FunGlass

Book of Abstracts

FunGlass School 2025/1

Lazy pod Makytou

June 23- 25, 2025

ORGANIZING INSTITUTIONS:

FunGlass School 2025/1

Book of Abstracts

Lazy pod Makytou, June 23-25, 2025

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Edited by Dr. Branislav Hruška and Vanda Mokráňová

ISBN 978-80-8295-046-8
EAN 9788082950468

Content

Developing damage-tolerant multi-material ceramics using finite element methods (FEM)

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ABSTRACT

Despite the brittle nature of ceramic materials that makes them susceptible to surface flaws and defects, tailoring the residual stresses within ceramic bodies can lead to damage-tolerant products, exhibiting complex failure characteristics, such as non-linear R-curve behavior. Engineering residual stresses in ceramics are challenging due to a limited understanding of how residual stresses evolve during fabrication. In this work, we employed the finite element method (FEM) to study the stress build-up in multi-layered ceramics with various architectures during sintering and the impact of residual stresses on the mechanical and thermal responses of laminar bodies to contact damage. Multi-layered ceramic systems, composed of $MgAl_2O_4$, Al_2O_3, and c-ZrO_2, were modeled by incorporating material properties and various layer architectures to investigate stress generation during fabrication. The impact of residual stresses on the various scenarios of materials failure, such as crack propagation, delamination onset, and the failure limit under different loading conditions, was evaluated. The experimental methods used to verify the simulation results, as well as their implications for developing damage-tolerant multi-laminar ceramics, are critically discussed. The architecture of laminated ceramics, including the thickness and orientation of various layers, was found to influence the residual stresses within the materials, thereby affecting their overall mechanical performance.

Keywords: Failure, FEM simulations, Multi-laminar ceramics.

Acknowledgment:

This work was supported by the EU NextGenerationEU through the Recovery and Resilience Plan for Slovakia under the project No. 09I03-03-V04-00196 and 09I01-03-V04-00014/2024/VA.

Multilayer ceramic composites by tape casting: role of suspension rheology

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ABSTRACT

Multilayer ceramic composites, strengthened by engineering residual stress profiles (ESP), are potential enablers for various applications, from high-temperature optical windows to protective display covers. Tape casting is a well-established technique for fabricating thin ceramic laminae that can be assembled to form multilayer ceramics with complex architectures. Successfully producing ceramic laminae through tape casting necessitates precise control over the rheology and processing of ceramic powders.

In this work, we investigated the effect of processing parameters on the rheological behaviour of aqueous ceramic suspensions and their tape casting. To this end, aqueous suspensions of Al_2O_3, $MgAl_2O_4$, and ZrO_2 were prepared using a commercial acrylic binder system. The effects of ceramic powder concentration (30 wt% -55 wt%), the amount of binder (25 wt%-45 wt%), and the plasticizer agent to binder ratio (0.01, 0.02 and 0.04) were studied in terms of suspension viscosity and rheological behaviour, as well as the properties of the produced ceramic tape.

The results revealed that the binder concentration determines the rheological behaviour of the suspension, e.g., the critical shear rate, while the effect of solid particle concentration was found to be minor. The plasticizer-to-binder ratio of 0.01 was identified to be crucial for the tapes flexibility. A green strength of 4.5 MPa was achieved for ZrO_2, which is vital for assembly of multilayer ceramics. The composition and properties of ceramic particles determined a limit for the solid loading. Based on these findings, key processing aspects were critically evaluated and used to optimize the composition of suspensions.

Keywords: Alumina, Multilayer structures, Rheological behavior, Zirconia.

Acknowledgment:

This work was supported by the EU NextGenerationEU through the Recovery and Resilience Plan for Slovakia under the project No. 09I03-03-V04-00196 and 09I01-03-V04-00014/2024/VA.

Insights from molecular dynamics on compositional effects in the structure of mixed alkali lime silicate glasses

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ABSTRACT

Chemical strengthening is a well-established technique to improve the mechanical performance of silicate glasses. Chemical strengthening is typically carried out by immersing glasses into a molten salt bath where larger cations, i.e., K^+, are stuffed into smaller alkali sites (Li^+, or Na^+) in glass, producing a compressive layer close to the surface. However, the mechanism of stress build-up during ion exchange is not fully understood due to the interplay of various parameters, such as compositional effects, stress relaxation, and structural evolution.

