ISMANAM 2025

29th International Symposium on Metastable, Amorphous and Nanostructured Materials

Program and Abstracts

Bratislava, Slovakia, June 22–27, 2025

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Program and Abstracts

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Organizers

Institute of Physics, Slovak Academy of Sciences

Institute of Experimental Physics, Slovak Academy of Sciences

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Foreword and Welcome to Participants

The International Symposium on Metastable, Amorphous, and Nanostructured Materials (ISMANAM) was established by Prof. Alain Reza Yavari to facilitate the exchange of knowledge on various types of metastable materials. Since its inception in 1994, ISMANAM has been held annually and served as a premier platform for sharing the latest knowledge on metastable, amorphous and nanostructured materials produced through various advanced techniques such as rapid cooling, mechanical alloying, thin-film deposition and many others. As interest in metastable materials continued to expand, ISMANAM remains at the forefront of this dynamic field, promoting cutting-edge research and facilitating connections between academia and industry. Over the years, ISMANAM has grown in both scope and participation. It has brought together leading researchers, industry experts, and emerging scientists, fostering collaboration and innovation in the field. The symposium has traveled to various notable locations all around the globe, allowing for a rich exchange of ideas and advancements in materials science. The ISMANAM 29 (2025) symposium attempts to offer a dynamic program featuring plenary, keynote and invited lectures, oral presentations and poster sessions supplemented by diverse social activities.

ISMANAM 29 expects to host over 140 participants from 27 countries. Its scientific program counts for 15 plenary lectures, 3 keynote lectures and 23 invited lectures to be presented by leading researchers in the fields of science and technology of metastable, amorphous and nanostructured materials, followed by numerous oral and poster presentations and intense discussions. The conference will take place in the unique and historically significant buildings of the Old Mayor Hall (Primatial Palace) and the Historical Building of the City Hall, both located in the heart of Bratislava’s Old Town. These beautiful and distinctive historical buildings should contribute to enhance the conference experience.

Alongside with the intense scientific activity we hope that the conference participants will enjoy also the social program as well as the summer atmosphere of Bratislava, which provides ample cultural, social and entertainment opportunities for organized and individual activities.

We most highly esteem the honor of hosting the conference and appreciate the willingness of the ISMANAM 29 participants to take part in this important scientific event. We express our most hearty welcome to the participants, wishing a pleasant and fruitful stay.

Irena Gejdoš Janotová, Dušan Janičkovič and Peter Švec Sr.

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ISMANAM 29
2025 BRATISLAVA

29th International Symposium on Metastable, Amorphous and Nanostructured Materials

June 22–27, 2025 | Bratislava, Slovakia

Scientific Program

Sunday, June 22, 2025

Time	**Mezzanine, Hall of Mirrors**
17:00 – 20:00	**Registration**
18:00 – 20:00	**Welcome Reception**

Monday, June 23, 2025

8:00 – 9:00	**Registration**		
9:00 – 9:20	**Welcome Address:** **Matúš Vallo, the Mayor of Bratislava** **Martin Venhart, the President of the Slovak Academy of Sciences**		
Time	**Hall of Mirrors (Chairman T. Kulik)**		
9:20 – 10:05	**Brian Cantor** Multicomponent High-Entropy Cantor Alloys		
10:05 – 10:50	**Jürgen Eckert** Tuning Disorder and Heterogeneity of Metallic Glasses		
10:50 – 11:20	Coffee break		
	Hall of Mirrors (Chairman E. Babic)	**Justi Hall (Chairman W. Botta)**	**Faust Hall (Chairman J. Bednarčík)**
11:20 –11:50	**Dariusz Oleszak** Medium and High Entropy Multicomponent Alloys - a wide variety of structures, properties and processing routes	**Daniel Şopu** Tuning the Degree of Rejuvenation in Metallic Glasses	**Kostas Georgarakis** Vitrification of metallic liquids-uncovering the structural pathway to metallic glasses
11:50 – 12:10	**Rafal Babilas** Structure, anticorrosion and mechanical properties of CoCrFeNiMs (Ms=Nb,Mo,B,Si) high entropy alloys prepared by rapid solidification method	**Shuang Su** Kinetic and thermodynamic studies of ion-induced gradient rejuvenated amorphous microwires	**Jerzy Antonowicz** Capturing Ultrafast Melting in Palladium
12:10 – 12:30	**Kaiju Lu** Achieving ultra-strong and ductile CoNi-based FCC multi-principal element alloys via alloying with Mo and W refractory elements	**Myeong Jun Lee** Fictive temperature-based annealing effects on metallic glasses with different initial structure	**Zuzanna Kostera** Crystallization kinetics of supercooled liquid Palladium
12:30 – 14:00	Lunch		

Time	**Hall of Mirrors (Chairman Motoki Ohta)**		
14:00 – 14:45	**Paola Tiberto** From Ribbons to Bulk: Tuning Magnetic Properties in Fe-Si-B Alloys with Advanced Manufacturing		
	Hall of Mirrors (Chairman Mo Li)	**Justi Hall (Chairman K. Georgarakis)**	**Faust Hall Chairman D. H. Kim)**
14:50 – 15:10	**Pere Bruna** On the improvement of the corrosion resistance of two families of High-Entropy Metallic Glasses	**Oleksandr Roik** Short-range order of the liquid Al-Sn-Cu alloys	**Purbasha Sharangi** Effects of Ni addition on the magnetic and structural properties in Fe-Si-B-Nb alloy by different casting techniques
15:10 –15:30	**Binbin Liu** Phase transformation and mechanical properties of silicide-strengthened (TiZrHfNb)$_{100-x}$Si$_x$ (x=0, 1, 5, 7, 10 and 15) high entropy alloys	**Min Kyung Kwak** Interfaces in Phase-Separated Pd-Au-Si Metallic Glass Alter Phase Transformation Kinetics	**Martin E. Stiehler** W-based metallic glasses for nuclear fusion applications
15:30 – 16:00	Coffee Break		
	Hall of Mirrors (Chairman Pere Bruna)	**Justi Hall (Chairman T. Spassov)**	**Faust Hall (Chairman M. Deanko)**
16:00 – 16:20	**Chun-Liang Chen** Effect of High-Entropy Reinforcements on the Strength and Toughness of Tungsten-Based Alloys	**Ying Ian Chen** 3D-printed Topologically Structured Electrodes with Exceptional Mechanical Properties and Electrochemical Performance for Flexible Li-ion Batteries	**Fushan Li** Structure, Properties and Crystallization Behavior of FeSiBPCuNb Soft Magnetic Nanocrystalline Alloy
16:20 – 16:40	**Marián Palcut** As-cast Al-Fe-Co-Ni-Cu alloys: microstructure, phase constitution, and oxidation resistance	**Sang Tae Woo** Effect of Nanoimprint-Induced Structural Heterogeneity on the Oxidation Behavior of Zr-Based Metallic Glasses	**Krzysztof Pajor** Effect of casting conditions on the structure and mechanical properties of bulk metallic glasses
16:40 – 17:00	**Vikas Shivam** Heterogeneous lamella structure induced precipitation-hardened Fe-rich complex concentrated alloys	**Sepide Hadibeik** Atomic Disorder in Laser Beam-Shape-Tailored 3D-Printed Zr-Based Bulk Metallic Glass Under In-Situ Heating During High-Energy X-Ray Diffraction	**Parthiban Ramasamy** Synthesis and characterization of soft magnetic metallic glass nanoparticles via laser ablation
17:00 – 17:20	**Emil Babic** Electronic structure of high-entropy alloys: prospects and challenges	**Xiaoling Fu** Interfacial strain concentration and relaxation along crystalline-amorphous boundaries of B2-reinforced bulk-metallic-glass-composites during loading	**Prashanth Konda Gokuldoss** Additive manufacturing of Ti-Nb-based biomaterial
17:20 – 17:40	**Lin Liu** Unique deformation mechanisms in an FCC/BCC dual-phase high entropy alloy at high temperatures	**Seung Zeon Han** Strengthening by heterogeneously nucleated and grown G-phase in Cu-Ni-Si-Mn alloy	**Premkumar Murugaiyan** Ultra-Fine Nanocrystallization in Fe-Rich FeSiBPNbCu Alloys: Mechanisms and Microstructural Evolution
17:50 – 19:30	**POSTER SESSION (Picture Gallery, Chairmen J. Löffler, J. Perepezko)**		

Tuesday, June 24, 2025

Time	Hall of Mirrors (Chairman B. Cantor)		
9:00 – 9:45	**Takeshi Egami** Atomic Cooperativity and Deformation in Metallic Glasses		
9:45 – 10:30	**Jörg F. Löffler** Correlative Fast Differential Scanning Calorimetry on Metallic Glasses		
10:30 – 11:00	Coffee Break		
	Hall of Mirrors (Chairman J. Eckert)	**Justi Hall (Chairman M. Stoica)**	**Faust Hall (Chairman P. Tiberto)**
11:00 –11:30	**Paola Rizzi** Surface modification of biocompatible Ti-based amorphous alloys by dealloying to improve implant cytocompatibility	**Jozef Bednarčík** Structural Aspects of Stress-Induced Magnetic Anisotropy in Fe-based Nanocomposite: Insights from Synchrotron Experiments	**Nicoleta Lupu** Tailoring Microstructure and Creep-Induced Anisotropy in Co-Based Amorphous Wires for Enhanced Functional Magnetic Properties
11:30 – 12:00	**Jan Dusza** Hardness and strength of dual-phase boride/carbide high entropy ceramics at nano/micro scale	**Martin Cesnek** Probing Short-Range Order in Fe-Co-Si-B-Mo-P Amorphous Alloy Using Mössbauer Spectroscopy and High-Energy X-ray Diffraction	**Arcady Zhukov** Tailoring of soft magnetic properties and Giant Magnetoimpedance effect of amorphous microwires by stress-annealing
12:00 – 12:30	**Katalin Balazsi** Ceramic biomaterials: From traditional technologies to novel applications	**Florian Spieckermann** Application of synchrotron-based quantifiers for the characterization of conventionally and additively processed metallic glasses	**Kornel Richter** Magnetooptical observations of cylindrical magnetic microwires with Matteucci effect
12:30 – 14:00	Lunch		
	Hall of Mirrors (Chairman I. Škorvánek)		
14:00 – 14:45	**Motoki Ohta** Nanocrystallization Technology for High Fe Content Amorphous Alloy		
14:45 – 15:30	**Wei Hua Wang** A New Generation of High-frequency Amorphous/Nanocrystalline Soft Magnetic Materials for Matching Third-generation Semiconductors		
15:30 – 16:00	Coffee Break		

Time	Hall of Mirrors (Chairman J. Ferenc)	Justi Hall (Chairman W. H. Wang)	Faust Hall (Chairman O. Roik)
16:00 – 16:30	**Marián Deanko** Soft Magnetic Nanocrystalline Materials in Vacuumschmelze Portfolio and their Application	**Mo Li** Design strategy for metallic glass composites	**Eun-Ae Choi** A DFT study on the effect of vacancies on the formation of deformation twins in Cu alloys
16:30 – 16:50	**Walter J. Botta** Crystallisation of Metallic Glasses in Complex Multicomponent Carboborides	**Baoshuang Shang** Investigating the Formation Condition of Amorphous Solid	**Ahmad Oweisi Fordoei** Evaluation of hardening and structural change during deformation in as-cast CuZr based bulk metallic glass
16:50 – 17:10	**Kostas Georgarakis** Sustainable Aerospace Manufacturing: Recycling of Aerospace-Grade Titanium Alloys via Rapid Solidification of Swarf Waste	**Carlos Iglesias Fernández-Cuevas** Crystallization Temperature Driven Phase Evolution and Magnetic Behaviour in Fe-Ni-P-C Ribbons	**Jiri Houska** Cu-Zr-Al thin film metallic glasses in a wide range of compositions and growth conditions
17:10 – 17:30	**Witor Wolf** Characterization of different carbide distributions for a Cr-Co-Ni alloy	**Tatiana Damatopoulou** On advanced quality electromagnetic yokes based on amorphous ribbons for steel health monitoring	**Tomasz Koziel** B2 CuZr phase formation in Cu-Zr-Al bulk metallic glass matrix composites
17:30 – 17:50	**Ihor Shtablavyi** Geometrical porometry as a method for calculating the free volume of condensed systems.	**Bing Wang** The low temperature relaxation behaviors and their dynamic responses	**Jinfu Li** Glass-Forming Ability of Cu-Ag Eutectic Alloys
17:50 – 19:30	**POSTER SESSION (Picture Gallery, Chairmen Ian Chen, Yu. Plevachuk)**		

Wednesday, June 25, 2025

Time	Hall of Mirrors (Chairman T. Egami)		
9:00 – 9:45	**A. Lindsay Greer** Opportunities and Problems with Ultrafast Calorimetry of Metallic Glasses		
9:45 – 10:30	**John H. Perepezko** Examination of Amorphization and Primary Crystallization by High Rate Nanocalorimetry		
10:30 – 11:00	Coffee Break		
	Hall of Mirrors (Chairman A. Zhukov)	**Justi Hall (Chairman D. Sopu)**	**Faust Hall (Chairman D. Oleszak)**
11:00 –11:30	**Jarosław Ferenc** Ultra-rapid Annealing by Joule Heating: the Novel Setup for Precise Thermal Cycle and In situ Measurements	**Matthias Bönisch** Negative/zero/positive thermal expansion alloys	**Matej Baláž** Mechanochemistry - Solvent-free and green methodology to yield nanostructured metal chalcogenides with versatile applications
11:30 – 12:00	**Ivan Škorvánek** Impact of elevated temperature on soft magnetic properties of rapidly annealed nanocrystalline high-B_s Fe-Co-Cu alloys	**Do Hyang Kim** Ni-Ti based shape memory alloy nanostructures using amorphous phase as a precursor	**Naďa Mrkývková** Perovskite Thin Film Growth: Structural and Optoelectronic Characterization
12:00 – 12:30	**Mihai Stoica** Transition of fluctuation-modifying to bond-modifying Invar effect in ferromagnetic bulk metallic glasses	**Bo Zhang** Aging effects of Lunar Glasses	**Javier S. Blázquez** Dependences of phase distribution and magnetic properties on compositional tailoring in Mn(CoFe)(GeSi) series obtained from mechanically alloyed amorphous precursors
12:30 – 14:00	Conference Photo and Lunch		
	Hall of Mirrors (Chairman A. L. Greer)		
14:00 – 14:45	**Paul M. Voyles** Atomic Mobility in Metallic Liquids and Glasses		
14:45 – 15:30	**Eun Soo Park** Development of Super Plastic Bulk Metallic Glasses via Tailoring of Icosahedral Ordering		
15:30 – 16:00	Coffee Break		

Time	Hall of Mirrors (Chairman Eun Soo Park)	Justi Hall (Chairman N. Lupu)	Faust Hall (Chairman P. Rizzi)
16:00 – 16:20	**Witor Wolf** Tailoring Microstructures and Tribological Performance in Quasicrystalline-Reinforced Coatings and Surfaces	**Chae Woo Ryu** Medium-range atomic correlation and local chemical order in metallic glasses	**Neda Shojae** Novel antibacterial Ti-Based Alloys for Biomedical Applications
16:20 – 16:40	**ShuYi Liang** Creep and Cyclic Tensile Behaviors and Structural Evolution Mechanisms of Metallic Glasses	**Alexander Chizhik** Longitudinal and transversal flexibility influence on magnetic properties of amorphous glass covered microwires	**Fereshteh Sourani** High Corrosion Resistance and Biocompatible Zr-Based Bulk Metallic Glasses for Load-Bearing Implants
16:40 – 17:00	**Devinder Singh** Phase-separated Zr-Al-Fe-Y metallic glasses with suitable mechanical properties for possible implant applications	**Iryna V. Matsukevich** Effects of melting processing on the characteristics and structure of microporous metal-organic framework ZIF-62 glasses	**Petr Zeman** Dual-phase nanocomposite coatings based on crystalline ZrN and glassy ZrCu
17:00 – 17:20	**Caiyun Liu** A remarkable inversion of oxidation rate and unique oxide morphology of $Cu_{60}Zr_{40}$ metallic glass at 100-300 ^{o}C	**Felix Römer** Influence of remelting in PBF-LB of KUAMET$^{®}$6B2	**Elham Sharifikolouei** Frontiers of Amorphous Materials: Metallic glass thin films, microfibers and bulk systems for biomedical applications
17:20 – 17:40	**Feng Ye** Interface asymmetry and phase transformation of the Cu layer-inserted Al/Cu/Ni/Cu multilayers	**Ashwani Chaudhary** Comparative Tribological Study of Wrought and LPBF C300 Maraging Steel: Influence of Heat Treatment and Microstructural Characteristics	**Zhiyuan Jing** Tribo-corrosion behaviors of Al-based amorphous coatings prepared using HVAF spraying techniques

Thursday, June 26, 2025

Time	Hall of Mirrors (Chairman P. Voyles)
9:00 – 9:45	**Demie Kepaptsoglou** Advanced Analytical Electron Microscopy for Amorphous and Nanostructured Systems
9:45 – 10:30	**Christoph Gammer** Using TEM to Link Structure with Shear Band Evolution in Metallic Glasses
10:30 – 11:00	Coffee Break
	Hall of Mirrors (Chairman Ch. Gammer)
11:00 –11:30	**Sangjun Kang** Large-angle Lorentz 4-Dimensional Scanning Transmission Electron Microscopy for Simultaneous Local Magnetization, Strain and Structure Mapping
11:30 – 11:50	**Robin E. Schäublin** Phase Transitions in PdAuSi Metallic Glass During High-Rate DSC: An In-Depth Microstructural Analysis Using TEM and APT
11:50 – 12:10	**Sangjun Kang** Direct observation of quadrupolar strain fields forming a shear band in metallic glasses
12:30 – 14:00	Lunch
14:00 – 19:00	**Excursion – ELESCO, ISMANAM AWARDS**

Friday, June 27, 2025

Time	Hall of Mirrors (Chairman P. Rizzi)
9:00 – 9:45	**Tony Spassov** High-capacity Metal Hydride / Air Secondary Battery
9:45 – 10:30	**Walter J. Botta** Interface Energies and Hydrogen Storage Properties of Mg/Additives/MgH_2
10:30 – 11:00	Coffee Break
	Hall of Mirrors (Chairman J. Perepezko)
11:00 –11:30	**Oleksandr Roik** Fabrication of multicomponent nanoporous metallic materials by vapor phase dealloying
11:30 – 12:00	**Deliang Zhang** The Roles of Nanostructures in Enhancing the Strength-Ductility Synergy of Powder Metallurgy Near-alpha Titanium Alloys
12:00 – 12:20	**Javier S. Blázquez** Mechanochemical synthesis: a pathway to novel high-entropy oxide perovskite structures
12:25 – 12:40	**CLOSING CEREMONY**
12:30–13:30	Lunch

Plenary Lecture	**Keynote Lecture**	**Invited Lecture**	**Oral Presentation**

List of ISMANAM 2025 Contributions
(ordered alphabetically by presenting author)

Plenary Lectures

P-01 Interface energies and hydrogen storage properties of Mg/Additives/MgH2
Walter J. Botta

P-02 Multicomponent High-Entropy Cantor alloys
Brian Cantor

P-03 Tuning Disorder and Heterogeneity of Metallic Glasses
Jurgen Eckert

P-04 Atomic cooperativity and deformation in metallic glasses
Takeshi Egami

P-05 Using TEM to link structure with shear band evolution in metallic glasses
Christoph Gammer

P-06 Opportunities and Problems with Ultrafast Calorimetry of Metallic Glasses
Lindsay Greer

P-07 Advanced Analytical Electron Microscopy for Amorphous and Nanostructured systems
Demie Kepaptsoglou

P-08 Correlative fast differential scanning calorimetry on metallic glasses
Jörg F. Löffler

P-09 Nanocrystallization technology for high Fe content amorphous alloy
Motoki Ohta

P-10 Development of Super Plastic Bulk Metallic Glasses via Tailoring of Icosahedral Ordering
Eun Soo Park

P-11 Examination of Amorphization and Primary Crystallization by High Rate Nanocalorimetry
John H. Perepezko

P-12 High-capacity Metal hydride / Air secondary battery
Tony Spassov

P-13 From Ribbons to Bulk: Tuning Magnetic Properties in Fe-Si-B Alloys with Advanced Manufacturing
Paola Tiberto

P-14 Atomic Mobility in Metallic Liquids and Glasses
Paul M. Voyles

P-15 A new generation of high-frequency amorphous/nanocrystalline soft magnetic materials for matching third-generation semiconductors
Wei Hua Wang

Keynote Lectures

K-01 Ceramic biomaterials: From traditional technologies to novel applications
Katalin Balazsi

K-02 Ni-Ti based shape memory alloy nanostructures using amorphous phase as a precursor
Do Hyang Kim

K-03 Aging effects of Lunar Glasses
Bo Zhang

Invited Lectures

I-01 Mechanochemistry - Solvent-free and green methodology to yield nanostructured metal chalcogenides with versatile applications
Matej Baláž

I-02 Structural Aspects of Stress-Induced Magnetic Anisotropy in Fe-based Nanocomposite: Insights from Synchrotron Experiments
Jozef Bednarčík

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I-04 Negative/zero/positive thermal expansion alloys
Matthias Bönisch

I-05 Probing Short-Range Order in Fe-Co-Si-B-Mo-P Amorphous Alloy Using Mössbauer Spectroscopy and High-Energy X-ray Diffraction
Martin Cesnek

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Marián Deanko

I-07 Hardness and strength of dual-phase boride/carbide high entropy ceramics at nano/micro scale
Jan Dusza

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Nicoleta Lupu

I-13 Perovskite Thin Film Growth: Structural and Optoelectronic Characterization
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Dariusz Oleszak

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Kaiju Lu

O-32 Experimental and Molecular Dynamics simulation study on deformation mechanism of CoCrNi MEA under nanoscratch test
Vamsi K. Majeti

O-32 Effects of melting processing on the characteristics and structure of microporous metal-organic framework ZIF-62 glasses
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O-38 Synthesis and characterization of soft magnetic metallic glass nanoparticles via laser ablation
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Plenary Lectures

Interface energies and hydrogen storage properties of Mg/Additives/MgH_2

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Hydrogen is certainly one of the most important energy vector for renewable energy sources. It can be successfully stored in a safe and convenient way in the solid state in several alternative materials, such as MgH_2 that present high gravimetric (~ 7.66 wt.% H_2) and volumetric (~ 110 kg $H_2.m^{-3}$) capacities. Since the first studies of MgH_2-based systems the presence of "catalytic" additives was identified as relevant to accelerate the kinetics and decrease H_2 absorption/desorption temperatures.

However, despite extensive studies in the last many years there is no definitive picture for the activation mechanism associated with the different types of additives, with many evidences of positive effects from the presence of elemental additives, such as, Ti, V, Nb, Ni, Fe, oxides, such as Fe_3O_4, Nb_2O_5,V_2O_5, TiO_2 and many different types of alloys. Some of the additives can also improve hydrogen absorption to form MgH_2 at room temperature, such as observed in MgH_2-TiFe mixtures, and in fact, TiFe is one of the most effective additive in promoting the conversion of Mg to MgH_2.

One of the common feature related to most of the additives is their immiscibility with Mg, which suggests an important role of the interfaces energy that could be reduced by the presence of hydrogen [1].

In this work, we initially review the effect of the different additives in Mg/MgH_2-based systems, focusing in the effect of Fe and TiFe; the results are then discussed in association with calculated interfacial and formation enthalpies for Mg-Fe and Mg-TiFe systems, using Miedema's semi-empirical model [2].

The calculation results suggests that hydrogen is attracted to unstable interfaces between Mg-Fe and Mg-TiFe mixtures, thus in agreement with the observed catalyst effect. Also, depending on the additive fraction, attraction of hydrogen can stabilize the interface energy enhancing the system's overall stability through the formation of binary or ternary hydrides.

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Multicompononent High-Entropy Cantor alloys

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All human advances have depended on making new materials, and all materials are alloys, i.e. mixtures of several different starting materials or components. So the history of the human race has been the continued invention of new materials by discovering new alloys. Recently a new way of doing this, by manufacturing multicomponent high-entropy alloys, has shown that the total number of possible materials is enormous, even more than the number of atoms in the galaxy, so we have lots of wonderful new materials yet to find. And multicomponent phase space contains a surprisingly large number of extended solid solutions. The first group of these which was discovered are called Cantor alloys, an enormous composition range with a single-phase fcc structure, based loosely on the original equiatomic five-component Cantor alloy CrMnFeCoNi. It turns out that there are literally trillions of different local atomic and nanoscale environments in Cantor alloys, even with only five components, and the spread of different local structures has important effects on many aspects of the material structure and properties. This talk will discuss the enormous range and complexity of different local atomic and nanoscale environments in multicomponent high-entropy Cantor alloys and describe some of their effects on the structure and properties of the materials, including short-range order, atomic diffusion, dislocation slip and grain boundaries.

Tuning Disorder and Heterogeneity of Metallic Glasses

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Recent studies of glass-forming metallic systems have revealed intriguing complexity, e.g. unusual shifts in radial distribution functions with temperature change or upon mechanical loading in the elastic or plastic regime. Nearest neighbour distances and medium-range order structural arrangements appear to change, e.g. shorten upon heating or become larger with decreasing temperature. Concomitantly, temperature changes as well as static or dynamic mechanical loading within the nominally elastic regime can trigger significant changes in glass properties, which are directly correlated with local non-reversible configurational changes due to non-affine elastic or anelastic displacements. All these findings strongly suggest that the characteristics of the atomic structure decisively determine the properties of the glass and of nanostructured materials derived from glass-forming systems.

Residual stress engineering is widely used in the design of new advanced lightweight materials. For metallic glasses the attention has been on structural changes and rejuvenation processes. High energy scanning x-ray diffraction strain mapping reveals large elastic fluctuations in metallic glasses after deformed under triaxial compression. Transmission electron microscopy proves that structural rejuvenation under room temperature deformation relates to the shear band formation that closely correlates to the underlying distribution of elastic heterogeneities. Micro-indentation hardness mapping hints at an unsymmetrical hardening/softening after compression and further reveals the competing effects of stress and structure modulation. Molecular dynamics simulations provide an atomistic understanding of the correlation between shear banding and fluctuations in the local strain/stress heterogeneity. Thus, stress engineering and elastic heterogeneity together with structure modulation is a promising approach for designing metallic glasses with enhanced ductility and strain hardening ability.

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Atomic cooperativity and deformation in metallic glasses

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Various approaches have been taken to describe the structure of metallic glasses, for the purpose of capturing structural features which are relevant to the elucidation of properties. The topology of the nearest neighbor atoms is most frequently discussed, in the extension of the analysis of the crystalline structure. However, recent analyses suggest that a more extended medium-range order (MRO) is more important. The nearest neighbor shells, such as the icosahedral clusters, are always distorted, and some of them are unstable by themselves. Upon loading atomic bond rearrangements occur abundantly even in the elastic regime [1]. The nearest neighbor atomic configurations are not stable and are fluctuating down to $T = 0$ [2].

Upon the glass transition what freezes is not the nearest neighbor shell, but the MRO [3]. When external stress is applied some atoms yield locally right away, whereas the resistance to deformation is provided by the atomic cooperativity in the MRO. The rigidity of the MRO originates from the cooperative action of the interatomic potentials to form the density waves [4]. Thus, deformation in metallic glass is always highly cooperative. Whereas many localized deformation events occur, they do not perturb the MRO, rendering detailed local atomic dynamics irrelevant to the mesoscopic deformation phenomena. In the absence of the lattice structure which provides rigidity and stability to crystalline structure, cooperativity orchestrated by the MRO controls the behavior of metallic glasses.

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Using TEM to link structure with shear band evolution in metallic glasses

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Metallic glasses (MGs) show attractive properties but suffer from limited ductility caused by the formation of shear bands (SBs). A fundamental understanding of the shear banding process is therefore key for improving their mechanical properties. While atomistic simulations have demonstrated the importance of nanoscale structural variations and strains for the initiation and propagation of SBs, experimental studies are still scarce. In crystalline metals and alloys dislocations can be imaged using transmission electron microscopy (TEM), but the disordered nature of MGs hinders direct imaging of their atomic structure.

Recently, 4D scanning TEM (STEM) using precession nanodiffraction mapping has enabled us to map the atomic density and atomic strain distribution of an individual shear band at < 2 nm resolution [1]. The results show that the atomic density difference and associated strain field cause shear band segmentation and deflection. By comparing MGs with different structural states, we demonstrate that that the shear banding process is closely linked to the initial structure of the glass. In addition, to study the early stages of deformation localization in MGs, *in situ* deformation in the TEM is carried out using a nanoindenter holder. 4D-STEM allows mapping atomic strains at the nanometer scale during continuous in situ deformation [2]. This enables to uncover the nanoscale origins of SB initiation and thus draw a more direct structure-property relationship for MGs containing structural heterogeneities.

Several approaches were explored in recent years trying to improve plasticity of MGs such as artificially introducing crystalline phases, generating dual phase glassy structures or rejuvenation. Despite significant progress, there is still little direct experimental understanding on the effect of individual heterogeneities on the overall deformation mechanism. *In situ* testing in the TEM can yield key information that is not accessible using post mortem characterization. As an example, we studied a TiZr-based MG composite showing transformation-induced plasticity (TRIP) [3]. Only through real-time observation in the TEM it is possible to uncover the sequence of phase transformation and SB initiation. Local strain measurements demonstrate stress redistribution from the crystalline dendrites to the glassy matrix, making these regions preferential sites for SB nucleation.

In summary, the present work demonstrates that direct observation of the nanoscale transient strain evolution allows to understand the effect of local structural heterogeneities on deformation localization, thus helping to obtain a more complete picture of deformation mechanisms in complex disordered materials.

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Opportunities and Problems with Ultrafast Calorimetry of Metallic Glasses

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The technique of ultrafast (*flash* or *chip*) differential scanning calorimetry (FDSC) is now well established. The small sample mass (typically less than 1 mg) permits rapid heating and cooling (up to tens of thousands of degrees per second) while retaining reasonable spatial uniformity of temperature in the sample. Access to such high rates opens up many possibilities for quantitative studies on cooling the liquid or heating the glass:

- many melting/freezing cycles can be performed in a reasonable time, permitting acquisition of excellent statistics;
- rapid cooling permits glass formation in appropriate compositions;
- rapid heating permits the kinetics of structural relaxation and crystallization to be quantified over a wider range of temperature, under continuous heating or isothermal holds.

Some examples are given in this presentation. Metallic-glass (MG) samples can be rejuvenated by heating above the glass-transition temperature T_g and then quenching. The extent of this 'thermal rejuvenation' increases with the ratio of the cooling rate during the quench and the cooling rate that characterizes the state of the metallic glass before rejuvenation. A FDSC study of an annealed Au-based MG has reached a ratio of 10^7, higher than in any other study [1].

The Kissinger method shows that in continuous-heating calorimetry, the crystallization peak temperatures of MGs increase with heating rate. In most conventional DSC studies, the crystallization kinetics show an Arrhenius temperature dependence. An early FDSC study of a chalcogenide system showed non-Arrhenius behaviour, attributed to Vogel-Fulcher-Tammann temperature dependence of the liquid viscosity and enabling determination of the liquid's kinetic fragility [2]. Later studies have successfully matched calorimetric and direct viscometric data and have provided evidence for a fragile-to-strong transition in the liquid [3]. Other authors suggest that the non-Arrhenius behaviour reflects crystallization below and above T_g, reinforcing the interest in studies over a wide range of heating rate.

The crystallization of $Au_{49}Cu_{26.9}Ag_{5.5}Pd_{2.3}Si_{16.3}$ (at.%) MG has been very widely studied, including by FDSC. In particular, the literature shows consistent fittings of the C-curve in the TTT diagram. A new study finds that the fitted rates of crystal nucleation and growth are reliable when well below the nose of curve, correctly predicting the grain size formed in the FDSC samples. At higher temperatures, however, the standard analysis fails, as the number of nucleation events in the FDSC sample is much too low for Johnson-Mehl-Avrami kinetics to be valid. We show that using Poisson statistics it is still possible to semi-quantitatively characterize nucleation and growth rates in this regime [4]. We also explore the effects of pre-existing nuclei.

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Advanced Analytical Electron Microscopy for Amorphous and Nanostructured systems

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Engineering the structural or chemical architecture of functional materials at the nano or even atomic level enables emergent properties that rely on the interplay between fundamental properties of matter such as charge, spin and local atomic-scale chemistry. Thanks to advances in monochromators, state-of-the-art electron energy loss spectroscopy (EELS) in the scanning transmission electron microscope (STEM), offers nowadays the ability to map materials and atomic structures with an angstrom size electron beam and an energy resolution for EELS under 5meV [1]. These capabilities have allowed to probe the spectroscopic signature of phonons down to the single atom level [2] which in tandem with high precision imaging and other wealth of information available have allowed for exciting new experiments in the electron microscope that rival synchrotron light sources.

Here, we present applications for high spatial and energy resolution STEM-EELS in amorphous and nanostructured materials systems including the nanoscale fingerprinting of the optical properties and of characteristic molecular vibrations in glass Metalorganic Frameworks [3,4] as well as recent advances in the detection of spin waves (magnons) in an electron microscope

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Correlative fast differential scanning calorimetry on metallic glasses

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The investigation of reactions and transformations in complex materials and compounds is an important task in modern materials science. Fast Differential Scanning Calorimetry (FDSC) based on MEMS-chip technology is ideal to study the kinetics of such reactions, because it allows for measurements of up to several tens of thousands K/s heating and cooling rates [1-3]. To combine structural and calorimetric measurements, we integrated the FDSC device into the chamber of a scanning electron microscope (SEM) to study *in operando* a series of micrographs together with the FDSC curve [4]. Such correlative measurements are performed with rates of 5 K/s, which is sufficient to rapidly identify the regions of interest that deserve further investigations (see Fig. 1). Both methods reveal complementary information; for example, no change in microstructure is observed by SEM when the heat-flow curve shows an exothermic event (Fig. 1 (i)-(ii)). The FDSC can then be used to design specific sample states at millisecond time scales *in situ* to generate precise crystallization conditions for subsequent *ex situ* microstructure analysis, for example via X-ray diffraction or transmission electron microscopy (TEM).

The advances of this correlative technique are demonstrated on the example of a binary Au–Ge eutectic alloy, which serves as a model system that reveals glass formation and several metastable phases. With the new correlative technique, we are able to analyze in detail the glass transition, the activation energies and pathways of the involved (metastable) phase transformations, the microstructure evolution between metastable and stable phases, and the system's metastable and equilibrium melting temperatures.

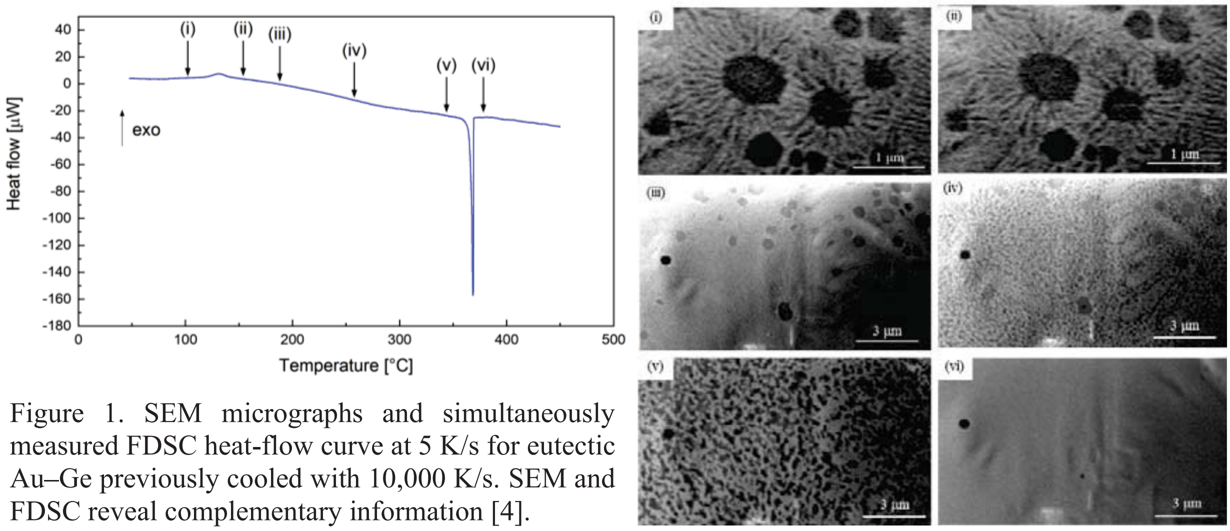

Figure 1. SEM micrographs and simultaneously measured FDSC heat-flow curve at 5 K/s for eutectic Au–Ge previously cooled with 10,000 K/s. SEM and FDSC reveal complementary information [4].

