alloys produced from recycled materials, along with a direct comparison with commercial alloys. Alloy ingots were obtained by continuous casting from recycled material and then heat treated in the T4 temper (solution heat treatment and natural aging). The scope of the research included chemical composition analysis, microstructural observations (LM, SEM/EDS), and phase identification by X-ray diffraction (XRD). Mechanical properties were determined based on Brinell hardness measurements and static tensile tests. Machinability was assessed by measuring cutting force components (Fc, Fp, Ff), surface roughness parameters (Ra, Rz, Rt), and chip shape analysis. The results show that, with appropriately selected processing conditions, it is possible to obtain a homogeneous, fine-grained microstructure without casting defects, despite the use of recycled material. T4 heat treatment significantly improves mechanical properties, reaching levels comparable to primary alloys. Machinability tests confirmed no deterioration in technological performance; under the selected cutting conditions, the total cutting force for commercial alloys was higher by approximately 20% (EN AW-2017A) and 14% (EN AW-2007), while maintaining comparable surface quality. The obtained results indicate that recycling 2xxx series aluminum alloys enables the production of materials with high performance properties without compromising their performance in machining processes. This forms the basis for their use in demanding engineering applications, taking into account economic and environmental aspects.

Keywords: 2xxx series aluminum alloys, recycling; microstructure, mechanical properties, machinability

From Defects to Plasticity: How Temperature and Chemistry Shape Irradiated Steels

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Abstract

Ferritic/martensitic (F/M) steels are promising structural materials for advanced fission and fusion reactors due to their resistance to swelling, good thermal conductivity, and irradiation stability. Their performance, however, is strongly influenced by minor alloying elements and impurities such as Ni, Si, and P, which can segregate under irradiation and alter defect evolution and mechanical properties.

This study investigates the combined effect of Ni, Si, and P on the irradiation response of a model Fe-9Cr alloy. Two materials were examined: a reference Fe-9Cr alloy and a Fe-9Cr-NiSiP alloy containing controlled additions of Ni, Si, and P. Ion irradiation was conducted at different temperatures and doses to simulate reactor-relevant radiation damage conditions.

Microstructural and mechanical characterization was performed using SEM, EBSD, TEM, APT, and nanoindentation. These complementary techniques enabled correlations between irradiation-induced microstructural changes and variations in hardness and plasticity.

Preliminary results show that Ni, Si, and P promote the formation of fine defect clusters and increase irradiation-induced hardening compared with the reference alloy. APT analyses reveal P segregation and changes in Cr clustering behavior, indicating modified defect–solute interactions and reduced defect mobility. The findings demonstrate that even minor alloying additions can significantly influence defect evolution and mechanical stability in irradiated F/M steels.

This work provides new insight into the relationship between alloy chemistry, defect dynamics, and irradiation hardening, highlighting the importance of controlling minor alloying elements in the development of radiation-resistant steels for next-generation nuclear energy systems.

Keywords: ion irradiation, irradiation-induced defects, plastic initiation, dislocation

Growth Mechanism of Glucose Monohydrate Thin Films Deposited by Pulsed Electron Beam Deposition

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Abstract

Pulsed Electron Beam Deposition (PED) has been extensively studied for inorganic and polymer-based materials, whereas the deposition of small-molecule organic compounds remains largely unexplored. In this work, glucose monohydrate was selected as a low-molecular-weight model compound – a monomer of cellulose – to investigate the growth mechanism of organic thin films deposited by PED.

Films were deposited on Si substrates at room temperature using a 10 kV electron beam at an Ar pressure of 6 mTorr. The deposition process was carried out with a decreasing number of pulses, i.e., from 40,000 to 5,000 pulses. Film morphology and topography were analyzed by optical microscopy and tapping-mode AFM, while thickness was determined from SEM cross-sections. The chemical structure of the deposited glucose was analyzed by FTIR (for thicker films) and XPS for the entire series. The physical structure of the films was examined by XRD.

The deposited films exhibited island-like growth with hierarchical roughness developed on two topographical levels. AFM observations showed that film continuity strongly depended on the number of pulses. A threshold for continuous film formation was identified between 5,000 and 10,000 pulses, indicating a transition from isolated islands to a coalesced layer. Although the glucose target is crystalline, the deposited films at each stage of growth were found to be amorphous. Defined chemical and structural changes occurring during PED of glucose may account for this behavior.

These results provide the first insight into the growth behavior of small-molecule organic films deposited by PED and form a basis for future studies on more complex saccharide and polysaccharide systems.

Keywords: Pulsed Electron Beam Deposition (PED), thin organic films, glucose monohydrate

Acknowledgements

This research was funded by the National Science Centre, Poland, within project SONATA-19 (no. 2023/51/D/ST11/00263).

Parylene-Aerogel Composites

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Abstract

Parylene technology, due to its excellent barrier, mechanical, chemical, biological, optical, and thermal properties, as well as its unique process properties of penetrability and conformability, is finding increasing industrial applications. A prime example of such an application are textile-aerogel composites produced using Parylene C coating technology.
Because this technology delivers monomers to the surface in gaseous form and their polymerization occurs via free radicals, it is possible to supersaturate the layered structure of fabrics and granular aerogel (fabric-aerogel-fabric) with Parylene C. This polymer integrates the composite components by covering all accessible surfaces of the structure with a thin coating, which causes the components to bond together at the points of contact, creating nodes. This results in flexible composites with excellent insulating properties. Furthermore, a Parylene C coating on fabrics increases resistance to open flames compared to uncoated fabrics. Textile-aerogel composites produced in this way can be successfully used to produce specialized clothing used, for example, in the metallurgical industry.

Keywords: Parylene C, Parylene technology, composites, aerogel

Interlayer as a Self-Healing Microcapules in Magnesium/ CFRP Composite

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Abstract

Currently, the most widely used structural materials, alongside metals,

are polymer composites based on glass, carbon, or aramid fibres. They are utilised for highly critical components by appropriately aligning the reinforcing fibres introduced into the matrix. These Fiber Metal Laminates continue to represent a modern group of composite materials and attract the attention of numerous research groups worldwide. The materials are characterised by very high strength-to-weight ratios, impact resistance, and low mass, although they comprise a fairly complex structure even at the manufacturing stage.

Regarding these materials, work is underway on the application of other combinations – not only involving aluminium alloys and glass fibres, but also magnesium or titanium alloys with carbon fibres, among others. It appears that the most challenging solution within these laminates is the use of magnesium alloy and carbon fibre composite. This structure is the most susceptible to accelerated galvanic corrosion, particularly pitting or intergranular corrosion, not only within the alloy itself but also at the metal/polymer composite interface.

Inspired by self-healing materials, I have introduced a new approach to laminates:

the application of an additional self-healing layer in the form of PU/PUa microcapsules with IPDI. This layer is intended to enhance delamination resistance at the interface and support the self-healing of areas vulnerable to corrosion.

The occurrence of galvanic corrosion in the FML laminate was confirmed through OCP, potentiodynamic, and EIS tests. Furthermore, based on the ILSS (interlaminar shear strength) flexural test, it was verified at the interface between the two different materials that the microcapsules promote the selection and improvement of the interlayer. It was observed that self-healing occurs at damage sites within the laminate as well as at the interface, thereby extending the service life of the material.

Keywords: FML, ILLS test, microcapsules, microstructure

Medical textiles as advanced Functional Biomaterials

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Abstract

Medical textiles constitute a rapidly developing group of advanced materials designed for healthcare, rehabilitation and biomedical applications. Their unique combination of mechanical performance, biocompatibility, flexibility, and tunable surface properties has enabled their widespread use in e.g. wound dressings, surgical sutures, vascular grafts, hernia meshes, tissue engineering scaffolds, wearable healthcare systems and other applications. Recent advances in textile engineering, including also electrospinning, three-dimensional textile structures, additive manufacturing-assisted textile fabrication and surface functionalization techniques, are discussed in the context of improving biological response and clinical effectiveness. The work also highlights the growing role of smart and multifunctional medical textiles incorporating antimicrobial agents, drug-delivery systems, conductive components, and biosensing capabilities. These innovations support the development of personalized healthcare solutions and continuous patient monitoring. It demonstrates that medical textiles are evolving from passive materials into multifunctional biomaterial platforms capable of interacting with biological systems and supporting regenerative processes.

Keywords: medical textiles, biomaterials, smart textiles

Study of the Influence of Waste Plant Biomass on Selected Properties of Polyurethane Materials

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Abstract

The use of bio-based raw materials in the synthesis of new materials is one way to reduce the demand for fossil fuels. The non-biodegradable nature of petroleum-based polymers, the significant greenhouse gas emissions and energy consumption during their production, and environmental regulations are driving the search for alternatives based on renewable raw materials. Plant-based biomass, due to its origin and large-scale availability, offers enormous potential as an alternative to petroleum-based raw materials in polymer production. Among polymeric materials, polyurethanes play a crucial role in modern industry and everyday life. They are created through the chemical reaction of polyols with isocyanates, allowing for the production of materials with various properties—from soft and flexible to hard and rigid. Products made from polyurethane materials are significant due to their versatility, durability, and insulating properties. They are essential in many industries, although they also pose environmental challenges.

Plant-based fillers used in the production of polyurethane materials are an ecological alternative to traditional mineral fillers. They enable lower production costs, a reduced carbon footprint, and improved selected mechanical and thermal insulation properties.

The aim of the presented research is to obtain thermally insulating rigid polyurethane foams with favorable performance characteristics using waste plant biomass.

As part of the research, the impact of varying plant biomass content on the performance properties of the resulting materials was assessed. The study aimed to demonstrate the effect of plant-based fillers on increasing the thermal insulation efficiency of polyurethane materials. The use of highly effective thermal insulation materials supports the concept of sustainable development, thus contributing to building a better future for all of us.

Keywords: polyurethanes, recycling, plant biomass

Shrinkage Stress Behavior of Liquid Rubber–Modified Dental Composites

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Abstract

Polymerization shrinkage remains a critical challenge in the performance and longevity of resin-based dental composites, as it generates stresses at the tooth–restoration interface. Such stresses may lead to create marginal gaps, microleakage, and secondary caries. In recent years, the incorporation of liquid rubber as a modifying phase has emerged as a promising strategy to reduce these stresses by enhancing the capacity for stress relaxation and energy dissipation. Therefore, this study investigates the effect of modification with liquid rubber on the development and evolution of shrinkage stresses in dental composites. Shrinkage stress development, polymerization shrinkage, and flexural stress relaxation were experimentally evaluated to assess the influence of liquid rubber modification. The results demonstrated a consistent reduction in shrinkage stresses for the modified materials, amounting to 19% for the flowable composite and 14% for the conventional one. A similar trend was observed for polymerization shrinkage, with values of 3.62% and 3.09% recorded for the unmodified and modified flowable materials, respectively, and 2.74% and 1.94% for the conventional composites. These findings were further supported by stress relaxation measurements, which revealed a noticeably lower fraction of unrelaxed stresses in the modified composites, with relative values of 0.523 and 0.347 for flow materials, unmodified and modified, respectively, and 0.473, and 0.336 for classic composites. The observed correlations indicate that the incorporation of liquid rubber enhances the viscoelastic response of the composites, thereby facilitating more effective stress dissipation during and after polymerization, which can improve longevity of dental composites.

Keywords: dental composites, shrinkage stress, liquid rubber

Acknowledgements

This work was supported by the project of Lublin University of Technology, Poland (grant FD-20/IM-5/078).

Effect of Plastic Deformation Route on the Microstructure and Mechanical Properties of Duplex Stainless Steel

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Abstract

Duplex stainless steel 1.4462 is widely used in chemical and petrochemical industries due to its high strength, corrosion resistance, and favorable combination of mechanical properties resulting from its dual-phase austenitic–ferritic microstructure. This study investigates the influence of hot rolling and cold drawing on the structural and mechanical behavior of the steel. Microstructural observations were carried out using optical microscopy (OM), scanning electron microscopy (SEM), EDS, and X-ray diffraction (XRD). Mechanical characterization included Vickers hardness measurements and static tensile tests according to PN-EN ISO 6892-1.
XRD analysis revealed diffraction peak shifts in cold-drawn samples, indicating lattice distortion and residual stress accumulation caused by plastic deformation. Microscopy confirmed the characteristic banded duplex structure with austenite bands distributed within a ferritic matrix, while EDS showed a homogeneous distribution of the main alloying elements.
Hardness measurements demonstrated a gradient across the rod cross-section. Hot-rolled specimens exhibited hardness values decreasing from approximately 320 HV at the edge to 265 HV in the core, whereas cold-drawn rods showed higher values ranging from 370 HV to 340 HV, indicating stronger strain hardening effects. Tensile tests confirmed that cold drawing increased yield and tensile strength but reduced ductility compared with hot rolling.
The results demonstrate that the deformation route significantly affects both the microstructure and mechanical properties of duplex stainless steel 1.4462. Cold drawing leads to higher crystallographic distortion, hardness, and strength, while hot rolling provides improved ductility and a more balanced structural state

Keywords: duplex stainless steel, plastic deformation, microstructural characterization

Acknowledgements

Conference participation was supported by the GreenMat project, co-funded by the European Union under the program “European Funds for Silesia 2021–2027.

Hydrophobically Modified Chitosan Nanomicelles for Localized Carboplatin Delivery in Ovarian Cancer

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Abstract

Ovarian cancer therapy remains limited by poor local retention and systemic toxicity of platinum-based drugs. In this study, hydrophobically modified chitosan (HMC) nanomicelles were developed as a mucoadhesive carrier system for localized carboplatin delivery.
Nanomicelles were synthesized using an oil-in-water emulsification method and characterized in terms of physicochemical and biological properties. The obtained particles exhibited an average hydrodynamic diameter of approximately 200 nm and an encapsulation efficiency of 44%. No detectable carboplatin release was observed within 24 h, suggesting strong drug–polymer interactions and a sustained-release profile.
In vitro studies confirmed good biocompatibility toward SK-OV-3 ovarian cancer cells, with cell viability remaining above 70%, as well as efficient cellular internalization of fluorescently labelled nanomicelles. Preliminary in vivo evaluation in a murine xenograft model demonstrated reduced tumour growth and lower Ki-67 expression compared with free carboplatin treatment.
The developed HMC nanomicelles represent a promising biomaterial-based platform for localized ovarian cancer therapy, combining mucoadhesive properties with sustained drug retention and enhanced therapeutic response. Further optimization and extended in vivo studies are required to fully evaluate their clinical potential.

Keywords: hydrophobically modified chitosan, nanomicelles, carboplatin delivery, ovarian cancer, drug delivery systems, biomaterials

Effect of Initial Microstructure on High Temperature Oxidation of MAR-M247 Nickel Based Superalloy

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Abstract

The effect of initial microstructure on the high-temperature oxidation behaviour of the nickel-based superalloy MAR-M247 was investigated. Three distinct microstructural conditions—fine-grained, coarse-grained, and columnar—were produced and exposed to air at 900 °C for durations up to 500 h. Oxidation kinetics, scale morphology, and subsurface degradation were evaluated to assess the role of grain size and grain orientation on oxidation resistance. The results demonstrate that the initial microstructure significantly influences oxide scale development, adherence, and internal oxidation behaviour. Differences in grain boundary density and diffusion pathways led to distinct oxidation mechanisms among the microstructures, with implications for long-term performance of MAR-M247 in high-temperature applications.

Keywords: high-temperature oxidation, nickel-based superalloys, microstructure, oxide scale formation

Crystallographically Gated Machine Learning for Functional Materials Discovery

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Abstract

Functional materials are essential for electromechanical devices, sensors, actuators, energy harvesting systems, and emerging energy storage technologies. Their functional response is not controlled by chemical composition alone, but is strongly constrained by crystallographic symmetry. For example, piezoelectric, pyroelectric, optical, and polar behavior can occur only in specific crystal classes. However, many machine-learning approaches predict these responses directly from composition, which may lead to physically inconsistent assignments.