In this study, we perform molecular dynamics (MD) simulations [1] to investigate the structural effects of Na^+/K^+ ion exchange in a soda-lime-silica glass ($15Na_2O$-$10CaO$-$75SiO_2$). Following the approach outlined in Ref. [2], we simulate the ion exchange process by substituting Na^+ ions with K^+ ions in the glass matrix and allowing the system to relax.

This computational strategy enabled investigating the possible stress buildup mechanisms during ion-exchange. Moreover, the simulations provided insight into ion dynamics, local density, ions ' coordination number.

Keywords: Glasses, Ion-exchange, Molecular dynamics simulations, mechanical properties, diffusion.

Acknowledgments
This work was supported by the project Funded by the European Union NextGenerationEU through the Recovery and Resilience Plan for Slovakia under the project No. 09I01-03-V04-00014/2024/VA.

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Chemical strengthening of mixed-alkali soda silicate glasses: experimental and molecular dynamics study of composition, structure, and property correlations

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ABSTRACT

Despite their outstanding damage tolerance, tempered glasses are prone to spontaneous failure and shattering, limiting their application. In contrast, ion exchange strengthening is a well-developed approach for producing mechanically reliable glasses. Although ion-exchange strengthening has been utilized to improve the mechanical performance of specialty glasses, its application for enhancing the strength of soda-lime silicate glass, such as window glass, has been limited thus far, due to the slow diffusion of cations involved in the ion-exchange process. In the present work, we investigated the correlations between the glass composition, alkali ions mobility, and the efficiency of ion-exchange strengthening.

Glasses with the chemical composition $(15-X)Na_2O \cdot XK_2O \cdot 10CaO \cdot 75SiO_2$, ($0 \leq X \leq 15$ mol%) were synthesized by melt-quenching. The samples were subjected to ion-exchange strengthening in molten KNO_3 at 430–470 °C for 4 hours. Physical and mechanical properties—including density, glass transition temperature (Tg), softening point (Ts), Vickers hardness, and crack initiation probability (CIP)—were evaluated alongside structural analysis by μ-Raman spectroscopy and X-ray photoelectron spectroscopy (XPS). A significant variations in the physical properties and structure of ion-exchanged glasses was confirmed. Molecular dynamics (MD) simulations were conducted to model the structure of the as-melted glasses across the compositional series and investigate the relationship between the glass composition, structure and ion mobility. The simulations revealed that increasing K_2O content leads to progressive network depolymerization, reflected in a higher proportion of Q^3 units and NBOs.

By combining experimental data with simulation insights, this study presents a compositional and structural framework to optimize ion exchange in silicate glasses, which has implications for improving mechanical performance in chemically strengthened systems.

Keywords:
Ion Exchange, Mixed Alkali Effect, ion mobility, micro-Raman spectroscopy, Molecular Dynamics Simulations

Synthesis, characterization, and optical properties of undoped KZGO Polycrystals

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ABSTRACT

Self-activated phosphors (SAP) have recently gained popularity for a variety of applications, including lighting devices, displays, scintillators, sensors, bioimaging, and luminescent security ink. However, their recent advances in white-light illumination have been restricted by considerable difficulties in obtaining broad emission. We present a novel white-colour-emitting SAP based on the undoped K_2ZnGeO_4 (KZGO) germanate. The polycrystalline powder was created utilizing a solid-state reaction technique. X-ray diffraction and scanning electron microscopy (SEM) investigations confirmed the single-phase crystal structure, revealing irregularly shaped particles. The luminescence properties were studied in depth. Surprisingly, when excited by ultraviolet (UV) and X-ray sources, this material produced broadband white light ranging from 400 to 700 nm. The CIE 1931 coordinates (x, y) = (0.388, 0.441) were determined using PL spectra collected at 366 nm excitation. The impact of structural defects on the luminescence of this SAP was also studied. The combined findings suggest that this SAP is a good candidate for white-light lighting and possibly other luminescent devices.