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Nanocrystallization technology for high Fe content amorphous alloy

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Fe-based amorphous alloy ribbons are recognized as a suitable material for transformer cores, achieving about 1/10 to 1/5 lower core losses compared to oriented Si-steel sheets used for similar applications. The randomness that appears as a characteristic of atomic structure of amorphous alloy has been confirmed to exhibit excellent soft magnetic properties. On the other hand, the saturation magnetic flux density (B_s), which is directly related to output density, is about 1.6 T, that is about 80% of Si-steel (B_s~2.0 T). To achieve the same output as Si-steel, it is necessary to increase the size of the core. Additionally, magnetostriction behavior has a great impact on the soft magnetic properties. Since the saturation magnetostriction constant (λ_s) of Fe-based amorphous alloys are about 30×10^{-6}, the increase in core loss in the high frequency range is noticeable. From this perspective, the demand for high B_s and low λ_s is high, and research and development have continued. In the 1980s, Fe-based nanocrystalline alloys capable of low magnetostriction were developed.1) Nanocrystalline alloys are obtained by subjecting the amorphous phase to heat treatment after obtaining it, resulting in fine crystal grains of about 10 nm precipitated within the amorphous matrix.1) By adjusting the composition so that the precipitated nanocrystalline phase has negative magnetostriction, it cancels out the positive magnetostriction of the remaining amorphous phase, achieving zero magnetostriction as a material.1) Furthermore, the random nanostructure makes magnetically soft as well as the amorphous phase. To stably generate this nanocrystalline structure, the composition includes Nb, which are expected to enhance the formability of amorphous phase, and Cu, which promotes the nucleation site of nanocrystals. The relative content of Fe, which serves as the magnetization carrier, is low, and it has not reached a high B_s that exceeds Fe-based amorphous alloys. On the other hand, in order to achieve a high B_s, it is necessary to increase the Fe concentration and reduce Nb. The thermal stability of the high-Fe content amorphous phase is lower than that of conventional nanocrystalline alloy compositions containing high-Nb, and there is a tendency of Cu clusters coarsening and decreasing the number density. Therefore, by rapidly heating to the temperature for grain growth before the number density of the Cu clusters decreases, fine nanocrystalline grains can be obtained.2) These alloys can be obtained in ribbon form as mentioned above, but when used as core materials for high frequencies, it is desirable for them to be in powder form from the perspective of suppressing eddy currents, and reports on the development of high B_s Fe-based nanocrystalline alloy powders will be presented. This research focuses on the generation process of Cu clusters and aims to develop compositions that can stably obtain nanocrystalline structures even from powders obtained as amorphous single phases without rapid heating, discovering a method to obtain high Fe content nanocrystalline structures in powder form.

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Development of Super Plastic Bulk Metallic Glasses via Tailoring of Icosahedral Ordering

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Icosahedral ordering, characterized by its forbidden five-fold symmetry, is closely linked to the extraordinary properties of metallic glasses. For instance, icosahedral short-range order (ISRO) is known to stabilize supercooled liquids and serve as a fundamental building block of amorphous solids. Additionally, icosahedral medium-range order (IMRO), modeled as interpenetrating icosahedra in metallic glasses, plays a crucial role in determining mechanical properties such as plasticity. Numerous experimental and computational studies have demonstrated the relationship between IMRO and plasticity in metallic glasses. However, research remains limited in elucidating the intricate interplay among microstructural variations with different degrees of icosahedral ordering, glass-forming ability, and mechanical responses through systematic compositional modifications. In this study, we systematically investigate the variation in quasi-glass-forming ability and mechanical responses by precisely tuning the microstructure through two distinct approaches: (i) destabilization of the icosahedral phase via Be addition in the Ti-Zr-Ni system and (ii) stabilization of the icosahedral phase via glue atom manipulation in the Zr-Cu-Ni-Al system. Our findings reveal that the precise control of ISRO/IMRO within the amorphous matrix significantly enhances the mechanical stability of metallic glasses, even inducing super plastic behavior. Furthermore, the synergistic effect between ISRO-mediated liquid phase stabilization and mechanical strengthening provides a novel pathway for developing bulk metallic glasses with both high glass-forming ability and superior mechanical properties. This study establishes a new guideline for designing advanced bulk metallic glasses with optimized stability and performance.

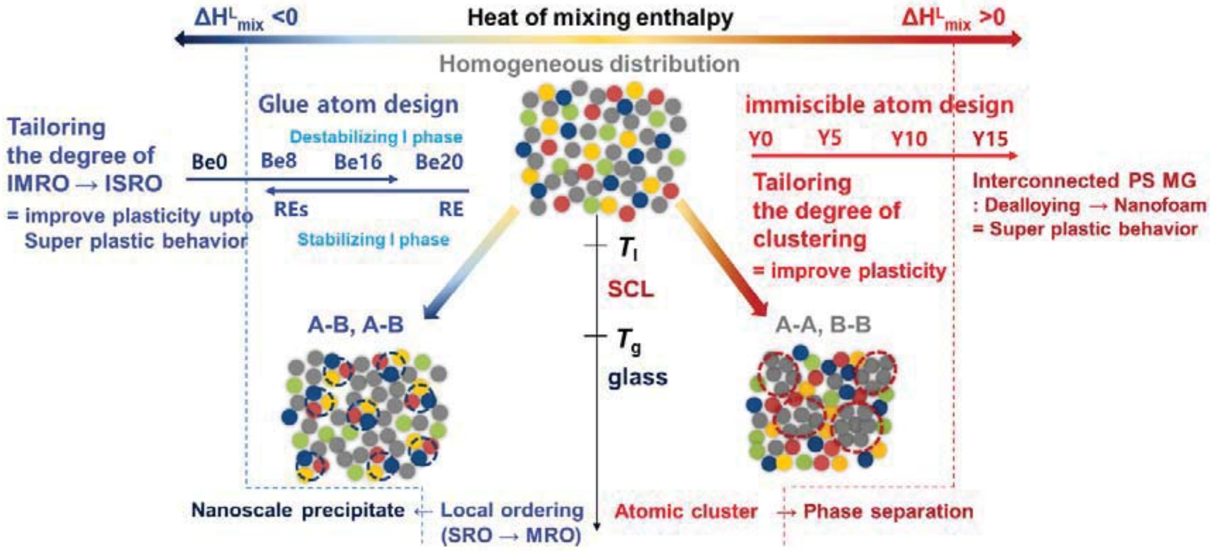

Figure 1. A schematic diagram for the heterogeneity and its role for the plasticity in metallic glasses. Heterogeneity (Local clustering versus Local ordering) in bulk metallic glasses improve plasticity.

Examination of Amorphization and Primary Crystallization by High Rate Nanocalorimetry

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As one of the main reactions that develop during heating of metallic glasses primary crystallization has received a continued attention to determine the phase selection and some kinetic behavior. The interest on primary crystallization is related to the enhanced strength and superior magnetic properties associated with the nanocrystal dispersion that forms during reaction. To provide for a directed control of the nanocrystallization a more complete understanding of the reaction kinetics is essential, especially for the nucleation stage. Conventional thermal analysis and TEM determination of nanocrystal populations are useful but can only cover a limited range of kinetic behavior. The recent advent of nanocalorimetry (Flash DSC) offers a significant extension of the kinetic range for study. The application of Flash DSC to the primary crystallization of amorphous Al[1] and Zn[2] alloys highlights the capability to measure the nucleation delay time that provides critical data for a quantitative nucleation kinetics model and for the elaboration of a complete TTT diagram[3]. For amorphous Fe base metallic glasses, the Fe nanocrystals formed during primary crystallization are known to be responsible for the enhanced soft magnetic behavior. In this case the size refinement of the Fe nanocrystals is the key objective to maximize the magnetic performance, but despite repeated attempts a size refinement below 10-15 nm has not been possible. The application of Flash DSC over an extended kinetic range has identified the influence of diffusion field impingement which inhibits further nucleation as the likely cause of the size refinement limitation[4]. As another use of Flash DSC, the transition has been elucidated between two amorphous phases in D-Mannitol[5]. The transition is related to a change in hydrogen bonding and involves an enthalpy change equivalent to about two-thirds of the crystallization enthalpy. The kinetics of the reaction between the two amorphous phases covers a range from conventional nucleation to a transition to a continuous or spinodal reaction. These examples document the enhanced capability of Flash DSC to examine new domains of kinetic behavior.

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High-capacity Metal hydride / Air secondary battery

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Rechargeable batteries are among the most widely used energy storage solutions today. However, common options such as lithium-ion and lead-acid batteries still face challenges related to safety, environmental impact, and economic feasibility. Another promising alternative is the nickel/metal hydride (NiMH) battery. By combining a metal hydride (MH) electrode with a reversible oxygen gas diffusion electrode (GDE), this battery offers a high theoretical specific energy of 440 Wh/kg (using an AB_5 alloy). In this study, we examined both electrode types and explored various optimizations to enhance their performance for potential prototype development. The investigation focuses on identifying the optimal combination of key performance indicators (such as discharge capacity, mechanical durability, and electrochemical stability) to enable their application in stationary electrical energy storage.

Considering the MH electrode promising performance of $LaNi_{4.5}Co_{0.4}Al_{0.1}$, prepared by induction melting and next hydrogen induced decrepitation, was recently proven [1]. Both the composition and microstructure of the electrode material were found to be responsible for its reliable hydrogen capacity and cycle stability. The gas phase hydriding of the alloys confirms the hydrogen capacity obtained under electrochemical conditions. Highest capacity of 300 mAh g^{-1}, remaining constant for 20 cycles was obtained for $LaNi_{4.5}Co_{0.4}Al_{0.1}$ + 15 mg Co_3O_4. This material maintains excellent capacity also at high current densities, making it a suitable electrode material in Ni/MH and MH/air batteries. For the counter electrode, a gas-diffusion electrode incorporating carbon and zeolite (clinoptiolite) was developed. To ensure the uniform distribution of the clinoptiolite particles in the carbon matrix, as well as mechanical stability of the gas-diffusion layer high-energy milling (5000 rpm for 1 min) and subsequent pressing of the mixture (300 kg.cm^{-2} at 280^{o}C) were applied. By partially replacing the teflonized carbon black in the gas-diffusion layer with clinoptiolite the necessary hydrophobicity could be attained while maintaining the high gas permeability of the zeolite material. The catalytic layer comprised a bimetallic catalyst consisting of Ag and γ-MnO_2 in a 1:1 mass ratio. In the durability tests high mechanical, chemical, and electrochemical stability (more than 750 cycles) was obtained for the newly developed composite gas-diffusion electrode [2].

To study the behavior of the rechargeable Metal hydride / Air secondary battery a special electrochemical cell was designed, operating in both half-cell mode and full MH/air battery mode, enabling simultaneous testing of both electrodes. The system achieved an average discharge voltage of approximately 1.0 V, closely approaching the theoretical value of 1.23 V for the MH/air system. Charge/discharge tests were conducted with a charge capacity of up to 300 mAh g^{-1} relative to the MH electrode, without restricting the achieved charge voltage, and a discharge cutoff of 1 V at a current density of ±10 mA cm^{-2} relative to the GDE. The battery demonstrated a lifespan exceeding 900 hours (180 continuous charge/discharge cycles).

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From Ribbons to Bulk: Tuning Magnetic Properties in Fe-Si-B Alloys with Advanced Manufacturing

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Amorphous soft magnetic materials are key components in improving the energy efficiency of electrical machines and passive components [1]. While melt spinning remains the primary method for producing high-performance amorphous ribbons, emerging additive manufacturing (AM) techniques now offer the potential to directly fabricate bulk elements with tailored properties. In this study, we investigate the magnetic behavior of Fe-Si-B-based alloys processed via conventional melt spinning and Selective Laser Melting (SLM), using the same alloy composition [2]. The melt-spun ribbons were produced under controlled conditions to ensure amorphous structure, while 3D-printed bulk samples were fabricated using SLM with varying process parameters (laser power: 20–60 W; scan speed: 350–900 mm/s).

Hysteresis losses were evaluated across 1 Hz to 1 kHz at a fixed peak induction ($J = 0.5$ T) using a digital wattmeter, and static magnetic properties were assessed via VSM magnetometry. Our results demonstrate that SLM processing conditions critically influence the microstructure—affecting porosity, surface morphology, and crystallinity—and thus the soft magnetic performance. Strategies for optimizing these parameters to enhance the amorphous phase content and reduce losses will be discussed [3].

This work illustrates how advanced manufacturing routes can be leveraged to engineer microstructure and magnetic properties concurrently, offering new opportunities for designing high-efficiency materials for energy applications.

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Atomic Mobility in Metallic Liquids and Glasses

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Dynamics in supercooled metallic liquids and metallic glasses are spatially, temporally, and compositionally complex. Those complexities are contained in electron correlation microscopy (ECM) data [1], but teasing them out from a large background of inherent randomness is challenging. Topological data analysis (TDA), an efficient method for reduced dimensionality representation and pattern-finding in spatiotemporal datasets [2], has proven to be a useful tool for finding meaningful patterns in complexity. Topological analysis of spatially-resolved ECM data of a metallic supercooled liquid shows evidence for dynamic facilitation, in which localized regions with fast dynamics speed up the dynamics of adjacent regions. Topological analysis of bond breaking in a molecular dynamics (MD) trajectory shows similar parallel behavior.

ECM with a nanometer-diameter probe applied to a ~40 nm thick sample probes a small enough number of atoms that even in equilibrium the two-time intensity correlation function $C_2(t_1, t_2)$ shows intermittent dynamics. Figure 1 shows an example experimental correlation function from a metallic liquid 4 K above T_g. The "boxy" features along the diagonal represent windows of time during which this small volume of liquid maintains significant structural correlation. The regions with a thin line along the diagonal are windows during which this volume fluctuates rapidly in structure. The time-average of this intermittent behavior yields a structural relaxation time consistent with other measurements, and simulations of these experiments from a MD trajectory for liquid $Cu_{50}Zr_{50}$ shows similar features. Topological data analysis is useful for identifying features in these data which may be connected to underlying, atomic-level relaxation events in the liquid.

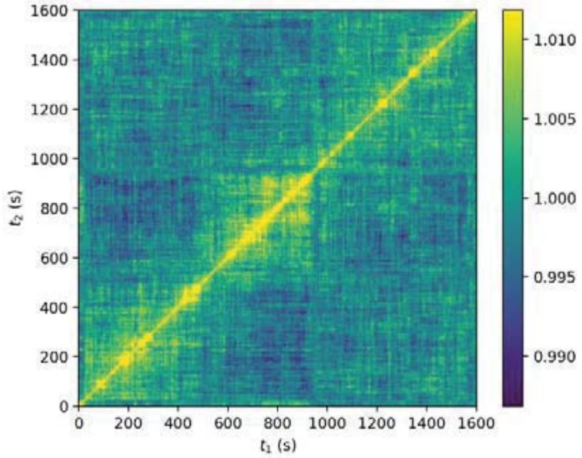

Figure 1: ECM two-time correlation function from a $Pt_{57.5}Cu_{14.5}Ni_{5.5}P_{22.5}$ alloy held 4 K above T_g. These data come from a single volume defined by the 1 nm probe diameter and the ~40 nm sample thickness.

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A new generation of high-frequency amorphous/nanocrystalline soft magnetic materials for matching third-generation semiconductors

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The prevalence of wide-bandgap semiconductors allows modern electronic devices to increase operating frequencies and the power density. However, development of soft magnetic materials with excellent soft magnetic properties matching the WBG-based devices remains challenging. Here, we report two advanced soft magnetic materials addressing distinct challenges in high-frequency and high-power applications. First, a $Fe_{75.5}Co_{0.5}Mo_{0.5}Cu_1Nb_{1.5}Si_{13}B_8$ nanocrystalline-amorphous composite alloy demonstrates exceptional high-frequency performance, achieving a record permeability of 36,000 at 100 kHz through magnetic-heterogeneous nanocrystallization. It is found that the Co addition induces magnetic inhomogeneity to promote nanocrystal nucleation, while Mo segregation inhibits crystal growth, forming an ultrafine dual-phase structure with low magnetic anisotropy and unique spin rotation dynamics. Second, a novel $(Fe_{0.8}Co_{0.2})_{85}B_{12}Si_2V_{0.5}Cu_{0.5}$ nanocrystalline alloy overcomes the traditional B_s-H_c trade-off by designing a transitional microstructure featuring sparse sub-5nm nanocrystals in an amorphous matrix. This configuration achieves unprecedented combined properties: B_s = 1.94 T and H_c = 4.3 A/m, enabled by quasi-dislocation dipole annihilation and enhanced magnetic exchange interactions. Both strategies highlight microstructure engineering through nanocrystalline-amorphous phase control, offering guidelines for next-generation soft magnetic materials in high-efficiency, high-frequency power devices. The former optimizes high-frequency permeability, while the latter reconciles ultrahigh saturation with minimal energy loss, collectively advancing beyond commercial nanocrystalline alloys.

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Keynote Lectures

Ceramic biomaterials: From traditional technologies to novel applications

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Approximately 400,000 artificial hip joint replacements are performed annually worldwide, and over 25 million individuals currently live with total hip replacements. However, implant longevity remains a concern, as wear and mechanical failure over time contribute to an increasing risk of implant loosening. Statistically, 10–20% of implants require revision surgery within 10 years post-implantation.

For successful long-term application within the human body, biomaterials used in orthopedic implants must exhibit a combination of critical properties. These include excellent biocompatibility, appropriate mechanical strength, favorable chemical stability, and surface characteristics that promote integration with surrounding biological tissues. These properties collectively influence the performance, safety, and functional durability of implants.

Recent advances in materials science have led to the development of novel ceramics for biomedical applications, particularly in load-bearing and low-load-bearing environments. Among these, silicon nitride (Si_3N_4) has emerged as a promising bioceramic due to its outstanding mechanical properties, wear resistance, and fracture toughness. Despite its bioinert nature, Si_3N_4 can be enhanced through surface modifications to improve biological responses.

Conversely, hydroxyapatite (HA), a calcium phosphate-based ceramic, is well-known for its high bioactivity and similarity to the mineral phase of natural bone. It is extensively used as a bioactive coating material in implantology. Coating bioinert ceramics such as Si_3N_4 with a thin layer of HA can significantly improve early-stage osseointegration and reduce the risk of implant rejection by promoting bone bonding in the critical initial healing phase.

The presentation will show an overview of bioceramic processing techniques, ranging from traditional sintering methods to innovative surface engineering and nanotechnology-based approaches. Furthermore, it will address current trends and fundamental scientific challenges in the development and application of bioceramics in orthopedics. Emphasis will be placed on the integration of mechanical performance with biological function to advance the next generation of long-lasting, high-performance implants.

Ni-Ti based shape memory alloy nanostructures using amorphous phase as a precursor

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Shape memory alloys (SMAs) are known to exhibit shape memory effect or superelastic effect due to their thermoelastic martensitic transformation. Among various SMAs, Ni-Ti and their derivatives have attracted much attention because of their superior shape memory property including high recovery strain, damping capacity and biocompatibility. On the other hand, due to low workability, the conventional way for producing Ni-Ti based SMA is confined to thermomechanical processes such as forging, rolling and drawing. Recent study shows that such low formability of SMA can be overcome by using amorphous phase as a precursor. In the present study, two different methods will be introduced for fabrication of NiTi-based SMA using amorphous phase as a precursor. Firstly, fabrication of Ni-TiZr-Cu based SMA using metallic glass precursor exhibiting glass transition, i.e. thermoplastic forming of amorphous alloy in the supercooled liquid state followed by crystallization into nanocrystalline structure exhibiting superior superelastic property. Secondly, fabrication of Ti-Ni-X-Gd based SMA nanostructures (X=Nb, Zr, Al, Si) via a hybrid approach combining liquid-liquid amorphous phase separation and selective chemical leaching. By tailoring the thermodynamic properties of the precursor alloy, nanoparticles and nanoporous structures with tunable morphology was synthesized. The dealloyed nanostructures exhibited thermally induced reversible martensitic transformation and demonstrated superior superelasticity

Aging effects of Lunar Glasses

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Physical aging is a long-lasting research hot spot in the glass community, yet its long-term effects remain unclear because of the limited experimental time. In this talk, we report the extraordinary aging effects in five typical lunar glassy particles with diameters ranging from about 20 to 53 micrometers selected from Chang’e-5 lunar regolith returned by China’s Chang’e-5 Mission. It is found that geological time scales’ aging can lead to unusually huge modulus enhancements larger than 73.5% while much weaker effects on hardness (i.e., varies decoupling evolutions of Young’s modulus and hardness during aging) in these lunar glassy samples. Such extraordinary aging effects are primarily attributed to the natural selected complex glassy compositions and structures, consistent with high entropy and minor element doping criteria, prevailing under the special lunar conditions and the extensive aging time for the lunar glasses. This study offers valuable insights for developing high-performance and stable glassy materials for radiation protection and advanced space explorations.

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Invited Lectures

Mechanochemistry- Solvent-free and green methodology to yield nanostructured metal chalcogenides with versatile applications

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Mechanochemistry utilizing forces of high-energy ball milling is a great tool for the preparation of metastable, amorphous, and nanostructured materials.[1,2] This lecture provides an overview of this exciting field (Fig. 1).

In the first part, it focuses on basic principles, historical overview, current state-of-the-art, *in situ* monitoring techniques and scalability. The second part showcases experiments from our laboratory, focusing mainly on nanostructured metal chalcogenides preparation and their applications in energy conversion (photocatalysis, thermoelectrics, water splitting) and medicine (photothermal ablation, microbiology). Also, the possibility of preparing these compounds by mechanically induced self-propagating reactions within few seconds is mentioned.[3] In the end, scrutinizing mechanochemical tools for the valorization of waste materials and the preparation of antibacterially active bionanocomposites based on silver nanoparticles is briefly mentioned.

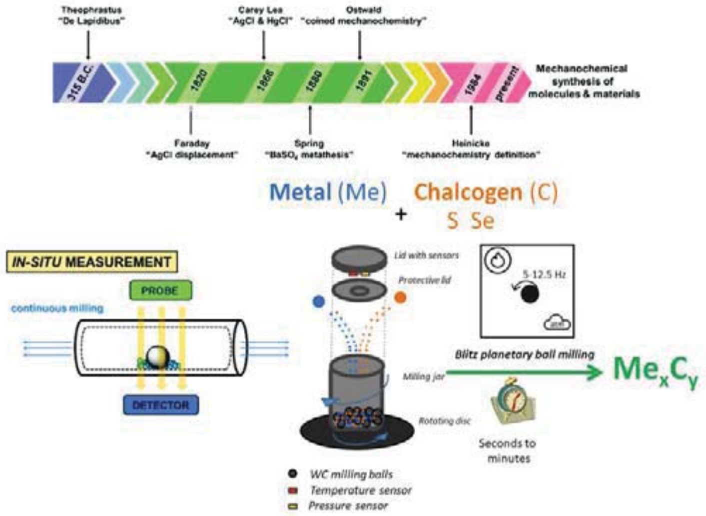

Fig. 1: Lecture overview: Historical milestones of mechanochemistry, *in situ* monitoring of mechanochemical reactions principles, blitz mechanochemical synthesis of metal chalcogenides. Adapted with permissions from Refs. 2 and 3 with permission from the Royal Society of Chemistry.

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Structural Aspects of Stress-Induced Magnetic Anisotropy in Fe-based Nanocomposite: Insights from Synchrotron Experiments

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Fe-based nanocrystalline alloys exhibit outstanding soft magnetic properties, including exceptionally high relative permeability (>100,000), remarkable saturation magnetization (>1.0 T), minimal coercivity, and nearly zero magnetostriction [1]. Heat treatment combined with tensile deformation offers a promising method for further optimizing the nanocrystalline microstructure, resulting in enhanced magnetic properties [2]. Research has demonstrated that stress-induced magnetic anisotropy in Fe-based alloys stems from the structural anisotropy of Fe_3Si nanocrystalline grains [3,4].

This contribution presents our latest results related to the study of structural aspects of stress-induced anisotropy in $Fe_{73.6}Cu_1Nb_3Si_{15.5}B_{6.9}$ alloy, which arises during nanocrystallization under tensile annealing [5]. Performing X-ray diffraction experiments with synchrotron radiation it was observed that Fe_3Si nanocrystalline grains exhibit greater lattice spacing in the tensile direction, while the transverse direction shows an opposite trend. The difference in lattice strain values between these directions is directly related to the applied tensile stress and serves as a parameter to measure stress-induced anisotropy (SIA). Strain pole figure (SPF) analysis confirms that SIA is uniaxial, with its primary axis aligned along the tensile direction. Comparative SPF data indicate uneven strain distribution across Bragg reflections, with the {400} plane family showing the highest SIA magnitude. Additionally, the SIA magnitude for specific Bragg reflections {hkl} inversely correlates with their Young's modulus, E_{hkl}.

Acknowledgements

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Dependences of phase distribution and magnetic properties on compositional tailoring in Mn(CoFe)(GeSi) series obtained from mechanically alloyed amorphous precursors

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MnCoGe alloys are interesting martensitic alloys with an associated magnetic transition leading to a sharp variation in magnetization at the transition (first order). This property makes them good candidates for magnetic refrigeration applications due to their high magnetocaloric effect (MCE). MCE is observed as an adiabatic temperature change or as an isothermal entropy change (ΔS_m) with the application or removal of a magnetic field.

Production of Mn(CoFe)(GeSi)-type alloys by mechanical alloying generally leads to the stabilization of the high entropy states. As milling time increases, mechanical amorphization is observed followed, in some cases, by recrystallization of an austenitic hexagonal MnCoGe-type phase. Subsequent annealing above crystallization temperature yields the room temperature stabilization of austenitic phase for low Si content but coexistence of orthorhombic martensite and hexagonal austenite above Si/(Si+Ge) ratio ≥ 0.5 is observed [1]. Three are the phases that compete to appear in the content series (in an increasing order of entropy): orthorhombic martensite, hexagonal austenite and bcc solid solution. This microstructure differs from that obtained in arc melted systems but is preserved up to melting point. Phase dependence is sensitive to Mn off-stoichiometry content and Si/(Si+Ge).

MCE in this system, ascribed to a magnetic transition of the austenite phase, is enhanced as crystal size increases and correlated with the degree of amorphization of the precursor as-milled system [2]. Coexistence of austenite and martensite phases broadens the temperature range of significant ΔS_m values. The analysis of the field dependence of MCE as well as the field dependence of specific heat measurements highlight the magnetoelastic character of the transition and first order character, which are not evident from a conventional analysis (Banerjee criterion) due to the presence of a distribution of transition temperatures ascribed to the high energy milling processing used [3].

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Negative/zero/positive thermal expansion alloys

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Operation conditions in microelectronics, sustainable mobility, space exploration and high-precision optics increasingly involve large temperature swings and stricter dimensional tolerances, necessitating to master thermal expansion. However, customizing thermal expansion is difficult, especially for metals and alloys. First, because thermal expansion of conventional alloys is largely insensitive to alloying. Second, because their lattice expansion changes only little or not at all with orientation, ruling out crystallographic texture to adjust their expansion behaviour. Even the widely used Fe-Ni Invar alloys exhibit only a narrow range of small but positive expansion rates. Exceptions displaying negative thermal expansion exist, however most are non-metallic, often inadequately brittle compounds with cubic crystal structures, where introducing texture has no effect.

Recently, several groups demonstrated a new principle that enables tailoring of the macroscopic thermal expansion of a large class of alloys by simple thermomechanical processing. The materials' common feature are martensitic phases exhibiting strongly anisotropic thermal expansion. For a single alloy composition, controlled deformation permits tailoring the macroscale polycrystal thermal expansion across a broad range of expansion coefficients by introducing texture. Among these materials, Ti alloys forming metastable orthorhombic α" phases stand out for their giant contraction and expansion rates, particularly good deformability, and the strong response of their expansion behaviour to alloying.

This presentation will review early and recent discoveries from the last two decades and will give an overview of current developments. A novel multi-pronged strategy, leveraging the systems' pronounced metastability, incorporates phase composition, texture, and volume fraction simultaneously. It promises to tremendously enlarge the design space, providing ample opportunities for future research and innovative applications.

Probing Short-Range Order in Fe-Co-Si-B-Mo-P Amorphous Alloy Using Mössbauer Spectroscopy and High-Energy X-ray Diffraction

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Amorphous alloys exhibit unique magnetic and mechanical properties that are largely governed by their short-range atomic order, as the lack of long-range periodicity makes conventional crystallographic approaches insufficient for their characterization. In this study, we employ Mössbauer spectroscopy (MS) and high-energy X-ray diffraction (HEXRD) with total scattering and pair distribution function (PDF) analysis to investigate the structural evolution of a $Fe_{51}Co_{12}Si_{16}B_8Mo_5P_8$ amorphous alloy.

Mössbauer spectroscopy provides detailed insight into local magnetic interactions and atomic-scale disorder, revealing subtle changes in the hyperfine magnetic field distribution induced by thermal treatment. Simultaneously, HEXRD, coupled with total scattering analysis, confirms the absence of crystallization while detecting atomic rearrangements indicative of structural relaxation. PDF analysis highlights modifications in short- and medium-range order, demonstrating the sensitivity of these methods to atomic-scale changes.

The combination of MS and HEXRD techniques underscores their essential role in understanding the local structural and magnetic properties of amorphous materials, contributing to their optimization for advanced applications.

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Soft Magnetic Nanocrystalline Materials in Vacuumschmelze Portfolio and their Application

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With the ongoing miniaturization of power electronics driven by higher switching frequencies and the global request for increased efficiency, the demand for high performance magnetic materials has steadily increased. Magnetic components need to deliver their performance, even under extreme operating conditions.

Vacuumschmelze is a leading global manufacturer of advanced magnetic materials and magnetic components based on advanced nanocrystalline alloys that combine outstanding intrinsic magnetic properties with high versatility for customized solutions. The company started its production in 1923 with melting of alloys under vacuum. With more than a century of experience and outstanding process engineering competence, we provide high-quality materials tailored to specific magnetic and physical property requirements.

The nanocrystalline microstructure of Fe-Si-Cu-Nb-B enables the development of advanced soft magnetic materials, facilitated by the formation of Fe-Si grains with dimensions in the range of 10 – 15 nm and a magnetostriction close to zero.

This presentation highlights the latest developments for common-mode chokes in electromobility and solid-state transformers for smart grid applications. It includes results on DC stability and damping behavior, while aspects such as core loss characteristics and stability of temperature properties round off the discussion.

Hardness and strength of dual – phase boride/carbide high entropy ceramics at nano/micro scale

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The deformation and fracture characteristics of recently developed dual phase high entropy boride/carbide ceramics were investigated applying nano-indentation and micro-cantilever bending tests. Different processing routes have been applied for the preparation of the investigated systems, as reactive sintering and boro/carbothermal reduction.

The microstructure and fracture characteristics were investigated using X-ray diffraction (XRD), scanning electron microscopy (SEM) in combination with electron back scattered diffraction (EBSD) and transmission electron microscopy (TEM). Atomic structure and local chemical disorder were determined by means of scanning transmission electron microscopy (STEM) in conjunction with energy dispersive X-ray spectroscopy (EDS). Depth-sensing nano-indentation of individual grains and grain boundaries has been applied to study the nano-hardness and deformation characteristics on the non-deformed and worn surfaces of the composites prepared by different processing routes.

During micro-cantilever tests in bending deformation and fracture characteristics of individual grains and grain boundaries have been investigated. The bending strength of micro-cantilevers was strongly dependent on the character/size of the fracture origins.

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Ultra-rapid Annealing by Joule Heating: the Novel Setup for Precise Thermal Cycle and In-situ Measurements

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The iron-based, magnetically soft alloys with nanocrystalline-amorphous structure have been the object of extensive research since 1988, when Fe-Si-B-based FINEMET alloy was elaborated. The conventional method of obtaining them was 1 hour annealing of metallic glass ribbons containing grain refining elements that enhance heterogeneous nucleation and hinder grain growth. Another method, developed in 1990's, was flash annealing, where the pulse of constant current heated the ribbon. In this case, the duration of annealing cycle was of a few seconds, or even just a fraction of second. In 2010's, ultra-rapid annealing between preheated copper blocks was developed. In the latter two methods, extremely high heating rate caused the crystallisation temperature being significantly higher than that found in the conventional method. Very high heating rate and annealing temperature provoke intensive homogeneous nucleation of crystalline phase, so there is no need to use the grain refining alloying elements. The great number of nano-sized grains were produced by homogeneous nucleation in an amorphous phase due to extreme overheating of metallic glass. It was suggested that the nucleation rate may be higher, if the temperature is above the glass transition temperature.

The ultra-rapid annealing methods, either by pulse Joule heating, of by preheated blocks, allow for obtaining of nanostructured, magnetically soft alloys, but have some limitations in controlling and monitoring of the annealing process. In Joule heating method, excessive current or time, and – in particular – latent heat of crystallisation, lead to overcrystallisation and deterioration of soft magnetic properties of the nanocrystalline ribbons. In the technique of annealing between the blocks, heating rate can be controlled only roughly by e.g. insulating inserts between the blocks and the ribbon. The actual temperature during the cycle can be read from thermocouples with size larger than the thickness of a ribbon, which also affects the results of measurements. The progress of crystallisation can be *a posteriori* verified by the analysis of resistance of the ribbon. Apart from these, the value of glass transition temperature at very high heating rate is usually unknown.

In this work, we developed the experimental setup that allows to successfully overcome these problems and to consciously control the annealing process. The basic concept of this idea is heating the piece of ribbon by direct electric current, measuring of the ribbon temperature by a pyrometer, and regulating the current in real time by the feedback from the pyrometer to the microcontroller that handles all the process. Such method allows to precisely perform the heating cycle, including the predetermined heating rate and the duration of isothermal part. This way, if latent heat of crystallisation is released, the current is respectively reduced, maintaining the desired temperature and thus preventing from overheating. During the process, additional data are directly recorded: elongation of the spring-loaded sample, voltage drop across it, and current. From the analysis of these, resistivity of the sample and thermal expansion coefficient as the function of temperature or time can be derived. The changes in resistance and length depend on the crystalline volume fraction of the sample, thus allow the analysis of crystallisation kinetics, with the time resolution of 1 millisecond. The experiments conducted in the described setup proved that the use of this technique enables the control of microstructure by proper adjustment of heating rate, annealing temperature and time. This way, nanocrystalline alloys may be produced in solid state or in supercooled liquid state, depending on the ribbon's chemical composition and the applied parameters of thermal cycle.

Vitrification of metallic liquids – uncovering the structural pathway to metallic glasses

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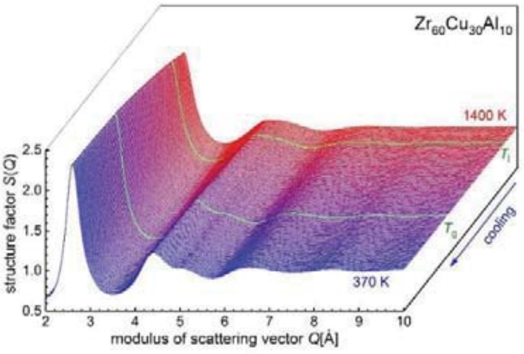
A metallic glass is formed when a molten metallic alloy is cooled rapidly enough that crystallisation is avoided. The transition of a liquid to a glass occurs with a remarkable slowdown of the dynamics in the undercooled liquid, a phenomenon which remains poorly understood. The dynamic arrest is manifested by an increase of viscosity by several orders of magnitude between the melting T_m and the glass transition temperature T_g. However, the way the atomic structure of the liquid converts to that of the glass is not well known. The main challenge is the sufficiently fast experimental acquisition of structural data in the undercooled liquid regime necessitated by the high cooling rates needed to avoid crystallisation.

Here we discuss the structural evolution of metallic liquids to vitrification observed in-situ using high-energy synchrotron X-ray diffraction and aerodynamic levitation. The structure in the undercooled liquid regime shows an "accelerated" evolution. Both the local order in the short (SRO) and medium range (MRO) increases "rapidly" as the undercooled liquid approaches T_g, below which the amorphous structure "freezes". Nevertheless, distinct differences between the evolution of SRO and MRO were observed. The structural rearrangements in the undercooled liquid are found to be correlated with a rapid increase in viscosity of the metallic liquid upon cooling. The findings shed light on the evolution of the atomic structure of metallic liquids during vitrification and the structural origins of the sluggish kinetics that suppress nucleation and growth of crystalline phases.



The evolution of the experimentally obtained structure factor $S(Q)$ of $Zr_{60}Cu_{30}Al_{10}$ during cooling from 1400 K (above the liquidus temperature T_l) to 370 K (below the glass transition temperature T_g) [1].

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Large-angle Lorentz 4-Dimensional Scanning Transmission Electron Microscopy for Simultaneous Local Magnetization, Strain and Structure Mapping

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Small atomic adjustments significantly affect magnetic properties. Strain, for instance, modifies magnetic anisotropy, enabling precise tuning of the magnetic microstructure. However, its nanoscale effects remain largely unexplored, and fluctuating strain complicates the direct correlation between structural changes and magnetic behavior.

To address this, we developed LA-Ltz-4D-STEM, a technique for simultaneously mapping structural information, strain, and magnetic fields at the nanoscale. By customizing STEM optics, we optimized lens configurations to access large diffraction angles in Ltz-STEM mode, allowing simultaneous structural and magnetic field mapping. This approach records both unscattered and diffracted electron beams, capturing the phase shift of the electron exit wave induced by local magnetic fields while preserving interatomic pair information.