This work presents FuncGPT, a crystallographically gated machine-learning framework for functional materials discovery. The framework uses crystallographic symmetry as an early physical guide before evaluating functional behavior. It first estimates the likely symmetry class of a candidate material and then determines whether the target response is physically allowed. Property prediction and candidate ranking are performed only within the symmetry-permitted domain, reducing non-physical predictions by design.

A GPT-based interface is integrated to make the framework more accessible and interactive. It allows users to query candidate materials, interpret predicted functional behavior, and obtain clear explanations of symmetry-based eligibility. This provides a practical route for screening dielectric, piezoelectric, pyroelectric, optical, and polar materials at an early design stage, especially when complete structural information is not yet available. Overall, FuncGPT combines crystallographic rules, machine learning, and an interactive response interface to support physically consistent and interpretable functional materials design.

Keywords: functional materials, FuncGPT, crystallographic symmetry, machine learning, GPT interface

Use of Differential Scanning Calorimetry for the Analysis of Mechanical Alloying Time in a TiCoCrFeMn High-Entropy Alloy

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Abstract

Mechanical alloying is a multi-parameter method used to produce alloys from elemental powders and one of the key aspects of this process is the time required to refine powder particles and obtain the desired phase structure. Determining the expected phases from equilibrium phase diagrams is relatively straightforward for binary alloys; however, it becomes considerably more complex for multicomponent systems, such as high-entropy alloys.

Mechanical alloying processes are typically monitored by X-ray diffraction (XRD) through analysis of changes in diffraction peak positions and crystallite size. However, this classical approach becomes less effective for newly developed multicomponent alloys due to the lack of appropriate entries in the powder diffraction file (PDF) database.

Therefore, in the case of mechanical alloying of high-entropy alloys, the required processing time was determined using differential thermal analysis (DTA) and thermogravimetric analysis (TG). During these measurements, controlled heating and cooling cycles were applied while changes in heat flux and sample mass were continuously recorded. The amount of thermal energy absorbed by the alloyed powder mixture during phase transformation processes, as reflected in the measured heat flux, was considered an indicator of the material's thermodynamic state, including the extent of phase transformations and diffusion phenomena during milling. It was assumed that longer alloying times correspond to higher energy input into the material; consequently, the thermal effects observed during calorimetric measurements should decrease in intensity with increasing milling time.

In the investigated case, a five-hour mechanical alloying process of equimolar Ti–Co–Cr–Fe–Mn powders resulted in a multiphase powder mixture consisting of two solid solutions with a BCC lattice that differed significantly in their lattice parameters, and an intermetallic phase corresponding to a C14 Laves phase with an HCP lattice.

Keywords: high-entropy alloys, mechanical alloying, differential thermal analysis (DTA), thermogravimetric analysis (TG)

Influence of Early Plastic Deformation on Yield Surface Evolution in LENS-Fabricated Inconel 718 Assessed by Multiaxial Testing and 3D EBSD

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Abstract

The present work examines the initial yield surface and its evolution under early-stage plastic deformation in Inconel 718 produced via Laser Engineered Net Shaping (LENS). Tubular specimens were tested under combined axial and torsional loading to determine yield surfaces at small plastic offsets and after pre-deformation levels up to approximately 1% plastic strain. Three-dimensional electron backscatter diffraction (3D EBSD) was used to quantify the as-built microstructural anisotropy and its evolution during the onset of plasticity, including changes in crystallographic texture and intragranular misorientation. The initial yield surface of LENS-manufactured Inconel 718 displayed pronounced directional dependence, reflecting significant mechanical anisotropy associated with the additive manufacturing process. Early plastic deformation led to notable distortions and rotations of the yield surface, suggesting rapid evolution of anisotropic hardening behavior. The combined mechanical and microstructural analysis demonstrates a strong linkage between microstructural heterogeneity, texture evolution, and yield surface development during the earliest stages of plastic deformation in Inconel 718.

Keywords: plastic deformation, Inconel 718, LENS, EBSD

Microstructural Evolution of the Transition Zone in CMT-Deposited Inconel 625 During Annealing at 650 °C

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Abstract

The microstructural characteristics, phase constitution, and chemical composition of the transition zone between a 16Mo3 steel boiler tube and an Inconel 625 weld overlay deposited by the Cold Metal Transfer (CMT) method were investigated. Particular attention was paid to the effects of post-deposition heat exposure at 650°C for 10 h on the evolution of the interfacial microstructure. The study focused on phase transformations, elemental diffusion across the interface, and the thermal stability of the deposited layer under elevated-temperature conditions representative of service environments. The studies on the effect of annealing on structural changes in the transition zone of the overlay weld showed that annealing the overlay made of the Inconel 625 alloy at a temperature of 650°C causes carbon diffusion from the base material toward the overlay, decomposition of martensite in the transition zone, precipitation of carbides as well as the formation of the γ″ phase comments.

Keywords: Cold Metal Transfer, transition zone, nickel alloy, boiler tubes

Acknowledgements

Research project partially supported by the AGH University of Science and Technology, Project 16.16.110.663 and by the program “Excellence initiative – research university” for the AGH University of Science and Technology.

Carbon Nanotubes - How to Analyze Them?

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Abstract

Methods for Carbon Nanotube Analysis: A Review of Techniques for Structural, Morphological, and Surface Characterization
Carbon nanotubes (CNTs) represent one of the most extensively studied classes of carbon nanomaterials, with their unique mechanical, electrical, and thermal properties making them attractive candidates for applications in tribology, electronics, composite materials, and biomedicine. Reliable characterization of CNTs is, however, a prerequisite for understanding the structure–property relationships that govern their functional performance.
This review article discusses the most important analytical techniques employed in CNT research. Raman spectroscopy enables identification of the degree of structural defectiveness (D/G band intensity ratio), wall number, and the presence of amorphous carbon phases. Electron microscopy — both scanning (SEM) and transmission (TEM/HRTEM) — provides information on morphology, tube diameter and length, as well as sample homogeneity. X-ray photoelectron spectroscopy (XPS) allows quantitative determination of surface chemical composition, identification of functional groups, and monitoring of modification and functionalization effects. Complementary information on covalently attached organic species is obtained by infrared spectroscopy (FTIR/ATR).
Textural properties of CNT samples — specific surface area (BET), pore size distribution, and micropore volume — are determined by gas sorption analysis. Thermogravimetric analysis (TGA) provides data on sample purity, residual metal catalyst content, and thermal stability. Comprehensive characterization of CNTs therefore requires the synergistic application of complementary techniques, enabling the rational design of functional materials based on carbon nanotubes.

Keywords: nanotechnology, nanomaterials, CNTs, analysis

3D-Printed Bioactive Polymer-Ceramic Composites for Bone Tissue Regeneration

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Abstract

Bioactive polymer-ceramic composites are widely investigated in bone tissue engineering due to their potential to enhance regeneration processes. Polymers offer significant advantages over traditional ceramic or metallic materials, including ease of processing, tunable mechanical properties, as well as good biocompatibility. However, polymers alone are not sufficient to achieve optimal performance, as the incorporation of bioactive ceramics is essential to mimic the composition of natural bone and to promote better osteointegration. Ceramics are extensively used in orthopedics because of their similarity to the mineral phase of bone, yet their inherent brittleness limits their use as standalone materials. Combining ceramics with a polymer matrix helps overcome this limitation by improving mechanical performance while preserving bioactivity.

The aim of this study was to develop an optimized polymer-ceramic composite capable of accelerating bone regeneration after implantation. A critical aspect of this work was the appropriate selection of both the bioactive ceramic phase and the inert thermoplastic polymer matrix. The resulting composite was used to fabricate granules, used for implant prototypes via 3D printing.

Experimental studies conducted in simulated biological environments demonstrated the material's ability to support apatite mineralization, indicating its potential to promote bone formation. Prior to in vivo evaluation, the material underwent extensive in vitro cell-based testing, confirming its cytocompatibility. Subsequent in vivo studies using an animal model further validated its biocompatibility and regenerative potential. The developed composite exhibits a well-balanced combination of bioactivity, mechanical stability, and printability, making it a promising candidate for next-generation bone implants.

Keywords: polymer-ceramic composites, tissue regeneration, 3D printing

Acknowledgements

The authors gratefully acknowledge the financial support of the project: "Bioactive composite granules with potential for 3D printing LIDER14/0266/2023".

Interaction Mechanisms and Wetting Behavior of Liquid Al on Ti+C Compacted Substrate

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Abstract

Aluminum (Al) and its alloys are widely used in the automotive industry due to their low density, good castability, and favorable strength-to-weight ratio. However, their limited mechanical performance has stimulated the development of aluminum matrix composites reinforced with ceramic phases. In this context, the present study investigates the high-temperature interaction between liquid Al and a Ti+C substrate produced from a compacted mixture of Ti and graphite powders.

Real-time observations of interfacial phenomena (including wetting, spreading, and infiltration) were performed at 800 °C under high vacuum using the sessile drop method combined with non-contact heating and a capillary purification procedure. This methodological approach effectively removed the native oxide film from Al and eliminated the influence of heating history inherent to conventional contact-heating configurations.

Initially, the Al/Ti+C couple exhibited non-wetting behavior for approximately 40 s. This stage was followed by reactive wetting accompanied by liquid metal penetration into the porous substrate, resulting in a decrease in the apparent contact angle to about 40°. Microstructural analyses (SEM and TEM) revealed that, under the conditions of this study, interfacial processes were dominated by reaction-controlled interactions between oxide-free liquid Al and Ti powder in the substrate, leading to the formation of the $TiAl_3$ intermetallic phase. Additionally, localized formation of TiC was detected, likely associated with transient thermal fluctuations that promoted short-range diffusion of carbon and titanium in liquid Al. The results also indicate the presence of reactively formed Al_2O_3, produced via redox reactions between oxide-free Al and oxidized Ti particles, which further influenced the wetting behavior of the Al/Ti+C system.

Keywords: wetting, liquid Al

Biofilm Formation and Antimicrobial Enhancement of PCL-based Polyurethane Biomaterials

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Abstract

The aim of this study was to investigate the effect of the molar ratio of reagents used in polyurethane (PU) synthesis on the susceptibility of their surfaces to colonization by selected bacterial species. The bacterial strains included Staphylococcus aureus, Staphylococcus epidermidis, Enterococcus faecalis, Enterobacter cloacae, and Pseudomonas aeruginosa, which are among the most common microorganisms encountered in the surgical field. Polyurethanes were synthesized using poly(ε-caprolactone) diol (PCL-diol), 1,4-butanediol (BDO), and hexamethylene diisocyanate (HDI). The molar composition of the monomers was adjusted to obtain hard segment (HS) contents ranging from 17.6 to 32.0 wt.%.

The bacteriological evaluation was performed for polyurethanes containing 17.6, 25.5, and 32.0 wt.% hard segments. Surface analysis after incubation in bacterial suspensions revealed progressive microbial colonization, leading to biofilm formation and degradation-related changes such as pits and cracks. Initial signs of biofilm formation were observed after one month of exposure, whereas after six months the entire surface of the samples was covered by biofilm. These findings indicate that the hard segment content significantly influences bacterial adhesion and the course of biological degradation processes in polyurethane materials.

To reduce bacterial colonization and biofilm formation, antimicrobial additives in the form of curcumin and silver were incorporated into the polyurethane matrix at concentrations up to 10 wt.%. The resulting composites exhibited improved resistance to bacterial adhesion and microbial growth, leading to enhanced antibacterial performance and increased potential for biomedical applications.

Keywords: polyurethane, biofilm, antimicrobial enhancement, biomaterials

Comparative Design and Material Selection for an Adjustable Bone Fixation Plate using FEA

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Abstract

Stabilization of bone fractures using fixation plates is the predominant surgical treatment; however, current systems offer limited flexibility once screws are tightened. Post-fixation repositioning requires complete plate removal and re-drilling, increasing operative risk and tissue trauma. Complications such as nonunion, malunion, inadequate plate stiffness, and plate fracture may further necessitate revision surgery. This study aims to design and select materials for an adjustable bone fixation plate that overcomes the inability to reposition fracture fragments after screw tightening. The proposed system consists of three detachable components: a left base plate, a right base plate fixed to bone fragments, and a replaceable central plate connecting both bases. The central plate attaches to pre-fixed bases, allowing independent fracture positioning without loosening screws. If complications occur, only the central plate requires replacement. Mechanical stability will be analyzed using 3D CAD and finite element analysis (FEA) under compression, bending, and torsion, with particular focus on von Mises stress distribution and displacement at the central plate junction. A comparative material study will be conducted for the central plate using Co-Cr-Mo and Ti-6Al-4V, with cortical bone as a reference. Co-Cr-Mo is expected to provide superior strength and wear resistance, while Ti-6Al-4V offers better stress shielding reduction due to its elastic modulus being closer to that of cortical bone. This study aims to validate that the proposed modular system enables independent fracture positioning, reversible plate replacement, and preserved screw fixation, establishing it as a promising solution for complex bone repositioning cases.

Keywords: adjustable bone fixation plate, cortical bone, finite element analysis

Acknowledgements

This work was supported by the Rector's grant for young scientists at Silesian University of Technology, project no. 32/014/SDU/10-22-93.

Insights into the Superparamagnetic Behavior of Fe-Loaded Mesoporous Silica for Application as MRI Contrast Agent

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Abstract

Iron-loaded mesoporous silica has attracted considerable interdisciplinary interests owing to its versatile functionality across multiple fields, including targeted drug delivery and cancer theranostics, heterogeneous catalysis, and energy storage applications such as lithium-ion and lithium-sulfur batteries. The incorporation of iron into the mesoporous silica framework uniquely combines the high surface area and tunable porosity of the silica matrix with the magnetic and catalytic properties of iron oxide, making it a multifunctional platform of broad scientific and technological applications. In this work, mesoporous silica with a cubic structure was synthesized via the sol-gel method, and iron oxide nanoparticles were incorporated at varying concentrations using ultrasonication. The structural and magnetic properties of the resulting composites were systematically characterized, with particular emphasis on X-ray diffraction (XRD), nitrogen adsorption-desorption (BET), and vibrating sample magnetometry (VSM). This analysis definitively confirmed the superparamagnetic nature of the Fe-loaded composite, as evidenced by the complete absence of remnant magnetization and coercivity. This superparamagnetic behavior is the critical property required for MRI contrast agents to prevent particle agglomeration and enable effective tissue imaging. Cytotoxicity assessment further indicated favorable biocompatibility at optimal Fe concentrations. It has been successfully demonstrated that Fe-loaded mesoporous silica exhibits genuine superparamagnetic behavior, establishing it as a promising and biocompatible candidate for MRI contrast enhancement applications.

Keywords: superparamagnetism, Fe-loaded silica,MRI contrast agent, mesoporous materials, remanence

Acknowledgements

This work was supported by the National Science Centre, Poland (UMO-2023/51/I/ST11/02716) and the Research Foundation – Flanders (G000225N).

Antibacterial and pH-Responsive Polymeric Materials Incorporating Natural pH-Sensing Compounds

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Abstract

Natural organic–inorganic hybrid pigments were developed by immobilizing pH-sensitive dyes onto mineral carriers to obtain sustainable multifunctional additives for polymer materials. Anthraquinone dyes (alizarin and purpurin) and selected azo dyes containing hydroxyl and carboxyl functional groups were deposited onto aluminum–magnesium hydroxides, vermiculite, and sepiolite through interactions with naturally occurring metal ions. The resulting hybrid pigments were incorporated into polymer matrices, where they served as colorants and functional fillers. The pigments enhanced mechanical performance, reduced flammability, and provided a distinct colorimetric response to pH variations, enabling intelligent sensing capabilities. In addition, the presence of mineral supports and bioactive natural dyes contributed to antibacterial activity against both Gram-negative Escherichia coli and Gram-positive Staphylococcus aureus, increasing the applicability of these materials in active and intelligent packaging systems. The combination of renewable dye sources with naturally occurring mineral carriers offers an environmentally friendly approach to the design of smart polymer materials. These results demonstrate that natural hybrid pigments can simultaneously provide coloration, functional reinforcement, antibacterial performance, and pH-responsive behavior, making them promising candidates for sustainable bio-based packaging applications.