Keywords: Broadband emission, germante, Luminscence, Phosphor, Polycrystalline

Acknowledgment:

This item is a part of dissemination activities of project FunGlass. This project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 739566. The authors also gratefully acknowledge the financial support from the EU NextGenerationEU through the Recovery and Resilience Plan for Slovakia under the project No. 09I03-03-V04-00198.

Cold sintering of glass – first experiments, preliminary plans

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ABSTRACT

The cold sintering process (CSP) is a relatively recent and innovative technique that enables the densification of ceramic, glass, and composite materials at significantly reduced temperatures, typically below 400 °C. This method utilises a transient liquid phase and uniaxial pressure to promote densification. In the initial step, inorganic powder materials are mixed with a transient solvent. Upon application of uniaxial pressure and moderate heat, a dissolution–precipitation mechanism is initiated, facilitated by the liquid phase. This results in the formation of surface species such as ≡Si–OH and ≡Si–O–Na^+, which subsequently undergo condensation and precipitation, aided by the evaporation of water, leading to material compaction.
To investigate optimal CSP parameters, H_2SiO_3 silicic acid powder was selected as the starting material. Sodium hydroxide (NaOH) solutions at concentrations of 5 M and 10 M, with varying volumes, were employed as the transient liquid to induce the hydrolysis of silicate structures via OH^- ions. The cold sintering experiments were conducted under uniaxial pressures ranging from 300 to 500 MPa at sintering temperatures between 150 °C and 225 °C. The heating rate was maintained at 20 °C/min, and the dwell time at the target temperature ranged from 30 to 120 minutes.
The resulting materials were characterised using scanning electron microscopy (SEM), thermogravimetric and differential thermal analysis (TG/DTA), and X-ray diffraction (XRD). Bulk density measurements were also performed. The influence of sintering conditions and NaOH concentration on the material's microstructure, phase composition (amorphous vs. crystalline), optical transparency, and densification was systematically examined. Based on these findings, recommendations were proposed for future CSP optimization, particularly for the preparation of YAG (yttrium aluminium garnet) and YAS (yttrium–aluminum–silicate) materials.

Acknowledgment:

The authors gratefully acknowledge the financial support from the Slovak Grant Agency of the Ministry of Education, Science, Research and Sport, VEGA 2/0077/24 and APVV- 23-0424.

Exploring the cold sintering of amorphous powders with a strong tendency toward crystallisation

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ABSTRACT

Cold sintering (CS) was employed to densify amorphous yttrium aluminium garnet (YAG) powders, which exhibit a high propensity for crystallization. The powders were synthesized via combustion synthesis, followed by a tailored burn-out process to maintain an amorphous structure. Densification was performed at temperatures ranging from 150°C to 400°C under pressures up to 400 MPa, with dwell times between 30 minutes and 2 hours. A 10 M NaOH aqueous solution served as the transient liquid phase. Sintering at temperatures up to 200°C preserved the amorphous state, while higher temperatures induced partial crystallization, yielding YAG and boehmite phases. The boehmite phase, attributed to the reaction of the NaOH solution with the glass matrix, led to precipitation of etched glass. Samples sintered at 350°C for 60 minutes exhibited translucency (see Fig. 1), which was associated with the presence of the boehmite phase. However, at 400°C, decomposition of the boehmite phase resulted in opaque, broken samples. Optimization of NaOH concentration, sintering parameters, or alternative transient liquid phases is recommended for future studies to enhance material properties.