We applied LA-Ltz-4D-STEM to a deformed amorphous ferromagnet with complex nanoscale strain variations [1-2]. The method revealed an anomalous magnetic configuration near shear bands, which exist in a magnetostatically high-energy state. Using pixel-to-pixel correlation across a large field of view, critical for analyzing industrial ferromagnetic materials, we classified magnetic moments into two groups: one influenced by magnetoelastic coupling and the other dictated by magnetostatic energy competition. This approach provides unprecedented insight into the interplay between strain and magnetism, offering a powerful tool for understanding and optimizing the nanoscale behavior of ferromagnetic materials

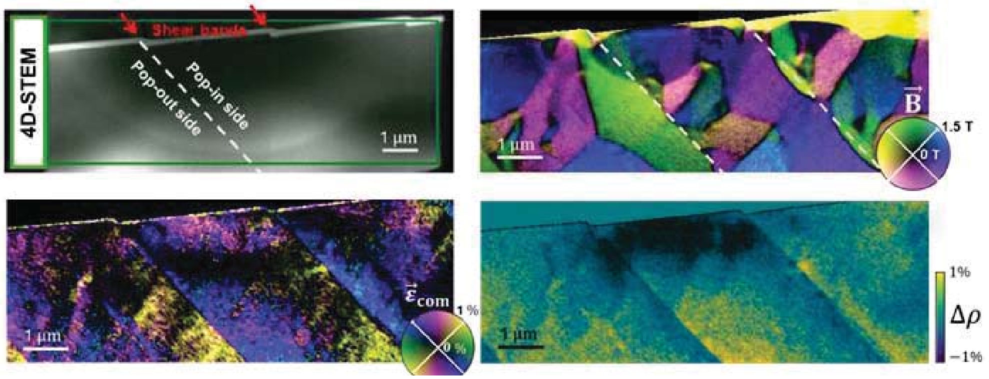

Figure 1: Magnetic field and strain visualization in a deformed amorphous metallic alloy using LA-Ltz 4D-STEM. STEM-ADF image shows shear offsets (red arrow). Magnetic field is mapped from diffraction ring shifts, with color indicating orientation and brightness indicating strength. Compressive strain and relative density maps reveal local distortion and densification near shear bands.

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Design strategy for metallic glass composites

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Metallic glass is known for its superb mechanical strength and processing ability, also unfortunately, its lack of sufficient plasticity and toughness to guarantee structural safety and reliability. Making monolithic metallic glass with ductility has been tried but only with limited success. The most promising solutions is to make metallic glass composites, which too faces various challenges and limitations. In this talk, we will go over several design principles that we learned from the theoretical and modeling work, along with experiment results. Our emphasis is on the functionality of dealing with the heterogeneities of various kinds and how we arrange them in the metallic glass matrix. We show that there are indeed "functioning" strategies that can lead to ductile and touch metallic glass composites. One is patterning the heterogeneities in certain geometric and topological ways so the glassy composites can undergo extensive local plastic deformation without risking being broken or brittle. Another way is to build local gradient for the heterogeneities such that the local stress concentration can be reduced. We demonstrate several successful cases with novel design of patterns of heterogeneities in metallic glasses from both theory and experiment [1].

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Tailoring Microstructure and Creep-Induced Anisotropy in Co-Based Amorphous Wires for Enhanced Functional Magnetic Properties

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In this work, we explore the potential to precisely control the microstructure and magnetic anisotropy through heat treatments, as the resulting changes in magnetic behavior are essential for specific applications. We have studied amorphous wires with a nominal composition of $Co_{68.15}Fe_{4.35}Si_{12.5}B_{15}$ and diameters of 120 μm, produced using in-rotating water spinning technology, with a saturation magnetization of 0.68 T, a coercive field of less than 8 A/m, and magnetic permeabilities of up to 200,000 at low magnetic fields (a few A/m). However, certain applications require controlled, constant values of magnetic permeability over a range of magnetic fields. This behavior can be achieved through thermal treatments under longitudinal stresses. The shape and inclination of the longitudinal B-H curves (Fig. 1) indicate induced perpendicular anisotropy in stress-annealed wires, with its magnitude depending on the annealing temperature, current through the wires, and applied longitudinal stress.

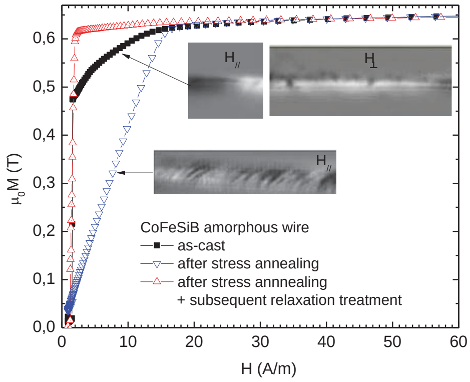

Fig. 1. The magnetization curves and magnetic domain structures of Co-based nearly zero magnetostrictive amorphous wires demonstrate the presence of induced perpendicular anisotropy in stress-annealed wires and the reversibility of magnetization processes with annealing.

This anisotropy was found to be reversible after subsequent heat treatment. The observed creep-induced anisotropy originates from the orientational ordering of small clusters in the amorphous matrix, creating anelastic strains perpendicular to the tensile stress applied during annealing. Our research has revealed a prolonged relaxation phenomenon lasting several days. To mitigate this effect, we aimed to reduce microscopic non-uniformities in the wires that contribute to creep-induced anisotropy. These changes are also evident in the magnetostrictive behavior of the wires, with λ_s varying from slightly negative values (-0.7×10^{-6}) in the as-cast state to slightly positive values ($+0.35 \times 10^{-6}$) after inducing perpendicular anisotropy. Understanding these aspects is essential for advancing cutting-edge sensing applications.

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Perovskite Thin Film Growth: Structural and Optoelectronic Characterization

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Perovskites are emerging as a significant player in the field of solar energy and light-based technologies. Their ability to convert light into electrical energy continuously improves, even achieving efficiencies comparable to established, high-quality materials such as monocrystalline silicon.[1,2] However, further increases in perovskite efficiency and stability require the reduction of non-radiative charge carrier recombination, which is caused by defects.[3] A deeper understanding of the formation of thin perovskite layers and the associated process control is a prerequisite for effectively reducing the number of defects.

This presentation will focus on techniques used to study the structural and optoelectronic properties of perovskites during formation, including in-situ photoluminescence spectroscopy and small/wide-angle X-ray scattering. The growth kinetics of perovskite layers during vacuum deposition and for wet phase growth will be described. The obtained results reveal the growth of perovskite layers from the initial stages, as well as the surface morphology, crystallographic structure, and evolution of defect density.

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Medium and High Entropy Multicomponent Alloys - a wide variety of structures, properties and processing routes

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Medium and high entropy alloys (MEAs, HEAs) are relatively new class of materials elaborated at the beginning of XXI century. The first equimolar CoCrFeMnNi alloy, so called Cantor alloy, described in 2004, revealed simple structure of single phase solid solution instead of complex phases expected. Nowadays, after 20 years of studies, it is obvious that multicomponent alloys are a new group of engineering materials, not a one season star. There are thousands of papers devoted to MEAs and HEAs.

There are several definitions of HEAs. Composition-based definition says that HEAs are composed of five or more principal elements in equimolar or near equimolar ratios. The requirement for equimolar concentrations originally was restrictive, however, after expanding, the definition was as follow: the alloy consisting of principal elements with the concentration of each element being between 35 and 5 at. %. An alternative entropy-based definition, separates low ($S < R$, where S is the total configurational molar entropy in an ideal solid solution and R is the gas constant), medium ($R < S < 1.5R$) and high ($S > 1.5R$) entropy alloys. In many cases a simple definition is used: multicomponent alloys showing the structure of fcc or bcc solid solution. For characterization of these alloys the following parameters, besides entropy ΔS, are used: enthalpy of mixing ΔH, Zhang parameter Ω (combining entropy, enthalpy and melting temperature) and δ parameter related to the differences in atomic radii. Additionally, valence electron concentration (VEC) value is considered.

The rules governing HEAs and MEAs formation, literature based examples of different multicomponent alloys currently explored and studied, and finally, the results of own experiments on HEAs and MEAs processed by conventional casting and mechanical alloying techniques are presented and discussed.

Magnetooptical observations of cylindrical magnetic microwires with Matteucci effect

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Thin magnetic cylindrical wires attract considerable attention due to interesting features of a domain wall motion like absence of the Walker breakdown [1]. Amorphous glass-coated microwires are composite material with very high domain wall velocities [2]. Owing to the amorphous state of wires, the magneto crystalline anisotropy vanishes. While several experimental techniques allow for well controllable deposition of magnetic structures with complex geometries, a reliable determination of the surface magnetization usually meets several obstacles in case of samples with curved surface.

Although several experimental techniques allow precise deposition of magnetic structures with complex geometries, accurately determining surface magnetization remains challenging, especially in samples with curved surfaces. In this study, we present a comprehensive analytical calculation of the Magneto-Optical Kerr Effect (MOKE) contrast in cylinders with reduced diameters. A deeper understanding of the underlying mechanisms enables the development of a new approach for interpreting magneto-optical observations of cylindrically shaped magnetic samples. We demonstrate that the cylindrical geometry results in a spatial distribution of incidence planes, each with a distinct tilt. Even when using light with a single polarization state (“s” or “p”), the varying orientations of these planes cause polarization rotation, allowing light to pass through a crossed polarizer-analyzer setup. Our analytical model predicts that axial variations in surface magnetization produce a distinctive black-and-white contrast. These theoretical predictions are experimentally validated on thin wires with well-defined cylindrical geometry.

Furthermore, we introduce a novel laser-based MOKE scanner designed for three-dimensional imaging of surface domain wall structures in microwires [3]. By synchronizing the periodic back-and-forth motion of the domain wall with MOKE imaging, we obtain time-resolved images of surface magnetism. Our results show that microwires with positive magnetostriction exhibit a tilted domain wall structure, which may account for the unusually high domain wall velocities observed in these materials. The MOKE data also provide an estimate of the surface magnetization direction in microwires, which exhibits a strong Matteucci effect.

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Surface modification of biocompatible Ti-based amorphous alloys by dealloying to improve implant cytocompatibility

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Implant infections and related biofilm formation are a major concern whenever implantable medical devices are considered. Since there is currently no standard treatment for implant-associated infections and antibiotic treatments are ineffective for biofilms, the best approach is to focus on the inhibition of both bacterial adhesion and biofilm formation by acting on the implant material itself. If metals are considered, Ti-based amorphous alloys are gaining importance as biocompatible materials due to the possibility i) to adapt the composition with the exclusive use of biocompatible elements and ii) to reduce the mismatch in Young's modulus between the bone and the implant material. Moreover, their biocompatibility and antibacterial activity can be improved by exploiting the dealloying process that is related to the dissolution of less noble elements from an amorphous phase enabling the surface diffusion of the noble adatoms that reorganise on the surface by forming ligaments and pores. Dealloying is an effective and simple process, that can effectively change both composition and morphology of the surface of the Ti-based amorphous alloys, so hindering the bacterial adhesion and the consequent biofilm formation.

In this work, Ti-Cu based amorphous alloys were considered and different dealloying strategies were adopted to design the surface composition and morphology: both electrochemical and chemical dealloying was performed and different electrolytes (basic and acid) were selected. In general, mixed Ti/Zr oxides were formed with thickness ranging from tens up to hundreds of nanometers with variable morphologies. The oxide layers were studied by means of different techniques: field emission scanning electron microscopy (FESEM), X-ray diffraction (XRD), atomic force microscopy (AFM), X-ray photoelectron spectroscopy (XPS). Moreover, wettability and cytocompatibility studies demonstrated the effectiveness of the dealloying process with the improvement of the cytocompatibility and antibacterial activity.

A key point in the design of Ti based alloys are the modified surfaces to which an optimised biocompatibility is associated. Therefore, the dealloying mechanism was studied in detail in order to enable a connection between morphology and composition of the dealloyed layer and antibacterial activity of the implantable material.

Short-range order of the liquid Al-Sn-Cu alloys

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The short-range order (SRO) in the liquid $Al_{80-x}Cu_{20}Sn_x$ (x = 13, 20, 28, 52) alloys has been investigated in a wide concentration range at 1300 ^{0}C using the high-temperature X-ray diffraction. The experimental total structure factors S(Q) and pair distribution functions g(R) of liquid ternary alloys have been compared with the ones of liquid binary Al-Cu and Al-Sn alloys investigated earlier [1, 2].

A transformation of the shape of the first peak of the S(Q) curve with the replacement of aluminum by tin has been found. A shoulder on a low-Q of the first maximum of the S(Q) appears, which position agrees with the position of the first peak of the total structure factor of liquid Sn. Obtained data indicates the presence of atomic clusters with the SRO similar to the liquid tin [2] in the investigated ternary melts. These atomic clusters are dominant in the liquid $Al_{28}Cu_{20}Sn_{52}$ alloy. The influence of the atomic size ratio and pair atomic interactions on the SRO of investigated liquid alloys have been discussed. The SRO of the investigated ternary alloys is mainly determined by the energy factor, which is associated with a difference in bond energy in Cu-Al and Cu-Sn pairs. It has been found that Cu additions to the Al-Sn binary alloys promote phase separation in the liquid state and may influence the miscibility stability.

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Impact of elevated temperature on soft magnetic properties of rapidly annealed nanocrystalline high-B_s Fe-Co-B-Cu alloys

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The growing technological demand for soft magnetic materials capable of operating in high-temperature environments has intensified research into FeCo-based nanocrystalline alloys. Magnetic components in generators, electric motors and transformers are frequently subjected to elevated temperatures, which can degrade their magnetic performance. Therefore, a deeper understanding of the stability of the functional properties of soft magnetic materials at elevated temperatures is crucial for assessing their application potential.

In this study, we investigated the influence of different thermal treatments on the structure and high-temperature soft magnetic properties of $Fe_{64}Co_{21}B_{15})99Cu_1$ ribbons prepared by planar flow casting. Special attention was given to the ultra-rapid annealing (URA) technique, which involves compressing samples between pre-heated massive copper blocks. This approach enables the synthesis of nanocrystalline soft magnetic alloys with a reduced content of non-magnetic elements, offering an attractive combination of high saturation magnetic flux density (B_s) and low coercivity (H_c) [1,2]. A description of our URA setup is available in a previous publication [3].

As-quenched amorphous ribbons were annealed by URA for 0.5 seconds at 490 °C. For comparison, a second batch was subjected to conventional annealing (CA) in a vacuum furnace at 370 °C for 30 minutes. Our results reveal that the high heating rate and short processing duration of URA promoted the formation of finer nanocrystalline grains, typically ranging from 15 to 20 nm, compared to CA. This grain refinement significantly improved magnetic softness, reducing coercivity from 161 A/m in CA-treated samples to 6 A/m in URA-processed ribbons.

The primary focus of this study was to characterize the soft magnetic behavior of the materials at elevated temperatures. Hysteresis loops were measured from room temperature (RT) up to 400 °C using a quasi-static Förster-type B–H loop tracer. Reference hysteresis loops were recorded at RT after each high-temperature cycle to monitor possible irreversible changes in the microstructure during thermal exposure. The results demonstrated that the URA-processed ribbons maintain excellent stability of coercivity from RT up to 250 °C, which highlights their strong potential for use in magnetic components operating in high-temperature environments.

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Tuning the Degree of Rejuvenation in Metallic Glasses

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Rejuvenation is the structural excitation process that can bring metallic glasses (MGs) to a higher energy state, usually increasing their free volume. Here, a dilution procedure performed by randomly removing atoms from the modeled glass matrix can be used to systematically control the degree of rejuvenation and identify the maximum rejuvenation threshold of MGs. A continuous increase in free volume activates the structural relaxation process during the rejuvenation process and the dynamic balance between free volume creation and annihilation defines the highest degree of rejuvenation of MGs. The degree of excess free volume correlates with the flow strain of the MG, while the structure and density at the highest rejuvenated state are similar to those found in shear bands [1]. In addition, the deformation mechanism of highly rejuvenated metallic glasses during uniaxial load-unload tensile tests is investigated to provide a systematic understanding of the relaxation and strain-hardening relationship [2]. The observed strain hardening in the highly rejuvenated metallic glasses corresponds to stress-driven structural and residual stress relaxation during cyclic deformation.

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Application of synchrotron-based quantifiers for the characterization of conventionally and additively processed metallic glasses

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Metallic glasses have long been in the focus of scientific interest. They are produced industrially in large quantities for electromagnetic applications because of their fantastic soft magnetic properties. However, their breakthrough for structural applications has been hindered by their limited size and brittleness. Most processes for producing metallic glass components rely on high cooling rates and therefore casting processes such as suction casting and melt spinning have been developed. All of these processes can produce mechanically attractive parts with high strength, good fracture toughness and sometimes even a small amount of plasticity under compressive, flexural or shear loads but are limited in size and geometric freedom. In contrast, the hope for additive manufacturing of metallic glass powders by laser powder bed fusion was to overcome size and geometry limitations. Unfortunately, this gain in geometric freedom comes at the cost of a complex, process-inherent heat treatment that fundamentally degrades the above mechanical properties due to structural relaxation and crystallisation within the parts. In this talk we will discuss how local structural quantifiers, such as measures of entropy or plane strain derived from synchrotron-based X-ray diffraction or atomistic modelling, can link structural and dynamic relaxation mechanisms in metallic glasses that affect the structural and mechanical properties of metallic glasses. From the lessons learned, we will show how these challenges may be addressed by controlling the energy input during the additive manufacturing of metallic glasses using different laser shapes. Other approaches involve the use of optimized alloys. Improvements in the mechanical properties such as strength and ductility are found in conjecture with low crystallinities and high densities.

Transition of fluctuation-modifying to bond-modifying Invar effect in ferromagnetic bulk metallic glasses

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Bulk metallic glasses (BMGs) are amorphous alloys obtained by vitrification of the melt during cooling. In contrast to crystalline materials, they lack long-range order (LRO), which gives them specific properties of which many are not fully understood (or investigated). Among them, ferromagnetic BMGs show a peculiar property, which is the Invar effect. The coefficient of thermal expansion (CTE) is anomalously low as long as the BMG is ferromagnetic and increases by up to one order of magnitude in its paramagnetic state. We have recently shown through atomic-scale investigations that the Invar effect is caused by an intrinsic property of the magnetic interactions of Fe–Fe [1] and that its origin lies in the short-range order (SRO) around the Fe atoms [2]. As temperature increases the magnetic interaction counteracts the normal thermal expansion and can even result in a net contraction of Fe–Fe bonds below the Curie temperature T_C. However, the BMG samples show a macroscopic thermal expansion, therefore the behavior of the other atomic bonds must be thoroughly characterized.

There are two classes of magnetic BMGs, where class (I) has a reduced CTE just at T_C (peak-type) and class (II) shows a reduced CTE in a large temperature range below T_C (step-like). Although the Invar effect seems to be universal in ferromagnetic BMGs [3], the experimental results show that a step-like CTE is associated with a more pronounced Invar effect. Some glass-forming alloy series show a gradual transition between the two types. For example, the BMGs of the alloy series $(Fe_xCo_{1-x})_{72}B_{19.2}Si_{4.8}Nb_4$ ($x = 0 \ldots 0.5$) show a gradual transition from type II to type I as the Co content increases. The data of the thermal behavior recorded from room temperature up to slightly below the glass transition indicates that type I alloys have less degrees of fluctuations in the magnetic system even at temperatures far below T_C, and therefore reveal a less pronounced Invar effect. Furthermore, we recently performed time-resolved synchrotron experiments at the BM23 beamline at ESRF, where we recorded EXAFS spectra at the Fe K-edge of four FeCoBSiNb BMGs. In this way, we could investigate the atomic environment around Fe atoms in detail, and will discuss the findings of this study in conjunction with the BMGs' thermal and magnetic behavior.

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The Roles of Nanostructures in Enhancing the Strength-Ductilty Synergy of Powder Metallurgy Near-α Titanium Alloys

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Titanium alloys are important engineering materials of the future due to their lightness, high strength, good ductility, good corrosion resistance and good biological compatibility with human bodies. Powder metallurgy titanium alloys fabricated by thermomechanical consolidation of powder blends and recycled chips have the advantages of lower cost and short processing route. Through powder processing, incorporation of certain alloying elements and heat treatments, nanostructures form in regions of the microstructures of the titanium alloys. They include β transformed domains consisting of nanometer sized α laths mixed with β phase and nanocrsystalline α regions. The nanostructures not only significantly enhance the strength of the alloys through grain boundary/interface strengthening and hetero-deformation induced stress, but also maintain a good tensile ductility through delocalization of strain distribution associated with the heterostructure and activation of <c+a> dislocation slip caused by the higher flow stress during plastic deformation. This talk will present our findings in studying the microstructures and mechanical properties of powder metallurgy near-α titanium alloys fabricated by thermomechanical consolidation of powders and chips, and discuss the roles played by the nano strucutre and heterostructures in enhancing the strength-ductility synergy of the alloys.

Tailoring of soft magnetic properties and Giant Magnetoimpedance effect of amorphous microwires by stress-annealing

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Studies of amorphous microwires have attracted attention due to their unique combination of magnetic properties such as their magnetic softness, magnetic bistability, giant magnetoimpedance (GMI) effect, as well as good mechanical properties and high corrosion resistance [1,2].The fabrication technique allows the preparation of amorphous microwires with diameters from 100 nm to 100 μm [1,2]. Magnetic properties can be tuned by appropriate annealing. Consequently, we provide our latest attempts on tailoring of magnetic softness and GMI effect of glass-coated magnetic microwires by stress-annealing. We studied the effect of stress-annealing (at temperatures, T_{ann}, up to 400 ^{o}C) on the hysteresis loops and GMI ratio, $\Delta Z/Z$, of Co-and Fe-rich glass-coated microwire prepared using Taylor-Ulitovsky method. In most of Co-rich microwires after conventional annealing a transformation of the linear hysteresis loop into a rectangular and elevated coercivities, H_c, ($H_c \approx 100$ A/m) are observed. After annealing of Co-rich microwires, a change in magnetostriction coefficients, λ_s, from low negative to low positive values is observed. Such magnetic hardening can be suppressed using stress-annealing: after stress-annealing smaller H_c ($H_c \approx 2$ A/m for $T_{ann} = 350$ ^{o}C) is observed. Similarly, stress-annealing of Fe-rich allows to induce a transverse magnetic anisotropy and substantially reduce H_c –value. Such transverse magnetic anisotropy substantially affected by T_{ann} as well as by stress applied during the annealing. After stress-annealing of both Co-rich and Fe-rich microwires, a substantial increase in GMI ratio is observed. The observed change in the hysteresis loop shape, and in ΔZ/Z - value and magnetic field dependence of ΔZ/Z after annealing have been discussed considering the internal stresses relaxation, induced magnetic anisotropy and modification in the λ_s sign and values.

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Oral Contributions

Capturing Ultrafast Melting in Palladium

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Due to its extremely short timescale, non-equilibrium melting of metals is challenging to probe experimentally. Consequently, our understanding of melting mechanisms relies primarily on theoretical predictions and computational modeling. This study investigates the ultrafast melting of polycrystalline palladium films using an optical laser pump combined with X-ray free-electron laser (XFEL) probing, complemented by large-scale molecular dynamics (MD) simulations. By capturing X-ray diffraction snapshots with sub-picosecond resolution, we track transient atomic structures during the transition from the crystalline to the liquid state. Correlating XFEL diffraction data with MD simulations bridges experimental and computational timescales, revealing a coherent microscopic picture of the melting process [1,2]. Our findings show that as the deposited energy increases, the melting process accelerates, shifting from a heterogeneous nucleation-driven mechanism—initiated within structurally disordered grain boundaries—to a homogeneous, catastrophic collapse of the crystalline order on a picosecond timescale, approaching the electron-phonon coupling limit.

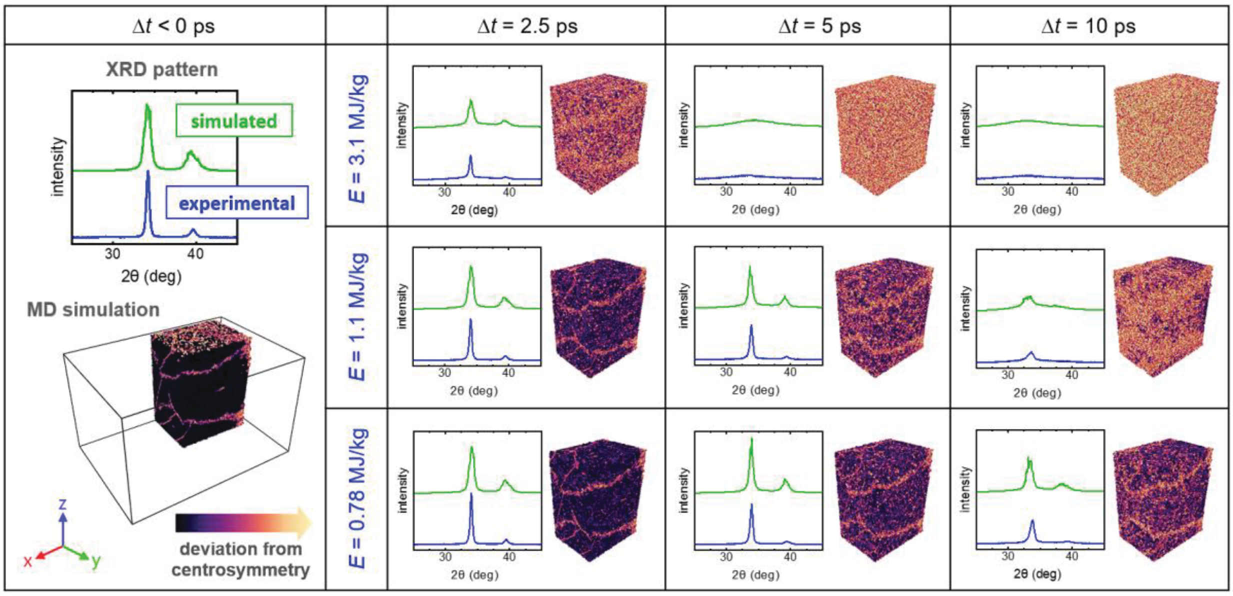

Figure 2. Structural evolution of polycrystalline palladium during ultrafast melting. The colour of atoms represents their deviation from centrosymmetry. The theoretical X-ray diffraction patterns are matched with experimental ones measured at corresponding pump-probe delay times Δ*t* and absorbed energy densities *E*.

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Electronic structure of high-entropy alloys: prospects and challenges

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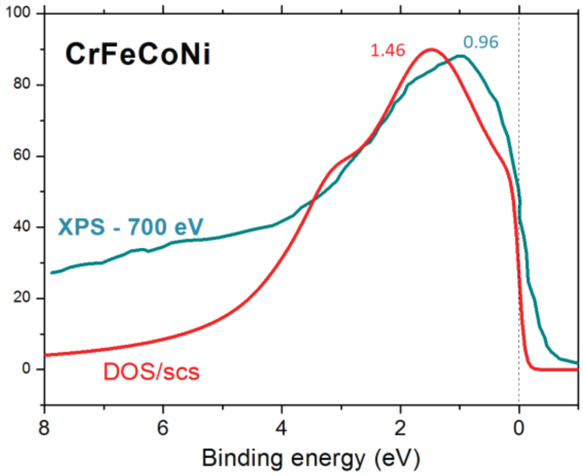
High-entropy alloys show some outstanding properties such as fatigue, irradiation and corrosion resistance. However, the understanding of their electronic structure, ES is still limited which is detrimental both for the design of HEAs and for their application. Further, the experimental studies of their ES are scarce even though photoemission spectroscopy, PES can provide good insight into the electronic density of states, DOS, thus explain their intrinsic properties (1., 2.). Here we show the correlation between the theoretical/calculated DOS and that depicted by corresponding PES spectrum, “experimental” DOS for three HEAs for which such comparison was possible. As illustrated below for CrFeCoNi HEA (3., 4.), despite a similarity between the shapes of theoretical and corresponding “experimental” DOS there is considerable quantitative difference between two DOS in all studied HEAs. Moreover, for the same HEA different ab-initio calculations often provide different DOS. We briefly discus the possible origins of these discrepancies.



Comparison of theoretical DOS (3.) with PES spectrum (4.) for CrFeCoNi HEA.

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Structure, anticorrosion and mechanical properties of CoCrFeNiMs (Ms=Nb,Mo,B,Si) high entropy alloys prepared by rapid solidification method

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The high entropy alloys (HEAs) represent a novel group of metallic materials, which has received increasing attention in recent years. Challenging the paradigm of conventional alloy development, the concept of high-entropy alloy involves the use of five or more principal elements in equimolar or near-equimolar ratios. As a result, these alloys characterize with a high value of the configurational entropy value, which contributes to stabilization of single phases of FCC, BCC, and HCP, and a culmination of these phases. The ability of HEAs to form solid phase solutions is largely due to their configurational entropy value greater than 1.5 R [1-3].

HEAs exhibit a variety of exceptional properties that open up their wide application possibilities. In particular, their high-temperature microstructural stability, long-term fatigue resistance, and high oxidation and wear resistance make them promising materials for high-temperature structural elements. Furthermore, HEAs can be characterized with improved irradiation resistance, creating perspectives of their use as structural materials in nuclear applications. The possible use of HEAs in electrocatalysis is also being considered, which is derived from its high corrosion resistance and notable catalytic activity [3-7].

In this work, CoCrFeNiMs alloys (Ms=Nb,Mo,B,Si) with high entropy alloys were prepared by two different methods to determine the effect of cooling rate and different alloying elements, including metalloids (Si,B) and refractory elements (Mo,Nb) on the structure and selected properties of ingots and plates. The structure was investigated extensively using X-ray diffraction, scanning electron microscopy, transmission electron microscopy and Mössbauer spectroscopy.

The CoCrFeNiNb and CoCrFeNiMo alloys were composed of a solid solution and intermetallic phases $(TM)_2Nb$ and Cr-Mo-TM. In the case of the CoCrFeNiB alloy, a complex phase structure was revealed, consisting of FCC solid solution and three types of borides. The addition of Si substantially altered the phase composition of the CoCrFeNi alloy, resulting in the formation of two intermetallic phases. The corrosion behaviour of the alloys was studied in 3.5% NaCl solution. The highest corrosion resistance was found to characterize the CoCrFeNiSi alloy, which exhibits the most uniform chemical element distribution. The most advantageous strength properties were shown by alloys with the addition of metalloids. For the CoCrFeNiSi alloy, the highest hardness value was obtained, while CoCrFeNiB showed the highest Young's modulus.

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Mechanochemical synthesis: a pathway to novel high-entropy oxide perovskite structures

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High-entropy materials present vast opportunities for developing innovative functional ceramics with diverse applications. Various synthesis methods have been investigated to achieve a single-phase structure that integrates multiple elements. In ceramic materials, the synthesis process plays a crucial role in determining powder morphology, elemental distribution, particle size, and overall processability.

In this work, a facile mechanochemical reaction at room temperature was successfully employed to synthesize novel single-phase perovskite-structured high-entropy oxides (HEOs), with the compositions $La_{1-x}Ca_x(Ni_{0.2}Mn_{0.2}Cu_{0.2}Fe_{0.2}Co_{0.2})O_3$ (where x= 0.0, 0.2, 0.3 and 0.4), and $(La_{0.35}Gd_{0.35}Ca_{0.3})(Mn_{0.5}Fe_{0.1}Co_{0.1}Ni_{0.1}Cu_{0.1}Mg_{0.1})O_3$. In the first compositional series, the impact of Ca substitution at the rare-earth (RE) site on structural and thermal stability is examined. While doping RE with divalent alkaline elements has previously been shown to enhance functional properties in simple RE-perovskites, its effect in HEOs remain largely unexplored. In the second compositional series, the influence of ions supplied by raw materials with different valence states on the structure, phase composition and thermal stability of HEOs is investigated. Specifically, the study explores the effect of different manganese feedstocks, MnO_2 and Mn_2O_3, on phase formation and stability.

All synthesized materials exhibit a single-phase perovskite structure, with lattice parameters influenced by the sizes of the incorporated ions. Elementa mapping confirms a homogeneous distribution of all elements across both the cationic and anionic sublattices. The combination of a straightforward synthesis approach and the use of simple binary oxide precursors opens new possibilities for designing a wide range of novel high-entropy compounds

Crystallisation of Metallic Glasses in Complex Multicomponent Carboborides

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FeCrNbB-based metallic glass coatings have been intensively studied to develop surfaces with high resistance against corrosion and wear [1]. One relevant issue to understood is the crystallisation mechanism, which can be drastically modified by compositional adjustments.

Crystallisation usually results in a conflicting role for the wear and corrosion properties, with corrosion resistance severely compromised due to the formation of hard borides phases, while, for the same reason, the wear resistance is maintained high, or even higher [2].

Therefore, the design strategy for selecting FeB-based alloys useful for high-performance coatings must consider not only compositions with high glass-forming ability, containing corrosion resistant elements, but also crystallisation mechanisms that does not require strong solute partitioning for the formation of the initial nanocrystalline phases.

Such conditions can be observed in different types of multicomponent alloys, such as $Fe_{0.25}Co_{0.25}Ni_{0.25}Cr_{0.125}Mo_{0.125})_{86-89}B_{11-14}$ [3] or $Fe_{0.25}Co_{0.25}Ni_{0.25}Cr_{0.125}Mn_{0.125})_{100x}B_{x}$ (x= 8-13) [4], where the crystallization reactions proceed with the initial formation of multicomponent solid solution bcc or bcc + fcc phases, with compositions close to the glassy matrix without any borides in the initial stages.

Another multicomponent compositional approach, can result in a polymorphic type of crystallisation with the initial formation of a complex multicomponent boride, as first observed in the $(Fe_{0.5}Co_{0.5})_{72}B_{20}Si_{4}Nb_{4}$ alloy, which formed a metastable $Fe_{23}B_{6}$-type phase [5].

In the present work we discuss the crystallisation mechanism of the glassy $Fe_{62}Cr_{8}Mo_{4}Nb_{4}B_{18}C_{4}$ alloy, which results in complex multicomponent carboborides phases, in view of a comprehensive analyses of the chemical and microstructural evolution. We also discuss the crystallisation of glassy and partially glassy powders of the same composition produced by gas atomisation and the prospects to obtain optimised tribological and electrochemical properties in coating applications.

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On the improvement of the corrosion resistance of two families of High-Entropy Metallic Glasses

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The study of High-Entropy Metallic Glasses (HEMGs) - materials that combine the chemical disorder characteristic of High-Entropy Alloys (HEAs) with the topological disorder characteristic of Metallic Glasses (MGs) - is gaining interest due to the possibility of creating new alloys with enhanced properties. These enhancements stem from the structural homogeneity, absence of grain boundaries, and high solubility of different metallic elements in this class of alloys [1]. One of the properties of HEMGs that can be tailored to meet industrial requirements is their corrosion resistance. Generally, the superior performance of these materials in harsh environments is attributed to the reduction in the effective diffusion coefficient and the synergistic effect of the multiple elements constituting the alloy on its macroscopic properties [2,3].

In this work, two different families of HEMGs are studied to shed light in the physico-chemical mechanisms controlling their corrosion behavior. On one hand, the corrosion resistance of FeCrCoNi(B,Si) HEMG has been investigated by means of linear polarization resistance experiments and its surface has been characterized using scanning electron microscopy (SEM) and X-ray photoelectron spectroscopy (XPS). The results indicate that the presence of B and the absence of crystallographic defects promote the stabilization of the passive film, which consists of a combination of oxides and hydroxides [4]. On the other hand, the electrochemical behavior of the well known PdPtNiCuP HEMG has been thoroughly assessed using linear polarization resistance and electrochemical impedance spectroscopy experiments, with the formation of oxide films analyzed via XPS. Additionally, the results have been compared with those of similar quaternary and ternary compositions - PdNiCuP and PdNiP – to evaluate the relative effects of the high-entropy effect and the synergistic influence of corrosion-resistant elements on the overall corrosion behavior. Unlike the FeCrCoNi(B,Si) HEMG, where passive film stabilization is attributed to specific elements, in the Pd-based HEMG, stabilization arises from the combined effect of all five elements present in the alloy. Finally, the results reveal a positive correlation between the configurational entropy and corrosion resistance

These findings provide a new perspective on controlling the corrosion resistance of HEMGs through the configurational entropy and the strategic selection of constituent elements.

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On advanced quality electromagnetic yokes based on amorphous ribbons for steel health monitoring

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A new electromagnetic yoke (EMY) to monitor the differential magnetic permeability and therefore the residual stresses on the surface of a magnetic steel, that is included between the two legs of the EMY is presented in this article. The calibration method is proposed and experimental results on corresponding characterization of magnetic steels are also presented. With this yoke, a large variety of magnetic measurements may be realized in the field, with particular emphasis in the Quality Control Lab of steel manufacturing industries.

The calibration process is provided by using two yokes face-to-face: exciting one of them, the output signal is related to their permeability. This way, the permeability of the EMY is determined, while the Ampere's law determines the differential permeability of the under test magnetic steels. The sensitivity of measurement has been proven to be significantly better than conventional soft magnetic steels, even made of electric steel laminar.

Crystallization Temperature Driven Phase Evolution and Magnetic Behaviour in Fe-Ni-P-C Ribbons

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An optimized processing of Fe-Ni-P-C ribbons allows tailoring their magnetic properties for various applications. Melt-spun FeNi ribbons offer high thermal stability and soft magnetic behaviour, ideal for electronics [1]. Their high reactivity also enables efficient degradation of organic pollutants in wastewater treatment [2, 3].

A master alloy $Fe_{40}Ni_{40}P_{13}C_7$ made of Fe, Ni, P, and C precursors was used to produce melt-spun amorphous ribbons. Fe and Ni were primary components, while P and C were added to promote the amorphous phase formation, nanocrystallization upon annealing, and enhance catalytic activity and corrosion resistance [1-3]. The ribbons were annealed at 350–430 °C for 1 h to study the effect of crystallization temperature on the crystallographic structure and magnetism.

X-ray diffraction (XRD) and vibrating sample magnetometry (VSM) revealed a saturation magnetization of 76-95 Am^2/kg and a maximum coercivity of 55.7 kA/m at 390 °C, related to the lowest soft magnetic *fcc* FeNi phase content in the annealed ribbons. This research highlights the ability to fine-tune the magnetic properties of Fe-Ni-P-C ribbons by adjusting their crystallographic structure and composition through controlled annealing processes.