Keywords: natural dyes, organic–inorganic hybrid pigments, antibacterial activity, Escherichia coli, Staphylococcus aureus, pH-responsive materials, smart packaging

High-Temperature Plasticity and Failure Mechanisms of Mg-Y-RE-Zr Magnesium Alloy

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Abstract

The aim of this study was to investigate the high-temperature plasticity of the Mg-Y-RE-Zr magnesium alloy (WE43), to determine the zerostrength temperature and zero ductility temperature, to identify the dominant fracture mechanisms under elevated temperature conditions. The study was determined using a Gleeble 3800 thermomechanical simulator, which made it possible to define the upper limit of plastic processing for the investigated alloy.
Uniaxial tensile tests were carried out in the temperature range of 200-450 °C in order to determine stress–strain curves and to evaluate the changes in flow stress and plastic deformation capability with increasing temperature. Microstructural analysis was performed using optical microscopy, while the fracture characteristics were examined by means of scanning electron microscopy (SEM).
The results revealed a clear dependence of mechanical properties on temperature. With increasing temperature, a significant decrease in flow stress was observed, accompanied by a change in the dominant failure mechanism from predominantly brittle to ductile. Correlation of the mechanical test results with microstructural observations made it possible to determine the effective temperature range for plastic processing of the WE43 alloy.
The results provide a basis for optimizing thermomechanical processing parameters of magnesium alloys containing rare earth elements and for determining their limiting operating conditions at elevated temperatures. Moreover, the obtained findings contribute to a better understanding of the deformation and fracture behavior of Mg-Y-RE-Zr alloys under high-temperature loading conditions..

Keywords: Mg-Y-RE-Zr magnesium alloy, high-temperature plasticity, fracture mechanisms, tensile test, mechanical properties, microstructure

Acknowledgements

The research was partially financed under statutory research BK-222/RM3/2026; (11/030/BK_26/1250) and pro-quality programs 11/030/SDU/10-21-04 and 11/030/SDU/10-04-06 of the Silesian University of Technology.

Specific Effects of Hydrogen Presence in Steels for the Power Industry

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Abstract

Hydrogen-assisted degradation is a broad issue concerning the durability of materials during their service life. Due to the wide range of hydrogen occurrence in metals, problems caused by hydrogen corrosion also encompass a wide range of issues: from decarburization by hot hydrogen to cracks and blisters, delamination, “fish eyes” cracks around non-metallic inclusions, snowflake cracks, and characteristic fracture cracks in high-stress areas.

The first and most important criterion for assessing the effects of hydrogen in materials is the deterioration of mechanical properties, primarily manifested by a decrease in ductility in the form of reduced elongation and reduction in tensile strength, as well as a decrease in impact strength. The so-called hydrogen embrittlement coefficient is most often determined in this case.

The worst and most dangerous effect of hydrogen in a material is microstructural changes resulting from cracks – delamination, hydrogen- or methane-filled bubbles, which can cause the complete destruction of structures, pressure vessels, pipelines, etc., with all their negative human, ecological, and economic consequences.

This paper presents the characteristic effects of hydrogen exposure in A508.3 steels for nuclear power and 10CrMo9-10 (10H2M) boiler steel. Detailed analysis focused on the characteristic "fish eyes" microcracks and degradation of mechanical properties.

Keywords: hydrogen, steel, power industry

Acknowledgements

The research financed by BK-219/RM0/2026 (11/990/BK_26/0092)

Influence Long-Term Thermal Exposure at 650°C on the Creep Resistance of X10CRWMOVNB9-2 Pipe Welds

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Abstract

X10CRWMOVNB9-2 steel is a modern martensitic heat-resistant steel currently used for seamless pressure equipment operating under supercritical conditions. The paper presents the results of a study on the strength properties and structure of an X10CRWMOVNB9-2 steel welded joint used for pressure components of power units. The paper presents an assessment of the suitability for further operation of both the parent material and a circumferentially similar welded joint of finished products in the form of X10CRWMOVNB9-2 steel pipes after annealing for 10000 hours at 650°C. Annealing at 650°C results in a faster increase in precipitate size and their coagulation along the grain boundaries of former austenite and martensite laths. The changes in mechanical and creep properties were compared with respect to the parent material's structure and the welded joint material.

Keywords: X10CRWMOVNB9-2 steel, similar welded joint, microstructure, mechanical properties, creep, annealing

Attention-Guided Surrogate Reconstruction of Multicomponent Phase-Field Simulations for Laser-Processed CoCrFeNi

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Abstract

Laser processing of multicomponent alloys involves strongly coupled thermal, chemical, interfacial, and flow phenomena, making direct experimental quantification costly and high-fidelity phase-field simulations computationally expensive. This work presents an attention-regularized multicomponent phase-field surrogate for rapid prediction of laser-induced temperature and phase evolution in CoCrFeNi alloy. The surrogate is developed to overcome the computational bottleneck of repeated phase-field simulations while preserving the thermodynamic and interfacial information required for Digital Twin construction and laser-microstructure interface quantification. A non-isothermal finite-element phase-field model is first used to generate physics-based spatiotemporal tensors under different laser powers and scan speeds. The model couples transient heat transfer with a moving laser source, LIQUID/FCC phase evolution, multicomponent diffusion, temperature-dependent material properties, meltpool flow, and Marangoni convection. The resulting temperature, phase-field, composition, and flow outputs form a thermodynamic tensor representation of the laser-microstructure response. A transformer-inspired interpolation engine is then implemented, where target laser conditions are treated as queries and available simulations as keys. Cross-attention weights are regularized using Gaussian locality in the laser-parameter space, preventing physically distant source cases from dominating the reconstruction. The hybrid attention weights predict temperature and LIQUID/FCC phase-field tensors for unseen processing conditions. The framework preserves meltpool position, thermal distribution, phase-interface morphology, and liquid-area evolution while reducing dependence on repeated finite-element simulations. This study provides a compact simulation-to-surrogate route toward Li-ion battery-powered Digital Twin-enabled quantification of laser-microstructure interfaces in multicomponent alloys.

Keywords: multicomponent phase-field model, CoCrFeNi alloy, laser-microstructure interface, attention-based surrogate model, digital twin

Microstructural Evolution and Asymmetric Reactive Diffusion Kinetics in FeNiCo/Cu Joints Brazed with Cu-Zn-In Filler Metal

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Abstract

The reliability of FeNiCo/Cu joints depends on the compensation of thermal stresses arising from significant CTE disparities. Conventional fillers often induce brittle IMCs. This study utilizes an innovative CuZnIn (CZI5) filler to lower processing temperatures and modify diffusion kinetics. The joint was brazed at 785°C (under argon) and was analyzed using SEM, TEM-STEM, and EDS. DSC analysis of the CZI5 alloy revealed solidus and liquidus temperatures of 778.5°C and 823.0°C, respectively. Results demonstrated a hermetic joint with distinct asymmetric reactive interfaces. At the FeNiCo/CZI5 interface, reactive wetting and selective Ni dissolution predominated. Intense Zn diffusion along grain boundaries generated a 23.1–26.2 µm diffusion zone and a compact g -CuZn(Ni) barrier layer, effectively inhibiting substrate erosion. Conversely, the Cu/CZI5 interface was characterized by bulk Cu dissolution and vacancy diffusion, forming a 31.5 µm ductile a-Cu(Zn) solid solution zone that optimally compensates for thermal stresses. Owing to its large atomic radius and steric barrier, indium did not penetrate the substrates, instead undergoing forced segregation in the joint center (locally>20 at.%). During cooling, hard g-Cu9(In,Zn)4 and δ-CuIn phases crystallized. Their concentration near the interface may initiate cohesive microcracks. While CZI5 creates a stable diffusion barrier on the Kovar alloy and a ductile buffer on the Cu, cooling rate optimization is essential to control the dispersion of brittle indium-based phases and ensure long-term structural integrity.

Keywords: brazing, FeNiCo, Rreactive diffusion, substrate dissolution, Cu-Zn-In filler metal

Acknowledgements

This work was funded by the Institute of Metallurgy and Materials Science of the Polish Academy of Sciences as part of a statutory task Z-3/2025.

Fatigue Properties of Twin/Matrix Microstructure in FCC Metallic Materials

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Abstract

It is well established that deformation twinning plays a significant role in shaping the mechanical properties of metallic materials. In recent years, particular interest has been focused on Twinning Induced Plasticity (TWIP) steels. These materials are characterized by a unique combination of high strength and above-average ductility, as well as the possibility of further modification of mechanical parameters as a result of strain hardening. For this reason, TWIP steels are finding increasingly widespread application in structures where it is possible to simultaneously increase the load-bearing capacity of components and reduce material wear.

Therefore, this study attempts to analyze the fatigue properties of a twinned induced twin/matrix structure in a specific crystallographic configuration in which the shear stress of the slip and twin systems of the twinning plane was minimized to practically zero. This configuration is characterized by a high yield strength (approximately 500 MPa) and limited plasticity, which favors early strain localization. Such a system provides a suitable model for fundamental research on the mechanisms of initiation and propagation of fatigue damage in layered structures. These results revealed that the fatigue life of the investigated specimens ranged from 8 000 to 23 000 cycles, with an average value of 15 350 cycles. Analysis of the final stage of fatigue demonstrated that approximately 200 cycles prior to failure, a rapid accumulation of plastic strain occurs. In the final loading cycle, the strain increased abruptly, reaching an average value of 5.13%, which clearly indicates the development of highly localized plastic deformation leading to specimen failure. Microstructural investigations showed that within the localization zone, the dominant deformation mechanism is the collinear slip system PI, operating on plane DB in the twin and plane D in the matrix, with the shear direction along the crystallographic direction [011].

Keywords: fatigue testing, deformation twinning, single crystals

Acknowledgements

This research was carried out within the statutory work no. Z-4 of the Institute of Metallurgy and Materials Science of the Polish Academy of Sciences. The support of AGH University of Cracow is also acknowledged.

Structural Evolution and Potential Shape Memory Behaviour of TiHfZrCoCuNi Alloys

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Abstract

NiTi-based high-entropy and multi-principal element shape memory alloys are promising high-temperature functional materials. TiZrHfCoNiCu alloys undergo martensitic transformation between ordered B2 austenite and B19' martensite [1]. In the B2 phase, Ti, Zr and Hf occupy Ti-type sublattice sites, while Ni, Co and Cu occupy Ni-type sites [2]. However, the role of Ti-type elements, especially Zr substitution in the Ti-Hf sublattice, remains insufficiently clarified.

In this work, the influence of Zr content on the phase constitution, microstructure and martensitic transformation of (TiHf)50−xZrx(CoCuNi)50 alloys was investigated, where x = 0, 8, 16, 24 and 32 at.%. The alloys were prepared by vacuum arc melting from pure elemental pieces, homogenised at 950 °C for 100 h under argon. The samples were characterised by XRD, SEM and DSC.

XRD showed that alloys containing 0–24 at.% Zr were composed of the cubic B2 phase, whereas the 32 at.% Zr alloy exhibited dominant martensite coexisting with B2 austenite. The lattice parameter increased linearly with Zr content, while the difference between coexisting phases decreased. DSC revealed no martensitic transformation for alloys with 0–16 at.% Zr. Transformation effects were observed for the 24 at.% Zr alloy between −50 and −120 °C and for the 32 at.% Zr alloy between 50 and 130 °C. SEM showed two chemically distinct matrix phases in the Zr-free alloy, whereas increasing Zr content led to more homogeneous matrix contrast. The 32 at.% Zr alloy exhibited plate-like martensitic morphology. All alloys contained Ti- and Zr-rich third-phase particles with minor Co, Ni and Hf. These results show that Zr affects phase stability and promotes potential shape memory behaviour.

Keywords: high-entropy shape memory alloys, TiHfZrCoCuNi alloys, martensitic transformation, B2 austenite, B19' martensite, Zr substitution

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Optimization of the Implementation of the Injection Process on the Example of a Selected Injection Mold for Automotive

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Abstract

The plastic injection molding process is one of the key areas of modern industrial production, where product quality, process stability, and economic efficiency directly impact a company's competitiveness. In particular, the implementation phase of a new injection mold is a critical stage, determining the subsequent course of mass production. It is at this stage that problems most often arise, related to process instability, high production rejects, and difficulties in meeting customer quality requirements.

A key aspect of the injection molding process is obtaining parts of appropriate quality, fully compliant with the technical documentation and customer expectations, while ensuring production starts in the shortest possible time. Optimizing injection process parameters not only allows for meeting rigorous quality standards but also reduces costs related to excessive material and energy consumption, as well as machine and personnel time. Minimizing production rejects is also particularly important, as they constitute a significant source of financial and organizational losses during the initial implementation phase of a new injection mold. This article focuses on the optimization of the injection molding process using a selected injection mold as an example. Methods and activities enabling effective and quick verification of processes, cost reduction and achieving process stability guaranteeing high quality of manufactured parts are described.

Keywords: automotive, plastic injection, polypropylene, optimization

High-Temperature Interfacial Interaction Between Liquid Magnesium and Group-VI Transition Metals (Cr, Mo, W)

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Abstract

Understanding the interfacial behavior between liquid magnesium and refractory metals is essential for the design of advanced casting processes, protective coatings, and containment materials used in high-temperature Mg processing. This work investigates the high-temperature interactions between liquid Mg and group VI transition metals of the periodic table: chromium, molybdenum, and tungsten.

Sessile drop experiments combined with a capillary purification procedure were performed to evaluate the wetting behavior of liquid Mg on Cr, Mo, and W substrates at 700°C under Ar+5 wt% H2 atmosphere. The results demonstrate that investigated Mg/metal systems exhibit non-wetting behavior, with average contact angles exceeding 90°[1,2].

Microstructural and chemical analyses of the solidified couples were conducted using scanning electron microscopy and energy-dispersive X-ray spectroscopy. The results reveal no intermetallic compound formation at the interfaces. Furthermore, no dissolution of the substrate materials into the liquid Mg was observed during the experiments.

These findings indicate that Cr, Mo, and W are chemically and thermodynamically stable in contact with liquid Mg within the investigated conditions. The strong non-wetting behavior and absence of interfacial reactions highlight the suitability of these refractory metals for crucibles, molds, containers, and other components, and protective barriers in Mg processing technologies. The study provides new insights into the interfacial stability of Mg with refractory metals. It contributes to the broader understanding of wetting and reactivity phenomena in liquid/metal systems relevant to high-temperature metallurgical applications.

Keywords: magnesium, refractory metals, contact angle, sessile drop, wetting

Acknowledgements

This research was supported by the National Science Centre of Poland within the OPUS 21 Project, no. 2021/41/B/ST5/02787 in the years 2022–2026.