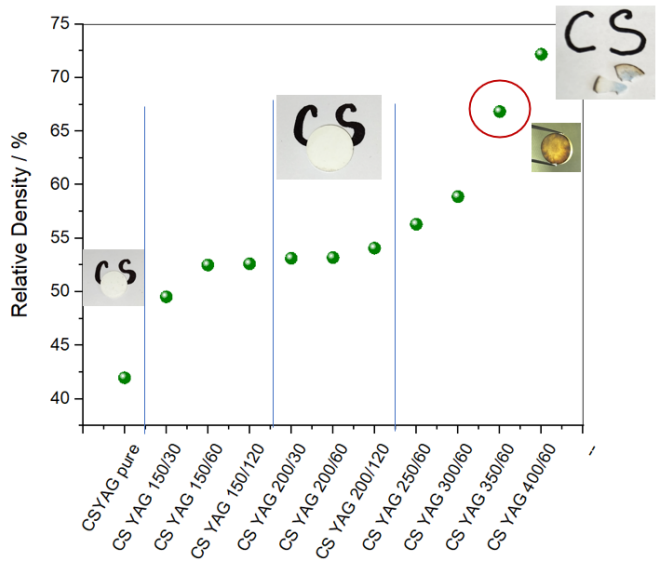

Fig. 1: The relative densities of samples prepared by CS with optical images.

Keywords: amorphous state, cold sintering, transient liquid, YAG

Acknowledgment:

This item is a part of dissemination activities of project FunGlass. This project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 739566.
The authors gratefully acknowledge the financial support from the Slovak Grant Agency of the Ministry of Education, Science, Research, and Sport, VEGA 2/0077/24, APVV-23-0352, and APVV-23-0424.

Exploring cold sintering pathways in bioactive glass system 45S5 and 1393

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ABSTRACT

Cold sintering has many advantages over conventional sintering techniques, such as lower processing temperature, compatibility with temperature-sensitive materials, fast processing, controlled volatilization, energy saving, and low environmental impact. Other advantage include controlled crystallization and/or reduced grain growth. All these unique features of cold sintering are highly desirable for the processing of bio-active materials, such as bioactive glasses, helping them to preserve the bio-activity and prevent decomposition of organic matters , including drugs and living tissues.
Bioactive glass is one of the materials whose potential is often impaired when conventional sintering results in undesired crystallization, phase separation, and incompatibility with temperature-sensitive additives, including degradation and volatilization of vital bioactive elements like phosphorus.
In the present work, crystallization and densification behaviour of the two most popular bioactive glasses,45S5 and 13-93, under cold sintering conditions were studied. The cold sintering parameters, such as the selection of transient liquid, solid-to-liquid ratio, temperature, pressure, and time, including the selection of transient liquid, solid-to-liquid ratio, temperature, pressure, and time, were optimized. The solid/liquid ratio of 40:60 cold-sintered samples with the highest density. The densification was also promoted by the increase of temperature, yielding glass with high mechanical strength; however, it also resulted in undesirable crystallization. Selection of transient liquid and dwell time was found to play a crucial role in the preparation of a highly dense glass with reduced content of crystalline phases and a high mechanical strength. A highly dense (98%), translucent 13-93 bioactive glass ceramic was prepared after 45 minutes sintering at 250 °C and under 300 MPa with a solid/liquid ratio of 40:60.

Keywords: Alkali Activation, Bioactive Glasses, Cold Sintering, Densification. 1393 and 45S5 Bioactive glasses

Acknowledgment:

Financial support of this work by the grant APVV23-0424 is gratefully acknowledged.

Bi_2O_3 and $Bi_4Ge_3O_{12}$-doped Yttria Fluorescent materials, take two: preparation using particle bead milling

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ABSTRACT

Yttria-based ceramics doped with Bi^{3+} ions are promising materials for photonic applications due to their tunable luminescence. This study investigates the effect of two different Bi^{3+} sources: Bi_2O_3 and $Bi_4Ge_3O_{12}$ on the photoluminescence properties of Y_2O_3 ceramics. The starting powders were weighed to achieve Bi^{3+} concentrations of 0.25, 0.5, 1, 2, and 4 atomic percent relative to Y^{3+} and subsequently homogenized and milled in isopropanol using a particle bead mill. The resulting suspensions were spray-dried to obtain dry powders composed of soft agglomerates, as confirmed by SEM/EDXS analysis.
The powders were uniaxially pressed into green pellets at 50 MPa and further compacted using cold isostatic pressing (CIP) at 1000 MPa. The pellets were sintered at 1400 °C for 2 hours.
Photoluminescence (PL) spectra of both material types exhibited a broad emission band in the visible range, centered around 500 nm (green), with a smaller shoulder near 415 nm (blue) under 330 nm excitation. According to literature, these emissions correspond to the $^1S_0 \rightarrow {}^3P_1$ transition of Bi^{3+} ions located in C_2 (blue) and S_6 (green) symmetry sites. Notably, the PL intensity of samples prepared using $Bi_4Ge_3O_{12}$ was approximately twice as high as that of samples prepared with Bi_2O_3.