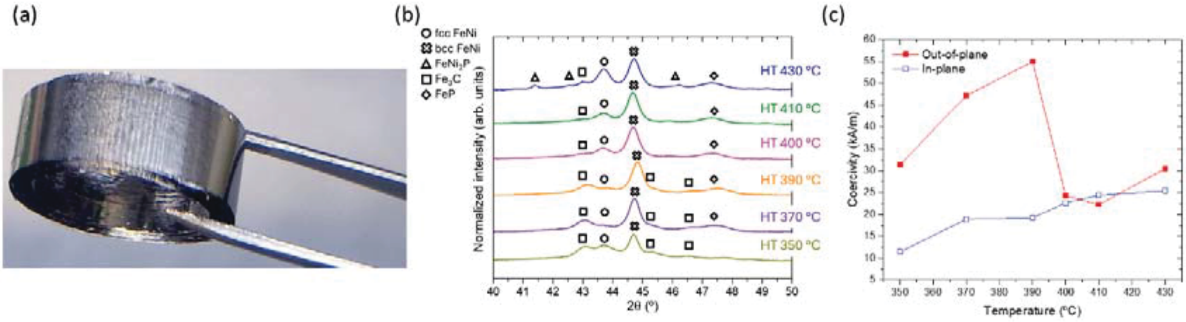

Figure 1. (a) Ribbon roll; evolution of (b) diffractograms measured by XRD and (c) out-of-plane and in-plane coercivity with the crystallization temperature.

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Interfacial strain concentration and relaxation along crystalline-amorphous boundaries of B2-reinforced bulk-metallic-glass-composites during loading

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Interfacial stress concentration promotes both martensitic transformation nucleation and shear band initiation in B2-reinforced bulk-metallic-glass-composites. As the martensitic transformation occurs in the crystalline (soft) regime, shear bands are often observed in the amorphous (hard) matrix. A long-standing question has been when the stress concentration will prompt the martensitic transformation and when it will give rise to shear band initiation. By definition, stress concentration results from the regional Young's modulus multiplied by the local strain concentration. The localized strain concentration along crystalline-amorphous boundary plays decisive roles in promoting phase transformation and localized shear events. By constantly tracking the interfacial strain distribution through Molecular Dynamics methods, the location and magnitude of the interfacial strain concentration and its relaxation are quantified and correlated with the regional modulus differences. We are proposing that the regional strain concentration and relaxation is always located along soft/hard domains during loading so as to maintain the compatibility of interfacial deformation.

Sustainable Aerospace Manufacturing: Recycling of Aerospace-Grade Titanium Alloys via Rapid Solidification of Swarf Waste

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Titanium alloys, particularly Ti-6Al-4V, are critical in aerospace applications due to their high strength-to-weight ratio and corrosion resistance. However, conventional subtractive manufacturing processes generate substantial quantities of swarf—fine titanium shavings that are often downcycled or discarded. This contributes to both significant material inefficiency and energy-intensive demand for primary titanium production, which is highly carbon-intensive. Recent research efforts focus on the efficient re-use/recycle of the manufacturing waste, without being downgraded, as feedstock in additive manufacturing processes. In pursuit of sustainable materials engineering aligned with net zero targets, this study explores the recycling of titanium swarf via rapid solidification micro-casting processes using arc-melting and copper mould casting. Comprehensive microstructural, mechanical, and chemical analyses reveal that the recovered materials retain performance comparable to virgin alloys. The process also significantly reduces embodied energy and CO_2 emissions, as validated through preliminary life cycle and techno-economic assessments. This work presents a scalable pathway for the closed-loop recycling of critical aerospace materials, supporting the transition toward a more resource-efficient and climate-resilient manufacturing ecosystem.

Atomic Disorder in Laser Beam-Shape-Tailored 3D-Printed Zr-Based Bulk Metallic Glass Under In-Situ Heating During High-Energy X-Ray Diffraction

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Additive manufacturing, especially laser powder bed fusion (LPBF), has enhanced Zr-based bulk metallic glass (BMG) through advanced laser-beam profiles. Compared to the conventional Gaussian beam (GB), shaped-beam (SB) technology improves material properties and efficiency, though its high-temperature and dynamic loading effects remain unclear. This study examines fully amorphous SB and GB samples, confirmed by X-ray diffraction (XRD), while transmission electron microscopy (TEM) reveals nanocrystals within the amorphous matrix. In-situ synchrotron XRD shows SB samples undergo slower structural relaxation. Pair distribution function G(r) and structure factor S(Q) analyses confirm this, linking SB printing to higher mean atomic volume V(T), thermal expansion coefficient (αth), and configurational entropy (Seq), suggesting a less relaxed state with better thermal aging resistance. Fluctuation electron microscopy (FEM) detects greater heterogeneity and medium-range ordering (MRO) in SB samples. Dynamic mechanical analysis (DMA) reveals lower tan δ, indicating reduced energy dissipation and improved mechanical damping.

Strengthening by heterogeneously nucleated and grown G-phase in Cu-Ni-Si-Mn alloy

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The increased content of additive elements in Cu-Ni-Si alloys can result in heterogeneous nucleation, leading to the formation of large particles at grain boundaries [1, 2]. This, in turn, impedes the strengthening process because the large grain boundary particles absorb elements that would otherwise form nano-scale precipitates, and the irregular shape of the grain boundary phase can cause stress concentration.

In this study, a Cu alloy containing 6 wt% Ni, 1.3 wt% Si, and an identical Ni and Si composition with an additional 2.4 wt% Mn was cast and homogenized. The Cu-Ni-Si alloy, both with and without Mn was prepared using a medium-frequency electric induction furnace with 99.99% Cu, 99.9% Si, 99.9% Ni, and 99.9% Mn. Tensile tests were conducted with a gauge length of 10 mm at a nominal strain rate of 10^{-3}/s using a universal testing machine (Instron 4206, USA). The grain morphologies and secondary phases of both the cast and homogenized specimens were examined using optical microscopy (OM; GX51, OLYMPUS) and a scanning electron microscope (SEM; JSM-6610LV, JEOL, Japan). Additionally, electron backscatter diffraction (EBSD; NordlysNano, Oxford) was performed at an acceleration voltage of 15 kV with a step size of 50 nm.The phase heterogeneously formed at the grain boundary is identified as Ni_2Si compound in the Cu-Ni-Si alloy, while the phase at the grain boundary is recognized as $Mn_6Ni_{16}Si_7$, known as the G-phase.

As a result, the high content of secondary elements in the Cu alloy led to the formation of large, heterogeneously nucleated grain boundary phases, which are known to be mechanically detrimental. However, the strength and ductility increased after the homogenization treatment. The presence of the G-phase at the grain boundary in the Cu-Ni-Si alloy results in higher strength and ductility compared to the alloy containing Ni_2Si. Contrary to the general notion that grain boundary phases decrease strength, the substantial coverage of the grain boundary by the film-shaped G-phase enhances its stability compared to the irregularly shaped Ni_2Si. This increased stability consequently contributes to the elevated strength and ductility of the Cu-Ni-Si alloy.

This study suggests that heterogeneously nucleated and grown phases can significantly enhance strengthening, contrary to the general notion that large grain boundary phases degrade the mechanical properties of alloys.

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Cu-Zr-Al thin film metallic glasses in a wide range of compositions and growth conditions

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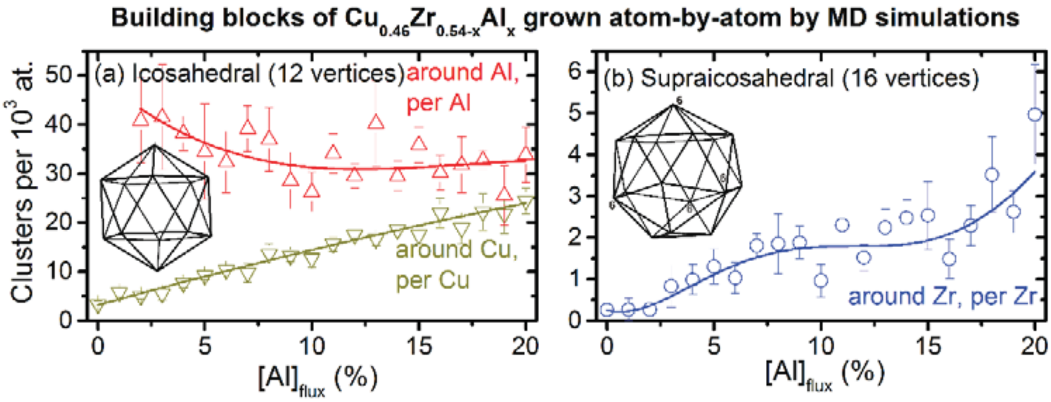
Cu-Zr-Al thin film metallic glasses are investigated by a combination of simulations of their atom-by-atom growth with magnetron sputtering. We fulfill all requirements which maximize the usefulness of the results: mutual support of modelling and experiment, simulation algorithm exactly reproducing what is happening in the experiment, wide compositional range (from pure Cu to pure Zr, from [Al] = 0 to 20%), wide range of growth conditions (energy, temperature, growth template). We focus on the homogeneity, densification, short-range order (bonding preferences and coordination numbers), medium-range order (common neighbor and network ring statistics) and functional properties. Special attention is paid to the building blocks of Cu-Zr-Al: not only icosahedral (12 vertices) but also newly identified supraicosahedral (16 vertices) clusters.

First, we identify crystalline Zr-rich compositions (on any growth template) and Cu-rich compositions (with a strong effect of growth template), and glasses (as homogeneous as what would result from a random distribution of atoms) at [Cu] = 20% to 80-85%. Increasing [Cu] in the glassy compositions leads to increasing coordination of both Cu and Zr, packing factor and icosahedron-like medium-range order. Second, increasing [Al] in glassy $Cu_{0.46}Zr_{0.54-x}Al_x$ preserves the homogeneity and once again leads to increasing coordination of all elements, packing factor and concentration of icosahedral clusters (around smaller Cu and Al) and supraicosahedral clusters (around larger Zr). All of that is achievable at low energy delivered into the growing films, while delivering too much energy (by bombardment or ohmic heating) may be even harmful.

While the atomic-scale simulations provide a lot of information not accessible experimentally, they are correlated with and explain experimental data including increasing hardness, Young's modulus, glass transition temperature and crystallization temperature with increasing [Cu]/[Zr] and [Al]/[Zr]. Collectively, the results are important for understanding the structures and properties of this class of metallic glasses, and for optimizing their compositions and pathways for their preparation.



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Comparative Tribological Study of Wrought and LPBF C300 Maraging Steel: Influence of Heat Treatment and Microstructural Characteristics

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A comparable study was conducted for the tribology behaviour of wrought and LPBF C300 maraging steel. Additionally, a heat-treatment was applied to both conditions at 490 ºC for 6 hours. At a load of 20 N for 30 minutes, the tribo-tests were conducted. Pre-tribology characterization such as microstructural analysis, phase detection, dislocation density, and length of HAGBs were analyzed using Field Emission Scanning Electron Microscopy (FESEM), X-ray Diffraction (XRD), and EBSD, respectively. The characterization of wear scars was carried out using FESEM-EDX, and X-ray Photoelectron Spectroscopy (XPS). Fe_3O_4, NiO, CoO, and MoO_3 were detected in all the non-nitrided samples. In addition to these, $Fe_{2/3/4}N$, and Al_2O_3 were also detected in all the nitride samples. For non-nitrided samples, due to the combined effect of grain size, length of HAGBs, and dislocation density in the LPBF samples, the wear resistance of samples was higher. LPBF samples have shown higher wear resistance and less wear depth when compared with wrought samples. Moreover, after heat treatment, the wear resistance increased, and wear depth decreased. All the nitride samples have shown the lowest values of COF and wear rates due to the formed hard compound layer.

Effect of High-Entropy Reinforcements on the Strength and Toughness of Tungsten-Based Alloys

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Tungsten-based alloys reinforced with AlCoCrFeNi and CoCrFeNiTa high-entropy alloys were produced using mechanical alloying. This study explores the effects of alloying elements, reinforcement phases, oxide formation, and processing parameters on the microstructural evolution and mechanical properties of the model alloys. The findings reveal that the Al and Ta elements in the reinforcement phases tend to dissolve, promoting the formation of complex oxide phases. This behavior inhibits the development of reinforcement phases, resulting in a decline in mechanical performance. Conversely, in the WMoTi alloys reinforced with AlCoCrFeNi sample, the introduction of Ti into the tungsten matrix facilitates the formation of AlCoCrFeNi reinforcement phases. These phases contribute to a fine-grained, twinned structure that is uniformly distributed within the matrix, significantly improving the material's strength and ductility.

3D-printed Topologically Structured Electrodes with Exceptional Mechanical Properties and Electrochemical Performance for Flexible Li-ion Batteries

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A key challenge in flexible batteries is developing electrodes that can endure repeated stretching while maintaining exceptional electrochemical performance. In this presentation, we introduce an additive manufacturing approach that integrates structural design through topology optimization with electrode fabrication via 3D laser printing—marking a significant shift from conventional battery electrode design and manufacturing methods. [1] The outstanding mechanical strength of these topologically structured electrodes is validated through finite element analysis and tensile strength testing. Notably, even under 50% stretching, the electrodes maintain their structural integrity, whereas conventional flat-film electrodes typically crack under similar conditions. Additionally, after 50 stretching cycles, the 3D-printed electrodes retain an impressive 98% of their original capacity. [2] These findings highlight the immense potential of additive manufacturing for advancing next-generation stretchable and flexible energy storage devices, including wearable technology and bio-integrated electronics.

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Longitudinal and transversal flexibility influence on magnetic properties of amorphous glass covered microwires

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Torsional, bending and spiral mechanical stresses have been applied to amorphous microwire to transform the magnetic structure (Fig. 1). The study of the magnetic domains and magnetization reversal in the surface of microwires has been performed by optical polarizing microscopy using the magneto-optical Kerr effect configuration [1].

The influence of torsion stress on domain structure and magnetization reversal has been found (Fig. 1a). The limits of the stress-induced inclination of magnetization have been determined in Fe- and Co-rich microwires. The stress-induced rotation of surface magnetization occurs across the longitudinally magnetized state (Fe-rich) and transversally magnetized state (Co-rich). The jump between inclined states and the formation of the dynamic structure containing different magnetic states are reversible mechanisms of the magnetization reversal in magnetic microwires.

Magnetic microwire was subjected to a bending-annealing-unbending procedure (Fig. 2b). A transition was observed from a two-domain structure at the unbent edge of the sample to a spiral structure in the transition zone and to a longitudinal domain wall in the central part of the sample.

Here we also present a method of preprocessing called spiral annealing (Fig. 1c). A gradual change in the anisotropy field was observed both within the microwire and on its surface. We have found a linear relationship between the local anisotropy field and the local geometric curvature of the sample.

Fig. 1. Torsion (a), bending (b) and spiral (c) mechanical stresses applied to the studied microwires.

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A DFT study on the effect of vacancies on the formation of deformation twins in Cu alloys

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Twinning-induced plasticity (TWIP) improves both the strength and ductility of metals by utilizing twin boundaries (TBs) to hinder dislocation movement. However, generating deformation twins (DTs) in pure copper (Cu) is challenging due to its high stacking fault energy (SFE) of about 50 mJ/m^2.[1] Alloying elements such as aluminum (Al) and zinc (Zn) have been used to reduce SFE in Cu alloys, but achieving a high twin boundary density remains a challenge. Recently, Cu-In alloys have shown the ability to generate high-density DTs through conventional deformation processes, achieving tensile strengths around 1.3 GPa.[2] The previous first-principles calculations revealed that the SFE can be more effectively lowered on the Cu (111) slip plane doped with an In atom and the energy barrier to generate a twin can be decreased significantly for a specific <112> slip direction in Cu-In alloy, compared to Cu-Al and Cu-Zn alloys.[3,4] However, it demonstrated that there are specific planes and directions where DTs are likely to form in Cu-In alloys, so there were limitations in identifying the cause of DTs' formation throughout the entire Cu-In alloy matrix.

In this study, we explored the role of copper vacancies (V_{Cu}) in the formation of DTs in Cu-In, Cu-Al, Cu-Zn alloys, and pure Cu using density functional theory (DFT) calculations. Our results showed that the formation energy of copper vacancies in Cu-In alloys was over 10,000 times more favorable than in pure copper. DFT simulations indicated that V_{Cu} did not enhance twinnability in Cu-Al, Cu-Zn alloys, or pure copper, but significantly improved twinnability in Cu-In alloys.

During the dislocation-induced deformation of Cu-In alloys, In atoms tend to move closer to one another due to applied stress. The larger atomic size of In atoms causes significant lattice distortion, making the material unstable. To alleviate this distortion, vacancies are formed between the In atoms, leading to the formation of highly stable In-V_{Cu}-In clusters. These clusters stabilize stacking faults and promote the slip of partial dislocations on adjacent planes, facilitating the formation of twin structures.

In conclusion, copper vacancies play a crucial role in enhancing the twinnability of Cu-In alloys, contributing to their improved mechanical properties. These findings offer new perspectives on the mechanisms governing twinning in copper alloys and highlight the potential for designing new alloys with tailored properties. Future research should focus on better understanding the interactions between vacancies, solute atoms, and dislocations to develop high-performance copper-based alloys.

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Tribo-corrosion behaviors of Al-based amorphous coatings prepared using HVAF spraying techniques

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As a lightweight and corrosion-resistant material, aluminum-based amorphous coatings can be widely used as surface protective coating materials for ship equipment in marine environment [1]. In this abstract, a kind of Al-based amorphous alloy coating (AlNiCoY) was prepared using HVAF spraying technique, which is dense and well bonded (Figure 1a), with a porosity of 0.31%, and a bonding strength of 35.19MPa. The amorphous content of the prepared coating is approximately 56%, accompanied by AlCo and AlNi nanocrystalline phases (Figure 1b-c). The coating hardness is 529.69 $HV_{0.1}$. The wear resistances of the Al-based amorphous coating have been tested and compared with 34CrMo1A hull steel in corrosion solution (including full immersion test and polarization test), and the mechanisms have been investigated. The results show that, under the full immersion condition, the friction coefficient of Al-based amorphous coating was between 0.40 and 0.43, and its wear rate was slightly lower than that of 34CrMo1A steel, showing partial loose and porous corrosion surface morphology (Figure 2a). The wear mechanism is mainly abrasive wear and corrosion wear. Under the polarization condition, the wear rate of Al-based amorphous coating increased, compared to that under the full immersion condition, and spalling was observed on the surface (Figure 2b). However, the superiority of Al-based amorphous coating to 34CrMo1A steel is much more prominent under the polarization condition, as its wear rate only around 60% of that of 34CrMo1A steel (Figure 2c). The analysis shows that the excellent anti-tribocorrosion performance of Al amorphous coating results from its high hardness and low porosity [2].

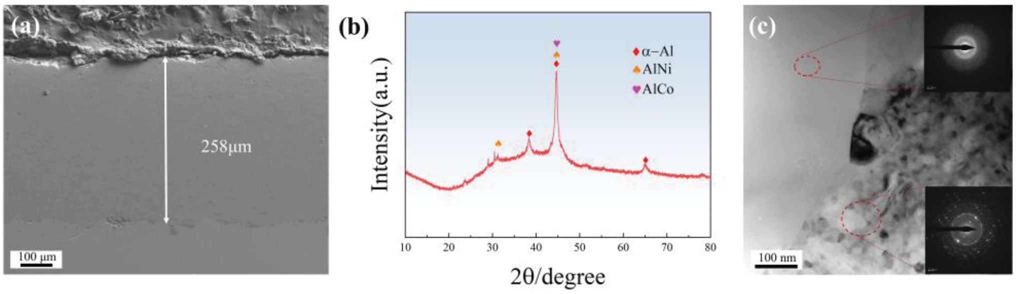

Figure 1. (a) Cross-sectional microstructure of Al-based amorphous coating, (b) XRD patterns of the Al-based amorphous coating, (c) TEM images of Al-based amorphous coating with corresponding SAD patterns

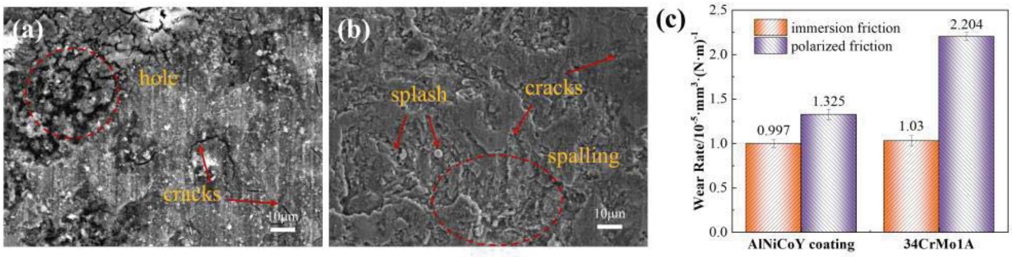

Figure 2. (a) Wear morphology of Al-based amorphous coating under full immersion condition (b) Wear morphology of Al-based amorphous coating under polarization condition (c) Wear rates of Al-based amorphous coating and 34CrMo1A steel under full immersion condition and polarization condition

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Direct observation of quadrupolar strain fields forming a shear band in metallic glasses

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The potential applications of metallic glasses are limited by their tendency to fail catastrophically at low strain due to shear banding. For decades, scanning/transmission electron microscopy (S/TEM) has been used to analyze shear bands and understand their formation. However, conventional S/TEM lacks direct reciprocal space information, preventing it from characterizing key structural variations, such as local atomic configurations [1], that influence the deformation of amorphous materials.

We present an algebraic method using singular value decomposition (SVD) to fit ellipses to amorphous diffraction rings in 4D-STEM data [2]. This approach improves precision and reduces computational cost compared to traditional nonlinear methods. Principal strains are extracted from the ellipse axes, transformed into loading coordinates, and used to compute the strain tensor. Deviatoric and volumetric strain components are separated to reveal local distortions and hydrostatic effects. In addition to strain mapping, 4D-STEM enables pair distribution function (PDF) analysis, providing insight into local atomic structure [3]. Applying this to a deformed $Fe_{85.2}Si_{0.5}B_{9.5}P_{4}Cu_{0.8}$ metallic glass, we identify complex residual strain near shear bands, including quadrupolar shear strain fields around inclusions. These vortex-like fields influence surrounding regions and contribute to shear band formation. Our method introduces new possibilities for studying amorphous materials and advancing our understanding of their mechanical behavior.

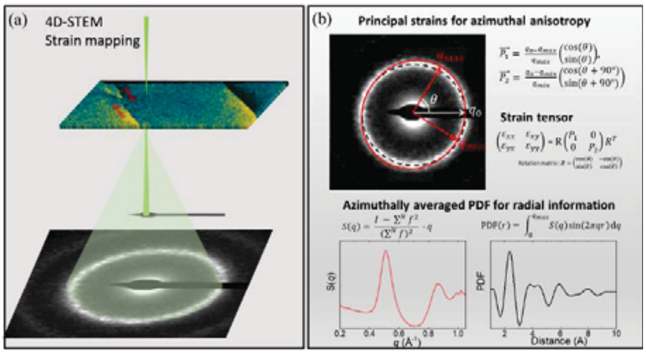

Figure 1: 4D-STEM-based strain and PDF mapping schematic. (a) A quasi-parallel electron probe scans the TEM lamella, recording spatially-resolved diffraction patterns. (b) Data processing: Principal strains ($\overrightarrow{\mathbf{P1}}$ and $\overrightarrow{\mathbf{P2}}$) are derived from diffraction ring distortion. Strain tensors are calculated by projecting principal strains onto the reference coordinate system. PDFs are obtained by Fourier sine transformation of $S(q)$.

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Crystallization kinetics of supercooled liquid Palladium

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We investigate the crystallization kinetics of supercooled liquid palladium using large-scale molecular dynamics simulations over a wide range of supercooling of 0.3–0.6 T_m (T_m = 1828 K). Our study reveals that the crystallization temperature significantly influences the morphology of the resulting polycrystalline structure, reflecting the kinetics of crystal nucleation and growth. A detailed analysis of the evolving grain structure enabled the extraction of the temperature-dependent homogeneous nucleation (Fig. 1a) and growth (Fig. 1b) rates, as well as the construction of a time-temperature-transformation (TTT) diagram (Fig. 1c). The analysis of the crystal growth rate suggests that the propagation of the crystallization front, occurring at several meters per second, is diffusion-limited rather than collision-limited. The critical cooling rate derived from the TTT diagram reaches 10^{13} K/s, consistent with the extremely poor glass-forming ability of elemental metals. We conclude that the primary factor limiting the supercooling of pure Pd liquid is the homogeneous nucleation of the crystalline phase, which reaches its maximum of 10^{35} $m^{-3}s^{-1}$ around 0.5 T_m.

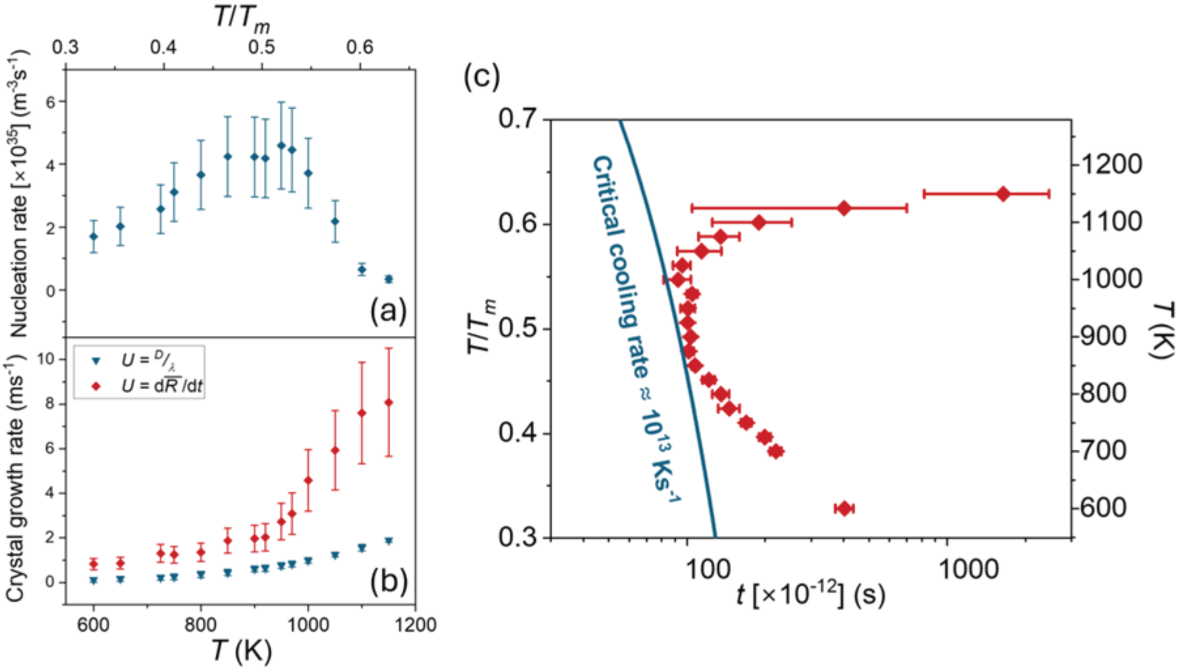

Figure 1. Homogeneous crystal nucleation (a) and growth (b) rates derived from the molecular dynamics simulations. The tip of the TTT diagram (c) for the crystallization onset marks the critical cooling rate for the

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B2 CuZr phase formation in Cu-Zr-Al bulk metallic glass matrix composites

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Bulk metallic glasses (BMGs) exhibit excellent strength and elasticity far above those of their crystalline counterparts, but suffer from limited plasticity. The introduction of a soft second phase can improve the deformation behaviour of BMG, but usually undesired macroscopic strain softening is observed in bulk metallic glass matrix composites (BMGMCs) due to lack of work hardening in the glass matrix and precipitates [1]. This drawback is eliminated in CuZr-based BMGMCs composed of a glassy matrix and ductile B2 CuZr phases. The B2 phase is prone to plastic deformation and can undergo a stress-induced martensitic transformation from a cubic B2 cubic to a monoclinic B19′ phase, imparting an appreciable work-hardening capability. The vital effect of the B2 CuZr phase on mechanical properties was confirmed in CuZr-based alloys with equiatomic or near-equiatomic concentrations of copper and zirconium [2-4]. This phase is thermodynamically stable at high temperatures (above 988 K), but if the system is given enough time, it decomposes eutectoidally to the orthorhombic $Cu_{10}Zr_7$ and tetragonal $CuZr_2$ brittle phases, which are equilibrium phases at room temperature. However, proper casting conditions and/or alloying with other elements can stabilize this phase to room temperature.

Pauly et al. [3] proposed a polymorphous crystallization mechanism of the B2 CuZr phase during solidification of the $Cu_{47.5}Zr_{47.5}Al_5$ melt, with a maximum solubility of approximately 4 at.% Al in B2 CuZr dendrites. Based on the ternary phase diagram and phase transformations observed during heating (differential scanning calorimetry and neutron diffraction at different temperatures) in the $Cu_{45}Zr_{48}Al_7$ alloy, another mechanism is proposed. Since the cooling rate of alloys produced by suction casting is relatively high, the first stage of solidification in the examined $Cu_{45}Zr_{48}Al_7$ alloy is most likely the formation of a mixture of B2 CuZr and $AlCu_2Zr$ phases (U22 transformation on the ternary phase diagram). The predominant B2 CuZr phase forms dendrites, while $AlCu_2Zr$ is located in the interdendritic spaces. As particles form in the liquid state, the precipitate assumes a spherical shape, with the subsequent growth of both phases being governed by diffusion within the liquid phase.

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Interfaces in Phase-Separated Pd-Au-Si Metallic Glass Alter Phase Transformation Kinetics

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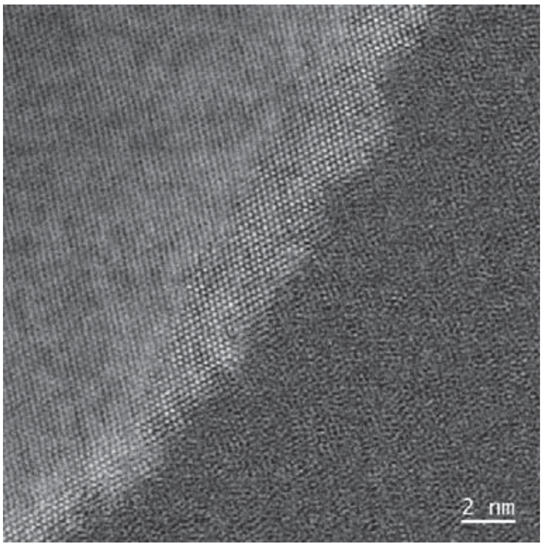
Structural differences depending on processing lead to materials with different properties and further, performance [1]. In the presence of multiple phases, the thermal properties, in particular, the temperatures at which the phase transformations take place, can be influenced by the interfaces between them, with potentially an interesting impact on the mechanical properties, such as ductilization leading to a higher fracture toughness [2]. Fast differential scanning calorimetry (FDSC) revealed upon heating above 5,000 K/s a double glass transition and crystallization, which indicate phase separation. Here, we identify the effect of the interface on the kinetics of the phase transformations, namely the glass transition and crystallization, of the phase-separated Pd-Au-Si metallic glass.

The material was investigated by transmission electron microscopy (TEM) for the microstructure, to gain insights into the correlation between the interface and the transformation kinetics. Moreover, uniaxial compression testing on micropillars was performed to probe the impact of the microstructural changes on mechanical properties. We anticipate that our study will provide a framework for exploring the relationship between processing, microstructure, and performance based on the advanced understanding of the interfacial effect on phase transformation kinetics and mechanical properties in metallic glasses.



HR-TEM in Pd-Au-Si of the boundary between a crystallized secondary-phase precipitate and the amorphous matrix after heating at 20'000 K/s up to 700 °C, revealing a rough interface.

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Fictive temperature-based annealing effects on metallic glasses with different initial structure

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Metallic glasses have drawn a lot of attention since their first observation due to attractive properties like high strength, fracture toughness and corrosion resistance. In most cases, metallic glasses are used as-is without any further processing, to retain their fully amorphous state, unlike most crystalline materials. Recently, it has been shown that the mechanical properties of metallic glasses can be tuned via annealing at certain fictive temperature, setting the structure into that of supercooled liquid at the fictive temperature. We aim to see how the process can affect metallic glasses with same composition but different initial structure. We've found that for metallic glasses with LDPR, mechanical properties can vary significantly with cooling rate because of its complex structure. After annealing at the same fictive temperature, structural analysis was done using high energy X-ray beamline, and the mechanical response of metallic glasses fabricated from different cooling rates were observed from utilizing uniaxial compression, Vickers Hardness and nanoindentation experiments. We expect this research to give new insights into post-processing methods of metallic glasses.

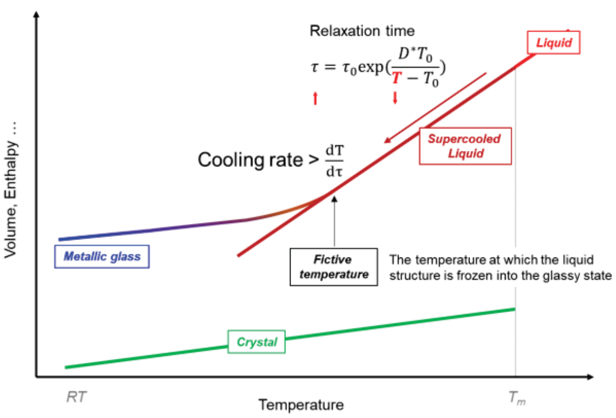

Figure 1. Schematic for the concept of 'Fictive Temperature' of glasses

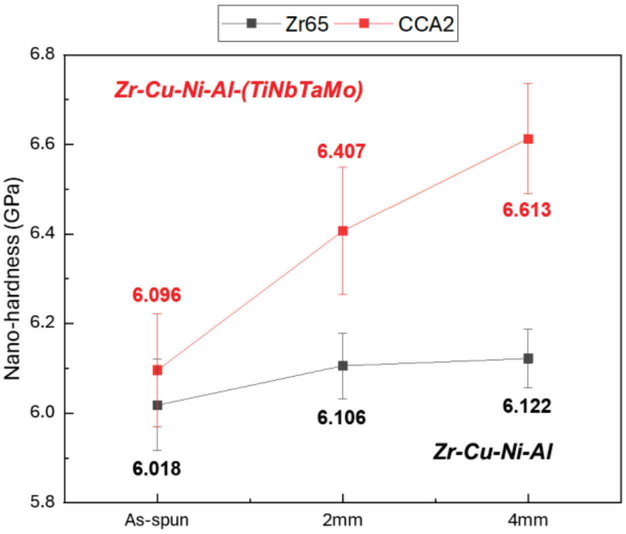

Figure 2. Change in nano-hardness with changing cooling rate, where the change is significant for metallic glass with complex structure

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Structure, Properties and Crystallization Behavior of FeSiBPCuNb Soft Magnetic Nanocrystalline Alloy

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The FeSiBPCu nanocrystalline soft magnetic alloy (known as NANOMET alloy) with high iron content has attracted considerable research interest due to its exceptional combination of high saturation magnetic induction (B_s), low coercivity (H_c), reduced core losses, and cost-effectiveness. Nevertheless, practical applications of many NANOMET alloys remain constrained by challenges such as limited amorphous forming ability and unfavorable crystallization kinetics. To overcome these limitations and achieve performance enhancement across extended annealing conditions, we systematically investigated the Nb/Si substitution strategy in the Fe81.3Si6B8P4Cu0.7 alloy system. Key findings include: (1) Partial replacement of Si with Nb effectively broadened the annealing processing window. The optimized Fe81.3Si4.4B8P4Cu0.7Nb1.6 alloy exhibited superior soft magnetic properties after annealing at 793 K for 5 minutes (B_s = 1.67 T, H_c = 4.5 A/m, μ_e = 15,848 at 1 kHz); (2) Enhanced heating rates increased α-Fe nucleation density, yielding finer grains (average diameter < 15 nm) through restricted growth. This microstructure refinement reduced magneto crystalline anisotropy, leading to significantly improved magnetic characteristics (B_s = 1.8 T, H_c = 2.06 A/m, μ_e = 19,027); (3) Kinetic analysis of non-isothermal/isothermal crystallization revealed that increasing the Nb/Si ratio decreased the α-Fe(Si) phase nucleation activation energy (E_{x1}) from 304 kJ/mol to 267 kJ/mol, while elevating the $Fe_3(B,P)$ phase formation activation energy (E_{x2}) from 446 kJ/mol to 600 kJ/mol. These dual effects synergistically promote α-Fe(Si) nucleation while suppressing $Fe_3(B,P)$ precipitation, thereby extending the optimal annealing window. This study establishes a viable pathway for optimizing both processing flexibility and magnetic performance in NANOMET-type alloys, potentially accelerating their industrial implementation.