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Analysis of the Braze-Weldability of a Dissimilar Joint of Titanium Alloy and Austenitic Stainless Steel Using Physical Simulation of Welding Processes

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Abstract

The growing importance of nuclear power generation has created an increasing demand for structures combining materials with high corrosion resistance and superior mechanical properties while simultaneously reducing manufacturing costs. In this context, dissimilar joints between Ti6Al4V titanium alloy and AISI 316L stainless steel appear particularly promising. However, the fabrication of such joints using conventional fusion welding techniques remains challenging due to the formation of brittle Ti–Fe intermetallic compounds, which significantly deteriorate the mechanical performance and corrosion resistance of the joint. Physical simulation of welding processes using the Gleeble 3500 thermo-mechanical simulator provides an effective tool for investigating the joining of dissimilar materials under conditions similar to those encountered in braze welding. The aim of this study was to evaluate the suitability of the Gleeble 3500 for performing physical simulations of the braze welding process of a dissimilar joint between Ti6Al4V titanium alloy and AISI 316L stainless steel using CR009A copper, CuNi5, and CuNi10 interlayers. In addition, the mechanical properties, microstructure, and elemental distribution within the simulated joints were investigated. The results confirmed the suitability of the Gleeble 3500 for controlled physical simulation of dissimilar braze-welded joints between Ti6Al4V titanium alloy and AISI 316L stainless steel. Although the investigated Cu-based interlayers did not fully suppress the formation of brittle Ti-Fe intermetallic compounds, the simulated joints exhibited measurable tensile strength and provided valuable insight into the diffusion mechanisms governing joint performance. Microstructural and compositional analyses revealed the critical role of interfacial reactions in strength degradation, highlighting the need for further optimization of interlayer composition and thermal processing conditions for titanium-steel dissimilar joints.

Keywords: Ti6Al4V, AISI 316L, dissimilar joints, Gleeble 3500, physical simulation, braze welding, copper interlayers, Ti–Fe intermetallic phases, microstructure, tensile strength

ZnO-Based Heterojunctions for Advanced Applications with Emphasis on Polymer/ZnO Systems

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Abstract

Zinc oxide (ZnO)-based heterojunctions have attracted significant attention for next-generation optoelectronic and energy applications due to their wide band gap, high exciton binding energy, and tunable surface properties. In this work, porous anodic alumina (PAA) templates fabricated under different anodization parameters are employed as a platform for the controlled growth of ZnO nanostructures, enabling precise regulation of morphology and spatial organization. The use of PAA with tunable pore geometry provides an effective route to engineer the structural properties of ZnO at the nanoscale.

This study focuses on the design of polymer/ZnO heterojunction systems, where ZnO nanostructures grown within PAA templates are integrated with functional polymers to enhance charge transport and interfacial interactions. The combination of template-assisted growth and polymer functionalization enables improved control over defect passivation, surface states, and energy band alignment. Various fabrication approaches, including solution-based deposition and surface modification techniques, are utilized to optimize the structural and optical properties of the resulting heterostructures.

The developed systems exhibit enhanced photoluminescence characteristics, indicating improved optical quality and reduced non-radiative recombination. Furthermore, the synergistic interaction between the polymer matrix and ZnO nanostructures contributes to improved device-relevant properties. These findings demonstrate the potential of PAA-templated polymer/ZnO heterojunctions for applications in UV optoelectronics, sensing, and flexible electronic devices, while providing insights into the rational design of hybrid nanostructured materials.

Keywords: ZnO nanostructures, polymer/ZnO heterojunctions, porous anodic alumina (PAA), photoluminescence, UV optoelectronics, hybrid nanomaterials

Nanomechanical Behaviour of Irradiated Cobalt-Free High-Entropy Alloy

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Abstract

High-entropy alloys (HEAs) have attracted increasing interests for nuclear engineering applications due to their outstanding mechanical properties under extreme conditions. Among the large compositional space, cobalt is not suitable due to its long-term radioactivity under irradiation environments. To address this challenge, we designed a Co-free HEA, $Ni_{43.5}Fe_{33.5}Mn_6Cr_{11}Al_6$. The nanomechanical behaviour was investigated under different ion-irradiation doses and temperatures. The nanoindentation tests were carried out using different loads, i.e., 40 mN, 60 mN, 80 mN and 100 mN. The results demonstrated that irradiation-induced defects significantly influence the nanomechanical response of the Co-free HEA. The HEA showed pronounced irradiation hardening, which is dose dependent. At 100 mN loading, the hardness of the HEA increased from 2.03 GPa to 2.37 GPa under high temperature irradiation. High temperature irradiation suppressed the hardening effect. They provide insights into the design of Co-free HEAs for radiation-tolerant structural materials.

Keywords: high-entropy alloy, nanoindentation, irradiation

Applicability of the Small Punch Test for Evaluating Impact Properties of Degraded Structural Steels

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Abstract

The integrity assessment of pressure components used in the energy and petrochemical industries requires reliable characterization of fracture resistance, particularly within the ductile-to-brittle transition regime. Conventional impact testing methods require relatively large material volumes, limiting their applicability for in-service components and degradation studies. Therefore, increasing attention is being paid to small-scale testing techniques capable of providing fracture-related parameters.

This study evaluates the applicability of the Small Punch Test (SPT) for assessing the impact properties of carbon steel P265GH and low-alloy steel 13CrMo4-5, widely used in the energy and pressure vessel industries. Standard Charpy V-notch impact tests were performed only for the as-received materials, while SPT investigations were carried out both in the as-received condition and after three heat treatment variants simulating microstructural degradation during long-term service. The applied heat treatments reproduced structural changes typical of industrial operating conditions.

The experimental program included microstructural observations and mechanical characterization by means of static tensile testing, Charpy impact testing, and the Small Punch Test. Both Charpy and SPT tests were conducted at room temperature and at reduced temperature achieved using liquid nitrogen, allowing analysis of temperature effects on ductile-to-brittle transition behavior and associated fracture mechanisms.

The obtained results indicate the possibility of identifying relationships between SPT-derived parameters and the absorbed energy measured in the Charpy test, while demonstrating sensitivity of the SPT response to microstructural degradation and testing conditions. The study provides a basis for further development of correlations between conventional and small-scale testing techniques.

Keywords: small punch test, impact properties, charpy V-notch, P265GH, 13CrMo4-5, microstructural degradation, fracture behavior

Microstructural Exploration of a Compositional Gradient in W-Ta-Cr-V High-Entropy Alloy Thin Films for Fusion Applications

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Abstract

Low-activation refractory high-entropy alloys (RHEAs) are promising candidates for plasma-facing components in fusion reactors. However, their structural integrity is strongly affected by elemental concentrations that alter phase stability under extreme conditions. Navigating this vast compositional space remains a significant challenge.

In this work, we investigate the influence of local stoichiometry on the microstructural evolution of the W-Ta-Cr-V system. Nanostructured thin films were deposited via magnetron sputtering. By strategically arranging targets, a continuous compositional gradient was introduced, enabling high-throughput combinatorial exploration within a single deposition.

Characterization was performed using XRD, SEM-EDS, and TEM to correlate the spatially varying composition with the resulting microstructure. Preliminary results indicate a predominant body-centered cubic (BCC) solid solution. SEM-EDS mapping reveals morphological transitions tied to local composition, while TEM uncovers fine-scale features, grain boundary characteristics, and nanoscale phase stability governed by specific stoichiometries.

These results highlight how local alloy chemistry controls microstructural evolution in W-Ta-Cr-V RHEAs. The findings demonstrate the effectiveness of combinatorial sputtering and advanced electron microscopy in accelerating the design of radiation-tolerant materials for next-generation nuclear systems.

Keywords: refractory high-entropy alloys, nanostructured thin films, magnetron sputtering

Functionalized Carbon Nanomaterials in Membrane Systems for Wastewater Treatment

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Abstract

The growing pressure on water resources, combined with the need to reduce the environmental impact of industrial activities, has increased the importance of technologies supporting sustainable water management and circular economy principles. In this context, membrane-based processes play a key role, enabling efficient wastewater treatment as well as water recovery and reuse in technological systems.

The increasing complexity of industrial effluents, particularly those generated in sectors such as electronics, metallurgy, and surface treatment technologies, poses significant challenges for conventional treatment methods. The presence of heavy metals and organic contaminants, characterized by high toxicity, persistence, and bioaccumulation potential, necessitates the development of advanced and efficient separation techniques.

Membrane processes are among the most effective methods for substance separation and are widely applied across various industrial sectors. A key direction in their development is the incorporation of nanomaterials into polymeric membrane structures, which may lead to improved performance, including enhanced stability and reduced fouling.

In this context, carbon nanomaterials, particularly carbon nanotubes, represent an important class of one-dimensional nanostructures with high specific surface area and tunable surface chemistry. Since carbon nanotubes are inherently hydrophobic, surface functionalization can improve their dispersion and facilitate their effective incorporation into polymer matrices.

This work presents an approach focused on the development of polymeric membrane materials incorporating functionalized carbon nanomaterials for wastewater treatment applications. Particular attention is given to the design of composite membrane materials with properties tailored for separation processes, with emphasis on the role of nanomaterial functionalization in advanced material design.

Keywords: carbon nanotubes, nanomaterials, nanostructured materials, composite membranes, surface functionalization, adsorption

Pressure-Assisted Synthesis of Star-Shaped Poly(γ-butyrolactone): A Sustainable Route to Biodegradable Polyesters

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Abstract

Poly(γ-butyrolactone) (PGBL) represents a class of biodegradable and biocompatible polyesters with high application potential in the biomedical and packaging sectors. It is characterized by a unique combination of exceptional elasticity (elongation at break: 1000%) and high tensile strength (50 MPa). With easy thermoforming (Tm~60°C, Tg~-51°C) and a rapid absorption rate (8-52 weeks), PGBL stands out as a rare and promising alternative to traditional aliphatic polyesters. Despite these outstanding properties, PGBL remains commercially unavailable due to the thermodynamic stability of its five-membered cyclic monomer (GBL), which typically resists ring-opening polymerization (ROP). Traditional routes require extreme conditions, metal-based catalysts requiring costly purification, or highly active organocatalysts that still lead to poor yields and limited structural control.

In our approach, a combination of pressure and a non-toxic, cheap organocatalyst (TBD) unlocked a new path for robust (even 15 min!) and efficient synthesis of well-defined and biocompatible star-shaped PGBL at room temperature under solvent- and metal-free conditions. Our methodology delivered high-quality polymers, reaching Mn=3,700-14,600 with excellent homogeneity (represented by narrow dispersity, Đ=1.05-1.41) and yields up to 60%. Pressure served here as a "synthetic game changer", suppressing termination and ensuring chain-end fidelity, confirmed via chain extension to star-shaped diblock copolymers (PGBL-b-PLA) allowing for precise fine-tuning of the material's properties. From a processing perspective, this method is 4-5 times less energy-intensive than maintaining sub-zero temperatures (e.g., -40°C) which, coupled with operational pressures aligning with industrial technology, ensures high scalability potential. These findings establish pressure-supported synthesis as a feasible industrial route that can become a significant milestone toward the large-scale production of this material.

Keywords: poly(γ-butyrolactone), ring-opening polymerization, pressure-assisted polymerization, topology, biodegradable polymers

The Interaction Between Creep and Fatigue in Two-Phase Titanium Alloy Ti-6Al-2Mo-2Cr at Elevated Temperature

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Abstract

One of the important criteria for selection titanium alloys for discs and blades of turbine engine compressor is their fatigue and creep strength at room and elevated temperature. Fatigue and creep properties of two-phase titanium alloys show strong dependence on microstructure, especially morphology of the a and b phases which can be controlled to certain extent by proper selection of hot working and heat treatment conditions. Quantitative determination of correlation between microstructural parameters and selected mechanical properties has been always very challenging task due to large number of factors affecting deformation and fracture behaviour of the two-phase titanium alloys under complex load and environmental conditions.

In the course of the research creep-fatigue behaviour of Ti-6Al-2Mo-2Cr alloy (VT3-1) was investigated and compared to low-cycle fatigue and static creep properties at the temperature of 400 and 450°C. The microstructure of the alloy was varied by means of changing conditions of heat-treatment. Constant load tensile creep tests were carried out. Tension-tension cyclic loading was applied at the constant stress ratio with and without hold time at maximum load. The relations between morphology of the alloy microstructure and the effect of load hold periods at peak stress was established. Relative contributions of cyclic and creep processes to the overall damage were evaluated as a function of stress level and test temperature. Characteristic features of fracture surfaces were identified by scanning electron microscopy methods.

Keywords: two-phase titanium alloys, creep, fatigue, microstructure

Comparative Microstructural Study of La-Containing and La-Free Ni-Ti-Y-Si High-Entropy Alloys

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Abstract

High-entropy alloys (HEAs) are multicomponent systems characterized by high configurational entropy, which can stabilize solid solution phases despite significant differences in atomic radii and chemical properties. This is a rapidly developing class of metallic materials possessing unique combinations of structural and functional properties. This study investigates the microstructural evolution of a NiTiYSi-based HEA system, specifically focusing on the effects of Lanthanum (La) addition. The alloys, including the La-containing variant and the baseline La-free alloy, were synthesized via arc melting under an argon atmosphere and subjected to a re-melting and homogenization process. Phase analysis and microstructural characterization were performed using X-ray diffraction (XRD) and scanning electron microscopy (SEM) coupled with energy-dispersive X-ray spectroscopy (EDS) and an electron backscattered diffraction detector (EBSD). The obtained results confirmed that both alloys exhibit multiphase microstructures, indicating that solidification in this complex system leads to phase separation and chemical partitioning.

Keywords: High-entropy alloys, microstructure, HEA

YOUNG RESEARCHERS ZONE

Limitations and Perspectives of Numerical Analysis of TPMS Structures in the Context of Energy Absorption

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Abstract

Triply Periodic Minimal Surface (TPMS) structures are increasingly investigated as a promising class of architected materials for energy absorption applications. However, their numerical analysis remains challenging due to complex geometry and highly non-linear deformation mechanisms observed under different loading conditions. This work focuses on the limitations of numerical approaches used to model TPMS structures subjected to quasi-static compression and dynamic loading. A critical review of selected literature is presented, with emphasis on common modeling assumptions related to material constitutive behavior, boundary conditions, and damage representation in energy absorption studies. Particular attention is paid to challenges associated with numerical stability, mesh dependency, contact formulations, and strain-rate effects, which significantly influence the predicted energy absorption performance in both quasi-static and dynamic analyses. Based on the identified limitations and the author's own research concepts, perspectives for improving numerical modeling strategies are discussed. The study highlights the need for more robust and physically consistent numerical frameworks to reliably assess and compare the energy absorption capabilities of TPMS-based materials under different loading regimes.

Keywords: triply periodic minimal surfaces, TPMS, energy absorption, numerical modeling, dynamic loading

Nano-structured Porouse Co3O4 Thin Film: Oustanding Material for Oxygen Evolution Reaction

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Abstract

Cobalt oxides are a highly promising class of materials for water splitting due to their abundance, good stability in alkaline media, and favorable interaction with reaction intermediates and products. In this work, cobalt oxide thin films were prepared by plasma-enhanced chemical vapor deposition (PECVD) followed by thermal annealing. Detailed structural and compositional characterization revealed that the as-deposited material consists mainly of small cobalt oxide clusters embedded in an amorphous carbon matrix. Thermal annealing induces a transformation into crystalline spinel cobalt oxide accompanied by carbon removal, leading to the formation of the target catalytic material. This approach enables precise thickness control and, importantly, allows for the introduction of structural defects which are considered key catalytic sites for the oxygen evolution reaction. The resulting spinel cobalt oxide exhibited high current density of Co^{4+} formation, comparable to metal-doped spinel cobalt oxides, exceeding undoped Co_3O_4 spinels. Moreover, the material showed low oxygen evolution overpotential as well as with good long-term stability after 500 voltamperometric cycles. These results provide valuable insight into the role of PECVD processing and post-treatment annealing, and may guide the future design of PECVD-derived materials for water-splitting applications.