Keywords: Bi_2O_3, $Bi_4Ge_3O_{12}$, Y_2O_3, Ceramics, Photoluminescence, SEM/EDXS/EBSD

Acknowledgment:

This item is a part of dissemination activities of project FunGlass.
This project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 739566.

Constructing high-performance metal sulfide-based photo-absorbers for H_2 generation

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ABSTRACT

Using solar energy to produce hydrogen (H_2) from water is thought to be a viable approach to addressing the world's energy issues. In particular, the use of semiconductor photocatalysts in photocatalytic water splitting has shown great promise as a sustainable, affordable, and clean method of producing solar H_2. However, the hydrogen production efficiency in particulate photocatalysis systems is still low. In this perception, we combined an ultrasonication technique with a straightforward solvothermal approach to synthesize novel hierarchical $Zn_{0.6}Cd_{0.4}S$ modified TiO_2-based MXene composites. Their ideal energy bandgap and the ability to tune it make the synthesised nanocomposites the most reliable materials for harvesting both UV and visible light. When exposed to UV light, $Zn_{0.6}Cd_{0.4}S$ modified TiO_2-based MXene composites showed an H_2 generation rate that was 7670 times greater than the TiO_2-based MXene composites. When exposed to visible light, it was 653 times higher. $Zn_{0.6}Cd_{0.4}S$ modified TiO_2-based MXene composites thus seem to be an ideal choice for high-performance H_2 production, also due to their high stability, and harvesting light capacity at a wider wavelength range than TiO_2-based MXene composites.

Keywords: Hydrogen evolution, Nanocomposites, Photocatalysis, Solvothermal synthesis

Acknowledgment:

This item is a part of the dissemination activities of the project FunGlass.
This work was also supported by the Slovak Research and Development Agency under the contract by grant VEGA1-0045-24.

Degradation of pollutants on membranes with photocatalytically active coatings

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ABSTRACT

TiO_2 has gained attention as a material for application in photocatalytic wastewater treatment. The photocatalytic decomposition of organic molecules in purified wastewater, including dyes, hormones, and drugs works efficiently if photocatalyst is dispersed in water. However, catalysis is followed by a difficult phase of catalyst separation by filtration. This problem can be avoided by coating the catalyst on an inert membrane. The model pollutant methylene blue served as a reference for the degradation of organic molecules. The pure TiO_2 photocatalyst in dispersion in a UV-irradiated vessel achieved 96% degradation of the methylene blue with the concentration of 20 ppm and a photocatalyst concentration of 0.5 g/L in 60 minutes. In the case of TiO_2 coating, the degradation efficiency depends on the size of the surface area of the membrane. The surface adhesion was attained by using a mixture of TiO_2 powder and sol-gel based SiO_2 with 90 wt.% of TiO_2. The homogeneity of the coating was inspected by confocal and electron microscopies. The catalyst was deposited on inert 3D printed gyroid-type membrane providing a large surface area and showed 79% degradation. In a further study, we mimicked real conditions and placed the gyroid in a device where pollutants flow through the coated gyroid. The efficiency of the degradation in a flow device reached 70%. The decrease in efficiency is compensated by a simple filter change and the possibility of up-scaling.

Keywords: coating, membrane, photocatalyst, pollutant.

Acknowledgment:

This item is a part of dissemination activities of project FunGlass.
This project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 739566.

Optical properties of laser engraved glass slide

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ABSTRACT

The fabrication of microfluidic devices on glass substrates traditionally involves intricate, multi-step chemical procedures such as photolithography, chemical etching/drying, and thermal or anodic bonding [1]. However, high-power laser technology offers a streamlined alternative, enabling device prototyping without the use of hazardous chemicals, projection masks, or bonding equipment. In this study, we examined the influence of laser power and scanning speed on the optical transmittance of laser-engraved regions on glass slides. A 20W diode laser was employed at varying power levels and scanning speeds on black acrylic-coated glass substrates. An image of laser engraved glass slide is given in **Figure 1**. The resulting surface morphologies and UV-Vis transmittance characteristics were analyzed in the context of smart windows based on olfactory-responsive hybrid MOF glass [2] and MOF glass composites [3], as envisioned in the HyBreath Glass Project.