Glass-Forming Ability of Cu-Ag Eutectic Alloys

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Alloys near the eutectic point generally exhibit superior glass-forming ability, and exploring high-glass-forming alloys based on eutectic reactions has become one of the guidelines for designing metallic glass compositions. However, due to the poor glass-forming ability of pure metals and low-concentration alloys, along with the experimental challenges in synthesizing metallic glasses, a quantitative relationship between glass-forming ability and alloy composition across the entire binary eutectic system has not yet been established. In this study, Cu-Ag binary eutectic system alloys are investigated using molecular dynamics simulations to systematically analyze their glass-forming ability and the structural and dynamical properties of the melts as functions of temperature. The results reveal that for hypoeutectic alloys (with Ag as the solute) and hypereutectic alloys (with Cu as the solute), the critical cooling rate R_c (K/s) for forming glass follows an exponential decay with increasing solute content x (at%): $R_c = A\exp(-kx)$, where $A = 4.61\times10^{12}$ and $k = 0.25$ for the Cu-rich side, and $A = 4.43\times10^{12}$ and $k = 0.19$ for the Ag-rich side. The R_c value of the eutectic alloy is approximately 8.5×10^{7} K/s, which is about five orders of magnitude lower than that of the pure components. The optimal glass-forming ability of Cu-Ag alloys near the eutectic composition arises not only from their lowest liquidus temperature and highest glass transition temperature but also from their atomically closest-packed melt structure and slowest melt dynamics under identical undercooling conditions.

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Creep and Cyclic Tensile Behaviors and Structural Evolution Mechanisms of Metallic Glasses

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Microstructural heterogeneity, an intrinsic characteristic inherent to metallic glasses, persists as a critical research focus in advanced materials science. Nevertheless, establishing fundamental correlations between this structural heterogeneity and mechanical properties remains a formidable challenge in amorphous materials research. This study investigates the creep and cyclic tensile behaviors of metallic glasses, along with their deformation mechanisms, utilizing dynamic mechanical analyzer (DMA). The results demonstrate that under elastic cyclic tensile loading near the glass transition temperature—at stress levels far below the yield strength—the defect concentration in metallic glasses gradually decreases until reaching a steady state. The evolution of ratcheting strain aligns with creep strain under mean stress, while enhanced structural homogeneity induced by creep aging further confirms the microstructural evolution during cyclic loading. By employing a modified hierarchically correlated creep model, the time-dependent anelastic deformation component and microscopic evolution mechanism are elucidated. Qualitatively determining the intensity ratio between two deformation mechanisms during deformation facilitates distinguishing the forms of β relaxation (single peak, shoulder, or excess wing), thereby revealing the intrinsic characteristics of different types of metallic glasses. This approach aids in identifying structural aging and rejuvenation states of metallic glasses and clarifies the role of various processing techniques in regulating their thermodynamic behaviors and structural evolution.

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Phase transformation and mechanical properties of silicide-strengthened $(TiZrHfNb)_{100-x}Si_x$ (x=0, 1, 5, 7, 10 and 15) high entropy alloys

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Refractory high entropy alloys (RHEAs) mainly based on refractory elements are developed for high temperature applications because of their high melting temperatures, high-temperature structural stabilities, and their resistance to heat softening [1-2]. However, those RHEAs with better resistance to heat softening such as MoNbTaW, exhibit room temperature brittleness [3], while their counterparts with excellent tensile ductility inversely suffer from rapidly softening at elevate temperature [4].

Ceramic phases including silicide are commonly introduced to RHEAs to enhance the resistance to heat softening [5]. However, the formation of silicide severely deteriorates room temperature ductility in spite of improved high-temperature performance. From this aspect, it is reasonable to choose a ductile RHEA as the prototype alloy to form silicide strengthened composite materials, so as to balance room temperature ductility and higher resistance to heat softening. Nevertheless, in addition to form silicide, Si has been confirmed to promote the precipitation of brittle intermetallic phases in these RHEAs with higher Al content [6-7].

Therefore, the ductile equimolar TiZrHfNb RHEA with good stability is selected to form silicide strengthened $(TiZrHfNb)_{100-x}Si_x$ (x=0, 1, 5, 7, 10 and 15, in at. %) alloys. The addition of 1% Si could result in the formation of silicide during solidification. The microstructure and the type of silicide show strong dependence on Si content. The former changes from hypoeutectic to hypereutectic as the Si content increased from 1% to 15%, while the latter evolves from M_3Si silicide to tetragonal-M_5Si_3 silicide, and finally to the co-existence of both tetragonal- and hexagonal- M_5Si_3 silicide. The metastable M_3Si silicide transfers to tetragonal-M_5Si_3 silicide after homogenization annealing. The formation of silicide significantly improves high temperature mechanical performance at 800°C and 1200°C. The annealed 5% and 10% Si-alloyed samples possess reasonable tensile ductility at ambient temperature, while exhibit good balance of strength and plasticity at 1200°C. The finding indicates the possibility of developing silicide-strengthened RHEAs with good balance between room temperature ductility and resistance to heat softening, yet a systematical investigation on fabrication methods and heat treatment is further required.

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A remarkable inversion of oxidation rate and unique oxide morphology of $Cu_{60}Zr_{40}$ metallic glass at 100-300 ºC

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Metallic glasses (MGs) possess unique mechanical, physical, and chemical properties [1], while oxidation resistance is one of the most critical prerequisites for ensuring precise processing and environmental stability under service conditions [2]. Therefore, it is crucial to investigate oxidation behavior of MG under different environmental conditions for optimizing the performance in practical applications [3]. However, an observable change of oxidation rate was reported in $Cu_{66}Zr_{34}$ MG at temperature much below the glass transition temperature (T_g), which could not be interpreted by the common oxidation mechanism at temperatures near T_g [4].

In this study, the oxidation of the $Cu_{60}Zr_{40}$ MG in air was investigated over the temperature range of 100-300 ºC, and a complex, non-monotonic oxidation behavior was observed. Particularly, the sample oxidized at 250 ºC possessed the slowest oxidation rate given the fact of the thinnest oxides layer, indicating an inversion of the oxidation rate as function of oxidation temperature. This unique behavior is accompanied by topography change of the oxides on the surface and transition of the oxidation kinetics between parabolic and linear growth models. A large density of alternatively distributed zirconium oxide and metallic Cu-enriched sublayers formed at $T \leq 200$ ºC, while the amorphous zirconium oxide layer transferred to a stable crystalline state at $T > 250$ ºC. The accelerating effect of the segregated Cu layers aligning with the poor protection capacity of the crystalline zirconium oxide should be responsible for the remarkable inversion of the oxidation rate of this glassy alloy.

Meanwhile, the topography of the oxides on the surface and the cross-sectional morphology of the oxide layers were also discussed in detail. The oxides on the surface proceeded from oxide islands to volcanic caldera structures, and finally transformed to flower-like structures at temperatures below 200 ºC, which again changed to different-sized hemispherical particles at 250 ºC and above. And, the cross-sectional morphology simultaneously changed from alternatively distributed zirconium oxide and metallic Cu-enriched sublayers to vertically aligned oxides.

Overall, an inversion of the oxidation rate and a unique oxide morphology were observed and explained, providing valuable insights for making MGs a potential candidate for structural and functional applications.

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Unique deformation mechanisms in an FCC/BCC dual-phase high entropy alloy at high temperatures

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Dual-phase high entropy alloys (HEAs) are renowned for their favorable balance of strength and ductility at ambient conditions. However, their mechanical properties, especially the associated deformation mechanisms at elevated temperatures, remain less explored. In this study, a new high entropy alloy AlCoCrFeTi0.5Ni2.5 consisting of FCC (i.e., L12) and BCC (i.e., B2 + A2) phases with nearly equivalent volume ratio was developed using valence electron concentration (VEC) principle, and this HEA was then subjected to compressive test at elevated temperatures ranging from 500 to 800°C. The results demonstrate that this HEA exhibits excellent high-temperature mechanical properties up to 700 °C, superior to most refractory HEAs and Ni- superalloy. Notably, its yield strength surpasses 1000 MPa, with pronounced strain-hardening evident at 600 °C. Upon reaching 700 °C, despite strain-softening occurring at the late deformation stage, the yield strength remains above 900 MPa. Microstructural analysis of the sample deformed at 600 °C indicates that stacking faults and deformation twins forms in the FCC phase, while martensitic phase transformation occurs in the BCC phase. It is revealed that the high-temperature twins in the FCC phase are triggered by the pre-existing local chemical ordered domains, while the martensitic laths in the BCC phase are activated via stress-induced phase transformation driven by stress concentration at the B2/A2 interface. The synergistic effect of multiple deformation mechanisms co-operating in both the FCC and BCC phases significantly enhances the strain-hardening capability, contributing to the remarkable mechanical properties at elevated temperatures. These findings provide valuable insights for developing dual-phase HEAs with outstanding mechanical properties over an extensive range of temperatures

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Achieving ultra-strong and ductile CoNi-based FCC multi-principal element alloys via alloying with Mo and W refractory elements

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FCC single-phase multi-principal element alloys (MPEAs) often suffer from insufficient strength, which limits their wide applications. Here a CoNi-based FCC MPEA (Co44Ni44Mo9W3, at.%) was designed by alloying with Mo and W refractory elements. The alloy possesses an ultrahigh yield strength of ~1050 MPa and good ductility of ~30 % at ambient temperature. The excellent mechanical properties were correlated to its superior lattice friction stress and grain boundary strengthening compared to most reported FCC MPEAs and conventional alloys. By density functional theory calculations, such extraordinary mechanical properties were further attributed to its high lattice distortion, low intrinsic stacking fault energy and high unstable stacking fault energy due to the synergistic addition of Mo and W. Transmission electron microscopy investigations revealed that the high ductility arises from the synergistic effect of planar slip bands, Lomer-Cottrel locks, along with stacking faults and deformation nano-twins.

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Effects of melting processing on the characteristics and structure of microporous metal-organic framework ZIF-62 glasses

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MOFs glasses are novel materials that can be obtained from the parent metal-organic framework (MOF) crystals. Among the different MOFs, ZIF-62 are structurally amorphous isotropic materials with a coordination network of metal Zn nodes and organic ligands as a frozen-in liquid. Furthermore, in the glassy state, ligand-metal-ligand bonds are maintained, with intermediate coordination networks. ZIF-62 glass (a_gZIF-62) has a high specific surface area, unique topology and structural tunability and is typically more chemically and thermally stable than most of the other various MOFs. When applied to gas storage, separation, and catalysis, it represents one of the most promising types of novel microporous materials. The framework structure, pore size, surface areas, crystal size and morphology are not the only factors that affect the properties of microporous materials. Controlling the morphology of a_gZIF-62 is therefore crucial, particularly for uses in gas separation and catalysis

Other advantages of MOF-glasses include also their formability and lack of grain boundaries, which is particularly important for homogenous membranes for gas separation and in lithium-ion batteries. The morphology of amorphous MOFs can be also modified to suit the requirements of a particular glass application through a smooth control of the melting conditions.

In this study we evaluated the possibility of influencing the characteristics of a_gZIF-62 through modification of melting conditions. The results obtained can be used as inputs for machine learning to predict the properties of MOFs and to obtain materials with specified properties.

Crystalline ZIF-62 was prepared by the solvothermal synthesis. Glass samples were obtained by in situ melting method, which involved a heating of crystalline ZIF-62 in an Ar atmosphere with precise temperature control (T = 440–470°C), at various holding time (τ = 1–10 min) and cooling rates ($\omega_{cool.}$ = 2–20 K/min). The synthesized crystalline ZIF-62 sample was single-phase material as documented by the powder XRD patterns. The TG results showed that ZIF-62 did not decompose at test temperatures ≤500°C, indicating high thermal stability of those crystals. The glass transition (347°C) and melting temperature (440°C) were determined by the double DSC scanning. The XRD results indicated that the samples still contain a significant quantity of crystalline phase after heat treatment at 440°C, demonstrating that this temperature is insufficient for melting of ZIF-62. Glass samples obtained at 450°C contain a very small amount of impurity ZIF-62 crystalline phase.

The observed CO_2 adsorption-desorption isotherms pronounced capillary-condensation hysteresis loops are caused by non-rigid aggregates of lamellar particles. The shape of these capillary-condensation hysteresis loops on the isotherms in the region of polymolecular adsorption indicated cylindrical and spherical shaped pores. It can be assumed that larger pores are related to the outer surface through narrow necks. The area of the hysteresis loop increases with increasing glass melting temperature, which indicates an overall increase of the porosity. It can be thus assumed that the increasing melting temperature facilitates pore formation during the synthesis.

Thus, this study has shown that melting conditions significantly influence microstructure of a_gZIF-62, and hence its properties. It was found that the optimum melting temperature is 460°C with a holding time of at least 5 minutes, which allows to obtain a homogeneous glass without crystalline inclusions keeping a regular microstructure, which is important for all a_gZIF-62 applications.

Ultra-Fine Nanocrystallization in Fe-Rich FeSiBPNbCu Alloys: Mechanisms and Microstructural Evolution

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The present work unravels the microstructural refinement mechanism of the $Fe_{83}Si_2B_9P_4Nb_1Cu_1$ melt-spun alloy during IR annealing treatment at a moderate heating rate. The developed alloy exhibits an ultra-fine nanocrystalline structure with an average grain size of ≤15 nm and a high nucleation density of α-Fe(Si) in the range of 10^{23} counts/m^3 [1]. Consequently, the refined nanocrystalline ribbon exhibits low magnetic coercivity (8 A/m) combined with a large magnetic flux density (1.68 T).

The origin of the ultra-fine nanocrystallization mechanism was systematically evaluated through a combination of experimental and theoretical models. The selective enrichment of P along the nanocrystal/intergranular amorphous regions during the solute redistribution process forms a core-shell-type chemical arrangement. Energy-filtered TEM and HAADF results confirm the formation of P-rich regions along the nanocrystal/matrix interfaces.

Furthermore, two theoretical models, namely the Cluster Plus Glue Atom model and the thermodynamic PHSS model, were used to explain the enhanced structural stability of the solute-redistributed nanocrystalline ribbons. To confirm the observed mechanism, in-situ TEM heating of the melt-spun alloy was conducted, capturing the fine nanocrystallization behavior.

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Evaluation of hardening and structural change during deformation in as-cast CuZr based bulk metallic glass

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Under imposed stresses, plastic deformation in a crystalline material takes place by the movement of lattice imperfections, i.e. dislocations. As plastic deformation proceeds, the density of dislocations increases and their interaction results in hardening of the material [1]. In amorphous materials like bulk metallic glasses plastic flow is considered to occur in zones that undergoes shear transformation as plastic event. At room temperature the localization of strain leads to the formation of shear bands where a restricted volume shears relative to the surrounding. During plastic flow the structural change within the shear band region leads to softening and is reflected by increased disordering and formation of free volume [2]. This means that during plastic flow bulk metallic glasses show usually strain-softening instead of strain-hardening [3]. Nevertheless, in a few experiments hardening and recovery phenomena were observed using cyclic nanoindentation [4,5].

To comprehend the process of deformation in bulk metallic glasses and to manipulate hardening, specially designed nanoindentation experiments have been carried out on an as-cast CuZr based bulk metallic glass of the composition $Cu_{45}Zr_{45}Al_5Ag_5$. In addition to continuous load-displacement curves, those that include unloading-reloading cycles and creep intervals at defined forces were taken. By unloading-reloading or creep a force overshoot is observed indicating hardening of the bulk metallic glass (cf. Fig. 1). The evaluation of the force overshoot is done with a Python script by calculating the deviation from the elastic line during reloading. In order to improve our understanding, the effect of different parameters like force decrement by unloading, unloading rate, reloading rate as well as total time for unloading, reloading and creep on the hardening have been investigated. The experimental results were also compared with computational modelling based on the shear transformation zone theory [5]. The observed trend of hardening with varying parameters can be qualitatively reproduced by the calculations.

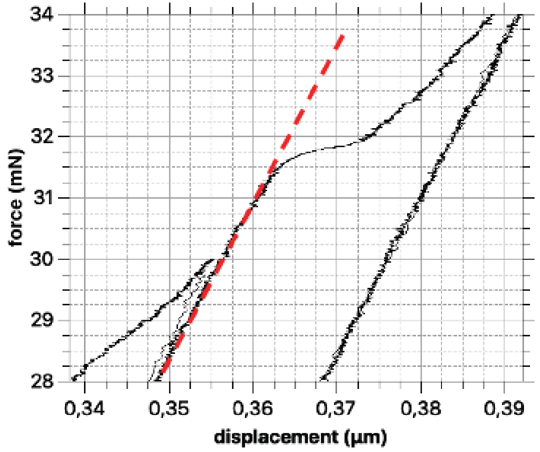

Fig. 1: Force-displacement curve of as-cast $Cu_{45}Zr_{45}Al_5Ag_5$ revealing force overshoot after unloading and reloading. Yielding after reloading occurs at higher force values compared to the yielding point before unloading (30mN). The force overshoot is calculated by the deviation from the elastic line (shown in red).

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Effect of casting conditions on the structure and mechanical properties of bulk metallic glasses

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The mechanical properties of conventional metallic alloys are mainly governed by structural defects such as vacancies, dislocations, and grain or phase boundaries. These defects influence atomic sliding along crystallographic planes, thereby affecting the strength and plasticity. In contrast, the mechanical behaviour of metallic glasses is largely determined by free volume, which serves as the primary site for plastic deformation. The amount of free volume depends on the cooling rate during solidification [1]. Huang et al. [2] demonstrated that mechanical properties vary with cooling rate, which they controlled by casting size. However, multiple factors influence the cooling rate during the casting process [3].

In this study, a $Zr_{52.5}Cu_{17.9}Ni_{14.6}Al_{10}Ti_5$ metallic glass was synthesized and suction-cast into a 3 mm diameter copper mould cavity under different cooling conditions. The mould was water-cooled at temperatures of 12, 22, 32, and 42°C, that corresponds to axial cooling rates of 243, 177, 134, and 90°C s-1, respectively [4]. The amorphous structure of the samples was confirmed using X-ray diffraction (XRD) and scanning electron microscopy (SEM-BSE). Cylindrical samples (3 mm diameter, 6 mm height) were prepared for uniaxial compression testing, with surfaces polished to ensure parallel alignment. Compression tests, conducted at strain rates ranging from 10−4 to 10−1 s−1, revealed enhanced plastic deformation in alloys processed at higher cooling rates (Fig. 1). Additionally, differential scanning calorimetry (DSC) at a heating rate of 20°C min-1 was used to determine the glass transition temperature (Tg), crystallization onset (Tx), and structural relaxation enthalpy. Nanoindentation measurements further established a correlation between cooling rate and hardness.

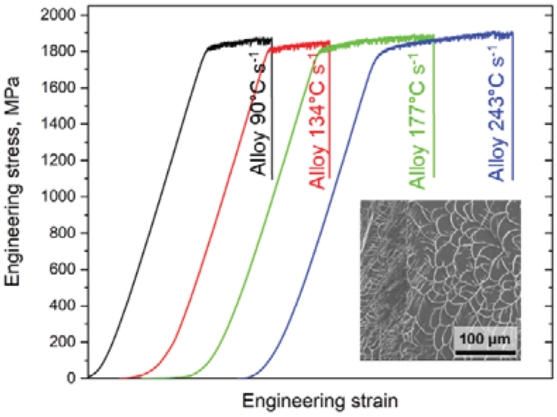

Fig. 1 Compressive stress-strain curves (strain rate of 10^{-4} s^{-1}) of $Zr_{52.5}Cu_{17.9}Ni_{14.6}Al_{10}Ti_5$ alloy cast using different cooling rates.

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As-cast Al-Fe-Co-Ni-Cu alloys: microstructure, phase constitution, and oxidation resistance

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High-entropy alloys (HEAs) are advanced metallic materials composed of five or more elements. HEAs have four major characteristics: high entropy effect in thermodynamics, cocktail effect in properties, hysteresis diffusion effect in dynamics, and lattice distortion effect in the structure. As a result of the cocktail effect, the physical and properties of these materials can be efficiently tailored by alloying. The HEAs can have an outstanding mechanical and radiation resistance, thermal stability, and high corrosion resistance. Therefore, the alloys can be utilized as turbine blades and high-speed cutting tools. Additionally, lightweight HEAs may be used in the transportation and structural sectors. In the present work, the microstructure, phase constitution and oxidation behavior of $AlFeCoNiCu_x$ alloys (x = 0.6-3.0) have been studied. The alloys were produced by repeated arc melting of high-purity Al, Fe, Co, Ni and Cu lumps in argon. After re-melting the alloys were rapidly solidified to form cast strips. The phase constitution of the as-cast $AlCoFeNiCu_x$ alloys was examined by room-temperature XRD. The alloys were composed of solid solutions with body-centered cubic (BCC) and face-centered cubic lattices (FCC). The fraction of FCC increased with increasing Cu concentration. The oxidation behavior was studied by isothermal annealing in flowing synthetic air at 1000 °C. The formation of an external protective Al_2O_3 scale has been found. The oxidation kinetics followed a parabolic rate law. The rate constants increased with increasing Cu concentration in the alloys. Scale spallation in the alloys with higher Cu concentration was observed. Spallation facilitated a penetration of oxygen through the scale and promoted the formation of copper oxides. The results are discussed and compared with those of previously studied high-entropy alloys. The oxidation mechanism of the $AlCoFeNiCu_x$ alloys in air is suggested. Concrete conclusions are provided for the design of oxidation-resistant HEAs.

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Additive manufacturing of Ti-Nb-based biomaterial

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β-type Ti–Nb alloys are promising candidates for orthopedic implants due to their excellent biocompatibility and ability to mitigate stress-shielding effects. The present study investigates the impact of laser remelting on material homogenization, defect reduction (including porosity, twins, and dislocation density), Nb diffusion, microstructural evolution, and mechanical properties in Ti-40Nb alloy fabricated via selective laser melting (SLM) of in-situ alloyed elemental powder. X-ray diffraction analysis revealed the presence of both α' and β phases in the as-built and remelted SLM samples. The remelting process created a wider and deeper melt pool which reduced the cooling rate providing sufficient time for Nb diffusion. Scanning electron microscopy (SEM) images of the remelted sample revealed a relatively homogeneous microstructure with reduced porosity, increased grain size and increased size and morphology of α' martensite. Transmission electron microscopy (TEM) analysis also indicated a reduction in dislocation density and twins. The remelted sample exhibited a hardness of 368 ± 13 HV, yield strength of 820 ± 35 MPa, compressive strength of 1480 ± 50 MPa, and an elastic modulus of 33 ± 3 GPa. These results highlight that the remelting process effectively maintained a desirable combination of low modulus and high strength, with enhanced Nb diffusion and reduced internal and external defects. The study suggests that laser remelting is an effective strategy for fabricating homogenized Ti-40Nb alloys from elemental powders through in-situ alloying, offering significant potential for orthopedic applications.

Synthesis and characterization of soft magnetic metallic glass nanoparticles *via* laser ablation

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Metallic glass nanoparticles (MG NPs) are highly promising materials for various industrial and technological applications, where the distinct mechanical [1] or catalytic [2] properties of each constituent metal are combined within a single nanoparticle [3-5]. Laser ablation in liquid (LAL) for metallic glasses is challenging, especially when the metallic glass undergoes crystallization even at high cooling rates. In this research, metallic glass nanoparticles are prepared from two different glass-forming alloys $Fe_{82}Si_5B_{10}P_3$ and $Fe_{75}Co_8Si_4B_{13}$, in water and in two organic solvents, ethanol and acetone. An in-depth analysis of the structure and elemental distribution of the obtained nanoparticles, down to the single-particle level, was conducted using advanced transmission electron microscopy (TEM), energy-dispersive X-ray spectroscopy (EDX), X-ray diffraction (XRD), and X-ray photoelectron spectroscopy (XPS) methods. This analysis revealed an amorphous phase and the presence of oxide layers. Additionally, in-situ carbonization through the decomposition of solvents further stabilizes the alloy system, enabling the successful achievement of the amorphous phase in the NPs. The carbon-rich molecules in solvents enhance the relative fraction of MG-NPs, and the completion kinetics of oxygen lead to the formation of Fe oxide. Further magnetic measurements confirmed the contribution of MG and Fe oxide NPs to the magnetism. This work presents a novel approach to producing magnetic MG-NPs for advanced multifunctional applications.

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Fabrication of multicomponent nanoporous metallic materials by vapor phase dealloying

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Nanoporous metallic materials based on 3d transition metal (TM) may be considered as a replacement for noble metal-based catalysts for ORR and HER. Unlike noble porous alloys, which can be obtained by chemical or electrochemical dealloying of more active components (non-noble metals) from precursor alloys, the fabrication of porous TM-based alloys by using these methods faces significant challenges. Active TM has a tendency to be dissolved or oxidized during chemical or electrochemical etching. A very promising method for the fabrication of TM-based alloys is vapor-phase dealloying (VPD), which utilizes large differences in saturated vapor pressures between constituent elements. According to the VPD method, the component with a high partial vapor pressure (Zn, Mg, Ca) can be selectively removed from an alloy precursor.

Porous Co-Cu, Ni-Cu, Ni-Co-Cu, Mn-Fe-Co-Ni-Cu alloys were fabricated by eliminating Zn from the precursor alloys with Zn content in the range from 60 to 82 at. % using the custom-built VPD system [1]. As-quenched ribbons and slices obtained by wire-cutting electrical discharge machining of ingots were used as precursor alloys. All fabricated materials contain copper, which has been added to enhance the ductility of both as-quenched ribbons and slices. The XRD studies point out the formation of several FCC solid solutions of TM with a small amount of ZnO or MnO. Porous alloys have a spongy microstructure with a wide pore size distribution (Fig.1). The surface area of these metallic materials was estimated from 2 to 17 m^2/g by the multi-point BET method using N$_2$ adsorption/desorption experimental data. It is also demonstrated that porous high-entropy alloys composed of TM can be fabricated from as-quenched ribbons using the VPD [2].

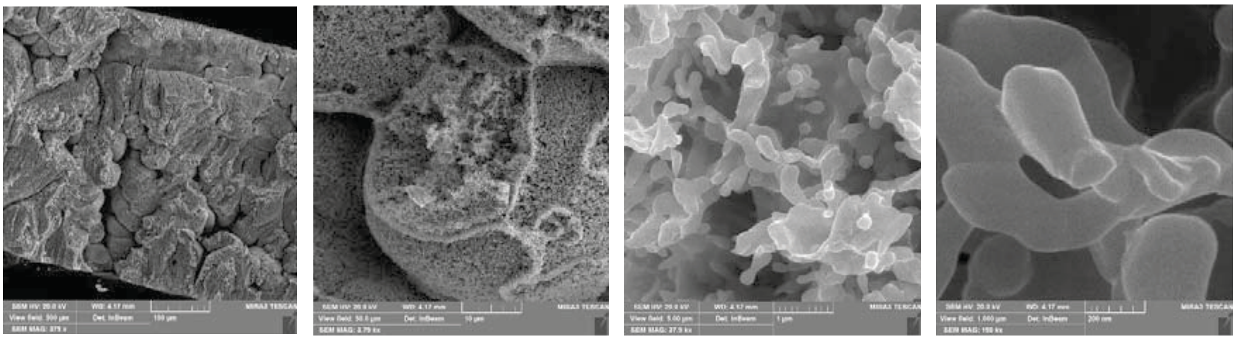

Fig.1 SEM micrographs of the cross-sections of porous Co-Ni-Cu alloy fabricated from the TM-Zn precursor slice by VPD at different magnifications.

The results of electrocatalytic activity studies using linear sweep voltammetry methods indicated that fabricated porous materials with high Co and low Ni content demonstrate the best activity in the HER, and the materials with low Co and high Ni content are suitable for the OER.

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Influence of remelting in PBF-LB of KUAMET®6B2

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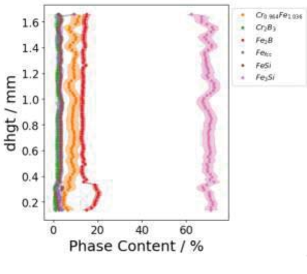
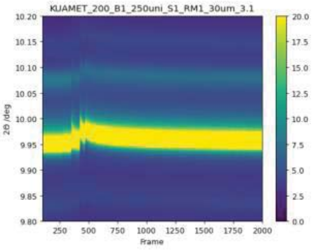
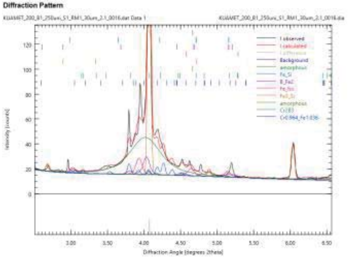
Reducing energy losses is a key requirement in developing soft magnetic materials. Among the bulk metallic glass (BMG) systems, Fe-based BMGs are most attractive for engineering applications due to their low raw material cost, excellent magnetic properties, ultrahigh strength, and good corrosion resistance[1]. Fe-BMGs exhibit a high saturation magnetization, low coercivity, and low magnetostriction, and a relatively low conductivity[2]. In recent years, interest has focused on nanocrystalline soft magnetic alloys, whose magnetic properties benefit from their chemical and structural variations at the nanoscale. Nanocomposites can be engineered with distinct advantages over amorphous alloys in high-temperature stability and saturation magnetization, making them superior candidates for long-term operation[3]. Nanocrystalline commercial alloys are produced by annealing an amorphous alloy under optimal annealing time, annealing temperature, and heating rate to precipitate α-Fe [4]. Unfortunately, the nanocrystalline Fe- BMG's suffers from extreme embrittlement. Thus, they must be annealed in the final core geometry and handled very carefully. In recent years, the possibility of additive manufacturing of metallic glasses has drawn much attention, overcoming the geometrical restrictions of traditional manufacturing techniques. This technique provides high heating and cooling rates, making it suitable for producing metallic glass parts with dimensions much bigger than their critical casting diameter. Besides the high heating and cooling rates, the layer-by-layer construction of the part results in a complex heat treatment of the preceding layers, often leading to severe crystallization and cracking. To overcome this issue, multi-scanning techniques have been proposed to enhance amorphous content, reduce residual stresses, and enhance chemical homogeneity [5,6]. In the current study, we take a closer look at the effects of reheating on KUAMET®6B2 Fe72.6Si11.3B10.9Cr2.2C3.0 (at%), by investigating the stresses and structural changes in situ, utilizing a mini-PBF machine and high-energy synchrotron radiation at the European Synchrotron Radiation Facility ESRF, paired with a high-framerate detector.







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Medium-range atomic correlation and local chemical order in metallic glasses

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The compositional atomic order in metallic glasses is investigated through simulations, with a particular focus on medium-range order (MRO). Many metallic alloy liquids and glasses exhibit MRO, characterized by oscillations in the atomic pair distribution function (PDF) beyond the first peak, with an exponential decay over distance. To explore the influence of local chemical order on MRO, we analyze the compositionally resolved PDF and its MRO behavior across various binary metallic alloy glasses. Our findings reveal that compositional ordering is predominantly confined to nearest-neighbor atoms, while MRO remains largely insensitive to compositional order. These results reinforce the perspective that MRO oscillations in the PDF primarily reflect atomic density fluctuations rather than detailed local atomic configurations. Our study enhances the fundamental understanding of atomic-scale structural characteristics in metallic glasses by demonstrating the universal nature of MRO. These insights provide valuable guidance for tailoring the atomic structural organization of metallic glasses, which is essential for optimizing their physical properties.

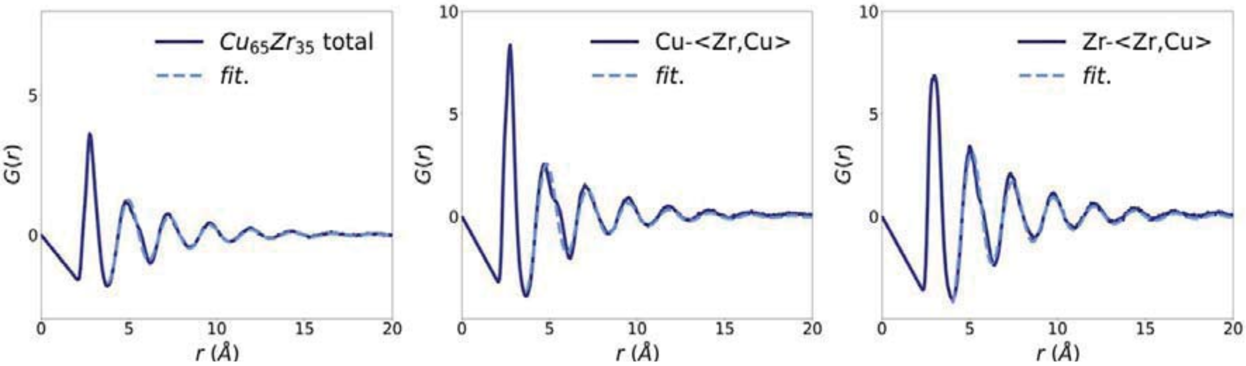

Figure 3 The total and differential PDFs for $Cu_{65}Zr_{35}$ glass. The dashed lines represent the fitted curves highlighting the medium-range order.

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Analysis of Deformation Behavior of Zr-Cu-Al Bulk Metallic Glass with Gradient Relaxation Structure by Digital Image Correlation

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The authors have been studying on controlling the relaxation state of metallic glasses. Recently, we have reported that a structural rejuvenation, i.e., getting back a less relaxed state, can be obtained using a simple thermal treatment consisting of low-temperature annealing just over T_g followed by quenching [1-3]. It is suggested that this thermal rejuvenation is very effective from the perspective of recovering the good mechanical properties lost by relaxation. As a result, density decrease, mechanical softening and improved plasticity as well as local structure change could be actually confirmed [4,5].

Furthermore, we developed a new method to tailor the rejuvenation state precisely, leading to the formation of 2D or 3D-controlled gradient glassy structure [6,7]. We found that the metallic glass with the 2D-gradient rejuvenation structure exhibits a unique deformation process with a significant ductility and apparent work hardening behavior [6]. It is due to anomalous shear band evolution and propagation behavior, however the detailed mechanism has not been clarified yet. In this study, the mechanism of deformation behavior in the Zr-Cu-Al bulk metallic glass with the gradually changed glassy structure is discussed using a digital image correlation (DIC) analysis. It is believed that the results obtained bring beneficial information for improving ductility and industrial application of metallic glasses.

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Investigating the Formation Condition of Amorphous Solid

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The formation of amorphous alloys can occur through various methods, which can be structurally categorized into transformations from disorder to disorder, such as the preparation of amorphous materials from the gaseous state through condensation, and the preparation of glass by rapid cooling of the liquid state. Another type is the transformation from order to disorder, which refers to the preparation of amorphous solids starting from a crystalline structure by introducing external forces. Both methods can be attributed to the study of amorphous formation conditions under the action of external fields, as shown in Figure 1. In this report, the presenter will introduce their work progress in the formation of amorphous under external fields [1-2]. From a theoretical analysis perspective, the micro-mechanism of the influence of external fields on the ability to form amorphous will be discussed, and feasibility analysis along with specific implementation strategies to enhance amorphous formation ability will be provided. This aims to offer theoretical guidance and reference for better utilization of external fields to control amorphous formation in experiments.

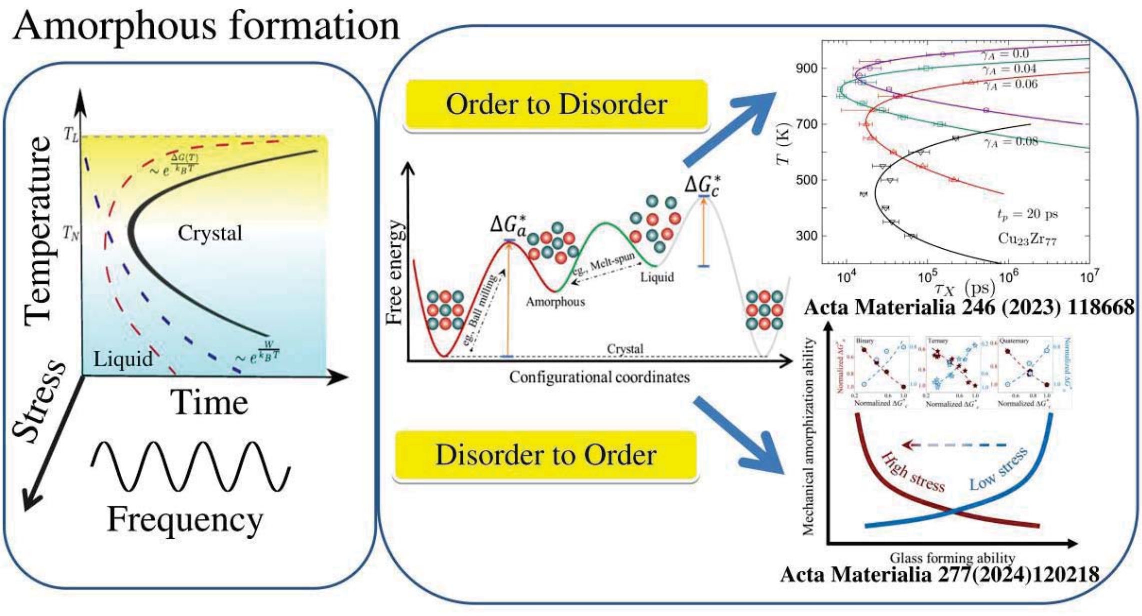

Figure 1: The Amorphous formation process

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Effects of Ni addition on the magnetic and structural properties in Fe-Si-B-Nb alloy by different casting techniques

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Amorphous soft-magnetic materials play an important role as core constituents in improving the energy transformation efficiency of electrical machines and passive electrical components [1]. Although the melt-spinning process remains one of the main techniques for obtaining amorphous soft-magnetic ribbons, new and efficient production methods based on additive manufacturing have been developed in recent years. These techniques allow us to overcome technical limitations characteristic of casting processes and to print complex 3D geometries [2].

The aim of this work is to investigate the interplay between magnetic and structural properties of Ni addition to Fe-Si-B-Nb alloy produced by different casting techniques such as rapid solidification, suction casting and selective laser melting. It has been reported that the addition of nickel (Ni) to Fe-Si-B-Nb BMGs has shown significant improvements in both their soft magnetic properties and plasticity. Fe-based BMGs that incorporate Ni exhibit a good glass forming ability (GFA), reasonable soft magnetic properties, and improved mechanical performance [3].