Keywords: Cobalt oxides; PECVD; Oxygen Evolution Reaction, Oxygen Vacancies

Lightweighting of Gears Using TPMS Lattices and Neural Networks

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Abstract

Traditional gear lightweighting has typically relied on drilling holes or reducing the thickness of the gear web. Although these approaches are easy to implement using conventional manufacturing methods such as drilling or casting, they offer only limited mass reduction and impose strong geometric constraints. The emergence of additive manufacturing (AM) enables far greater design freedom, including the fabrication of complex lattice architectures such as triply periodic minimal surfaces (TPMS), which have recently attracted significant research interest due to their high stiffness-to-weight ratio. By integrating neural-network-based optimization of TPMS lattice parameters, it becomes possible to systematically tailor internal gear structures and achieve substantially improved mass reduction and stress distribution in lightweighted gears.

Keywords: gear, TPMS, additive manufacturing, neural networks, lattice structures

Performance of an Inclined Additively Manufactured Aluminium Heat Pipe with Internal Grooves

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Abstract

A heat pipe (HP) is a passive heat transfer device capable of transporting significant heat fluxes without external energy input. In this study, a geometric modification in the form of an internal grooved structure is investigated. The complex groove geometry, which would be difficult to achieve with conventional methods, was enabled by metal additive manufacturing using Powder Bed Fusion (PBF) technology. An over half a meter long aluminium heat pipe was experimentally tested in a non-vertical position. The study focuses on the influence of internal groove geometry on thermal performance and operational range. Previously gathered results indicate an increase in the dry-out limit and highlight the potential of additive manufacturing for lightweight thermal management.

Keywords: heat pipe, additive manufacturing, grooved structure, thermal performance, dry-out limit

Green Synthesis of Graphene Quantum Dots: From Fruit Waste to Optoelectronic Applications.

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Abstract

This presentation explores the properties and applications of Graphene Quantum Dots (GQDs) as a biocompatible alternative to highly toxic heavy-metal quantum dots. It highlights an innovative "green synthesis" approach using fruit extracts as sustainable carbon precursors. The resulting nanostructures exhibit strong and stable green photoluminescence. The presentation demonstrates the immense interdisciplinary potential of these nanomaterials: from serving as active sensitizers in Dye-Sensitized Solar Cells (DSSCs) in optoelectronics, to acting as highly sensitive pH sensors and efficient nano-carriers for targeted cancer therapy in biomedicine.

Keywords: graphene, quantum, dots, solar , synthesis

Effect of Glow Discharge Cleaning on Tribological Performance of Magnetron Sputtered MoS_2(Ti) Coatings on Anodized 6061 T6 Aluminum

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Abstract

This study investigates the feasibility of applying magnetron-sputtered MoS_2(Ti) coatings onto anodized 6061-T6 aluminum for tribological applications. Although anodizing improves hardness and load-bearing capacity, aluminum alloys still exhibit high friction under sliding conditions. To address this limitation, low-friction MoS2-based coatings were deposited using magnetron sputtering, with a particular focus on the influence of glow-discharge cleaning parameters and interlayer architecture (Ti and Cr/Ti) on coating performance. Three surface preparation variants were examined (0 V, −500 V, and −1000 V), and their effects on plasma stability, surface integrity, and coating adhesion were evaluated. The coatings were characterized in terms of chemical composition, morphology, mechanical properties, adhesion (Rockwell-C Daimler–Benz test), and tribological behavior under ambient conditions. The results showed that all coating systems exhibited very good adhesion (HF1) and stable low-friction performance, with steady-state coef-ficients of friction in the range of 0.08-0.11. High-bias glow-discharge cleaning (−1000 V) led to arc-related local surface damage on anodized substrates, indicating increased susceptibility of the oxide layer to plasma-induced defects. However, no clear correlation be-tween cleaning potential, interlayer type, and tribological performance was observed.

Keywords: magnetron sputtering, 6061-T6, MoS_2, tribology, coating

Clothing for People with Sensory Issues

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Abstract

Research suggests that even up to 16,5% percentage of the UK population is affected by sensory issues. Furthermore, there is a strong correlation between Autism Spectrum Disorder (ASD) and Sensory Processing Disorder (SPD) with over 90% of autistic individuals reporting significant sensory issues. With the increase of 787% in recorded ASD diagnoses in the UK between 1998 and 2018, the topic of sensory issues calls for our attention. Experiencing them can lead to irritation, confusion, lack of focus, or even self-harm. This presentation is devoted to the analysis of the currently available clothing products for people with sensory issues and recognizing existing lack of solutions. Analysis of the current state on the market helped to determine important properties that should be included in sensory-friendly design. Moreover, it allowed to pinpoint the gap in current products such as a complete lack of formal or semi-formal clothing. Result of which, a design of semi-formal shirt for an adult woman experiencing sensory issues will be presented. In the developed clothing product, some innovative solutions were applied such as increased width of seam allowance, hidden fidget, printed tag in a QR form, magnetic fastening of the shirt cuffs, and others to meet the needs of potential users. The prototype of the shirt was made from the SFF/Viscose woven fabric. Recommendations for further development of the product and future research of the topic will also be discussed.

Keywords: sensory issues, autism, clothing design, inclusive design, SPD

Termomechanical Properties of Epoxy Resin Composites Containing Carbon Nanofillers

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Abstract

This study presents a comprehensive characterization of the mechanical performance and microstructural evolution of novel epoxy resin composites doped with reduced graphene oxide (rGO) powder. While the material was engineered to optimize structural integrity for advanced engineering applications-specifically, next-generation hydrogen transmission pipelines and pressure vessels-the primary objective of this extended research is to elucidate the fundamental thermomechanical properties and molecular-level interaction mechanisms of the polymer matrix. The research evaluates the material's behavior across a broad spectrum of graphene powder additions (from 0 to 2 wt%), specifically contrasting the anomalous plasticization phenomena at sub-critical levels (< 0.5 wt%) with the pronounced structural reinforcement observed at higher concentrations (0.5–2 wt%). The experimental phase involved the fabrication of seven composite series. The analytical methodology encompassed static flexural and compressive strength testing, Vickers hardness measurements, and differential scanning calorimetry (DSC). Empirical investigations were corroborated by advanced quantum chemical simulations using the PM6 semi-empirical method within the Scigress software. The results highlight a distinct, concentration-dependent dual effect of the graphene powder on the mechanical performance of the composites. At trace rGO additions below the critical threshold, a pronounced increase in material plasticity was observed, directly correlated with a localized reduction in cross-linking density. This behavior transitions sharply as the filler content scales up, leading to significant mechanical reinforcement, enhanced matrix stiffness, and restricted polymer chain mobility within the constrained region. While overall integration induced a slight alteration in flexural properties, the upper limits of the investigated range yielded considerable improvements in hardness, elasticity, and resistance to macroscopic deformation. The integration of DSC and mechanical analyses confirmed the existence of a specific critical transitional threshold within the studied spectrum. Molecular simulations substantiated that the initial reorganization of polymer chains at lower concentrations promotes the formation of robust nanocrystalline regions as the graphene powder content increases. These findings provide critical insights into the structural evolution of graphene-reinforced epoxies, offering a viable pathway toward the optimal design of cost-effective, highly durable composites for demanding, high-stress engineering environments.

Keywords: rGO, epoxy, hydrogen, composite, mechanical properties

Functionalized Acrylic Hydrogels as Next-Generation Sorption Platforms

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Abstract

This presentation details the development of a new generation of sorption materials based on poly(acrylic acid) (PAA) hydrogels functionalized with ionic liquids. The research, conducted by the Student Research Circle NANO at Lodz University of Technology, focuses on addressing the urgent need for efficient environmental remediation tools, specifically for the removal of heavy metals from aqueous environments. The core innovation of this project lies in the application of radiation-induced synthesis as the primary cross-linking method. Unlike traditional chemical synthesis, radiation cross-linking eliminates the need for potentially toxic initiators and catalysts, resulting in materials with higher purity and a significantly improved environmental profile. This methodology strictly adheres to the principles of "green chemistry" by enabling efficient, rapid processing at room temperature.

Keywords: PAA, hydrogels, ionic liquids, radiation, metal sorption

Sustainable Fashion Design through Textile Upcycling

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Abstract

The presentation entitled "Sustainable Fashion Design through Textile Upcycling" presents the outcomes of a student design project focused on the use of reused materials in garment creation. The aim of the study is to demonstrate the potential of upcycling as a strategy for sustainable fashion design and to promote awareness of sustainable design practices. The analysis is based on two original collections. The "Lacevolution" collection was created from used curtains and tablecloths, with particular emphasis on their decorative qualities, such as lace and embroidery. The "ReJeans" collection was developed from used denim garments, which were transformed into new clothing forms through the application of patchwork techniques. The presentation discusses the design process, including material selection, deconstruction, and redesign, in the context of both the limitations and potential of secondary raw materials. Particular attention is given to the aesthetic, functionality, and environmental aspects of the presented projects. The presented examples indicate that upcycling can serve as an effective tool for reducing textile waste and for developing innovative design approaches aligned with the principles of a circular economy.

Keywords: textile upcycling, sustainable fashion, circular economy, reused materials, textile waste

Impact of the Ventilation System on the Aerodynamics of the Eagle Three Solar Car

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Abstract

During the preparation of a bachelor's thesis, a ventilation system for the Eagle Three solar car was developed. The proposed solution is based on a similar system implemented in the Eagle Two model. Computational fluid dynamics (CFD) simulations were conducted to verify whether the design criteria were met. The total volumetric flow rate in the ventilation system was 155 m^3/h. The simulation results indicate that the ventilation system affects aerodynamic forces. Specifically, the drag coefficient was reduced by 3%, while the downforce coefficient increased by 24%.

Keywords: CFD, solar car, ventilation, aerodynamics, drag reduction

Bioactive Cellulose-Based Composite Dressing in the Treatment of Diabetic Foot Syndrome

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Abstract

Prolonged wound healing is a significant clinical problem, carrying the risk of reduced mobility and limb amputation. In the diabetic patient population, tissue regeneration is further impaired by vascular changes and neuropathy resulting from chronic hyperglycemia. The resulting diabetic foot ulcers are the most common complication of the disease, and their treatment remains a major challenge for modern medicine. One of the promising materials used in the treatment of such wounds is bacterial cellulose, which has the ability to regulate the wound microenvironment. It is characterized by high biocompatibility and susceptibility to chemical modification, enabling the controlled transport of active substances and the maintenance of an appropriate level of moisture conducive to tissue regeneration. The aim of this study was to use additive manufacturing technology to produce a variety of mesh structures made of poly(ε-caprolactone) (PCL) filament, a material characterized by biodegradability and high mechanical strength. The printed scaffolds were then immersed in a pre-prepared bacterial cellulose suspension and subjected to a 24-hour freeze-drying process, resulting in a composite material. The resulting porous structures were functionalized by impregnation with a 2% chitosan solution containing a bioactive substance to impart properties that promote the healing of diabetic foot ulcers. For comparison, a second variant of the material was prepared, in which the bacterial cellulose suspension was combined with chitosan (in a 7:3 mass ratio) and the bioactive substance via homogenization, followed by a 24-hour freeze-drying process. Characterization of the resulting composites included evaluation of surface morphology, analysis of chemical structure using Fourier-transform infrared spectroscopy (FTIR), as well as analysis of porosity and water absorption capacity. Based on the conducted studies, a composite variant exhibiting the greatest application potential in the treatment of diabetic foot syndrome was selected.

Keywords: diabetic foot syndrome, bacterial cellulose, PCL, composite material, additive manufacturing technology

Computational Characterization of Diketopiperazine-Based Scaffolds as Potential Modulators of NTSR1

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Abstract

Diketopiperazines (DKPs) are structurally constrained cyclic peptide scaffolds capable of forming diverse non-covalent interactions. Their compact architecture and conformational rigidity make them useful molecular frameworks for studying ligand–receptor recognition. In this study, selected crystallographically characterized DKP derivatives were investigated as potential modulators of neurotensin receptor 1 (NTSR1) using molecular docking and molecular dynamics simulations. The work focused on comparing functionalized GEBVEQ-like DKP scaffolds with smaller DKP analogues in order to evaluate how scaffold size, aromatic substitution and conformational constraints influence predicted receptor binding. GEBVEQ was used as the main reference scaffold, while selected smaller DKPs were analyzed as simplified structures for comparison. Docking analysis was used to identify binding poses, interaction patterns and key receptor residues involved in ligand recognition. Molecular dynamics simulations were applied to assess the stability of selected receptor–ligand complexes and to characterize ligand-induced conformational effects. This computational study provides insight into the relationship between DKP scaffold architecture and predicted NTSR1 recognition. The results support functionalized DKPs as useful molecular scaffolds for exploring receptor modulation and provide a basis for further structure-guided optimization.

Keywords: DKPs, NTSR1, molecular docking, molecular dynamics simulations, molecular scaffolds

Data-Driven Modelling of Thermally Damaged Recycled Aggregate Concrete for Sustainable Cementitious Materials

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Abstract

The replacement of natural aggregate with recycled concrete aggregate (RCA) is a practical approach for reducing construction and demolition waste and improving the sustainability of cementitious materials. However, predicting the residual compressive strength of RCA concrete after high-temperature exposure remains challenging because thermal damage, aggregate properties, and mixture-related parameters interact in a nonlinear manner. This study presents a data-driven framework for estimating the residual compressive strength of thermally damaged RCA concrete. A database of 238 experimental results from unstressed residual property tests was collected from published studies. Seven input variables were considered. Four progressive input configurations, ranging from four to seven variables, were examined to evaluate how additional thermal and mixture-related information affects prediction reliability. The supervised machine learning models were developed and compared: Support Vector Regression, Decision Tree, M5P Linear, M5P Model Logarithmic, Random Forest, Gradient Boosting Decision Tree, Extreme Gradient Boosting, Light Gradient Boosting Machine, Multi-Layer Perceptron, and Kolmogorov–Arnold Network. The models were trained using an 80:20 stratified data split, while cross-validation was applied only within the training subset to avoid data leakage. Model performance was assessed using statistical error metrics, prediction error dispersion, distributional comparison, and interpretability analyses, including Sobol sensitivity analysis, SHAP, partial dependence plots, and individual conditional expectation. The results showed that the seven-input configuration provided the most reliable predictions. Among all models, KAN achieved the highest testing accuracy, with R2 = 0.959, followed by GBDT with R2 = 0.946. M5P Log, XGBoost, LightGBM, and MLP also showed acceptable predictive performance, with R2values above 0.92. Error-dispersion and distributional analyses further confirmed that KAN and GBDT produced the most stable predictions. Interpretability analyses indicated that exposure temperature and the RCA-to-ambient-strength indicator were the dominant factors controlling residual strength. The proposed framework provides an accurate and interpretable tool for post-fire assessment of RCA concrete and supports the development of sustainable cementitious materials.

Keywords: RCA, residual compressive strength, supervised machine learning models, exposure temperature, interpretability analyses

Development of a Method for Obtaining Foamed Biodegradable Polyurethane with the Addition of Bioactive Ceramics

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Abstract

Polyurethanes are polymers that contain of two types of segments hard and soft. The ratio of soft to hard segments can be varied to tune the mechanical properties of the polymer over a wide range That is why, such materials may find a lot of applications, one of which is tissue engineering. In this work to polyurethane synthesis polycaprolactone-diol (PCL), 1,6-hexamethylene diisocyanate (HDI) and 1,4-butanodiol (BDO) were used. Then bioceramics fillers in the form of hydroxyapatite (HAp) and zirconium oxide (ZrO2) powders were added. Hydroxyapatite was added in order to increase biocompatibility, when zirconium oxide enabled visibility in roentgen radiation. Moreover HAp with different grain size and humidity performed a function as a foaming agent. Surface morphology, porosity grade, chemical structure and contact angle measures were carried out. The obtained results reveal that the porosity range is combined with the filler's grains size, namely the addition of minor particles result in the increase of the material's porosity. Additionally, the constitutional water in HAp also appeal to the porosity of the material.