Figure 1. Logo and name of the project laser engraved on microscope slide.

Keywords: Diode laser, glass engraving, fluidic device, UV-Vis transmittance.

Acknowledgment: Authors acknowledge the HyBreath Glass project (project code: 09I03-03-V04-00484), funded under the Fellowships for Excellent Researchers R2 program as a part of the Recovery and Resilience Plan of the Slovak Republic.

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Visible-light-assisted Pd-embedded ZIF-62 glass as a co-catalyst for efficient photocatalytic H_2 production

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ABSTRACT

The present study investigated the potential of Pd nanoparticles embedded in ZIF-62 glass as a co-catalyst for photocatalytic water splitting. The incorporation of Pd nanoparticles within the porous ZIF-62 matrix was hypothesized to enhance stability and facilitate hydrogen evolution. The synthesized Pd@ZIF-62-a_g/g-C_3N_4 composite demonstrated a hydrogen evolution rate of 48 µmol g^{-1} h^{-1} under 405 nm irradiation at 250 mW. However, the photocatalytic activity of the composite was found to be significantly lower than that of 1.5 wt.% Pd@g-C_3N_4 (454 µmol g^{-1} h^{-1}), primarily due to the encapsulation of Pd and the reduction in porosity that occurred during the thermal treatment of ZIF-62. Notwithstanding this limitation, the study underscores the promise of metal-embedded MOF-based photocatalysts and offers insights into the tunable hydrogen production and integrated gas separation properties for future advancements in solar-driven water splitting.

Keywords: Solar-driven water splitting, Green Hydrogen, Photocatalyst, Metal-organic frameworks, Pd nanoparticles

Acknowledgment:
Vega project 1-0045-24 for supporting this project

This item is a part of the dissemination activities of the project FunGlass. This project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 739566.

Defect-engineered Bi_2WO_6/g-C_3N_4 Z-scheme heterojunction via NH_3-assisted one-step calcination for enhanced visible-light photocatalysis

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ABSTRACT

Persistent contamination of aquatic environments with antibiotics, such as tetracycline (TC), raises serious ecological and public health concerns. In this study, we developed a novel defect-engineered Bi_2WO_6/g-C_3N_4 Z-scheme heterojunction using an NH_3-assisted one-step calcination process. This method enabled the simultaneous growth of g-C_3N_4 on Bi_2WO_6 and in-situ formation of oxygen vacancies, significantly enhancing visible-light absorption and reducing charge recombination. The optimized heterostructure exhibited excellent photocatalytic activity, degrading over 98% of TC within 60 min under visible light. This increased efficiency results from the formation of a direct Z-scheme charge transfer pathway and the creation of mid-gap states by oxygen vacancies, which act as electron traps and reaction sites. Various characterization techniques, including XPS, DRS, and PL, confirmed the successful implementation of defect engineering and the improvement of charge dynamics. This strategy offers a scalable and effective approach for developing advanced photocatalysts, providing a promising solution for breaking down persistent pharmaceutical contaminants in wastewater.

Keywords: Z-scheme heterojunction; Oxygen vacancies; Photocatalysis; Bi_2WO_6/g-C_3N_4 composite; Tetracycline degradation.

Acknowledgment:

This item is a part of dissemination activities of project FunGlass.
This project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 739566.