Ribbons were obtained by a conventional melt-spinning process, in which the pre-alloy was first inductively melted in a quartz tube equipped with a nozzle and then injected under vacuum onto a rotating copper wheel by insufflating high-purity Ar. On the other hand, the 3D printed cubic samples were obtained by additive manufacturing via Selective Laser Melting using powder of the same alloy as precursor.

X-ray diffraction (XRD), differential scanning calorimetry (DSC), and differential thermal analysis (DTA) have been used to characterize the structure and thermal behavior of the samples. Room temperature DC hysteresis loops of ribbons and all printed samples were measured by a vibrating sample magnetometer. AC magnetic characterization has been performed on ribbon samples to evaluate the energy loss behavior with frequency. Ribbon samples have been annealed in a vacuum furnace below the crystallization temperature to release the quenched in stress.

The GFA of the ribbons has been studied by evaluating the critical casting thickness yet granting amorphous structure according to the XRD data. The GFA of the plates is improved, as testified by an increase of the thickness value, from 800 μm to almost 1000 μm, able to maintain the amorphous structure upon the addition of 2 at. % Ni to Fe-Si-B-Nb alloy. The notable enhancement in GFA proves the beneficial impact of Ni incorporation on the alloy's compositions. A small reduction in saturation magnetization (J_S) and coercive field (H_C) has been observed with addition of 2 at. % Ni for the as cast ribbons. Furthermore, the soft magnetic properties improve significantly in the form of reduced coercivity and energy losses after annealing.

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Frontiers of Amorphous Materials: Metallic glass thin films, microfibers and bulk systems for biomedical applications

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Metallic glasses represent a groundbreaking material class where crystallization is suppressed during solidification, resulting in a disordered atomic structure. Their exceptional properties, including high strength, biocorrosion resistance, and tunable conductivity, make them valuable for diverse applications such as structural components, biomedical systems, and electromagnetic shielding. Our group works on harnessing the potential of metallic glasses across diverse applications, including their use in flexible electronics, structural materials, and biomedical technologies. we have fabricated Fe-based[1] and Co-based[2] metallic glass microfibers with exceptional mechanical and electromagnetic properties. Nanoindentation tests revealed very high hardness (11.31 ± 0.60 GPa) and elastic modulus (110.54 ± 11.24 GPa), positioning them as mechanically robust materials. These fibers also demonstrated anisotropic electromagnetic interference (EMI) shielding, with up to a 25-fold attenuation increase in the Ku frequency band, making them ideal for advanced electronics and aerospace geometries.

In the biomedical field, we have discussed different metallic glass systems for their application as antibacterial coating, dental and orthopedic implants. First, we have presented a series of different compositions of Zr-Cu-Ag ternary metallic glass thin films showing a superhydrophobic nature measured by both dynamic and static water contact angle measurements leading to a ≈ 95% antibacterial activity[3]. In another system, we have introduced five new biocompatible Ti-based metallic glass compositions with different metalloid and soft metal content for a synergistic improvement in corrosion properties. Without any potentially harmful elements such as Cu, Ni or Be, these novel alloys can eliminate the risk of inflammatory reaction when utilized for permanent medical implants[4]. Moreover, bulk $Ti_{40}Zr_{10}Cu_{36}Pd_{14}$ metallic glass as dental implants were investigated for its performance in the inhabitation of oral biofilm formation in comparison with the gold standard Ti-6Al-4V implant material. The antibacterial properties were verified towards the oral pathogen Aggregatibacter actinomycetemcomitans responsible for oral biofilm formation. After 24 h of direct infection, metallic glasses reported a >70% reduction of bacteria viability and the number of viable colonies was reduced by ~8 times[5]. We have further used thermoplastic forming on $Ti_{40}Zr_{10}Cu_{36}Pd_{14}$ metallic glasses and studied its effect on the cytocompatibility[6].

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Heterogeneous lamella structure induced precipitation-hardened Fe-rich complex concentrated alloys

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Developing materials with enhanced strength and ductility synergy is a vital requirement for most engineering applications for enhanced engineering reliability and energy efficiency [1]. However, achieving these two properties simultaneously is generally exclusive. The alloy design approach of complex concentrated alloys in a multi-component space with the concept of increased configurational entropy has provided new avenues with lots of opportunities [2,3]. In the present work, we have designed a series of Fe-rich, non-equiatomic alloy compositions by following the semi-quantitative method based on the CALPHAD approach. The composition of the alloy is selected in such a way that it leads to the formation of a precipitation-hardened microstructure of FCC (matrix phase) and B2 and $L1_2$ as the precipitates phase. The alloys are prepared through arc melting and further subjected to homogenization and cold rolling treatment. The solution-treated alloys were aged at 600, 700, and 800 °C at different holding times to understand the precipitation kinetics and microstructure evolution. The $L1_2$ phase takes the lamellar shape in the FCC matrix and is distributed at different length scales. The heterogeneous precipitation of the $L1_2$ phase in the FCC matrix helps in achieving an excellent combination of room-temperature mechanical properties. The yield and ultimate tensile strength of the developed alloys are ~ 1GPa and ~1.4 GPa, respectively, with an appreciable ductility of ~ 20 %. The high content of Fe shows excellent cost performance and mass density, along with the possibility of overcoming the strength ductility trade-off.

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Novel antibacterial Ti-Based Alloys for Biomedical Applications

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Ti-based alloys are widely studied for biomedical implant applications due to their high strength, low elastic modulus, superior corrosion resistance, and excellent biocompatibility [1]. However, the limitations associated with them, including stress shielding and implant infection, remain [2, 3]. To address these issues, recent research focuses on developing Ti-based alloys incorporating antibacterial agents (Cu, Ag) in the composition . In this study, three novel Ti-based alloys adding Cu and Ag were synthesized: $Ti_{40}Zr_{25}Cu_{20}Pd_5Fe_{10}$, $Ti_{40}Zr_{25}Cu_{20}Pd_5Ag_{10}$, and $Ti_{40}Zr_{25}Cu_{20}Pd_5Ag_5Fe_5$. Bulk alloys were manufactured by arc melting followed by melt spinning for the formation of metallic glass ribbons. Their microstructure, thermal stability, mechanical properties, corrosion resistance, and antibacterial performance were systematically characterized. Scanning Electron Microscopy with Energy Dispersive X-ray Spectroscopy (SEM-EDX) confirmed the homogeneity of the elemental distribution. X-ray diffraction (XRD) analysis revealed that the addition of Ag promoted an amorphous structure in $Ti_{40}Zr_{25}Cu_{20}Pd_5Ag_{10}$ and $Ti_{40}Zr_{25}Cu_{20}Pd_5Ag_5Fe_5$, whereas $Ti_{40}Zr_{25}Cu_{20}Pd_5Fe_{10}$ exhibited partial crystallinity. X-ray photoelectron spectroscopy (XPS) was performed to evaluate surface chemical states after immersion in Hank’s Balanced Salt Solution (HBSS) and electrochemical analysis. Differential scanning calorimetry (DSC) was used to assess the thermal behavior of the alloys. Electrochemical analysis demonstrated that the potentiodynamic polarization curves of all three alloys in HBSS displayed excellent corrosion resistance, a critical property for biomedical implants exposed to physiological environments. Based on nanoindentation analysis, the average elastic modulus/hardness for $Ti_{40}Zr_{25}Cu_{20}Pd_5Fe_{10}$, $Ti_{40}Zr_{25}Cu_{20}Pd_5Ag_5Fe_5$, and $Ti_{40}Zr_{25}Cu_{20}Pd_5Ag_{10}$ are 90.8/7.49 GPa, 93/7.86 GPa, and 97.1/8.04 GPa, respectively. Although increasing Ag content raised the elastic modulus and hardness, all three synthesized alloys exhibited acceptable mechanical properties compared to similar compositions in previous studies [4, 5]. The antibacterial efficacy of the alloys was evaluated by challenging them against *Staphylococcus aureus* by direct contact for 2h. $Ti_{40}Zr_{25}Cu_{20}Pd_5Ag_{10}$ and $Ti_{40}Zr_{25}Cu_{20}Pd_5Ag_5Fe_5$ demonstrated superior antibacterial activity, likely due to Ag ion release, compared to the control sample ($Ti_{40}Zr_{25}Fe_{25}Pd_{10}$). The combination of enhanced antibacterial properties, improved mechanical performance, and superior corrosion resistance makes these Ti-based alloys promising candidates for biomedical applications, particularly in the development of structural materials for hard tissue replacements, dental implants, and artificial joint implants.

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Geometrical porometry as a method for calculating the free volume of condensed systems

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The concept of free volume has not lost its importance for almost a hundred years to explain phase transformations and transport properties of condensed systems. Bachinsky's works [1] had already concluded that the viscosity of liquids is related to the free volume. This theory was later developed in the studies of Turnbull and Cohen [2, 3]. The free volume theory is still used to explain many physical phenomena. Particularly, the free volume theory is used to explain the formation of amorphous alloys and diffusion in inorganic and organic disordered systems [4, 5]. Despite this, there is currently no reliable method for studying interatomic voids with high accuracy.

Most common methods for studying the free volume in condensed systems are both experimental and those based on computer simulations. Experimental methods include the study of positron annihilation and the method of X-ray diffraction analysis. However, these methods only allow to calculate the average values of the free volume without the possibility of analyzing the individual characteristics of the interatomic voids. These restrictions of experimental methods can be overcome by using computer simulations at the atomic level. As a result of computer simulation, the atomic positions can be obtained, which can be used to detect interatomic cavities. The most common among these methods are the method of statistical and geometric analysis [6] and the marching cubes algorithm [7]. However, the first of these methods gives overestimated results of the determined free volume, and the second aggregates small cavities into one large combined cavity, so it is inaccurate.

We propose a new method based on the analysis of interatomic voids based on the atomic coordinates obtained by computer modelling. The method is based on filling the cavities between atoms with an ordered array of dots, similar to the gas-liquid porometry method. Therefore, this method can be called the method of geometrical porometry. Further analysis of the distribution of points in the cavities makes it possible to identify voids through which atoms of a certain radius cannot penetrate. The method also allows determining the volume of the voids, the coordinates of their centres of mass, and their spatial distribution. This method can be used for both crystalline and disordered materials.

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Phase-separated Zr-Al-Fe-Y metallic glasses with suitable mechanical properties for possible implant applications

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Research on phase separation in metallic glasses (MGs) is driven by a deep interest in understanding the structure and properties of disordered materials, as well as their potential for structural and functional applications. The structure and physical properties of phase-separated MGs have characteristics different from those of other MGs [1]. Recent reports have demonstrated successful achievements in the preparation of phase-separated MGs, which offer a unique opportunity to design composites or alloys with hierarchical microstructures at different length scales [2].

In this presentation, we will discuss our recent findings on the development of new $Zr_{70-x}Al_{12.5}Fe_{17.5}Y_x$ (x = 0-25 at.%) MGs with nanoscale phase separation and suitable mechanical properties for biocompatible applications [3, 4]. The glasses with $x \geq 10$ show a typical liquid phase separation-induced two-glassy phase (Zr-rich and Y-rich) morphology with droplet-like microstructures (nano-amorphous domains). The size of the domains increases with increasing Y addition. Atom probe tomography (APT) analysis confirms the formation of nanometer-sized Y-enriched clusters for x=15 and 20. The effect of microstructural variation due to phase separation on the mechanical properties was studied using micro- and nano-indentation techniques. The micro-hardness and nano-hardness are found to be in the range of 4.58-5.73 GPa and 5.22-6.11 GPa for the alloys with x = 0-25. The hardness and elastic modulus decrease gradually with the increase in Y content. The Zr-based MGs exhibit Young's moduli in the range of 81-91 GPa, which are lower than that of Co-Cr-Mo, 316L SS and Ti-6Al-4V commercial implant alloys. Evaluation of the cytocompatibility of the MG ribbons reveals high metabolic activity and well-spread human gingival fibroblast (HGF) cells on the surface of x = 10 and 15 samples. Thus, the two glassy-phase Zr-based MGs free of toxic elements (Ni and Cu) exhibit suitable mechanical properties and biocompatibility, making them strong contenders for use in implant applications.

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High Corrosion Resistance and Biocompatible Zr-Based Bulk Metallic Glasses for Load-Bearing Implants

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The distinctive microstructure and exceptional properties of Ni-free Zr-based bulk metallic glasses (BMGs) have garnered significant attention in recent years. The amorphous structure provides good biocompatibility, elevated strength, lower Young's modulus, and elevated fatigue limit. This unique combination of attributes has sparked significant interest in exploring their applications in the biomedical field, for example for use as osteosynthesis devices, and load-bearing implants. However, the majority of recognized Zr-base alloy compositions exhibiting high glass-forming ability (GFA) include metal elements such as Be, Ni, Co, and Cu, which are associated with possible severe allergy reactions. To guarantee long-term safety in human body applications, it is thus essential to create novel Ni-free Zr-based bulk metallic glasses for biomedical purposes. This study aims to design Zr-based BMGs for biomedical applications, focusing on achieving excellent chemical biocompatibility and high corrosion resistance.

Master alloys with different compositions were prepared via arc melting (AM/0.5–Edmund Bühler). Melt-spinning experiments were conducted under a high purity Ar atmosphere (99.9%), with the vacuum maintained at approximately 5×10^-6 mbar. X-ray diffraction (XRD) was performed in reflection mode using Co Kα radiation to analyze the structural properties of the melt-spun ribbons, complemented by TEM imaging and SAED pattern analysis. Differential scanning calorimetry (DSC) was conducted at a heating rate of 20 K/min in an Ar atmosphere. Cytocompatibility was evaluated using human bone marrow-derived mesenchymal stromal cells (hBMSCs) through indirect cytotoxicity assays following ISO 10993 guidelines. Cell viability and metabolic activity were assessed using the Alamar Blue assay and LIVE/DEAD staining, while May-Grunwald/Giemsa staining was employed to observe metal particle internalization.

The XRD patterns shows broad diffraction maxima within $38° \leq 2\theta \leq 50°$, confirming their amorphous structure. The smaller Cu atoms might be replaced with the larger Pd, Pt, and Au atoms with an atomic radius of 0.137, 0.139, and 0.144 nm, respectively, which could lead to such peak shifting in XRD patterns. The ZAFT-Pd alloy exhibits a lower crystallization temperature, likely due to the lower eutectic temperature of the Pd-Zr system. The increased metabolic activity of cells exposed to the ZAFT-Au sample may be attributed to the high corrosion rate of ZAFT-Au, leading to the release of ions that may create a favorable environment for human mesenchymal stromal cells. The electrochemical corrosion results demonstrate superior barrier properties for ZAFT-Pd and ZAFT-Pt alloys due to their stable and passive oxide layer formation. The indirect cytocompatibility results indicate that the samples did not adversely affect the cells' metabolic activity. Samples incubated in culture medium for 1 and 3 days exhibit comparable performance, with no statistically significant differences observed.

In conclusion, this study identifies Zr-Au-Al-Fe-Ti and Zr-Pd-Al-Fe-Ti alloys as promising candidates for biomedical implants. ZAFT-Pd exhibits the highest GFA, supported by its significantly negative PHSS and PHS values and a wide supercooled liquid region. The metabolic activity of cells exposed to alloy supernatants reveals that ZAFT-Au alloys support the highest metabolic activity. These findings contribute to the advancement of Ni-free Zr-based metallic glasses for long-term medical applications, underscoring the importance of optimizing alloy compositions.

W-based metallic glasses for nuclear fusion applications

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Metallic Glasses (MGs) exhibit an impressive set of properties offering high potential to overcome several materials challenges in Nuclear Fusion (NF). Their high mechanical strength and corrosion resistance is combined with high radiation tolerance including possible self-healing of irradiation-induced structural changes. However, materials challenges of NF also include high temperatures and neutron-induced transmutation that can render some of the chemical elements within MG alloys radioactive. Dedicated design of MGs for NF is practically non-existent as seemingly contradicting constraints arise when attempting to reconcile low-activation behaviour with high glass-forming ability [1]. Nevertheless, the high compositional flexibility of MGs is expected to allowthem to be tailored for optimal use in various areas of NF [1]. Here, we present preliminary results of our research on W-based MGs for NF. Outstandingly high hardness for metallic materials has been found in combination with high glass-transition and crystallisation temperatures. We also propose the development of a dedicated roadmap to focus the future efforts for design and application of MGs for a wide range of applications in the NF sector.

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Kinetic and thermodynamic studies of ion-induced gradient rejuvenated amorphous microwires

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Rejuvenation treatments have emerged as an effective strategy to enhance the energy state of metallic glasses (MGs), significantly improving their ductility at room temperature. These rejuvenated MGs exhibit a high free volume content, and ion irradiation has proven to be a particularly effective method for introducing substantial excess free volume to the surface of MGs, thereby elevating their energy states. In this study, we utilized a combination of conventional differential scanning calorimetry (DSC) and flash DSC to quantitatively assess the impact of free volume content on the thermal behaviors of CuZr-based amorphous microwires (AMs) subjected to ion irradiation under continuous heating conditions. Our experimental work established the correlation between transformation phenomena and the time/temperature scales of these AMs across a broad temperature range, from the glass transition temperature to the melting point. By analyzing characteristic temperatures and transformation enthalpy at various positions along the microwires, we were able to determine the energy state and effective cooling rate of the ion-irradiated AMs. This research provides critical insights into the thermal behavior of rejuvenated AMs and offers valuable guidance for the future design of AMs with enhanced free volume content.

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The low temperature relaxation behaviors and their dynamic responses

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As a typical metastable material, relaxation behavior is an intrinsic characteristic of metallic glasses. This non-equilibrium physical phenomenon is closely related to the evolution of their physical and mechanical properties, such as plastic deformation, stress relaxation, thermal stability, and glass transition. However, due to the disordered and complex structure of metallic glasses, characterizing their defects has long been a challenging issue in this field. Consequently, the physical mechanisms underlying relaxation behaviors, the correlations among different relaxation processes, and the relationship between relaxation behaviors remain subjects of ongoing exploration, constituting a core research problem in the study of metallic glasses. We achieved computationally simulated relaxation temperature curves that are consistent with experimental observations, exhibiting smooth and same trends with those in experiment. The computational methods employed include an integrated approach combining molecular dynamics, dynamic mechanical relaxation, and isoconfigurational ensemble simulations. We revealed that dynamic heterogeneity is a key parameter governing low-temperature relaxation behavior, uncovering the dynamical origin of low-temperature relaxation. It further elucidated the dynamical and structural mechanisms behind the low-temperature relaxation peak, supplementing the understanding of ultra-low-temperature relaxation modes. At the microscopic level, we also explained the origin of dynamic heterogeneity from the perspective of flow units, and demonstrated that low-temperature relaxation serves as the precursor to α-relaxation, thereby establishing a connection between the two. Additionally, we explored the interplay among relaxation processes under pressure conditions. From perspectives of atomic physics, percolation, and other physical principles, we investigated the microscopic mechanisms of relaxation behaviors and their interrelationships. This work provides a reliable theoretical foundation for the targeted modulation of low-temperature relaxation behavior in metallic glasses, thereby enabling the modulation of their mechanical properties.

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Characterization of different carbide distributions for a Cr-Co-Ni alloy

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Multi-principal element alloys (MPEAs) or high/medium-entropy alloys are characterized by not having a well-defined solvent. More than a new class of materials, they represent a new conception of alloy design. Among the face-centered cubic (FCC) MPEAs, the Cr-Co-Ni system stands out for having toughness values among the highest ever observed for any engineering material. Additionally, alloying with small amounts of carbon can further elevate this property [1,2]. As such, this study aimed to investigate the effect of C addition to a Cr-Co-Ni alloy and better understand the effect of carbide distribution on the material's hardness and microstructure. To achieve this, the alloys were produced and processed by two different routes: with and without a precipitate dissolution step. In the first case, a heterogeneous dispersion of second-phase particles was obtained, while for the second route, the distribution was homogeneous and more efficient in increasing the final hardness. Characterization was carried out via optical microscopy, scanning electron microscopy (with energy dispersive X-ray spectroscopy), X-ray diffraction, transmission electron microscopy, Vickers micro-hardness and tensile testing. Alongside Hall-Petch (HP) analysis, microstructural characterization revealed almost no precipitation hardening effect for the carbides but a strong HP strengthening effect. In summary, a comprehensive investigation of carbide precipitation (considering different fractions, particle sizes and distributions) within a Cr-Co-Ni FCC matrix was studied. The findings are anticipated to significantly contribute to the understanding and guidance of future processing strategies for high-performance MPEAs.

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Tailoring Microstructures and Tribological Performance in Quasicrystalline-Reinforced Coatings and Surfaces

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Quasicrystals exhibit an interesting range of physical and chemical properties, as low coefficient of friction during sliding against other solids, low surface energy, low thermal conductivity, high hardness, high elastic modulus, and excellent wear resistance, among other attributes. However, quasicrystalline phases are brittle at room temperature, prompting research into composite microstructures that embed them in ductile matrices like Al-FCC. Such aluminum-based quasicrystalline alloys and composites, due to their exceptional physical properties, show great potential as materials for tribological protection applications. However, applications involving these interesting materials are still incipient. One of the main reasons for this lies in the difficulties and costs associated with their fabrication. These phases generally form in narrow compositional regions and are formed through complex reactions which, in general, occur in conjunction with the formation of other intermetallics and which, in the absence of a tough matrix, result in a highly fragile material with little possibility of application. The solution to these issues usually involves the use of rapid solidification methods and/or powder metallurgy, which makes these materials more expensive and restricts their applications. In the present work, the recent advances in our studies regarding Al-based quasicrystalline alloys, focusing on the improvement of their wear resistance while, at same time, aiming at simplifying their fabrication methods, will be presented. It will be shown that different manufacturing methods can be used to produce different microstructures containing quasicrystals and complex intermetallic phases, including conventional casting, spray-forming, high-velocity oxygen fuel, high-pressure torsion, laser remelting and laser cladding. It will be shown that the Al-Cu-Fe-Cr system is one of the most promising quasicrystal-forming systems to be used as protective coatings against wear. Decagonal and icosahedral quasicrystals can form in this system, depending on chemical composition and solidification rates. Additionally, it has been shown that they can be embedded in an Al-FCC matrix by applying both rapid and slow solidification routes, making this a very flexible system in terms of fabrication methods.

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Effect of Nanoimprint-Induced Structural Heterogeneity on the Oxidation Behavior of Zr-Based Metallic Glasses

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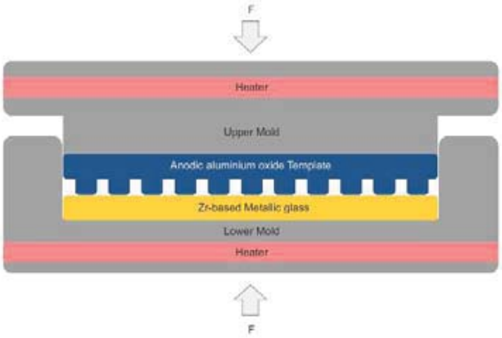
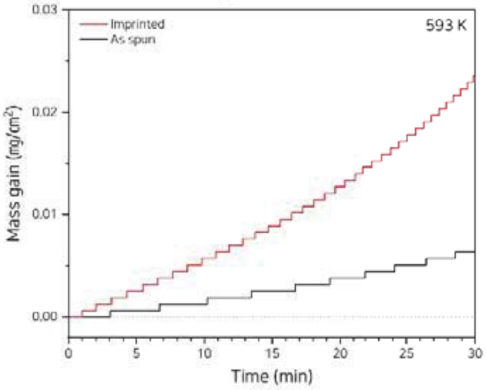
Nanoimprint lithography can modify functional properties such as optical, chemical, and electronic characteristics by creating nanostructures [1-3]. In this study, Zr-based metallic glasses were nanoimprinted to generate zirconia surfaces with catalytic potential. Subsequent oxidation was used to control the thickness and crystalline structure of the oxide film, aiming to enhance functionality. However, unlike the as-spun sample, the imprinted sample exhibited an uneven oxide film under identical heat treatment conditions. This discrepancy appears to be closely linked to shear bands induced by residual stress after demolding. This study will explore the key factors influencing oxidation behavior and potential strategies to mitigate oxide film inhomogeneity.

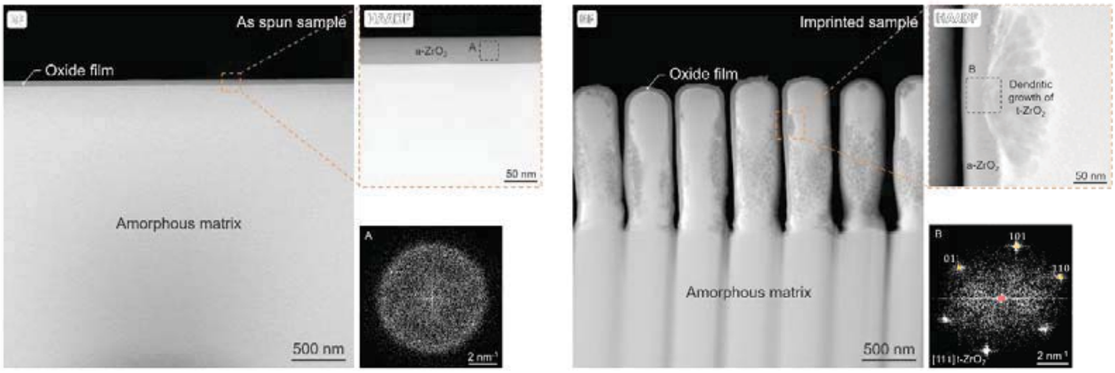
Thermal nanoimprint lithography process



Thermal gravimetric curve



Zirconia film formed on the sample oxidized at 593 K for 30 minutes



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Interface asymmetry and phase transformation of the Cu layer-inserted Al/Cu/Ni/Cu multilayers

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Al/Ni multilayers, as a type of nanoscale multilayers exhibiting a self-propagating reaction, have attracted great attention due to a fairly large enthalpy of reaction, high energy release rate, fast combustion, relatively inexpensive, and readily available through those physical vapor deposition techniques and mechanical processing [1]. These advantages are of interest as heat sources for bonding and joining, ignitors, and thermal battery [2-3].

Interfaces with intensive mixing of elements could be observed in the Al/Ni multilayers fabricated by magnetron sputter-deposition [4-5]. The intermixing reduces stored chemical energy and reaction rate, especially for those multilayers with modulation period less than 25 nm [6]. How to regulate interface structure to diminish the detrimental effect but retain self-sustaining reaction is highly important for the applications.

Thin Cu layers are inserted at the interfaces of initial Al/Ni binary multilayers during magnetron deposition to form the $(Al/Cu/Ni/Cu)_4$ (ACNC) multilayers. The effects of thin Cu layers on interface structure, atomic diffusion, and phase transformation were studied. TEM results confirmed the asymmetric interface structure and distinct interdiffusion between Cu and Ni of the as-deposited ACNC multilayers. CuAl2 preferentially formed but totally disappeared at higher temperatures. The integrated and dense Ni/Cu/Al interfaces (Cu deposited on Al layer followed by an upper new Ni layer) in the middle and upper Al layers strongly hindered the diffusion at early stage, which suppressed the formation of Al3Ni in a large scale but did not change the phase composition at 773K compared to the multilayers without Cu added. The findings suggested that the inserted Cu layer could avoid the energy reduction caused by intermixing of Al and Ni, but have less effect on the final products, which might help to realize the balance of storage stability and reaction performance with respect to the applications.

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Dual-phase nanocomposite coatings based on crystalline ZrN and glassy ZrCu

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Recently, magnetron sputter deposition has been demonstrated to be a suitable deposition technique for the preparation of metallic glasses as thin films (TFMGs). Thanks to non-equilibrium conditions of the low-temperature plasma and very high cooling rates on atomic scale at the substrate, TFMGs can be prepared with much wider composition variety and solubility than bulk metallic glasses (BMGs). Moreover, TFMGs have shown properties and characteristics that are superior to BMGs, and metallic and ceramic coatings, e.g., a better balance of ductility and strength. The amorphous structure of TFMGs along with their unique properties also provides a possibility to combine TFMGs with nanocrystalline materials in a dual-phase structure. This might allow to overcome the shortcomings of both types of materials and further improve the properties or even discover novel properties based on the synergetic effect of the two phases.

The current study focuses on the preparation of dual-phase thin-film materials in the ternary Zr–Cu–N system by reactive magnetron co-sputtering and systematic investigation of their structure and properties. The coatings were deposited in Ar+N_2 mixtures using three magnetrons equipped with two Zr targets and one Cu target. The magnetron with the Zr targets were operated in dc regimes while that with the Cu target in a high-power impulse regime. All the coatings were deposited onto rotating substrates with rf biasing without external heating. The elemental composition of the coatings was controlled in a very wide composition range.

We have demonstrated that reactive magnetron co-sputtering allows to prepare a novel type of the Zr–Cu–N coatings with a nanocomposite structure consisting of two phases, crystalline ZrN and glassy ZrCu [1]. So far, only the nanocomposite Zr–Cu–N coatings based on ZrN and Cu phases have been reported in the literature [2]. We showed that by varying the process parameters, we are able to control the elemental composition of the coatings so that the stoichiometry of the two phases remains as much the same as possible and only the fractions of the phases varied. The structure of the as-deposited Zr–Cu–N coatings undergoes a gradual transition from an amorphous-like state to a nanograined and finally to a nanocolumnar structure. The self-formation of the dual-phase nanocomposite structure significantly impacts the mechanical properties and deformation behavior of the Zr–Cu–N coatings due to the synergetic effect of the two phases. The hardness reaches a maximum enhancement of 38% compared to the rule of mixture at approximately 50 mol.% ZrN, concurrently accompanied by a reduction in plasticity. We attribute this behavior to the optimum size (3–5 nm) of ZrN nanocrystals enveloped by a relatively thin amorphous ZrCu phase, hindering dislocation movement out of the jammed nanocrystals. For higher ZrN fractions (>80 mol.%), the hardness and plastic work fraction follows the rule of mixture and nanocomposite Zr–Cu–N coatings with lower hardness but higher plasticity, compared to the binary single-phase ZrN coating, are prepared.

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Phase Transitions in PdAuSi Metallic Glass During High-Rate Differential Scanning Calorimetry: An In-Depth Microstructural Analysis Using TEM and APT

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Metallic glasses are materials with unique atomic structures and intriguing phase transition behaviors [1]. Understanding phase transitions under non-equilibrium conditions, such as rapid heating during differential scanning calorimetry (DSC), is critical for advancing their applications. High-resolution techniques such as transmission electron microscopy (TEM) and atom probe tomography (APT), when paired with calorimetric data, offer valuable insights into their microstructure evolution.

Using Flash DSC, which allows heating rates up to 60,000 K/s, we investigated a $Pd_{74}Au_8Si_{18}$ metallic glass with rare phase transitions [2]. The as-quenched material presented a homogeneous chemistry. We could overcome challenges in sample transfer (with pearl samples 10-30 µm in size) as well as in focused ion beam (FIB) preparation of TEM lamellae and APT tips. We developed optimized workflows for the TEM imaging/diffraction of metastable microstructures.

Fast DSC at 100 K/s heating rate revealed one glass transition and two crystallization peaks (T_{x1}/T_{x2}). At T_{x1}, TEM showed globular, Au-rich (~13 at.%), FCC crystalline precipitates (50 nm) in a Au-depleted (~5 at.%) amorphous matrix (see Fig. 1). At T_{x2}, precipitates grew slightly while the matrix crystallized into a coherent orthorhombic structure, undisturbed by the precipitates. Experiments at 20,000 K/s revealed a double glass transition phenomenon. Based on these observations, we will discuss the peculiar phase transitions in the $Pd_{74}Au_8Si_{18}$ metallic glass.

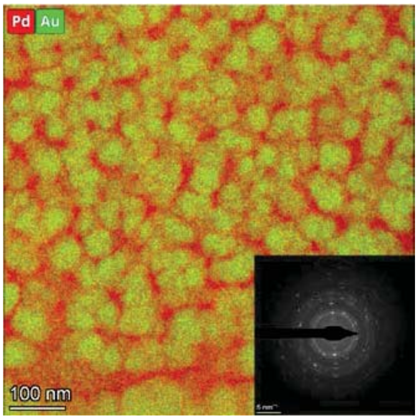

Fig. 1. Chemical map of a PdAuSi metallic glass after heating at 100 K/s up to 490 °C (T_{x1}), revealing globular, crystalline Au-rich precipitates in a Au-depleted amorphous matrix.

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Poster Contributions

Study of the ferromagnetic nanoparticles - biological cells adherence by TEM imaging at room temperature

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Transmission Electron Microscopy (TEM) is a powerful technique for imaging nanoparticles embedded in biological samples at high resolution. Proper sample preparation is essential to ensure that biological specimens are sufficiently thin, structurally preserved, and well-contrasted for clear imaging. The conventional method for preparing biological samples for TEM is the cryogenic technique, which requires expensive equipment for rapid freezing and sectioning of the samples Additionally, a specialized TEM holder capable of low-temperature operation is necessary during imaging. Moreover, the rapid freezing process may alter the morphological structure of biological cells, potentially introducing artifacts in the cross-sectional images.

In this work, we propose a simple and cost-effective protocol for preparing biological samples for TEM imaging at room temperature, which preserves cell integrity and enables the evaluation of nanoparticle adherence to the cell membrane. The method was tested on human osteosarcoma cells (HOS) and adipose-derived mesenchymal cells (ASC). Magnetic nanoparticles (MNPs), obtained via ball milling of Fe-based ferromagnetic ribbons were used for this study. HOS and ASC cells were cultured in four commercial T25 flasks until confluence. MNPs were added to two flasks, while the remaining two flasks were used as control samples without nanoparticles. After 24 hours, the cells were trypsinized, incubated for a few minutes at 37 °C, and centrifuged for 5 min. at 300G to form a cell pellet. Thus, two sets of samples were prepared: HOS/ASC with MNPs and HOS/ASC without MNPs (control).

Following dehydration and fixation in EPON resin, ultrathin sections of 60 nm thickness were obtained using an ultramicrotome. The cross-sections were then examined by TEM (Libra 200 MC) at 80 kV and room temperature. The TEM images shown in Figure 1 demonstrate that both the MNPs and the structural integrity of the biological cells are well preserved after sample preparation using this protocol, making it suitable for studying the interaction of nanomaterials with the cell membrane.

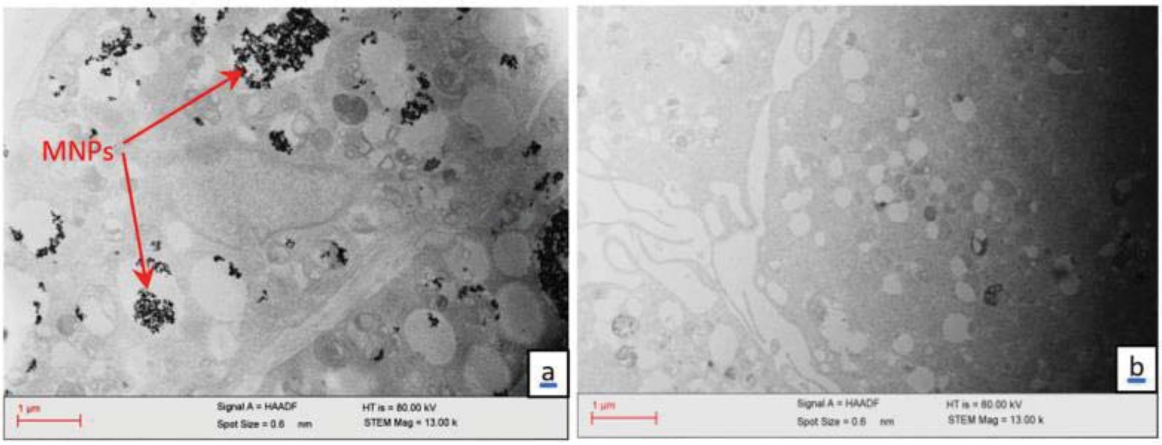

Figure 1. TEM images of MNPs-ASC cells (a) and ASC control cells (b).

Financial support from NUCLEU Programme - Contract No. 18N/01.01.2023, project PN 23 11 01 01 is highly acknowledged.

Significant Enhancement of Yield Strength in $Ti_{80}Cr_{20-x}(CoFeNi)_x$ Alloys Through Phase Stability Modulation and Ultrafine Eutectic Structure

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This study investigates the microstructural evolution, mechanical properties, and deformation behavior of $Ti_{80}Cr_{20-x}(CoFeNi)_x$ (x = 0, 3, 6, 9, 12, 15, 17, 20 at%) alloys to enhance their strength. The incorporation of equiatomic (CoFeNi) significantly influences phase stability, leading to the formation of the ω phase within the β-Ti matrix, as well as a β + Ti_2Ni-type ultrafine eutectic structure.

As the (CoFeNi) content increases, the ω phase forms within the β-Ti matrix, resulting in a substantial increase in yield strength from 920 MPa to 1255 MPa, while maintaining high plasticity above 40% in $Ti_{80}Cr_{14}(CoFeNi)_6$ and $Ti_{80}Cr_{11}(CoFeNi)_9$ alloys. With further additions of (CoFeNi), the ultrafine eutectic structure (UFEC) gradually develops, reaching a peak yield strength of 1550 MPa at 15 at% alloying content, accompanied by reasonable plasticity of 27%. However, at the highest alloying level $Ti_{80}(CoFeNi)_{20}$, the material exhibits maximum yield strength but becomes brittle due to the dominant UFEC matrix and the absence of strong interactions between slip bands in β-Ti dendrites and shear bands in the ultrafine eutectic matrix.