Keywords: PCL, Hap, ZrO2, tissue engineering, surface morphology

Dynamic, Smart and Natural Biomaterials as Next - Generation Strategies in Regenerative Medicine

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Abstract

Traditional implantable biomaterials, although widely used in medicine, often exhibit limited long-term efficacy due to the host's immune response, particularly inflammation and fibrosis. In response to these limitations, new-generation biomaterials are being developed, designed as dynamic, bioactive systems capable of adapting to the biological environment. The aim of this review is to discuss contemporary biomaterial design strategies, with particular emphasis on dynamic and "living" implants, smart biomaterials, and naturally derived materials. Active implant systems, utilizing mechanostimulation or stimulus-responsive hydrogels, enable the prevention of fibrosis and the prolongation of implant function.Concurrently, the development of natural biomaterials, such as collagen, cellulose, and chitosan, allows for high biocompatibility and a better replication of the extracellular matrix. The combination of these materials with 3D/4D printing technologies and bio-inspired strategies forms the foundation for future, smart regenerative and implant therapies.

Keywords: implantable biomaterials, host's immune response, stimulus-responsive hydrogels, extracellular matrix, 3D/4D printing technologies

Eco-Friendly Elastomeric Composites Based on NR and SBR with Controlled Fragrance Release and Thermochronic Behaviors

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Abstract

Elastomer-based materials are widely used across industrial sectors, yet increasing environmental awareness is driving the development of sustainable and functional composites. This study focuses on the design of eco-friendly elastomeric composites with enhanced functional properties, based on natural and synthetic rubber matrices. Composites containing natural rubber (NR) and styrene-butadiene rubber (SBR) were prepared with silica fillers and selected additives, including thermochromic pigments and fragrance compounds, to obtain materials capable of controlled sensory and functional responses. The research aimed to develop smart composites exhibiting controlled release of fragrances, thermochromic behavior in response to temperature changes, and antimicrobial activity. The materials were characterized in terms of rheological behavior, solvent resistance, swelling behavior, and mechanical performance. The influence of silica content and fragrance oil modification on material properties was examined, with particular focus on diffusion, stability, and interaction with elastomer matrices. The antimicrobial performance of the materials was evaluated against selected microorganisms, including Escherichia coli, Staphylococcus aureus, Candida albicans, and Aspergillus niger. The results show that the developed composites exhibit promising functional properties, including enhanced fragrance absorption, thermally responsive color change and antibacterial activity. Differences in solvent resistance and swelling behavior between NR- and SBR-based materials highlight the influence of polymer structure on performance. Fragrance modification further improved antimicrobial properties. These findings confirm the potential of sustainable elastomeric composites for smart materials, functional coatings and environmentally friendly polymer technologies.

Keywords: natural rubber, SBR, elastomeric composites, antimicrobial performance, thermochromic pigments

Influence of Glow Discharge Cleaning on the Tribological Properties of Magnetron-Sputtered MoS_2(Ti) Coatings Deposited on Anodized 6061-T6 Aluminum

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Abstract

This work examines the applicability of magnetron-sputtered MoS_2(Ti) coatings on anodized 6061-T6 aluminum intended for tribological applications. While anodizing significantly enhances the hardness and load-carrying capability of aluminum alloys, these materials still tend to exhibit relatively high friction during sliding contact. To overcome this drawback, low-friction MoS_2-based coatings were deposited by magnetron sputtering. Particular attention was given to the effects of glow-discharge cleaning conditions and interlayer design (Ti and Cr/Ti) on the resulting coating performance. Three substrate pretreatment variants were investigated using cleaning potentials of 0 V, −500 V, and −1000 V. Their influence on plasma behavior, substrate surface condition, and coating adhesion was systematically assessed. The deposited coatings were characterized with respect to their chemical composition, surface morphology, mechanical properties, adhesion (evaluated using the Rockwell-C Daimler–Benz test), and tribological performance under ambient conditions. The findings revealed that all coating configurations provided excellent adhesion, corresponding to the HF1 classification, and maintained stable low-friction behavior. The steady-state coefficient of friction ranged between 0.08 and 0.11. Glow-discharge cleaning performed at the highest bias voltage (−1000 V) resulted in localized surface damage associated with arc events on anodized substrates, suggesting that the oxide layer becomes more vulnerable to plasma-induced defects under these conditions. Nevertheless, no direct relationship was identified between the cleaning voltage, interlayer configuration, and the tribological properties of the coatings.

Keywords: MoS_2(Ti), magnetron sputtering, anodized 6061-T6 aluminum, glow-discharge cleaning, low-friction coatings

"Green synthesis" of ZnO NPs Using Milk Thistle Seed Extract – Characterization and Toxicity Assessment.

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Abstract

Silymarin is a complex of flavonolignans with hepatoprotective properties, extracted from milk thistle (Silybum marianum). Its mechanism of action involves antioxidant activity, stabilization of hepatocyte membranes, and stimulation of protein synthesis. Furthermore, it exhibits anti-inflammatory and anti-fibrotic effects, allowing for its use as an adjunct in the treatment of liver damage caused by toxic and pathological factors. The aim of this study was to develop a "green synthesis" of ZnO nanoparticles (ZnO NPs) using milk thistle seed extract. The extract obtained from ground milk thistle seeds is rich in polyphenols and flavonolignans, which can form complexes with Zn^{2+} ions, acting as ligands that stabilize the forming ZnO nanostructures. The resulting nanoparticles exhibit a homogeneous distribution, possess polyhedral cores, and have hydrodynamic diameters below 100 nm. Furthermore, the synthesized ZnO nanoparticles were characterized and compared with commercial ZnO nanoparticles using UV-Vis absorption spectroscopy, scanning transmission electron microscopy (STEM), atomic force microscopy (AFM), and their toxicity was compared relative to the human embryonic kidney HEK 293 cell line using the 3-(4,5-Dimethyl-thiazol-2-Yl)-2,5-Diphenyltetrazolium Bromide (MTT assay). ZnO nanoparticles synthesized using milk thistle extract are promising materials for biomedical applications. The use of readily available plant-based raw materials enables a significant reduction in synthesis costs and provides an environmentally friendly and safer alternative to conventional chemical methods, thereby enhancing the application potential of the resulting nanomaterials.

Keywords: green synthesis, ZnO nanoparticles, milk thistle, plant extract, nanomaterials

How To Build a Car? The Design of Eagle Three Solar Vehicle, The Successor to the Championship-Winning Design

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Abstract

This poster addresses the engineering challenges associated with the development of ultra-efficient, sustainable solar cars intended for international racing and future everyday transportation. The primary objective of this study is to present a comprehensive analysis of the aerodynamic optimization, structural integrity, and design methodology applied in the development process of the Eagle Three solar cruiser, created by the Lodz Solar Team. This was done to optimize operational parameters and enhance safety compared to its championship-winning predecessor, Eagle Two. The design process involved an iterative engineering approach utilizing simulation techniques to evaluate structural parameters and fluid mechanics. A comprehensive methodology was applied, integrating CFD to refine the exterior shape for minimized aerodynamic drag, alongside rigorous FEA to validate the yield strength, energy absorption, and overall durability of the safety roll cage. These computational investigations were complemented by an empirical review of historical telemetry and structural data derived from the pioneering Eagle One and the successful Eagle Two models. The redesigned exterior shapes significantly reduce the aerodynamic drag coefficient. Structural simulations of the safety roll cage confirm a substantial increase in torsional rigidity and impact resistance. Furthermore, the integration of strategic colors was evaluated not only for their visual aesthetics but also for their functional role. A comparative analysis confirmed that the architectural evolution directly eliminated the structural limitations identified in earlier iterations. This phenomenon, combined with the integration of an ergonomic and advanced design, significantly enhances both the durability and the operational efficiency of the car. The design of Eagle Three is intended to represent a viable pathway toward the next generation of competitive, safe, and efficient solar-powered vehicles.

Keywords: aerodynamic optimization, solar cars, safety roll cage, CFD, FEA

Influence of TPMS Architecture on the Strenght Characteristics of Lightweight Gears Designed for Additive Manufacturing

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Abstract

The subject of this study is a numerical analysis of innovative gear designs in which the traditional solid tooth geometry has been replaced with Triply Periodic Minimal Surface (TPMS) lattice structures. The research aims to evaluate the potential for mass reduction in critical transmission components while maintaining their load-carrying capacity. Using nTopology software, gear teeth were modeled with Gyroid, Diamond, and Schwarz P infills of varying relative densities. Static structural simulations were performed in Ansys Workbench to analyze von Mises stress distributions and local deformations in the contact zone and at the tooth root. The results allow for an assessment of the stiffness of the engineered teeth and the identification of deformation mechanisms within TPMS structures under inter-tooth forces. This work represents a step toward developing ultra-lightweight drivetrain components that cannot be manufactured using conventional machining methods.

Keywords: TPMS, numerical analysis, lattice structures, static structural simulations, von Mises stress distributions

Integrated Optimization of the Star 266 Off-Road Truck Tarpaulin System

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Abstract

The Star 266 off-road truck is a legend of the automotive industry, with over 17,000 units produced for the Polish Army. Despite its age, it continues to be widely used and restored. The primary protective equipment of the cargo body is a heavy tarpaulin made of PVC-coated PE fabric (650 g/m²). Because fitting this cumbersome tarpaulin meets the definition of working at height, it requires a strict occupational safety regime. This work presents an integrated optimization of the Star 266 tarpaulin system focusing on two key areas: material strength and Occupational Health and Safety (OHS). For material strength, optimization under cargo loading is performed using the Finite Element Method. The proposed solution reinforces the tarpaulin with a high-strength fiber mesh permanently fixed to its inner side. Using the square mesh size as the design variable, the structural problem is solved via the Steepest Descent method to minimize local stress concentrations. Constraints include the maximum mass suitable for safe handling at height and the maximum material elongation allowed to prevent permanent PVC deformation. Simultaneously, a comprehensive OHS analysis integrates hazard identification (via Preliminary Hazard Analysis and Job Safety Analysis) and risk assessment (using the semi-quantitative Risk Score method). This highlights key risks such as slip hazards, musculoskeletal strain, and loss of balance under adverse conditions. Prioritized risks are evaluated using the 5 Whys method to develop targeted control measures and a standardized safe mounting procedure. Ultimately, an algorithm is developed to integrate both optimization procedures. This holistic approach combines the selection of optimal tarpaulin material parameters with systemic OHS solutions, ensuring maximum operator protection while maintaining the vehicle's technical functionality.

Keywords: Finite Element Method, OHS, material strength optimization, risk assessment, Preliminary Hazard Analysis method

Loads and Design Guidelines for a Courier Bike Frame

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Abstract

Bicycle courier work involves transport in a dynamic urban environment. It requires navigating diverse road conditions, with constant exposure to significant and rapidly changing musculoskeletal loads. The load distribution at the contact points between the bike and the courier (handlebars – drivetrain) is transient, i.e., time-dependent. Therefore, the selection of the bike frame material is crucial due to the variable loads acting on both the material and the human body. While a courier may use any type of bicycle, the frame material should be analyzed according to its specific type. The load modeling was conducted using two methods. The analysis involves assuming sequential static loads as instantaneous projections of dynamic loads. The ANSYS software was used for the analysis. For simplification, a combined mass of 80 kg for the courier and cargo was adopted. This mass is distributed across the handlebars and the drivetrain in different ways, depending on instantaneous conditions. The load simulation will allow for the determination of the maximum deformation, which is consistently located on the rear stay of the bicycle (above the drivetrain). This is the area most susceptible to damage; during operation, this is where frame cracking and weld destruction occur. The minimum deformation value is found at the rear hub and around the front fork. From a mechanical perspective, a bicycle frame is a simple truss. Therefore, modeling the distribution of loads and deformations acting upon it is possible using both this software and classical analysis of a truss loaded at the nodes. The HOBO UA-004-64 Pendant G acceleration sensor will be used for this purpose, featuring a three-axis accelerometer recording data at a frequency of up to 100 Hz . One sensor was placed in a measuring band on the user's leg (recording accelerations acting on the musculoskeletal system), and the second one on the bicycle structure (measuring loads on the frame). The results allow for the analysis of the nature of dynamic overloads during riding. Loads can be modeled stochastically or in a repeatable manner. The first method involves riding in selected terrain and averaging the obtained results. The second method involves using a repeatable riding cycle in a closed-loop mode. Determining accelerations using two methods allows for the verification of their repeatability. Additionally, materials can be subjected to non-standard loads with magnitudes exceeding the values established above.

Keywords: dynamic urban environment, musculoskeletal loads, load simulation, ANSYS software, acceleration sensor

Nanoemulsion Stability as a Function of Interphase Properties and Emulsifying Systems

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Abstract

Nanoemulsions are nanodisperse systems with a developed interfacial surface. Their stability and stabilization effectiveness depend on the properties of the interfacial layer formed by surfactants and on the interactions between the oil phase and the emulsifier layer. The aim of this study was to evaluate the effect of the emulsifier system (Span 60 and Polysorbate 20) on the stability of O/W nanoemulsions, considering the role of the oil phase in modifying interfacial properties. Nanoemulsions were obtained by homogenization and then characterized using dynamic light scattering (DLS), optical microscopy using Sudan III staining according to our own methodology, and measurements of viscosity, density, and pH. Stability was analyzed over time (4, 8, and 12 weeks) by monitoring changes in particle size and polydispersity index (PDI). To illustrate the effect of the oil phase, three representative model systems were selected, corresponding to different levels of nanoemulsion stability: high (sesame oil), intermediate (sunflower oil), and low (avocado oil). Nanoemulsions with sesame oil showed the smallest changes in particle size and low PDI values, indicating a homogeneous and stable structure. Systems with sunflower oil showed moderate changes over time, whereas nanoemulsions with avocado oil exhibited high polydispersity and clear signs of destabilization. The obtained results indicate that despite the use of a constant emulsifier system, the properties of the oil phase significantly influence stabilization efficiency. Differences in nanoemulsion stability were interpreted as the result of different interactions between the oil phase and the surfactant layer. The conducted studies emphasize the importance of designing emulsifier systems with the characteristics of the oil phase in mind to obtain stable nanostructured dispersion systems.

Keywords: O/W nanoemulsions, DLS, PDI, emulsifier system, interfacial properties

Properties of Epoxy Resin Composites Containing Graphene Powder

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Abstract

Epoxy resins are fundamental to advanced engineering applications, including the structural integrity of next-generation hydrogen storage and transmission infrastructure. This study investigates the microstructural and thermomechanical evolution of novel epoxy composites doped with carbon nanofillers - specifically reduced graphene oxide (rGO)-to elucidate the matrix's molecular-level interaction mechanisms across a broad spectrum of filler concentrations. Seven distinct composite series were fabricated, covering an rGO concentration range from 0 to 2 wt%, utilizing a strategy of partial curing agent substitution to evaluate its impact on cross-linking density. The thermomechanical performance was characterized using static flexural and compressive strength testing, Vickers microhardness measurements, and differential scanning calorimetry (DSC). Furthermore, empirical data were corroborated by advanced quantum chemical simulations using the PM6 semi-empirical method to analyze physicochemical interactions at the epoxy-graphene interface. The investigation revealed a concentration-dependent dual effect of the carbon nanofiller. At sub-critical concentrations (< 0.5 wt%), an anomalous plasticization phenomenon was observed, directly correlated with a localized reduction in the polymer's cross-linking density. Conversely, scaling the filler content to the 0.5–2 wt% range induced a sharp microstructural transition leading to significant mechanical reinforcement, enhanced matrix stiffness, and restricted polymer chain mobility within the interfacial zone. A specific critical transitional threshold was identified where peak crystallinity maximized compressive strength, notwithstanding alterations in the glass transition temperature. Molecular simulations confirmed that initial polymer chain reorganization promotes the formation of robust nanocrystalline regions as filler content increases. These findings provide crucial insights into the structural evolution of nanofiller-reinforced epoxies, establishing a viable pathway for the optimal design of cost-effective, highly durable composites for demanding, high-stress engineering environments.

Keywords: rGO, epoxy, hydrogen, composite, mechanical properties

Reliability and Validity of a Proprioceptive Ankle Device in Younger and Older Adults

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Abstract

Ankle proprioception is crucial for maintaining postural equilibrium, and its age-related decline is heavily linked to balance deficits and fall risks. However, clinical tools capable of reliably differentiating between the sense of motion (SoM) and sense of position (SoP) remain limited. This study evaluated the test-retest reliability, structural stability, and discriminative validity of a newly developed Active Ankle Movement Assessment (AAMA) device. Proprioceptive acuity was assessed in 26 younger adults and 21 older adults. SoM sensitivity was measured by rotating a dual-platform setup at a slow speed of 0.5°/s until detected by the participant, while SoP acuity was evaluated using both active and passive joint position matching methods across multiple target angles. Reliability was quantified using the ICC3,1, Standard Error of Measurement (SEM), and Minimal Detectable Change (MDC90), alongside Bland-Altman plots for systematic bias and Receiver Operating Characteristic (ROC) curves for age-group discrimination. The AAMA device demonstrated excellent relative reliability for SoM sensitivity (ICC = 0.958–0.982) and passive SoP acuity (ICC = 0.814–0.989) across both cohorts, accompanied by low absolute error (MDC90 ≤ 0.33°) and trivial systematic bias. ROC analysis revealed high area under the curve properties for SoM and passive SoP, confirming strong discriminative power to identify age-associated sensory degradation. These findings indicate that the AAMA device is a highly valid and repeatable diagnostic tool for profiling ankle proprioception. While it shows strong clinical potential for early screening of age-related balance instabilities, the lower reliability observed during active matching suggests that the active SoP methodology requires further optimization before clinical deployment.

Keywords: ankle proprioception, AAMA, SoM, SoP, ROC

Acknowledgements

The abstract was created as part of participation in the project titled "IMPROVE – International Mission to Promote Research and Optimal Values in Education" as part of the programme of the National Agency for Academic Exchange STER – Internationalization of doctoral schools – 2024 Call.

Sonochemical Synthesis of Biocompatible Hydrogels Containing L-Lysine

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Abstract

Hydrogels are used across a wide range of sectors, with biomedical applications among the most prominent. They are incorporated into medical devices such as aortic grafts and breast implants, employed as scaffolds for cell culture, utilised as drug-delivery platforms, and integrated into modern wound dressings. The synthesis of polymeric hydrogels using ionising radiation – particularly electron-beam irradiation – is well established and widely implemented in industry. However, this approach presents several limitations. Operating radiation equipment requires specialised expertise and rigorous safety training, while the systems themselves entail high maintenance costs. In addition, the replacement of radiation sources can be complicated by geopolitical constraints, further challenging the long-term viability of this method. In this work we propose an alternative approach to synthesis of hydrogels with the use of ultrasonic waves. Sonochemistry relies on the interaction of sound waves with frequencies above 20 kHz with aqueous solutions of polymers (oligomers, macromonomers) in order to facilitate the desired reactions. Tailoring we can produce hydrogels with desirable physicochemical and biocompatible properties. In order to synthesise biomaterial for the application as wound dressing, we combined poly(ethylene glycol) diacrylate (PEGDA) and poly(ethylene glycol) methyl ether acrylate (PEGA) macromonomers as the hydrogel matrix, with low molecular weight hyaluronic acid (HA) and L–lysine as bioactive additives, positively influencing the process of wound healing. Synthesis was carried out in an ultrasonic reactor at 620 kHz, 50 W, with Ar atmosphere and at 20 °C. The swelling kinetics, equilibrium swelling degree of hydrogels and gel fraction content were determined. The cytotoxicity of trigonelline hydrogels was studied using the MTT assay. The biological studies were performed on human endothelial cells EA.hy926. Incorporating bioactive L-lysine into the hydrogel yielded a biomaterial with optimal physicochemical and cytotoxic properties. The hydrogels were also analysed in terms of kinetics of release of the aforementioned bioactive substances, which is an important factor for the application as biomaterials.

Keywords: biomedical applications, ultrasonic waves, hydrogel matrix, bioactive additives, swelling kinetics

Sound-Absorbing ECOmposite

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Abstract

Today, when designing composite materials, more and more attention is being paid to environmental issues and to the possibility of using recycled raw materials. In this study, we tried to develop eco-friendly sound-absorbing composites made from materials that come from municipal waste, and we evaluated their acoustic properties. Aim of the study: The base material was made of polylactic acid (PLA) fibers. As the material added to strengthen the composite, we used selected types of municipal waste, such as eggshells, ash, nut shells, used dried coffee and tea. The composites were produced by hot pressing at a temperature of 170°C. Their acoustic properties were then tested, focusing on how well they absorb sound. The aim of the study was to create biodegradable composites with high sound absorption while also utilizing waste materials. The results showed that the produced composites were very thin, up to about 2 mm. They absorbed sound well at high frequencies. The best sound absorption was found in composites containing crushed nut shells and loose-leaf tea. The composite with 20% nut shells reached a sound absorption coefficient of about 0.8 at a frequency of 6 kHz. The composite with loose-leaf tea reached a similar absorption coefficient (about 0.8) at a frequency of 5.5 kHz. The analysis showed that the acoustic properties of the composites are strongly affected by three factors: the percentage of the reinforcing phase, the size of the particles, and the distribution of the particles within the material. When the structure became too dense, as seen in the composite with 30% nut shells, the ability to absorb sound decreased. The results confirm that selecting the right reinforcing material, especially its structure, how finely it is crushed and the right amount of waste material, makes it possible to obtain eco-friendly composites with good acoustic properties.

Keywords: epoxy composites, Vickers microhardness, quantum chemical simulations, anomalous plasticization phenomenon, nanofiller-reinforced epoxies

The Comparison of Physicochemical Properties of Mother-of-Pearl Powders Derived from Pearl and from Freshwater Pearl Mussel

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Abstract

Nacre is a naturally occurring material. It consists of an organic protein component called conchiolin and an inorganic component, bioactive calcium carbonate in the form of hexagonal aragonite plates. Together, they form a compact and durable structure. Thanks to its valuable amino acids, mother-of-pearl possesses many beneficial properties used in medicine and cosmetology, such as healing, regenerative, and antioxidant properties. Nacre is produced by certain mollusc shells, such as clams, nautiluses, and sea snails. Mother-of-pearl differs from pearls in that it is the inner layer of the shell, while pearls are formed internally within the mollusk's body as a separate structure. This paper presents the results of a comparative analysis of the morphology, chemical structure, phase composition, and thermal properties of nacre and pearls derived from the shell of the freshwater mollusk of the species *Margaritifera margaritifera*, also known as the freshwater pearl mussel. The powder was obtained by grinding nacre and pearl at low temperatures. For the study, the powder was fractionated, resulting in particle size ranges of <25, 25-50, 50-75, and 75-100 μm. All powders were assessed for surface morphology using scanning electron microscopy (SEM). Their chemical composition was also analyzed using infrared spectroscopy (FTIR) and crystal structure was assessed using X-ray diffraction (XRD). The final step was the analysis of the organic and inorganic phases, which was performed using thermogravimetric analysis (TGA). In summary, the conducted research allowed us to determine the differences between nacre taken from shells and pearls. Determining this relationship will allow for the selection and better use of these materials in the medical industry.

Keywords: freshwater pearl mussel, calcium carbonate, surface morphology, medical industry, nacre and pearls

Ti/C Multilayer Nanocoatings: Synthesis and Characterization

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Abstract

Titanium and carbon-based nanocomposites represent a promising group of materials, combining the favorable mechanical properties of classical Ti/C coatings with new functionalities arising from size reduction to the nanoscale. Particular interest has been devoted to two-dimensional crystalline structures, including MXenes - a group of 2D materials with exceptional electrical, mechanical, and sorption properties, whose synthesis via bottom-up approaches remains an open research challenge. In this study, two types of multilayer Ti/C nanocoatings were fabricated and characterized. The first series of coatings was deposited by magnetron sputtering (MS), while the second was produced using a hybrid method combining MS with radio frequency plasma-enhanced chemical vapor deposition (RF PECVD). Selected samples were subjected to vacuum annealing at 500°C to induce interfacial reactions at the Ti/C boundaries and promote spontaneous formation of 2D crystalline structures. The coatings were characterized using a range of analytical techniques, including atomic force microscopy (AFM), X-ray photoelectron spectroscopy (XPS), wettability measurements, scanning electron microscopy coupled with energy-dispersive X-ray spectroscopy (SEM/EDS), and Raman spectroscopy. The results showed that coating roughness decreases with increasing carbon content, while XPS analysis revealed signals potentially indicative of local TiC phase formation. Following thermal treatment of the hybrid coatings, carbon graphitization was observed alongside the appearance of additional peaks in the Raman spectra, which may suggest further phase transformations requiring confirmation in subsequent studies. The obtained results confirm the feasibility of fabricating multilayer Ti/C nanocoatings by both methods and provide a solid foundation for further investigation into the spontaneous formation of 2D crystalline structures at Ti/C interfaces.

Keywords: multilayer Ti/C nanocoatings, 2D crystalline structures, magnetron sputtering (MS), vacuum annealing, titanium and carbon-based nanocomposites

The Relationship Between Structure and Properties in Shape-Memory Polyurethanes: The Role of Isosorbide and Castor Oil in Shaping the Thermomechanical Response

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Abstract

Shape-memory polymers (SMPs) constitute an important class of functional materials whose performance properties stem directly from their molecular structure and the nature of their phase segmentation. In the case of polyurethanes, which have a segmented structure, the relationship between the soft and hard segments plays a key role, determining the transition temperatures and the ability to undergo reversible shape change. The aim of this study was to analyze the effect of modifying the composition of the soft segment on the thermal and thermomechanical properties of shape-memory polyurethanes prepared based on polycaprolactone diol, with the addition of isosorbide and castor oil. In addition to biocompatibility, the components used introduce varying chain stiffness and potential hydrogen bonding, influencing the degree of phase separation. The materials were characterized using differential scanning calorimetry (DSC), thermogravimetric analysis (TGA), dynamic mechanical analysis (DMA), and FTIR spectroscopy, which enabled the determination of the glass transition temperature of the soft segments, thermal stability, and moduli as a function of temperature. The obtained relationships confirm the possibility of precisely tailoring the thermomechanical response of SMPs by controlling their chemical composition, which is important in the context of designing materials with specified functional parameters, including for biomedical applications.

Keywords: SMPs, shape-memory polyurethanes, molecular structure, thermomechanical properties, biomedical applications

Eco Composites and Their Properties

Student Scientific Association ECOresearch

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Abstract

The aim of the project was to develop eco-friendly composites with good sound-absorbing properties, made entirely from environmentally friendly materials and from recycled raw materials that come from municipal waste. When designing modern composite materials, more and more attention is paid to environmental issues and to the possibility of reusing waste. For this reason, this project tried to combine these two goals: to create a biodegradable material that also absorbs sound effectively. A material like this could, in the future, become an eco-friendly alternative to the traditional acoustic panels used in construction and interior finishing. Matrix in composite was a nonwoven fabric made of polylactic acid (PLA) fibres. PLA is a biodegradable plastic made from renewable raw materials, which makes it a good choice for an eco-friendly material. As the material placed between the layers of the matrix to give the composite the desired properties selected types of municipal waste were used: eggshells, ash, nut shells, used, dried coffee, and tea. All of these materials are waste that normally ends up in the bin, but in this project they were given a second life as a valuable part of the composite. The composites were made layer by layer. The reinforcement was placed between the layers of PLA nonwoven fabric. This stack of layers was then bonded together using a press, with hot pressing at a temperature of 170°C. Under the heat and pressure, the PLA fibres partly melted and joined together, permanently sealing the waste particles inside the structure and forming a uniform, solid material. Samples of fixed dimensions were then cut from the finished composite sheets for further testing. The composites that were obtained were very thin, reaching only about 2 mm. The cut samples were tested for their acoustic properties, with a focus on the material's ability to absorb sound. During the measurements, the sound absorption coefficient was determined as a function of frequency. The tests allowed a comparison of how the type of waste used, its percentage content, and how finely it was crushed affected the final acoustic properties of the material. Despite being very thin, the composites showed a high ability to absorb sound at high frequencies. The best results were obtained for samples containing crushed nut shells and loose-leaf tea. The composite with 20% nut shells reached a sound absorption coefficient of about 0,8 at a frequency of 6 kHz, while the composite with loose-leaf tea reached about 0.8 at a frequency of 5,5 kHz. The analysis showed that the acoustic properties are strongly affected by the percentage of the reinforcing phase, the size of the particles, and how they are arranged within the structure. When the structure was too dense as seen with 30% reinforcement the sound absorption became worse. The results confirm that the right choice of waste material, especially its structure, how finely it is crushed, and how much of it is used, makes it possible to obtain eco-friendly composites with good acoustic properties.

Keywords: eco-friendly composites, sound-absorbing properties, PLA, municipal waste, sound absorption coefficient

Iron Warriors – Poland’s Double Record Holders

Student Scientific Association Iron Warriors

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Abstract

A super-efficient prototype vehicle built by students from the Lodz University of Technology will be on exhibit at the stand. The Iron Warriors team is currently working on two such vehicles – the internal combustion-engine Eco Arrow 3 and the battery electric Eco Arrow 2 Electric (on display at the stand). The vehicle weighs just under 50 kg, which is only possible thanks to the use of advanced materials and technologies – the entire monocoque is made of a carbon fibre-based composite, with FDM and SLA 3D printing being frequently used technologies, and the bodywork is coated with a paint that not only improves aerodynamic properties but is also extremely light (the vehicle was painted with just a single coat). The vehicle’s record as of 20 April 2026 stands at 2,212 km per litre of 95 octane petrol equivalent (approximately 234 km/kWh). We’re heading off to the next competition on 17 May, hoping to break that record! By comparison, the record for a combustion engine vehicle is 837 km per litre of 95 octane petrol. The team is currently working on an improved version of the monococque (Eco Arrow 3.5).

Keywords: prototype vehicle, petrol, electricity, record, energy efficiency, aerodynamics

Lodz Racing Team – Formula Student

Student Scientific Association of Automotive Enthusiasts - Lodz Racing Team

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Abstract

Lodz Racing Team is a student engineering group from the Lodz University of Technology focused on the design and development of a Formula Student race car. The team brings together students from various disciplines who collaborate on building a fully functional single-seater vehicle to compete in international Formula Student competitions.

Keywords: race car, student engineering group¸ aerodynamics, design, mechanics

Lodz Solar Team Paddock | University Solar Motorsport

Student Scientific Association of Automotive Enthusiasts - Lodz Solar Team

Lodz University of Technology, Poland

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Abstract

The "Lodz Solar Team Paddock" is an exhibition space dedicated to the activities of the Lodz Solar Team, a championship-winning team operating as a project of the Student Scientific Associationof Automotive Enthusiasts (Studenckie Koło Naukowe Miłośników Motoryzacji). The stand details the research and engineering achievements in the field of university solar motorsport and the design evolution of the sustainable Eagle vehicle series. The booth features conceptual designs alongside physical, proprietary structural components, demonstrating the practical application of advanced materials and innovative manufacturing technologies. An integral part of the exhibition includes displays related to the rigorous motorsport environment, featuring trophies acquired during international competitions. These serve as empirical verification of the aerodynamic performance, mechanical reliability, and energy efficiency of the developed solutions. This space creates a platform for expert discussion on technological optimization and the transfer of knowledge from the academic environment to the modern automotive sector.