These findings provide a systematic understanding of phase stability, microstructural transformations, and mechanical performance in $Ti_{80}Cr_{20-x}(CoFeNi)_x$ alloys. The study highlights an effective approach for tailoring strength and ductility in β-Ti alloys through phase modulation and microstructural refinement.

Oxide nanostructure cathodes and engineered anodes for rechargeable Zn-ion/air batteries

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A number of energy harvesting, conversion and storage technologies are being actively pursued worldwide to meet the ever-increasing demand for energy. Lithium-ion battery (LIB) is currently the leading energy storage technology. However, LIBs suffer from certain limitations such as low energy density, high cost and safety issues. Recently, metal–air and metal-ion batteries have attracted attention as a promising energy storage technology owing to their high theoretical energy density, better safety and abundance. Among these Zn–air and Zn-ion batteries have come to prominence owing to their high theoretical energy density, and favorable electrochemistry of zinc which is also an earth-abundant element unlike Li. An efficient bifunctional catalyst which can perform both oxygen reduction reaction (ORR) and oxygen evolution reaction (OER) is required for rechargeable Zn-air batteries. Zn-ion batteries on the other hand work on the principle of zinc intercalation and stripping. Nobel metal-based materials such as Pt/C or IrO_2 are well known electrocatalyst but are not cost effective. Transition metal oxides such as MnO_2, Mn-Co oxide exhibit bifunctionality owing to the multiple valence states of Mn and Co. Transition metal vanadium oxides (TMVO) such as zinc vanadium oxide (ZVO) possess a layered structure that enables intercalation of cations while multiple oxidation state of vanadium maintains electroneutrality. This makes TMVOs suitable cathode catalysts for rechargeable Zn-ion batteries. Co-Mn oxides and ZVO nanostructures were explored in this study as the cathode catalysts for rechargeable Zn-based batteries. Co-Mn oxides with different levels of Mn ($Mn_xCo_{3-x}O_4$) were obtained as nanocages using zeolitic-imidazolate framework (ZIF) as a template. ZVO nanobelts were processed by a hydrothermal synthesis method. ZIF derived Co-Mn oxide with a Co:Mn ratio = 1 exhibited the best performance signifying the importance of an optimum level of Mn doping. It displayed an onset potential 0.9 V vs RHE and half wave potential of 0.76 V in case of ORR. For OER, the overpotential was observed to be 410 mV to reach a current density of 10 mA/cm^2.These results are comparable to performance of Pt/C electrocatalyst. ZVO, on the other hand delivered a specific capacitance of 275 $mAh\ g^{-1}$ (@ 1 C rate), coulombic efficiency of 99.6 % and 94% capacity retention after 200 cycles. These results suggest that the studied transition metal oxides are efficient bifunctional cathode catalysts for rechargeable Zn-air/ion batteries. The anode has been engineered in different ways to make it better than commercial Zn (C-Zn) foil anodes. Here we report the engineered anode obtained by surface modification of Zn by ZIF and electrodeposition of Zn (E-Zn) over Cu foils. The E-Zn anode displayed relatively larger current density and superior rate capability compared to commercial Zn (C-Zn) foil anode. The E-Zn anode also exhibited high capacity retention of ≥97% after 100 cycles. The anode modified with the ZIF with a sulfhydryl group (ZIF-8-SH) outperformed C-Zn and other ZIF modified Zn anodes. The ZIF-8-SH modified Zn anode exhibited improved corrosion resistance in KOH with significantly reduced corrosion current density **(2.6×10^{-6} mA cm^{-2}**) compared to unmodified Zn **(1.1×10^{-5} mA cm^{-2}).** It also showed better cyclability.

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Bulk metallic glasses surface modification by low-temperature plasma nitriding and oxidation

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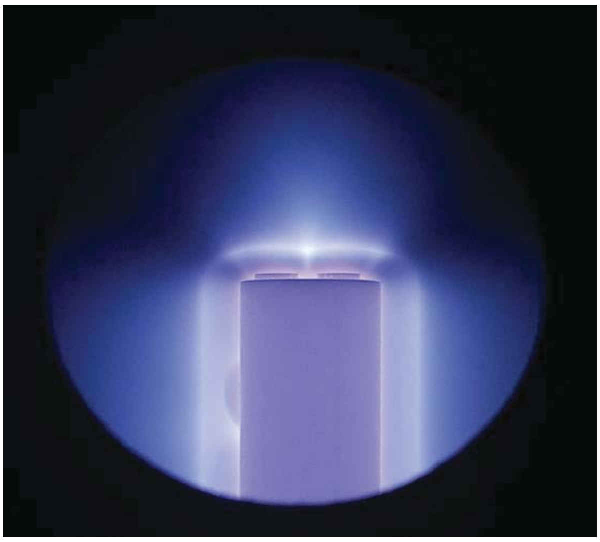
Bulk metallic glasses are modern engineering materials with unique functional properties. The Zr-based alloys are particularly attractive as they exhibit high glass forming ability as well as good mechanical properties [1]. They also exhibit good corrosion resistance [2] and low coefficient of friction in contact with various other materials [3]. Due to their relatively high thermal stability, reaching as much as 300 °C, they can be surface treated in low-temperature plasma in order to further improve their mechanical properties [4].

Several plasma-assisted processes such as nitriding and oxidation of the $Zr_{48}Cu_{36}Al_8Ag_8$ BMG at temperatures below glass transition temperature (T_g) have been performed using assorted technological parameters in order to investigate the possibility of applying such treatments without the crystallization of the glassy substrate. The surface treatments impact on the mechanical properties and wear resistance of the treated glasses was examined and described in relation to the XRD results and microscopic observations.



View of glow discharge oxidation of a Zr-based BMG

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Long-term magnetic stability of nanocrystalline FeCuBPSi alloys

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Nanocrystalline FeCuBP soft magnetic alloys were investigated earlier and variation with different P and Cu additions yielded materials with high magnetic saturation and low coercivity. These magnetic properties are advantageous in terms of possible miniaturization, enhanced efficiency and low material cost of electric devices. Thanks to appropriate annealing, they achieve a more uniform and fine structure containing nanocrystalline bcc-Fe phase in amorphous matrix. [1, 2]. In previous work we investigated the effect of short-term annealing with rapid cooling in Ar atmosphere on magnetic properties and microstructure of $Fe_{80-x}Cu_1B_{11}P_4Si_{4+x}$ with x = 4 and 8; slight variation of P-content has also been investigated [3].

Present work investigates long-term stability of samples thermally treated in Ar atmosphere at 500°C after several months of room-temperature aging and also after their subsequent simulated accelerated aging at 120°C/5 hours. This test could reveal the effect of long-term aging on possible deterioration of soft magnetic properties, which we consider important for subsequent processing of more massive magnetic cores in industrial scale production. Less stable samples were those with Si 8 at. %, however, they achieved better magnetic properties after 500°C annealing. The increase in coercivity after 26 months was 8.7 and 10.2 % for $Fe_{78}Cu_1B_{10}P_3Si_8$ and $Fe_{76}Cu_1B_{11}P_4Si_8$ samples, respectively. After simulated aging $Fe_{78}Cu_1B_{10}P_3Si_8$ even decreased by 1.3%. The most stable sample was $Fe_{80}Cu_1B_{11}P_4Si_4$, whose coercivity at first decreased by 8% and after simulated aging by -3.8%. Its magnetic saturation remained unchanged at 1.74T. The aged samples were checked by XRD measurements for possible occurrence of oxides on the ribbon surfaces.

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Experimental and thermal study of SAC305-xGa solder alloys

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Solders are essential for creating strong, conductive joints in electronic circuits without damaging sensitive components. The quality of these connections directly affects the performance and lifespan of electronic devices. As technology evolves, developing advanced solder materials remains crucial for improving device reliability and durability.[1] The global restriction of lead-containing solders, driven by environmental and health regulations, has made the use of lead-free soldering alloys essential.

As electronic devices continue to shrink in size, ensuring the reliability and mechanical performance of these alternatives has become a critical focus in the industry.[2] Sn–0.3Ag–0.5Cu (SAC305) solder alloys are considered one of the most promising options among lead-free alternatives, mainly because of their excellent solderability and mechanical properties. However, a low melting temperature and wettability comparable to lead-based solders are not achieved, so research on Sn-based alloys is ongoing, with continuous efforts to improve performance by exploring various methods and adding different elements.[3]

This study investigated how adding gallium (Ga) affects the microstructure and properties of SAC305 lead-free solder compared to pure SAC305. Experiments for analyzing structure, composition, and morphology of materials at the micro and nano scale using experimental techniques (scanning electron microscopy, energy-dispersive X-ray spectroscopy, X-ray diffraction, differential scanning calorimetry). The microstructure of pure SAC305 solder contained Cu_6Sn_5 and Ag_3Sn intermetallic compounds. The addition of Ga resulted in structural modifications and a finer microstructure. Ga enriched the Ag areas in SAC305+2wt%Ga, forming Ag_2Ga. New formed phases Cu_2Ga (appeared in all Ga-enriched alloys) and $CuGa_2$ (in alloys with 4wt%Ga and 6wt%Ga). These compounds partially replaced Cu_6Sn_5 in samples with lower Ga content, and Cu_6Sn_5 was completely absent in SAC305+6wt%Ga.

This work was supported by Slovak Grant Agency VEGA (project 1/0389/22)

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Exploring the Mechanochemical Reduction of Ilmenite for the production of TiFe Hydrogen Storage Alloys

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$TiFeH_x$ has recently emerged as a realistic candidate for solid-state hydrogen storage applications.[1] Partial substitution of Fe with other transition metals (e.g. Ni, Cu, Mn) allows a reversible hydrogen absorption and desorption at moderate conditions and good sorption kinetics. The volumetric hydrogen storage capacity for TiFe can be as high as 110 kgH_2/m^3 (3.7 MWh/m^3), which is significantly higher than that for liquid hydrogen. Besides the technological benefits, one of the main advantages of the TiFe system is cost. Fe and Ti are relatively cheap and abundant raw materials which are easily recyclable. However, in October 2020, titanium was included in the list of critical raw materials by the EU, due to its economic importance and to an increased supply risk. Nonetheless, Norway has large resources of titanium ores in the form of ilmenite, $FeTiO_3$, estimated to about 5% of the World's total reserves. Ilmenite may clearly be an ideal starting point for production of TiFe as it contains the two metallic constituents in the correct stochiometric ratio.

In this work, the production of TiFe from Norwegian ilmenite via mechanochemical methods is explored. In particular, high energy ball milling is used to promote the mechanochemical reduction of ilmenite by alkaline earth hydrides. Results from Powder X-ray Diffraction (PXD) analysis and Scanning Electron Microscopy (SEM) show that the reduction of ilmenite can be partially achieved depending on the ball milling technique and reducing agent employed during processing. In particular, it is shown that the amount of $FeTiO_3$ phase decreases as a function of milling time, suggesting a gradual conversion of ilmenite to a Fe/Ti cubic phase. The results are discussed with respect to the milling conditions chosen for this work, such as milling atmosphere and milling intensity. Additionally, the purity of the starting ilmenite ore is considered for the evaluating the phase distribution in the final powders after the milling process and for assessing the potential of the mechanochemical reduction products for hydrogen storage applications.

This work was supported by the Research Council of Norway through the Norwegian Centre for Hydrogen and Ammonia Research HYDROGENi [applications.

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A study on chromaticity and mechanical properties of Cu-Ge-Al alloys with bimodal-sized intermetallic compound

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Recent studies on Cu-based alloys reported the influence of solute elements on optical and mechanical properties of Cu-based alloys [1-3]. The Cu-Ge-Al alloys with different contents of Ge and Al solutes were designed to investigate the influence of solute elements on microstructural evolution and chromatic and mechanical properties of the alloys. The addition of 0−9 at.% of Al solute in $Cu_{97}Ge_3$, $Cu_{95}Ge_5$, and $Cu_{93}Ge_7$ alloys leads to microstructural evolution from single-phase (α-Cu) to dual-phase structure consisting of α-Cu matrix and bimodal-sized ζ-$Cu_{17}Ge_3$ phase. Alloys with small amounts of the Ge and Al show the single-phase structure or dual-phase structure with nanoscale ζ-$Cu_{17}Ge_3$ precipitates. An increase of Ge and Al solutes induces the formation of microscale interdendritic ζ-$Cu_{17}Ge_3$ phase with the α-Cu matrix and the nanoscale $Cu_{17}Ge_3$ precipitates during solidification. The chromaticity (CIE a* and b* values) of the alloys is significantly influenced by solute content as well as microscale ζ-$Cu_{17}Ge_3$ phase. However, the nanoscale ζ-$Cu_{17}Ge_3$ precipitates are ineffective in changing chromaticity. For the mechanical properties of alloys, the nanoscale ζ-$Cu_{17}Ge_3$ precipitates and microscale ζ-$Cu_{17}Ge_3$ phase contribute to improvement of Vickers hardness by precipitation hardening and dispersion hardening effect. These results provide an effective way to expand the chromatic color range and improve the mechanical properties by developing dual-phase Cu-based alloys with bimodal-sized second phase.

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Maximum achievable N content in amorphous nitrides

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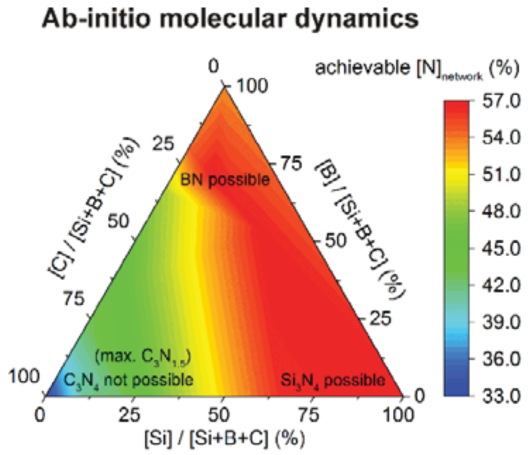
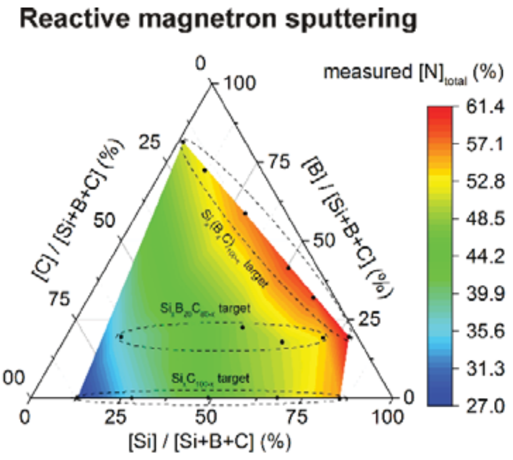
The contribution deals with amorphous nitrides prepared by atom-by-atom growth. This time I do not focus on the relationships between compositions and properties, but on something even more fundamental: what is the achievable range of compositions (which in this case means what is the maximum achievable N content), defining the achievable range of properties.

Structures of amorphous CNx, Si-C-N, B-C-N and Si-B-C-N are predicted by extensive ab-initio molecular-dynamics simulations (over 15 000 trajectories) in a wide range of compositions and densities. When and only when the structures are allowed to include unbonded N2 molecules, the predicted lowest-energy densities are in agreement with the experiment. The main attention is paid to the N2 formation, with the aim to predict and explain the relationships between [Si]/[B]/[C] ratios and the maximum achievable content of N bonded in stable amorphous networks ([N]network). The results reveal that N2-free networks are characterized by maximum [N]network between 34% (CNx) and 57% (SiNx). Networks formed in parallel to the formation of unbonded N2 molecules (which subsequently either diffuse out or stay trapped in the material) are characterized by maximum [N]network between 42% (CNx) and 57% (SiNx). The measured total N contents in (Si)-(B)-C-N films prepared in our laboratory by reactive magnetron sputtering are in a very good agreement with the prediction. Further analysis shows that while the N2 formation takes place at a packing factor below the critical value of 0.28 which is valid in a wide range of compositions, the lowest-energy packing factor (sometimes below 0.28, sometimes above 0.28) depends on the composition.

The presented methodology constitutes a new way how to support the experiment by ab-initio simulations. The results are important for the design of amorphous nitrides for various technological applications, prediction of their stability, design of pathways for their preparation, and identification of what may or may not be achieved in this field.


Ab-initio molecular dynamics


Reactive magnetron sputtering

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Mechanically Alloying Synthesized Nanostructured Electrodes and Electrolytes for Advanced Batteries

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Modern energy technologies depend on the production of over one billion lithium-ion batteries annually to power consumer electronics. However, a major challenge remains: the limited energy density and safety of these batteries, which fail to meet the growing demands of emerging applications such as electric vehicles, portable devices (e.g., smartphones), and industrial tools. To advance safe, efficient, and sustainable energy storage, nanomaterials synthesized through mechanical alloying have shown significant promise. This presentation explores our research addressing these challenges. For instance, ion gel electrolytes hold great potential for solid-state batteries due to their exceptional properties. However, their low lithium-ion transference number restricts practical implementation. To overcome this limitation, we developed amine-functionalized boron nitride (BN) nanosheets via a controlled ball milling process, where nanosheet formation and NH group functionalization occur simultaneously. When incorporated into ion gel electrolytes, these functionalized BN nanosheets enhance ion transport properties [1]. Another critical issue in lithium-sulfur batteries is the migration of polysulfide intermediates from the cathode to the anode, which degrades cycling performance. To address this, we integrated functionalized boron nitride nanosheets with negatively charged groups onto a commercial Celgard separator. This boron nitride separator effectively inhibits polysulfide migration due to the strong electrostatic repulsion between the negatively charged nanosheets and polysulfides. As a result, lithium-sulfur cells using this separator demonstrate excellent long-term cycling stability—lasting up to 1,000 cycles—and achieve a high capacity of 718 mAh/g at a high current of 7C (1.18 A/g) [2, 3].

Furthermore, controlled ball milling (mechanochemistry) offers broad applications in battery materials development. This presentation will provide a comprehensive review of the latest advancements in this field.

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Carbon formation characteristics of IPA decomposed on the nickel impregnated SBA-15

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According to statistics provided by the Taiwan Environmental Protection Administration (TEPA), the amount of waste organic solvents is as high as 192,830 tons per year. Most of it is disposed of by distillation or incineration procedures. Using organic solvents to synthesize materials will not only reduce the cost of pollutant control but also decrease the risk of pollution. In this study, pyrolytic chemical vapor deposition (CVD) was employed for the synthesis of carbon nanotubes via isopropanol at 600-800ºC in nitrogen atmosphere, with Santa Barbara Amorphous-15 (SBA-15) selected as the template and various concentrations (2, 5, 8 wt %) of nickel as the catalyst. A number of techniques were used to characterize the physicochemical properties of SBA-15 and carbon nanotubes, including surface area and pore size analysis, scanning electron microscopy (SEM), transmission electron microscopy (TEM), energy dispersive X-ray spectrometry (EDS), zeta potential, X-ray diffractometry (XRD), and Raman scattering spectrometry.

The BET surface area/average pore diameter of SBA-15 was 714 m^2/g and 45.5 Å. It was classified as a mesoporous material composed of long granular shapes and an orderly hexagonal structure. Nickel loading on SBA-15 was conducted under various concentrations (2, 5, 8 wt %) as the catalyst. The average pore diameter increased with the decrease of BET surface area, and total pore volume was due to pore blockage after the metal impregnated on the SBA-15.

The hollow structure of carbon nanotubes was synthesized at various concentrations (2, 5, 8 wt%) of Ni-SBA-15 at various temperatures (600, 700, and 800°C). The outside diameter of Ni-SBA-15 increased as the temperature decreased. In XRD analysis, diffraction peaks were evidenced at 43.2°, analogous to a typical graphite. Raman scattering spectrometry showed that 8% Ni-SBA-15 evidenced a high degree of graphitization at 700ºC.

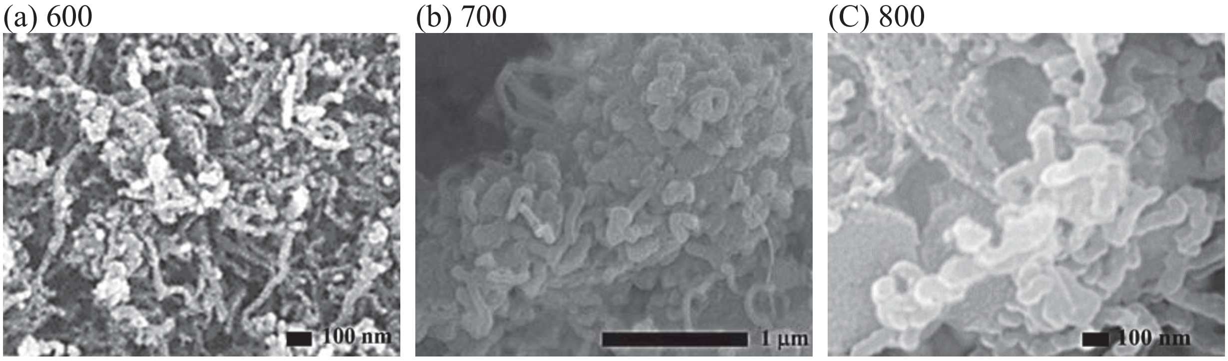

Figure 1 SEM morphology of carbon formation on 2% Ni-SBA-15 at 600-800 ºC

Effect of MoO_2 Powder Packing Density on Sintering Kinetics and Grain Growth

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MoO_2 powders were subjected to uniaxial compaction at varying pressures, ranging from 100 to 800 MPa. This process yielded a series of green compacts with densities spanning from 55% to 65% of the theoretical maximum, respectively. Following compaction, these samples were sintered in a controlled N_2 atmosphere at temperatures ranging from 650 to 1050 °C for a duration of 1 hour. Subsequently, a detailed analysis was conducted to investigate both the densification kinetics and the grain growth behavior exhibited by the sintered MoO_2 samples. Prior to sintering, an examination of the compaction process revealed a linear relationship between the logarithm of the applied uniaxial pressure and the resulting green density. This correlation held true within the investigated pressure range, specifically before the onset of any observable fracture or localized deformation in the compacts. Upon sintering, the relative densities of the MoO_2 samples demonstrated a positive correlation with both the initial green density of the compacts and the sintering temperature employed. Notably, at any given sintering temperature, those samples exhibiting the highest initial green density also displayed the most pronounced densification rates. Furthermore, it was observed that the grain size within the sintered samples was directly proportional to the achieved relative density. This grain growth behavior was found to adhere to an Arrhenius-type relationship, suggesting a thermally activated process. An analysis of the apparent activation energies for densification revealed that these values varied depending on both the initial green density of the compact and the specific sintering temperature. At lower sintering temperatures, the apparent activation energies were determined to be 50.8, 39.6, and 26.1 kJ/mol for compacts with initial green densities of 55%, 60%, and 65%, respectively. In contrast, at higher sintering temperatures, the corresponding activation energies were found to be 19.8, 21.5, and 25.4 kJ/mol.

Enhancing Ductility in Metallic Glasses through High-Pressure Torsion

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Metallic glasses (MGs) exhibit high yield strength due to the absence of crystallographic slip systems, but their post-yield deformation is highly localized in shear bands (SBs), leading to brittle failure and limited ductility [1]. To address this, severe plastic deformation (SPD) methods have been explored to enhance ductility by altering the amorphous structure. Among these, high-pressure torsion (HPT) has proven effective, introducing a high density of SBs and local heterogeneities, which increase free volume and improve tensile ductility [2]. Despite these findings, most analyses have relied on bulk-averaged data, leaving the microscopic mechanisms behind improved ductility in HPT-processed MGs insufficiently understood.

In this study, we employ advanced 4D-STEM techniques capable of nanoscale strain and local density mapping [3,4] to investigate structural evolution in HPT-processed Vitreloy 105. The resulting microstructure features interconnected pre-existing SBs that act as barriers to strain localization. This network disperses deformation, preventing linear SB propagation and giving rise to complex, plaid-like strain fields—evidence of a transition from localized to more distributed plastic flow. Such delocalized deformation suppresses catastrophic shear banding, thereby enhancing ductility.

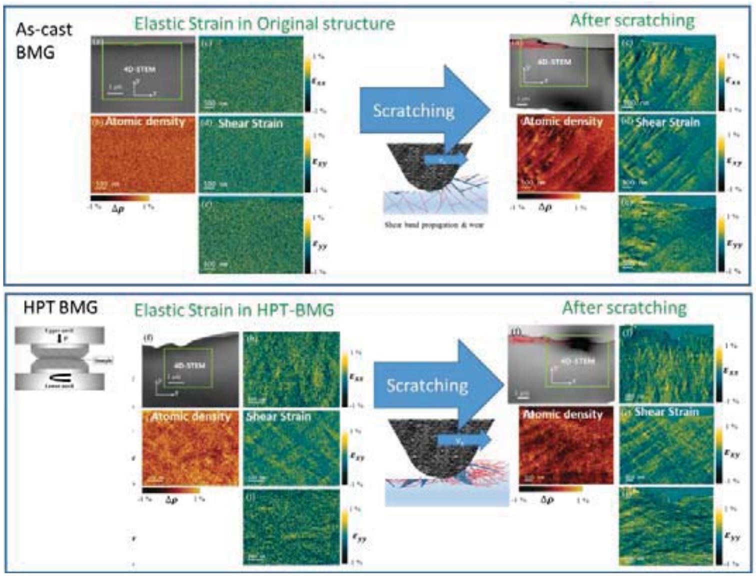

Figure 1. Nanoscale structural comparison of as-prepared and HPT-processed Vit105 metallic glasses before and after deformation using 4D-STEM. HAADF-STEM images with strain and relative density maps show localized strain in the as-prepared sample, while the HPT-processed sample exhibits more homogeneous plastic flow due to pre-existing shear bands and structural heterogeneity.

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Nanocrystalline and amorphous $Al_{40}Mg_{40}Ti_{20}$ and $Al_{40}Mg_{20}Ti_{40}$ alloys

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$Al_{40}Mg_{40}Ti_{20}$ and $Al_{40}Mg_{20}Ti_{40}$ powder alloys were prepared by mechanical alloying using a high-energy ball mill. It was found that mechanically driven reactions led to fcc and hz nanocrystalline phases formation in the case of the $Al_{40}Mg_{40}Ti_{20}$ alloy and an amorphous phase creation in the case of the $Al_{40}Mg_{20}Ti_{40}$ alloy. Thus, the replacement of a part of Mg by Ti changed the course of the mechanical alloying process and phase composition of its product, increasing the tendency towards amorphisation.

The final products of mechanical alloying were consolidated by high-pressure pressing. The nanocrystalline structure of the fcc and hz phases was preserved during consolidation of the $Al_{40}Mg_{40}Ti_{20}$ alloy powder at 500 °C. The amorphous structure was retained during consolidation of the $Al_{40}Mg_{20}Ti_{40}$ alloy powder at 420 °C. However, a partial crystallization of the amorphous phase occurred, leading to an fcc phase formation. The hardness of the nanocrystalline alloy and the alloy containing the amorphous phase was 445 HV1 (4.37 GPa) and 595 HV1 (5.84 GPa) respectively. The density of the $Al_{40}Mg_{40}Ti_{20}$ alloy and $Al_{40}Mg_{20}Ti_{40}$ alloy was 2.729 g/cm^3 and 3.383 g/cm^3 respectively.

Crystallization Kinetics of Bulk Metallic Glass with Oxidation-Induced Heterogeneity

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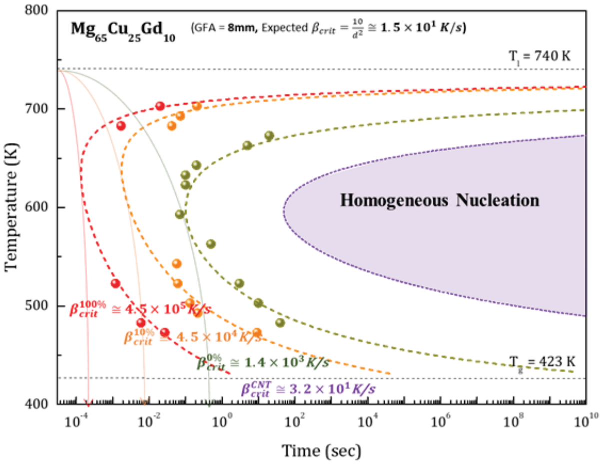
Oxidation increases the critical cooling rate of bulk metallic glass (BMG) and deteriorates its mechanical properties [1-2]. Therefore, various manufacturing processes and alloy compositions have been developed to improve oxidation resistance [3-5]. However, there are no quantitative studies on how much oxidation actually promotes the crystallization of BMG, leading to larger critical cooling rates. Time-temperature transformation (TTT) diagrams as a function of oxidation with time.

In this study, annealing under various conditions was performed to control the degree of oxidation of Mg-Cu-Gd BMGs, well-known glass formers, and the crystallization behavior of each case was investigated and compared. To obtain information on a wide temperature and time scale, fast differential scanning calorimetry (DSC), which can operate at a speed of up to a few 10^4 K/s, about tens of thousands of times faster than conventional DSC, was utilized. The TTT diagrams that the critical cooling rate drastically increases with increasing oxidation. This study allowed for a comprehensive understanding of the heterogeneous crystallization behavior of BMGs when oxidized. This stresses the need for heterogeneity control represented by oxide when dealing with the crystallization behavior of BMG.



Time-temperature transformation diagrams reflecting oxidation. The calculated CNT curve is shown in purple.

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Variations in the Motion of Magnetic Particles in a Thin Film under Magnetic Fields

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This study explores the development of an interactive informative panel that dynamically displays patterns, numbers, text, and designs in real time by leveraging the unique properties of magnetic materials. This functionality is realized by integrating solenoid pixel circuits with magnetophoretic films containing magnetic nanoparticles.

To achieve this, nanoscale magnetic nanoparticles were encapsulated to fabricate an ultra-thin film with a micrometer-scale thickness. This film was then integrated with functional circuit substrates, designed with various pixel structures, using a flexible substrate. External energy inputs allowed for precise control of the magnetic configurations in individual unit pixels, while the interactions among multiple pixels within the working area facilitated the formation of dynamic dots, lines, and surfaces.

The behavior of the magnetic nanoparticles is governed by external magnetic fields, enabling controlled movement and pattern formation through magnetophoretic principles. The interplay between magnetic forces, interparticle interactions, and substrate constraints determines the stability and responsiveness of the display. Additionally, the ability to reconfigure magnetic patterns dynamically provides a foundation for programmable surfaces that adapt to changing environmental inputs.

This approach offers a cost-effective and energy-efficient alternative to conventional display technologies while leveraging the inherent advantages of magnetic materials, such as long-term stability, rapid response times, and tunable configurations.

Investigation of helium ion irradiation response with Zr-based metallic glasses with different glassy structure

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Nuclear power generation can generate large amounts of energy reliably, and is considered as one of the most suitable energy sources for modern industries that require highly concentrated and advanced energy supply. Enhancing the safety of nuclear power generation needs the development of structural materials that can ensure stable and secure reactor operation. In fusion process, the reaction between deuterium and tritium generates helium, which is then implanted into the structural components of the reactor. Therefore, the development of structural materials with high resistance to helium ion irradiation damage is directly linked to improving the safety and longevity of nuclear reactors.

Amorphous alloys, owing to their inherently disordered atomic structures, lack crystallographic defects which typically act as helium ion trap sites, and are thus expected to exhibit enhanced resistance to helium ion irradiation. Various studies have been conducted to explore their applicability in nuclear materials. Since the properties of amorphous alloys are known to vary with structural configuration, we differentiated the structure of Zr-based metallic glass samples by changing the quenching rate during glass forming and examined how these structural differences influence their response to helium ion irradiation. Helium ion microscope was used for helium ion irradiation, and atomic force microscope was utilized to analyze the resulting swelling. We expect the results to provide valuable insight into the application of metallic glasses for nuclear structural materials.

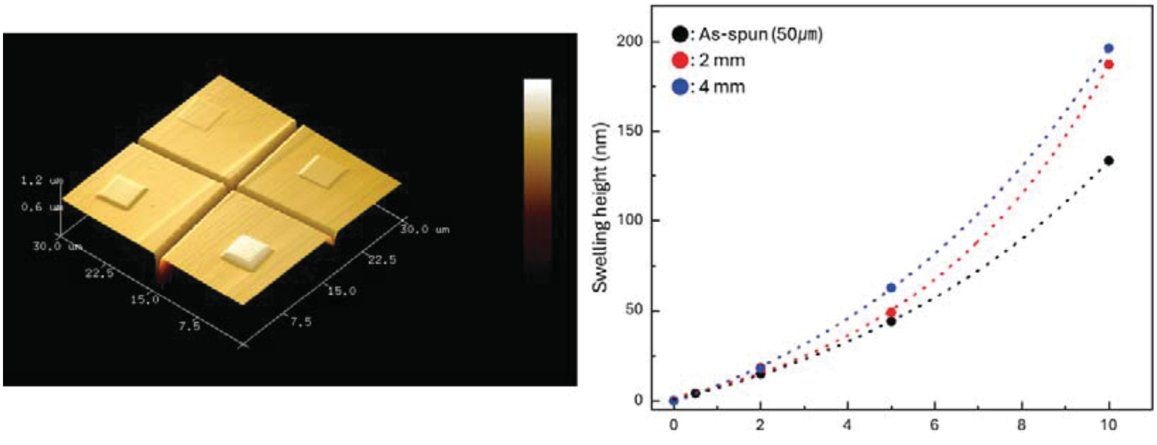

Figure 4. AFM image of as-spun ribbon sample (left) and swelling height of metallic glass samples with different cooling rate at different irradiation dose (right)

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Enhanced Antibacterial Activity of Surface-Modified $Zr_{50}Cu_{50}$ Metallic Glass

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Research on metallic glass powders and ribbons as functional materials, including thermoelectric materials, shape memory alloys, and supercapacitors, has been actively conducted in recent years [1–5]. Our study aimed to investigate the potential bactericidal properties of metallic glasses with high Cu content for functional applications. $Zr_{50}Cu_{50}$ metallic glass was selected due to its high Cu content, simple chemical composition, and good glass stability [6].

Typically, Zr-based metallic glasses have an amorphous zirconium oxide film that strongly inhibits further oxidation. However, surface defects can compromise the glass stability of the amorphous oxide film, leading to the formation of a thick natural oxide layer.

In this study, we demonstrated that the oxidation behavior of melt-spun $Zr_{50}Cu_{50}$ metallic glass foil was affected by the surface casting defects on the wheel side, leading to a significant improvement in antibacterial properties. The superior antibacterial properties of the wheel side were attributed to the metallic Cu islands exposed on the surface.

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Nanostructured amorphous arsenoselenides

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Expensive costs of technically complicated process to grow crystals make necessary to search for possible alternatives among which amorphous substances prepared from high-entropy melt such as glass with simpler and cheaper production technology seem to be more appropriate. Such class of amorphous materials can be well exemplified by semiconductor covalent-type chalcogenide glasses (ChG), especially glassy Arsenoselenides (g-As-Se). The fibers based on g-As-Se are very promising materials for contemporary optoelectronics, photonics, acoustooptics, xerography, etc. It has been established that functional capabilities of g-As-Se are susceptible to modification caused by nanostructurization processes under the action of external factors, including those offered by mechanochemistry through high-energy mechanical ball milling in a dry or wet mode. By such approach, it is possible to change exploitation properties of ChG, which usually left unchanged under traditional glass production technologies. Interconnected nanostructurization and re-amorphization (i.e. amorphization of a substance originally being in a vitreous state) processes resulting in development of new family of materials with extra-ordinary properties, the nanostructured mechanically activated amorphous na-As-Se. Atomic and atomic-deficient holes (volumes) modification in the covalent lattice of these materials (e.g. by high-energy milling in a planetary mill) allows formation of characteristic inhomogeneities at the finest atomic and subatomic levels with properties unusual for macroscopic materials obtained by rapid quenching of the melt.

On the other hand, arsenic compounds (arsenicals) have a long and complex relationship with human health and are one of the oldest drugs for a variety of human diseases. Arsenic trioxide (As2O3) has achieved groundbreaking success in the treatment of acute promyelocytic leukemia. However, the contradiction between the high efficacy and systemic toxicity of arsenic drugs limits their clinical therapeutic efficacy in solid tumor treatment. Therefore, a new generation of arsenicals has been developed (arsenic sulfides and selenides). The most studied among arsenic sulfides is tetraarsenic tetrasulfide As4S4 (α-modification or mineral realgar, and β-modification) showing cytotoxic, antiproliferative and anticancer effects. Arsenic sulfides are studied mostly in the form of nanoparticles, as they exhibit improved properties in comparison to their bulk forms, which are poorly soluble. Only very recently a publication regarding to ultrathin 2D arsenoselenide nanosheets (As2Se3) for photothermal-triggered cancer immunotherapy was published [1] very promising results. A combination of selenium and arsenic could be an excellent strategy for lowering the toxic effects and increasing therapeutic efficacy.

In the presented work the structural properties of nanostructured arsenoselenides with different compositions were modified using nanomilling and studied in details using the X-ray diffraction by evaluating of the results based on relation to the first sharp diffraction peak (XRD-FSDP), positron annihilation lifetime spectroscopy (PALS) and quantum-chemical ab-initio simulation. The samples were also tested for photothermal effect, and their biological effects were also studied.