Keywords: racing, solar, electric, motorsport, endurance

Photogrammetry - the Use of Photogrammetry and 3D Printing in Architecture and Heritage Conservation, While Maintaining the Principles of Sustainable Development

Student Scientific Association Creative Architectural Design (CAD)

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Abstract

The exhibition "Photogrammetry – the use of photogrammetry and 3D printing in architecture and heritage conservation, while maintaining the principles of sustainable development", prepared by the SKN CAD Student Research Group operating at the Department of Digital Technologies in Architecture and Urban Planning within the Institute of Architecture and Urban Planning at Lodz University of Technology, presents the latest results of a research project dedicated to the application of photogrammetry and 3D printing technologies in the processes of conservation, reconstruction, and dissemination of architectural heritage. The research grant received financial support from the Lodz University of Technology Foundation. The project aligns with the principles of the New European Bauhaus, integrating the values of inclusivity, sustainability, and heritage protection. The scope of the research included the selection of objects, 3D scanning, digital model development, 3D printing, followed by model testing and consultations with blind and visually impaired individuals, highlighting the need to create tactile forms of presenting architectural details that are normally inaccessible to them. An important aspect of the research is also the use of biodegradable materials in 3D printing, supporting an environmentally responsible approach.

Keywords: 3D printing, architectural heritage, sustainable development, New European Bauhaus, biodegradable materials

Acknowledgements

The SKN CAD group is supervised by Associate Professor Anetta Kępczyńska-Walczak, Ph.D. Eng. Arch., coordinator of the European grant New European Bauhaus Academy (NEBA) at Lodz University of Technology. Mateusz Grabowski Ph.D. Eng. Arch. is also involved in the presented student research project.

SKN Nano Student Stand: Chemical Shows & Scientific Curiosities

Student Scientific Association Nano

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Abstract

Visit the SKN NANO booth to experience live chemistry demonstrations and discover the innovative research being conducted by students from the Faculty of Chemistry at Lodz University of Technology. Our team is showcasing how modern science can address global environmental challenges, such as recovering heavy metals like copper, iron, and cobalt from contaminated water using specially designed eco-friendly hydrogels. Beyond the experiments, you can learn about the daily activities of student researchers at PŁ and see firsthand how we develop sustainable technologies to protect our planet's water resources.

Keywords: eco-friendly hydrogels, heavy metals, sustainable technologies, chemistry demonstrations, environmental challenges

SKN Włókno Re-design Over Fast Fashion

Student Scientific Association Włókno

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Abstract

The student research group's booth offers an opportunity to learn about the team's activities and explore contemporary fashion design. Visitors can deepen their knowledge of knitwear, woven fabrics, and the design process, with a focus on upcycling and sustainable garment creation. A key highlight of the showcase is the critical analysis of fast fashion's impact and the promotion of ethical industry practices. The booth also features selected projects and garments, providing a direct insight into the members' creative work and technical development.

Keywords: contemporary fashion design, design process, upcycling, sustainable garment creation, fast fashion

Students' Applications of 3D Printing

Student Scientific Association Druku 3D

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Abstract

Students from Lodz University of Technology will showcase their best projects created with 3D printing technologies.

Keywords: 3D printing technologies, additive manufacturing, prototyping, filaments, advanced materials

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Zadanie publiczne Łódź dla nauki - granty na inicjatywy akademickie 2026-2027 jest finansowane z budżetu Miasta Łodzi.

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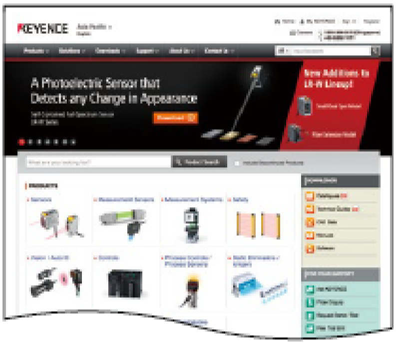

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Founded: May 1974
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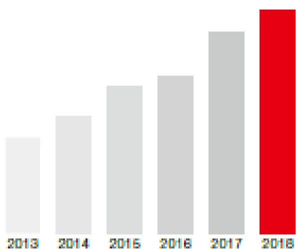
2018 Global Sales: 5,241,928,000 USD
Worldwide Employees: 7,941

Note: US dollar amounts are converted from Japanese yen for convenience only at 112 JPY = 1 USD, the approximate exchange rate on March 20, 2019.



2009 — Designed high-power fiber laser marker with the world's smallest head size

2010

2011 — Invented rapid set-up vision sensor

2012 — Developed auto-teaching machine vision system

2013 — Developed world's fastest 2D/3D laser scanner with a sampling rate of 64,000 profiles/sec

2014 — Created a revolutionary all-in-one intuitive machine vision system that fuses high-speed cameras, intelligent lighting, and a powerful algorithm (LumiTrax™)

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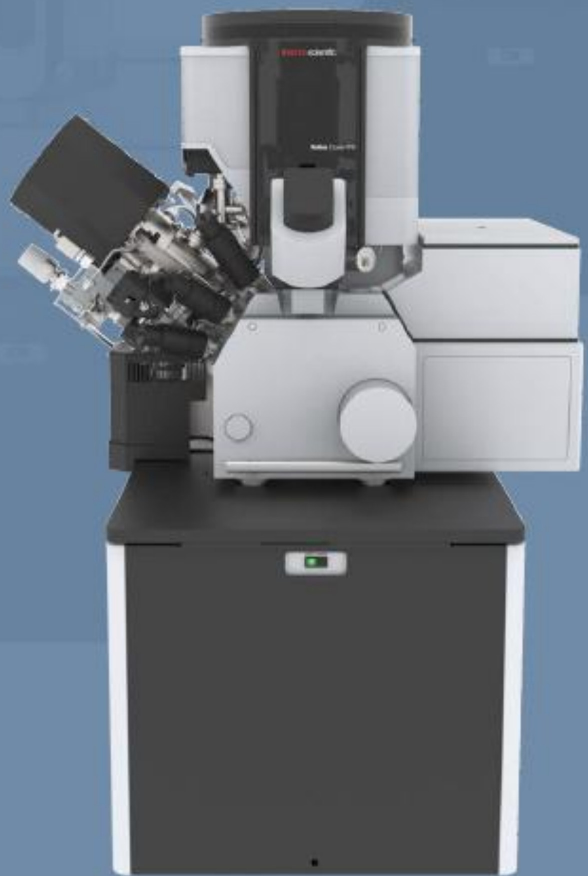
2017 — Developed a new generation of 3D Laser Scanning Confocal Microscope, measuring across 50 mm with nanometer resolution



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The Institute was established in 1953 as the Laboratory of the Technical Textiles Industry.

The Institute of Security Technologies "MORATEX" conducts scientific research, development work, and implementation activities in the field of materials engineering, with results applied in the area of national security.

Scientific research and development work are supported by the following activities:

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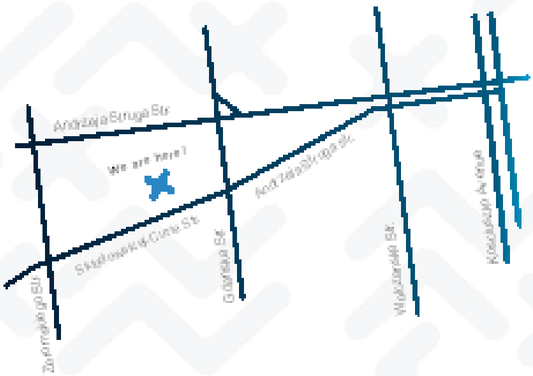
- standardization,
- certification,
- innovation and invention.

The Institute has a certified Internal Control System that enables, among other things, the implementation of technical assistance processes and R&D projects related to dual-use technologies and strategic products.

The Institute of Security Technologies "MORATEX" operates the following research laboratories:

- Metrological Testing Laboratory together with the newly established CompositeLab Laboratory Unit,
- Ballistic Testing Laboratory,
- Chemical Testing Laboratory meeting the requirements of PN-EN ISO/IEC 17025:2018-02,
- and the Product Certification Department meeting the requirements of PN-EN ISO/IEC 17065:2013-03 — all accredited by the Polish Centre for Accreditation and by the Minister of National Defence in the field of defence and security.
- in 2023, a new ErgoSecurity Laboratory was also established.

Technology begins in the laboratory



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NOMATEN

Centre of Excellence in Multifunctional Materials for Industrial and Medical Applications

NATIONAL CENTRE FOR NUCLEAR RESEARCH ŚWIERK

The NOMATEN Centre of Excellence is a research centre established at the National Centre for Nuclear Research (NCBJ) in Poland. It brings together international research teams working on innovative, multifunctional materials that combine advanced structural and functional properties for demanding industrial, nuclear and medical applications. NOMATEN develops partnerships with both industry and research organisations to transform scientific knowledge into market-oriented solutions in the field of advanced materials and radiopharmaceuticals.

NOMATEN is built on the idea of connecting materials design, manufacturing, advanced characterisation, modelling, functional testing and radiopharmaceutical research within one interdisciplinary environment. This integrated approach enables the Centre to address complex technological challenges, from the atomic scale to real operating conditions.

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- Materials Design and Manufacturing
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- Materials Characterization
- Novel Radiopharmaceuticals for Medical Purposes

WHY NOMATEN?

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- Advanced infrastructure
- A bridge between science and application
- Strategic location within NCBJ

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NOMATEN

Centre of Excellence in Multifunctional Materials for Industrial and Medical Applications

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nomaten.ncbj.gov.pl

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FUNDING

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 857470

NCBJ | cea | VTT | Ministerstwo Nauki i Szkolnictwa Wyższego | European Funds Smart Growth | Republic of Poland | European Union European Regional Development Fund

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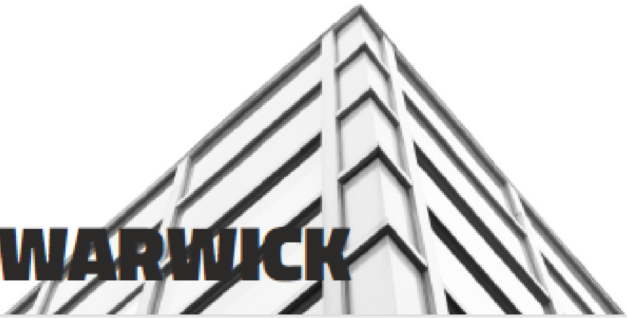

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- 1963 RETECH
- 1984 SECO/WARWICK USA
- 1991 PL + USA SECO/WARWICK
- **2005** SECO/WARWICK acquires 100% of the shares of the American company
- 2006 RETECH USA
- 2007 WGPW stock listed
- 2010 SECO/WARWICK CHINA
- 2014 SECO/WARWICK GERMANY
- 2016 SECO/WARWICK SERVICES
- 2017 SVT USA
- 2017 SECO/WARWICK INDIA
- 2019 SŁAWOMIR WOŹNIAK CEO SECO/WARWICK GROUP
- 2024 RETECH has acquired ReMelt

SECO/WARWICK
INVENTION MEETS RELIABILITY

MARKET DIVISION

42% USA **32%** EU
18% ASIA **8%** other

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Sławomir Woźniak | CEO
Piotr Walasek | CFO
Bartosz Klinowski
Earl Good

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SECO/WARWICK is called the Manufacturing World Leader and the Manufacturing Company of the Year. SECO/WARWICK was among top Polish the innovation leaders ranking carried out by "Rzeczpospolita", and in the following years it was placed on podium in the ranking of Lubuskie Voivodeship innovative companies.

SECO/WARWICK is an **INNOVATION LEADER** and 6 **INNOVATION SYMBOL** for research and development projects implemented together with foreign and Polish technical universities and for the development of an innovative line for the graphene production. We are **MERITORIOUS FOR INVENTION** (2018) on the 100th anniversary of establishing the Polish Republic Patent Office.

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ABOUT THE COMPANY

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We deliver complete solutions based on equipment from renowned manufacturers, our own software and the team's practical experience. We combine design, manufacturing, programming, commissioning and process optimization.

WHY SMG SOLUTIONS

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- focus on quality, safety, reliability and responsibility for results
- in-house design, manufacturing and service capabilities, plus R&D projects

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ELECTRONICS design, service, diagnostics and modernization of industrial equipment	**WORKSHOP** CNC, turning, milling, drilling, grinding, MIG/MAG/TIG

WORK AREAS

- design and modernization of machines, lines and production stations
- integration of control systems, drives, sensors and safety systems
- production support, diagnostics, service and process optimization

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SCOPE OF SERVICES

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Industrial electronics: circuit design, service and diagnostics of devices regardless of manufacturer and age; modernizations and embedded systems.

Mechanical engineering and design office: production lines, stations and machines; rebuilds, relocations, safety audits and adaptation to machine directive requirements.

Industrial electrical engineering: EPLAN schematics and documentation revisions, installation assembly, measurements, network diagnostics and fiber-optic work.

Machining workshop: machining and welding work: turning, milling, drilling, grinding, MIG, MAG, TIG.

SELECTED PROJECTS

- mechanical design and machine projects
- grinding machine and line modernizations
- parquet palletizing and robotic workstations
- machine safety using AIRSKIN
- multi-variant gripper and magnetic gripper controller
- PC-based robot control application

EU-FUNDED R&D PROJECT

Laser marking device for automotive body component engraving (Patent P.420242)
The project aimed to develop a marking device resistant to overloads during robot motion and capable of marking components while they are being moved. The solution combines transport and marking in one cycle, reducing part manufacturing time and limiting the need for a separate workstation.

Innovation: a mobile marking device mounted on a moving robot arm, enabling permanent QR and VIN markings directly in metal and feature reading by X-ray CT after mechanical surface abrasion.

ASSUMED VS. ACHIEVED

Parameter	Assumed	Achieved
Speed	5 char./s	>=5 char./s ✓
Noise	<=50 dB	<50 dB ✓
Accuracy	+/-0.1 mm	<=0.05 mm ✓
Optical fibre	min. 7 m	10 m (up to 20 m) ✓
Robot mounting	YES	verified ✓
Operation in motion	YES	90°, 100% speed ✓
Reading after abrasion	X-ray CT	X-ray CT confirmed ✓
Final TRL	VII	VII ✓

CONCLUSIONS

- developed a solution combining laser marking with robot mobility and parallel component transport
- laser power calibration is key for different coating systems (30-80%)

FUNDING

Project co-financed under the Smart Growth Operational Programme 2014-2020, Sub-measure 1.1.1. Project value: PLN 5,023,204; NCBR funding: PLN 3,818,632. Agreement no.: POIR.01.01.01-00-0268/17

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TECHNOLUTIONS

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The second pillar of our business is our calibration laboratory services, accredited by the PCA. We provide custom testing, equipment maintenance, and specialized training. Hundreds of installations have given us valuable experience in a variety of fields. This allows us to share our expertise with you, tackle challenges, and work together to achieve our goals.

Research & Testing Laboratory:

- Surface Layers and Coating Characterization
- Microscopic Analysis
- Corrosion Resistance Evaluation
- Tribological Wear Testing
- Surface Topography Characterization
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CORNING 175 YEARS

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We are a global leader in optical solutions for industry. What do we do in Poland? We're revolutionizing communication! We design and manufacture **cables, optical fiber, and telecommunications equipment.** Thanks to our work, billions of people around the world can use social media, watch HD videos, and shop online. During our internships, students get an inside look at our company, participate in real-world projects, and take on responsible tasks while learning from experienced professionals.

In addition to manufacturing optical fiber, Corning makes a significant contribution to the advancement of science and technology. We created **Gorilla® Glass**, which is likely used in your smartphone's screen. Additionally, we also contributed to the development of **the Hubble** and **James Webb telescopes**.

Industries: mechanics, automation, electronics, optoelectronics, telecommunication, logistics, management, production engineering, nanotechnology, polymer technology.

Where to find us: Stryków and Mszczonów.

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