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Analysis of growth of intermetallic layers (Cu_3Sn, Cu_6Sn_5) at Sn-solder/Cu substrate interface

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Solder joints represent critical interconnects in electronic packaging, providing essential electrical, thermal, and mechanical connections between various components. The integrity and long-term reliability of these interconnections affect the functional performance and operational lifespan of electronic devices. At the interface, intermetallic compound (IMC) layers grow, creating interconnections. Their thickness, morphology, and composition influence mechanical strength, electrical conductivity, and resistance to electromigration and thermomechanical fatigue. Understanding the microstructural evolution and phase transformations occurring at the interface, both during soldering and in-service conditions, is important for the design and optimization of electronic assemblies [1]. Extensive research has focused on SAC solder at the Cu interface, where two primary intermetallic layers: Cu_6Sn_5 and Cu_3Sn, are typically formed. While Cu_6Sn_5 layer is generally considered beneficial for initial bonding, the excessive growth of the more brittle Cu_3Sn layer, particularly during extended thermal aging, is undesirable due to its tendency to degrade mechanical reliability and lead to a formation of voids [2-3]. This work investigates the microstructure evolution at the SAC305-xNi/Cu interface using scanning electron microscopy, energy-dispersive spectroscopy, and x-ray diffraction, supported by Thermo-Calc and DICTRA calculations. The primary goal is to determine how the addition of Ni influences the growth of IMCs at the solder/substrate interface. In this study, different Ni additions (0.05-0.4 wt.%) were investigated and compared to pure SAC305 solder. The addition of Ni resulted in the formation of a more uniform Cu_6Sn_5 layer at the interface compared to SAC305. Furthermore, the addition of Ni significantly suppressed the formation of the Cu_3Sn phase; this phase did not form in samples with Ni even after 1000h of aging at 150°C, whereas it appeared in SAC305 after just 200 hours of aging at 150°C. The overall thickness of the interface was observed to increase with increased aging time. Wetting angle measurements revealed that Ni additions improved the wettability of the solder, as the wetting angle decreased. The kinetics of growth of Cu_3Sn and Cu_6Sn_5 at the Cu/solder interface were also simulated using DICTRA software. The computational results were in agreement with the experiments.

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Fe(Co)-B-Sn Metallic Glasses Characterized by Mössbauer Spectrometry and AFM/MFM

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Though invented a long time ago, metallic glasses still attract the researchers' interest. The particularly advantageous magnetic properties of Fe-based metallic glasses prepared by the planar flow casting are applied in various areas of technical practice. Hence, novel chemical compositions of this sort of alloys are continuously investigated.

Here, we discuss microstructural features of Fe-based metallic glasses with addition of 7 at. % Sn. In addition, 25 at. % of Fe was replaced by Co aiming at improvement of their magnetic parameters. These two batches of Fe(Co)-B-Sn samples were inspected by Mössbauer spectrometry in the as-quenched state and also after annealing at the first crystallization step. Experiments were performed in transmission geometry at room temperature and also at 4.2 K without and with external magnetic field of 6 T oriented perpendicular to the gamma radiation. The latter was provided by ^{57}Co/Rh and ^{119m}Sn(CaSnO$_3$) radioactive sources. In this way, hyperfine interactions at both ^{57}Fe and ^{119}Sn resonant nuclei were inspected. They offer close insight into the bulk microstructural arrangement of the investigated samples from a viewpoint of two compositional atoms. On the other hand, characterization of surface features was performed by atomic force and magnetic force microscopy.

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Comparison of the tribological and anticorrosion properties of multi-principal element alloys: CoNiMo, CoCrNiMo, $CoCrCu_{0.1}NiMo$

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In recent years, there has been great interest in the scientific community in multi-principal element alloys (MPEAs) containing more than three chemical elements, of which two have dominant shares [1]. High-entropy alloys (HEAs) and medium-entropy alloys (MEAs) represent the class of materials within the broader family of MPEAs. According to definition, HEAs represent alloys containing at least five chemical elements with shares of 5-35 at. %, while MEAs constitute alloys composed of three to four main elements with equiatomic proportions [2]. The aim of this work was to develop alloys of CoNiMo, CoCrNiMo, and $CoCrCu_{0.1}NiMo$ for structural characterization and its influence on anticorrosion and mechanical properties. In further research, the properties of the alloys studied will be compared with other compositions of HEAs such as the CoCrFeNiMo or CoCrFeNiMn - Cantor alloy.

Ingots of CoNiMo, CoCrNiMo and $CoCrCu_{0.1}NiMo$ alloys were produced by induction melting of pure elements and slowly cooling in a ceramic crucible. Structural studies were performed using X-ray diffraction and scanning electron microscopy with energy dispersive X-ray analysis of chemical composition. Corrosion tests were carried out by electrochemical measurements using the potentiodynamic method and electrochemical impedance spectroscopy in an aqueous solution of 3.5% NaCl at 25°C. Studies using scanning Kelvin probe force microscopy were also conducted to assess the formation of galvanic cells that constitute a source of corrosion. Vickers hardness and tribological tests using the pin-on-disc method were also carried out.

All of the studied alloys were characterized by a binary-phase structure. Corrosion tests indicated that the CoCrNiMo and $CoCrCu_{0.1}NiMo$ alloys had significantly better corrosion resistance compared to the CoNiMo alloy. The $CoCrCu_{0.1}NiMo$ alloy showed potentials (E_{OCP}, E_{corr}) that were most directed toward positive values compared to CoNiMo and CoCrNiMo. However, the CoCrNiMo alloy was characterized by a lower corrosion current (j_{corr}) and a higher polarization resistance (R_{p}). SKPFM maps showed that the phases of the CoCrNiMo alloy had the lowest Volta potential differences, indicating resistance to galvanic corrosion. Among the studied alloys, the CoCrNiMo alloy showed the highest hardness, while CoNiMo had the lowest.

The work was supported by the National Science Centre of Poland under research project no. 2022/47/B/ST8/02465 and pro-quality competition for funding of breakthrough research as part of the Excellence Initiative – Research University programme of the Silesian University of Technology no. 10/020/SDU/10-21-04.

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Soft Explosive Crystallization and Viscous Flow in Fe$_{83}$B$_{17}$ Amorphous Alloy: Glass Transition Temperature Insights

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The rapid heating of amorphous metallic alloys can induce unconventional crystallization phenomena, significantly affecting their microstructure and mechanical behavior. This study investigates the phenomenon of explosive crystallization in Fe$_{83}$B$_{17}$ amorphous ribbons induced by rapid Joule heating. We analyze the heating rates required to trigger this phenomenon, the propagation velocity of the crystallization front, and the associated plastic deformation at the amorphous-crystalline interface. Our results reveal that explosive crystallization occurs at heating rates above 10 °C/s, leading to a sharp increase in the transformation rate and significant plastic deformation, with strain values reaching up to 20%. The calculated viscosity values during this process fall below 10^7 Pa·s, indicative of a visco-plastic state associated with the supercooled liquid region near the glass transition temperature (Tg). However, despite this observation, the exact determination of Tg remains challenging due to the rapid kinetics of the transformation. Thermographic imaging and strain measurements suggest that plastic deformation occurs in tandem with the crystallization front, reinforcing the hypothesis that atomic mobility at the interface resembles that of a material at Tg. Additionally, X-ray diffraction analysis confirms that explosive crystallization does not alter the final crystalline phases but significantly reduces grain size, consistent with homogeneous nucleation in a viscous regime. These findings provide new insights into the interplay between rapid heating, crystallization dynamics, and plastic deformation in Fe-based amorphous alloys, with implications for materials processing and functional applications.

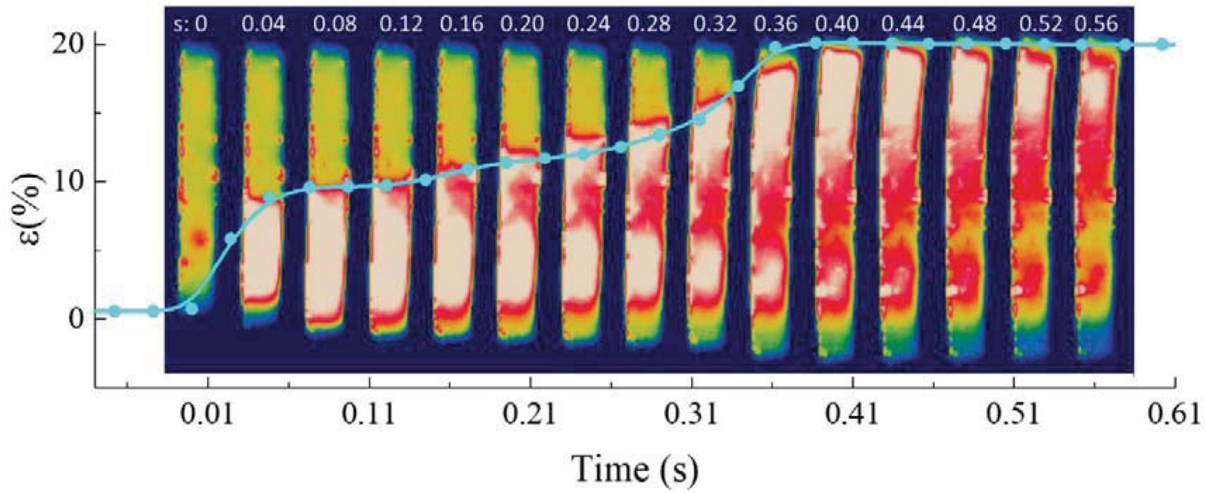

Fig.: 1: Sequential capture of thermographs at 40 ms intervals, overlaid with the deformation ε(t) of a 13.5 mm sample subjected to a stress of 10 MPa and a heating rate of □□= 34 °K/s.

Synthesis of amorphous Co-based multi-component thin film by magnetron sputtering

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Amorphous thin films based on cobalt deserve attention due to their multiple applications and unique physical and chemical properties, such as enhanced corrosion resistance and improved soft magnetic characteristics [1]. Cobalt thin films demonstrate favorable electrical properties, including low resistivity and high conductivity, essential for integrated circuits (ICs) applications, magnetic sensors, and data storage technologies. For efficient operation, these devices must integrate soft magnetic thin films with a certain thickness [2]. So, the research focuses on studying the deposition processes and understanding the relationships between the processing conditions and the resulting film properties to expand the range of applications for cobalt-based thin films.

Magnetron sputtering of different durations was used for synthesizing multicomponent thin films of CoFeMnMoSiB on a glass substrate in this study. The surface structure and internal structure of the films were studied using X-ray and AFM methods. Film thickness was measured by interference microscopy. These films can be utilized as coatings in optical devices. So, we studied absorption and transmission in a range of wavelength 300-1100 nm, depending on the film thickness.

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Direct Visualization of Magnetic Domain Walls in Submicronic Amorphous Wires

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Rapidly quenched amorphous submicronic magnetic wires with diameters between 90 and 950 nm and either high or nearly zero magnetostriction, display a magnetically bistable behavior [1]. Bistability implies the propagation of a single magnetic domain wall from one end of the wire towards the other, with velocities that can differ significantly with magnetostriction.

Here, we report on the Lorentz transmission electron microscopy (LTEM) study of magnetic domain walls in $Fe_{77.5}Si_{7.5}B_{15}$ and $(Co_{0.94}Fe_{0.06})_{72.5}Si_{12.5}B_{15}$ amorphous submicronic wires with high and nearly zero magnetostriction, respectively. Experiments have been performed using a Libra 200 MC Carl Zeiss ultra-high-resolution microscope in Fresnel configuration. Domain wall observations have been achieved under an applied magnetic field H with various amplitudes and directions. Lorentz microscopy data has been correlated with hysteresis loop measurements and domain wall velocity measurements for a comprehensive investigation.

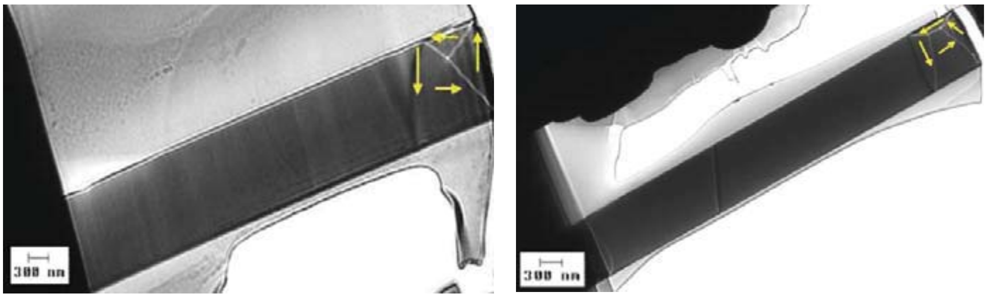

Fig. 1. Domain wall images observed on: (left) - a $(Co_{0.94}Fe_{0.06})_{72.5}Si_{12.5}B_{15}$ submicronic amorphous sample with nearly zero magnetostriction having 900 nm in diameter, with no applied field (H = 0 A/m); and (right) - a highly magnetostrictive $Fe_{77.5}Si_{7.5}B_{15}$ sample with 900 nm in diameter, subjected to H = 300 Oe.

Fig. 1 shows domain wall images observed in a nearly zero magnetostrictive submicronic amorphous sample with 900 nm in diameter, with no applied field (left), and in a highly magnetostrictive one with the same diameter, subjected to 300 Oe (right). For nearly zero magnetostrictive samples, the structure of the domain wall does not change with different values of the field, nor with its direction. For highly magnetostrictive ones, the domain wall displays an elongation that increases with the value of the applied field (right).

The differences in hysteresis loop parameters and in domain wall velocities displayed by the two types of submicronic amorphous wires can be linked to the differences in their domain wall structures. These results are essential to fully understand the magnetic behavior of rapidly quenched submicronic amorphous wires with cylindrical symmetry.

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Alloy Design and Optimized Metal Oxide Photo-reactive Nanostructure for Water Splitting

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Titanium-based alloys offer numerous advantages, such as being lightweight, having adequate strength, good corrosion resistance, and reasonable cost, making them suitable for a variety of applications and a subject of continuous study. Additionally, TiO_2, a titanium oxide with outstanding properties such as strong oxidation power, high chemical stability, and efficient light absorption, is actively researched in the field of water-splitting photo-electrodes. To simultaneously leverage the strengths of these materials, this study proposes a method for developing photo-electrodes by forming TiO_2 and other functional oxides on a titanium-based alloy substrate in a single step. In this study, a Ti-based alloy was developed through alloy design, considering the formation of oxide nanostructures. The alloy was selected as a precursor to form multi-functional oxides through a one-step hydrothermal process, an uncomplicated method for oxide formation. This approach represents a novel and valuable effort to expand the application of Ti-based alloys in functional materials. The alloys were designed as binary alloys, consisting of titanium and a minor element, chosen based on various thermodynamic parameters and oxidation stability using the Ellingham diagram. Additionally, the minor elements were selected for their potential to form oxides with band structures favorable for photo energy absorption when combined with TiO_2. Consequently, this study aimed to confirm the relationship between the oxide morphology, the compositional gradient in the depth direction, and the water-splitting properties of the functional oxides formed according to the selected minor element.

Tetragonal-to-Cubic Phase Transition in Gd-doped $BaTiO_3$ Nanorods: Diamagnetic-to-Ferromagnetic Shift and Enhanced Photocatalytic Properties

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This study details the hydrothermal synthesis and characterization of Gd^{3+}-doped $BaTiO_3$ nanorods ($Ba_{1-x}Gd_xTiO_3$, x = 0 and 0.10). Comprehensive analysis using XRD, TEM, XPS, and Raman spectroscopy validated the successful incorporation of Gd^{3+}-ions into the $BaTiO_3$ lattice, confirming the formation of pure nanorods. Gd^{3+}-doping induced a structural phase transition from tetragonal to cubic, as evidenced by XRD and Raman spectroscopy. The optical band gap was reduced upon doping, and room-temperature ferromagnetism was observed in the Gd-doped sample (x = 0.10), attributed to oxygen vacancies and F-centers. Furthermore, Gd doping quenched photoluminescence, indicating improved charge carrier separation, which enhanced the photocatalytic activity for methylene blue degradation under UV light. The sample with x = 0.10 displayed the highest photocatalytic performance. These results suggest that Gd-doped $BaTiO_3$ nanorods are promising materials for spin-based electronics and photocatalytic applications.

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Structure-Property Relationships in Cu-Zr-Al Alloy: Influence of Crystalline Precipitates on Mechanical Performance

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This research delves into the synthesis, characterization, and properties of Cu-Zr-Al alloy, with a primary aim of enhancing their mechanical performance by integrating both amorphous and crystalline phases within the material. The primary focus is on the formation of the B2 CuZr phase during the solidification process, as well as its subsequent transformation into the martensitic B19' phase when subjected to deformation under specific conditions [1]. This transformation plays a critical role in the alloy's mechanical behavior, and understanding it provides valuable insight into improving the performance of these materials in practical applications.

The study employs a combination of alloy synthesis, casting techniques, mechanical testing, and advanced microstructural analysis to comprehensively investigate the properties of Cu-Zr-Al alloy. Metallic glasses, which exhibit remarkable strength and resistance to corrosion, have garnered significant attention in recent years. However, their brittleness limits their potential for use in structural applications where flexibility and toughness are essential. In response to this limitation, bulk metallic glass composites (BMGCs) are explored as a promising solution. By introducing crystalline phases into the glassy structure of the alloy, the goal is to retain the unique properties of metallic glasses, such as high strength and corrosion resistance, while enhancing their ductility and toughness for broader applicability [2].

For this study, Cu45Zr48Al7 at.% alloy was suction cast in an arc furnace under an argon atmosphere, with diameters ranging from 5 mm to 10 mm. This setup led to the formation of the B2 CuZr phase during solidification, which then undergoes a martensitic transformation to the B19' phase under deformation. The research also investigates how cooling rates affect the structure and properties of these composites.

The structural characteristics were examined using X-ray diffraction (XRD), while light microscopy helped quantify the amount of crystalline precipitates. Mechanical properties were assessed through uniaxial compression tests, focusing on compressive yield and fracture strength. Fracture analysis, conducted with scanning electron microscopy (SEM), highlighted the differences in fracture behavior across the alloys. Additionally, differential thermal analysis (DTA) provided insights into the glass transition, crystallization, and melting temperatures, revealing crucial details about the glass-forming ability and the formation of the B2 phase during solidification.

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Development of High Entropy Alloy via Thermo-Calc and remelting technique

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High entropy alloys (HEAs) have garnered significant interest in last two decades due to their exceptional properties, making them promising candidates for various industrial applications. These alloys typically consist of multiple principal elements in nearly equimolar ratios, the synergy of distinct elements in a system exhibits superior properties enabling them to be utilized in wide range of industries.

This article aims to comprehensively study and optimize the development of high-entropy alloys with basic alloy of Co-Cr-Mo-Ni and additional chemical elements obtain by arc remelting.

The initial selection of elements: Co, Cr, Mo, Ni, Mn, WC and FeTi + TiC is based on their potential to impart desirable mechanical and wear properties to the HEAs. The detailed literature was also guide the alloy selection with regard to targeted properties. Predictive modeling using Thermo-Calc software, was guide the assessment of phase formation in both equilibrium and non-equilibrium conditions. In this work, phase transformation simulation in the melted areas with prediction of precipitates was used. This computational analysis inform the optimal composition for achieving stable microstructures and desired properties in the final products.

This research aims to advance the development and application of HEAs by employing the arc-melting technique. A variable current value was used for remelting and protective argon atmosphere.

A Scanning Electron Microscope equipped with an Energy Dispersive Spectrometer revealed the structure, morphology and chemical composition. Essential for phase analysis, X-ray Diffraction confirmed the presence of phases predicted by computational models and detected any crystalline changes induced by processing conditions.

This work aims to bridge theoretical predictions with practical development, providing a deeper understanding of HEA behavior under various processing conditions.

Structure and electrical resistivity of the Bi-In-Sn-Zn-Cu-Ag alloys

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A new class of materials, known as high-entropy alloys of equiatomic composition with a high entropy of mixing, achieved by at least 5-6 components, is gradually replacing conventional alloys based on a single main element, which are generally thermodynamically unstable, and their phase transformations lead to a deterioration in characteristics with increasing temperature.

High entropy of mixing can stabilize the formation of solid solutions (simple bcc or fcc crystal structure) during solidification of these alloys. Stabilization of the solid solution and prevention of the intermetallic phases during solidification is provided by the high entropy of mixing in the solid and liquid states. High-entropy alloys have increased strength, high hardness, and thermal stability in combination with good resistance to oxidation and corrosion.

The main problems of research on multicomponent high-entropy alloys are related to the high melting temperatures of their constituent elements. Therefore, it is useful to study properties of similar multicomponent alloys consisting of elements with lower melting points, as well as of their subsystems with a smaller number of components, which can be considered as model systems.

These properties allow to expand significantly the scope of these alloys, which have recently begun to be intensively studied also as low-temperature solders [1-3]. In this work, structure and microstructure of multicomponent Bi-In-Zn-Sn-Cu-Ag alloy as well as their subsystems Bi-In-Zn-Sn-Cu and Bi-In-Zn-Sn, have been studied. Their electrical resistivity and DTA were measured in a wide temperature range including solid and liquid states.

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Development of Fe-rich complex concentrated alloys (CCAs) for high-temperature applications

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The complex concentrated alloys (CCAs) have gained enormous attention for almost two decades due to their exciting mechanical properties [1,2]. However, the major drawback of these alloys is the high cost accompanied by the equimolar proportion of constituent elements. In the present work, we have designed a series of Fe-rich non-equiatomic alloy compositions (Fe ≥ 40 at %) by following the pseudo-binary and semi-quantitative method based on the CALPHAD approach to meet the industrial applications at the temperature range of 500-700 °C. The composition of the alloys is selected in such a way that it leads to the formation of the FCC and $L1_2$ phases to mimic the superalloy-like γ-γ' microstructure. The first class of elements, which includes Fe, Ni, Co, and Cr, prefer to partition to the γ (matrix phase) and stabilize it. The second class of elements, Al and Ti, have greater atomic radii and large differences in binary mixing enthalpy with Ni promoting the formation of the ordered γ' phase. The as-cast alloys, after homogenisation treatment at 1100°C, followed by cold rolling subjected to the solutionising treatment. The single-phase FCC structure after solutionising treatment was subsequently aged at 600, 700 and 800 °C at different holding times to understand the precipitation kinetics. The microstructure stability, precipitation behaviour and high-temperature tensile properties were evaluated at the different states of the alloy.

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Formation of ordered metal arrays as a result of rapid solidification of alloys

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Ordered arrays of nano- and microparticles have unique physical properties due to the periodic arrangement of structural elements. Such materials are promising for use in photonics, magnonics, plasmonics, and other areas of physics. Various methods are used to form ordered arrays of nanoscale objects, including photolithography, self-organization of nanoparticles on various surfaces, and physical and chemical deposition methods. Most of these methods are complex, expensive, and cannot be used for mass production. In this regard, it is necessary to develop new methods for obtaining such structures.

One of the methods that make it possible to obtain ordered arrays of nanoscale structures is the self-organization process that occurs during crystallization of the melt. In this case, two crystallization modes can be used. where. In particular, the method of directional crystallization [1] can be applied, wherein the slow movement of the crystallization front leads to the formation of crystals with axes perpendicular to the liquid-solid interface. On the other hand, a rapid crystallization method can be used to form metastable phases that grow perpendicular to the cooling surface. Chemical or electrochemical etching of the resulting alloys removes the matrix phase and allows for the separation of ordered crystallites [2].

In this work, we have investigated the formation of arrays of metal nanorods because of rapid crystallization of tin-based alloys. The atomic composition of the alloys was close to the range of existence of solid solutions. Alloys were obtained by a planar flow casting method. As-quenched alloys were chemically or electrochemically etched to remove tin as a matrix component. X-ray diffraction analysis and electron microscopy were used for the study. The study revealed arrays of nanorods whose growth direction coincides with the direction of heat transfer.

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Electrochemical surface nanostructuring of Ti-Cu-(Pd)-based metallic glasses for improved pitting corrosion resistance

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Ti-Cu-(Pd)-based bulk metallic glasses (BMGs) are known for their exceptional strength-to-stiffness ratios, yet their high copper content adversely affects their biocompatibility, cytocompatibility, and corrosion resistance, which limits their use in biomedical applications. In this study, two specific BMG compositions – $Ti_{47}Zr_{7.5}Cu_{38}Fe_{2.5}Sn_2Si_1Ag_2$ and $Ti_{40}Zr_{10}Cu_{34}Pd_{14}Sn_2$ – were evaluated under simulated physiological conditions (phosphate-buffered saline, pH 7.4, 37 °C), examining their corrosion performance under both open-circuit and anodic polarization conditions. The Cu-rich $Ti_{47}Zr_{7.5}Cu_{38}Fe_{2.5}Sn_2Si_1Ag_2$ alloy exhibited poor passivation and limited pit repassivation capabilities. In contrast, the Pd-containing $Ti_{40}Zr_{10}Cu_{34}Pd_{14}Sn_2$ demonstrated superior pitting resistance and formed corrosion products enriched in Cu, Zr, and Pd, indicating a more stable passive behavior. To address the biocompatibility issues associated with copper, both alloys underwent a surface modification technique resembling dealloying, which formed nanoporous titanium/zirconium oxide films [1].

The surface nanostructuring process improved corrosion resistance, as validated through open-circuit potential (OCP), linear voltammetry (LVA), and electrochemical impedance spectroscopy (EIS) measurements. Structural and compositional changes were examined using X-ray diffraction (XRD), differential scanning calorimetry (DSC), scanning electron microscopy (SEM), energy-dispersive X-ray spectroscopy (EDX), and X-ray photoelectron spectroscopy (XPS), confirming the depletion of surface copper and formation of protective oxide films [2,3].

Following the pseudo-dealloying treatment, the Cu-rich alloy formed uniform nanoporous oxide layers that effectively suppressed pitting, while the Pd-containing alloy demonstrated less uniform oxide growth. EIS revealed that treated $Ti_{47}Zr_{7.5}Cu_{38}Fe_{2.5}Sn_2Si_1Ag_2$ samples developed thicker passive films (~16 nm) compared to the untreated state (~8 nm). These results underscore the detrimental role of copper in corrosion behavior and highlight the stabilizing influence of palladium, offering valuable insights for tailoring surface modifications and alloy compositions to optimize performance in biomedical environments [2-4].

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Nb-Zr-Pt-Ti high entropy alloy superconducting bulk: synthesis and structure-property correlation

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High entropy alloy (HEA) superconductors recently gained attention to researchers because of better chemo-mechanical property in addition to superconducting behaviour. Nb based HEAs were among those who have emerged successful as the superconducting bulks. However, the existing literatures still focuses on deciphering the superconductivity behaviour only based on valence electron count (VEC) or through structural disorderliness [1] different from the traditional superconductors. Traditional superconductors show variations in superconducting behaviour when microstructure is engineered.

This present work reports the novel Nb-Ti-Zr-Pt HEA with different alloy configurations as (Nb, Zr, Pt)67Ti33, Nb67(Ti, Zr, Pt)33 and (Nb, Pt)67(Ti, Zr)33 to understand the superconducting behaviour through a microstructure – functional property correlation approach. The bulk is synthesized through arc melting route. Different heat treatment conditions are utilized to engineer the microstructure, and its effect were analysed on critical temperature, Tc and critical current density, Jc. The microstructure evolution with phase stability were studied using advanced electron microscopy techniques. The functional characteristics were analyzed using magnetic property measuring systems (MPMS). The samples annealed at 1100 °C for 9 hrs are observed to attain relatively better functional behaviour with a high reported Tc of 8.3 K at 5 mT under zero field cooled (ZFC) condition and Jc of 80 kA cm-2 at 4.2 K under self-field condition for (Nb, Zr, Pt)67Ti33 alloy [2]. Possibility of formation of stoichiometric A15 Nb3Pt phase (as confirmed by Scanning and Transmission electron microscopic and X-ray diffraction technique) and magnetic flux pinning centers (as confirmed by modified Dew Hughes model) were identified to be responsible behind the variation in Tc and Jc.

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Achieving excellent tensile plasticity in amorphous microwires through ion-induced nonlinear gradient rejuvenation

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Amorphous alloys possess exceptional mechanical properties such as high strength and elasticity but suffer from limited tensile plasticity at room temperature, categorizing them as quasi-brittle materials. Ion irradiation has emerged as a promising method for improving their plasticity by inducing gradient rejuvenation structures that modify the distribution of free volume. In this study, H^+ irradiation was applied to amorphous microwires (AMs), introducing a unique nonlinear gradient rejuvenation structure with thickness of ~1.76 µm. Unlike traditional linear gradient structures, this structure features a novel free volume distribution that first increases to a certain depth and then decreases from the surface to the interior. It not only effectively hinders the propagation of the dominant shear band (SB) at the interface between high and low free volume regions but also promotes the formation and branching of numerous fine SBs within the rejuvenated region. The combination of these two effects results in significant enhancement of the tensile plasticity to ~2.97% while maintaining high yield strength (1680 MPa) of AMs. This outcome provides insights into the mechanisms enabling improved plasticity and highlights the potential of nonlinear gradient rejuvenation as a strategy to optimize the mechanical properties of bulk amorphous alloys, offering a promising pathway for developing next-generation high-performance metallic materials.

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Low temperature plasma assisted fabrication of multi-metallic nanomaterials for electrodes of energy storage systems

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In energy storage devices, electrodes are arguably the most significant components and one of the key fields in development of energy storage devices to maximize the ion storage capacitance, energy density and power density is based on an improvement of the electrode material characteristics [1], in particular, a fabrication of nanostructured material with high surface areas for achieving greater electrochemical activity and conductivity. In this work we propose a low-temperature plasma in liquid technology for a synthesis and surface modification of multimetallic electrode nanomaterials. A combination of such metals as Zn, Fe, Mo, Cu, Mn was selected with a deposition them on the activated carbon and natural fibers for the development of energy storage device with the enhanced electrochemical performance and charge storage capabilities.

The developed approach is based on non-equilibrium plasma in contact with a liquid with an additional laser-induced modification of the formed nanoparticles (NPs) for the synthesis of multimetallic oxide nanomaterials. The distinctive feature of the approach is simultaneous anodic dissolution of several solid metallic plates submerged in liquid and subjected to a plasma–activated electrolysis. As a cathode, stainless steel capillary was used, placed above the liquid surface. The argon gas was flown through the capillary with a flow rate 25-60 sccm to induce the breakdown near the liquid surface under the application of the high voltage of 1-3 kV (current 4 mA). As a laser source for the additional modification of the formed NPs, the unfocused beam of the third harmonic (355 nm, repetition rate 10 Hz and pulse duration 10 ns) of the Nd:YAG laser was applied. The phase composition, morphology, structure and optical properties of the formed NPs were investigated by SEM, EDX, TEM, XRD, Raman and optical absorption spectroscopy.

The influence of the major experimental parameters, such as composition and pH of the liquid, applied voltage on the morphology, composition and structure of nanomaterials was studied. The typical TEM images showed well-separated NPs with sizes in a range of 10 - 15 nm. The analysis of the EDX data confirmed the uniform distribution and presence of all the elements from the multimatallic anode in the NPs. However, the ratio of the components was different, which is associated with different electrochemical potential of metals or liquid composition. Based on the obtained results, it can be assumed that a mechanism of multimetal NPs synthesis in a developed approach includes an anode material dissolution with the subsequent processes of metal ions reduction with electrons and radicals formed due to the plasma cathode jet interaction with a liquid surface. Laser irradiation of the produced NPs provided a pathway to further tune the morphology and inner structure of the NPs. The developed approach can be extended to the nanomaterials of other composition, that allows its considering as a versatile tool for the production of nanomaterials of complex multielement composition for next generation energy storage devices.

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Hybrid solder joints: characterization of the core/shell Fe/oxide nanosized particles

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The iron oxide nanoparticles garner a great deal of attention due as a promising material in various applications. For instance, they can be used as biomaterials for targeted drug delivery, hyperthermia and thermoablation [1]. Furthermore, iron and iron oxide nanoparticles can be used in electronics to improve the mechanical reliability of the solder joints. It was shown that the minor additions of the metal and oxide nanoparticles into the SAC solder reveal notable enhancement in mechanical properties [2].

In the present study the effect of thermal oxidization on the chemical composition of passivated Fe-nanoparticles has been characterized by TEM, X-ray and BET measurements. It was shown that prior to thermal exposure, the core of Fe-nanoparticle is covered with Fe_2O_3. The average size of the nanoparticles was found to be 50nm, while the oxide shell was about 5nm. Subsequently, the nanoparticles were thermally treated, namely were capped in a furnace at 200^0C and 400^0C for 1 hour. The X-ray studies have shown more pronounced peaks corresponding to the Fe-oxide with increasing the temperature. Furthermore, the ratio changes between metal core and oxide shell after thermal treatments were investigated by TEM. In addition, the surface area measurements of the nanoparticles were performed by the BET technique. It was shown that the surface area values decreases by increasing of the thermal treatment temperature.

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Influence of V on the microstructure and mechanical characteristics of $(CrFeNiCu)_{100-x}V_x$ high entropy alloys

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In this study, the $(CrFeNiCu)_{100-x}V_x$ ($x = 0 - 20$ at.%) high entropy alloys have been designed via the consideration of the thermo-physical relationship between minor V and other major elements to investigate the effect of V content on the microstructure and mechanical behaviour of $(CrFeNiCu)_{100-x}V_x$ HEAs. The phase formation from dual phase FCC phases to the mixture of FCC1, FCC2 and BCC phases has been observed. The yield strength of the $(CrFeNiCu)_{100-x}V_x$ HEAs is enhanced from 291 to 1717.47 MPa, which is associated with the volume fraction of the BCC phase strongly. On the one hand, the plasticity of the alloys reduced from 45 to 10.65%, however, it could be considered a reasonable plasticity. These results show that adding a minor alloying element in high entropy alloys with consideration of thermo-physical parameters leads to forming a multiple solid solution structure with considerable excellent mechanical properties. Moreover, Thermo-physical parameters, such as the mixing entropy (ΔS_{mix}), the mixing enthalpy (ΔH_{mix}), atomic size difference (δ%), and the valence electron concentrations (VEC) were calculated to understand the microstructural variation. Meanwhile, the thermo-physical parameters were used to explain the formation of mixture BCC and FCC phases in the HEAs and discussed the relationship with mechanical parameters.

Influence of configuration entropy and cocktail effect on the corrosion resistance of Pd-based Metallic Glasses

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Corrosion of metallic materials is widespread, and one of the most common failure modes in these materials is precisely corrosion [1]. Every year, a large number of metallic materials worldwide incur additional maintenance costs due to corrosion, resulting in significant economic losses [2]. To mitigate these losses, it is crucial to explore new materials with excellent corrosion resistance. In this regard, high-entropy metallic glasses (HEMGs) have attracted considerable attention due to their unique design concept, outstanding performance, economic impact, and broad range of engineering applications.

However, research on the relationship between high-entropy properties and corrosion resistance remains limited, creating uncertainty about how configurational entropy and high-entropy effects influence the corrosion resistance of materials. In this study, the corrosion behavior of three typical Pd-based metallic glasses (MGs) [3-5] with different entropy values was investigated in 0.5 M H2SO4. The results indicate that the self-corrosion current of Pd-based HEMG is approximately 0.3% of that of ternary Pd-based MG, demonstrating a significant improvement in corrosion resistance with increasing entropy. The surfaces of the three metallic glasses were examined using X-ray Photoelectron Spectroscopy (XPS), revealing that the Pd content in the Pd-based HEMG is only 50% of that in other Pd-based MGs. However, it exhibits the highest Pd oxide content after corrosion. This result intuitively suggests that the cocktail effect in high-entropy materials enables each element to achieve optimal performance, synergistically enhancing corrosion resistance.

Furthermore, binding energy was used to directly correlate the corrosion resistance of the material with both the intrinsic stability of the material and the stability of the oxide film. These findings offer a new perspective on controlling the high-entropy effect through configurational entropy to regulate the corrosion resistance of MGs.

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Preparation and Characterization of New Highly Entropy Alloys

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Studies of high entropy alloys (HEA) gained great attention owing to their excellent physical properties, such as superior mechanical properties (high tensile strength, hardness, toughness, ductility) high corrosion resistance and hence different applications [1,2].

We present our attempts on preparation and characterization of new $Ni_xMn_xSi_xCo_xCu_xM_x$ (M= Al, Ti, Nb or a combination of them) using induction furnace and/or using VIM furnace (Vacuum Induction Melting Furnace). Alloy $Ni_{44}Mn_{10}Si_6Co_{20}Cu_{15}Al_5$ has been manufactured using a CONSARC VIM furnace of 75kW power and 2 liters capacity. The alloy has been poured directly into a chemically bonded sand mold and samples have been manufactured using LMD technology representing a higher cooling rate for comparison. Alloys $Ni_{39}Mn_{10}Si_6Co_{20}Cu_{15}Al_5Ti_5$ and $Ni_{34}Mn_{15}Si_6Co_{20}Cu_{15}Al_5Ti_5Nb_5$ have been manufactured using chemically bonded sand molds. The chemical compositions of prepared samples were analyzed by ICP-OES Radial (Thermo Fischer). Various physical properties, such as Vickers Hardness, magnetic properties (coercivity, saturation magnetization) and microstructure have been evaluated. Given that prepared alloys are similar to the nickel-based superalloys, the routes for further improvement of magnetic properties include the thermal treatment including a solubilization treatment followed by a precipitation treatment performed in order to precipitate Υ'NiAlTi hardening phases and doping by Ti and Nb.

The alloys present ferromagnetic behavior at room temperature. The coercivities of 0.27 mT and 6.5 mT are observed for $Ni_{44}Mn_{15}Co_{20}Si_6Cu_{15}$ and $Ni_{44}Mn_{10}Co_{20}Si_6Cu_{15}Al_5$ alloys respectively.

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