DLP-based additive manufacturing of porous photocatalytic glass-ceramic membranes for wastewater treatment

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ABSTRACT

Additive Manufacturing (AM) is revolutionizing the field of advanced porous materials by enabling precise control over structural design and functionality. In wastewater treatment, AM provides an innovative platform for fabricating tailored photocatalytic membranes with enhanced porosity and adjustable surface properties [1, 2]. Previous studies have demonstrated that recycled pharmaceutical vial glass-ceramic matrices increase porosity, surface area, and mechanical stiffness while promoting catalytic activity [3].
The current study investigates the fabrication of advanced glass-ceramic-supported photocatalytic membranes that incorporate selected photocatalysts, including 5 wt% TiO_2, Fe_2O_3, and TiO_2-Fe_2O_3 composites, to achieve visible light photoactivity. The waste pharmaceutical glass (60 wt%) was alkali-activated with 3M NaOH (30 wt%) and combined with 5 wt% photocatalytic elements through overhead mechanical mixing (500 rpm, for 3 hours), followed by spray drying. The resulting spray-dried particle granules exhibited a uniform spherical morphology, enhancing their processability for additive manufacturing. Digital Light Processing was employed to fabricate gyroid-structured scaffolds with well-defined porosity (70-95%), followed by three-stage sintering. The obtained 3D structures will display tailored bandgap energies (2.0-2.5 eV), enabling efficient photocatalytic activity for the degradation of organic pollutants under visible light. The development of micro- and nano-porous structures through heat treatments to create novel photocatalytic crystalline phases on the surface will be further studied for dye degradation. Thus, this work highlights the synergistic potential of additive manufacturing and glass-ceramic matrices in developing next-generation photocatalytic 3D structures, offering a sustainable and efficient solution for advanced wastewater treatment.

Keywords: glass waste and its upcycling, dark and photocatalytic filtration, digital light processing, wastewater treatment.

Acknowledgment:

This item is part of the dissemination activities of the FunGlass project.
This project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 739566. The authors also gratefully acknowledge the financial support from projects APVV-23-0352 and the Alexander Dubček University of Trenčín, as well as the internal Grant Scheme within Project D09_2024.

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Upcycling of industrial waste glass into ceramics for the degradation of organic pollutants in wastewater

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ABSTRACT

Many industrial companies provide necessary resources for daily human activity. The large number of products produced by these industrial companies produce a significant amount of waste. As the human population is increasing, the production of waste from industries is also growing. As a result, sustainable solutions are needed to address water pollution and waste disposal issues. Today, these wastes are considered an opportunity, and they are often referred as by-products since they can be repurposed to create new materials. The upcycling revolution demands redefining waste by transforming industrial waste into renewable resources for many applications. Wastes from different industrial companies can be used as a source of catalysts, porous glass ceramics, construction materials, etc. The main challenge for researchers is to determine whether waste can be converted into valuable resources for the future. This question encourage technology in several industries. Every year, approximately seven million tons of waste glass are sent to landfills without any significant reuse. Many end-of-life containers are considered not fully recyclable due to strict control on their chemical composition and purity standards. Upcycling presents a sustainable and energy-efficient solution by transforming these waste glass containers into valuable products. This study focuses on upcycling of waste pharmaceutical glass in a borosilicate system into various porous ceramics. Starting from the fine glass powders (consisting of 50–70 wt.%) are suspended in an alkaline solution (3M NaOH/KOH). These suspensions are then combined with photoactive materials such as TiO_2, Fe_2O_3 or g-C_3N_4 for potential applications in water treatment. These suspensions undergo vigorous stirring during the initial hardening phase, initiated by the interaction of glass and the alkaline activator. The gel phase is important for the consolidation which occurs at ~Tg (which is glass transition temperature ~550 °C) by thermal decomposition of gel) instead of traditional viscous flow sintering of glass, which is thoroughly optimized by thermogravimetric analysis. The resulting green bodies are first cured at 60° C for 3 days and then sintered at 550–700°C to form porous structures. This study also focuses on utilizing visible light instead of UV light because visible light photocatalysis utilizes approximately more than 40% of sunlight which is more sustainable. Photocatalysis is an eco-friendly method for wastewater treatment that requires light energy to activate a photocatalyst to break down the organic and inorganic contaminants in water. Unlike conventional methods photocatalysis can degrade the pollutants into harmless secondary products like CO_2 and H_2O. The focus is also given on incorporating photoactive semiconductors inside the glass matrix to avoid the leaching problems, improving the adsorption capacity and obtaining the desired properties by controlling the crystallization. The activity of the photocatalytic degradation reaction depends on many factors, such as adsorption of pollutant at the catalyst surface, band-gap energy, surface area, particle size, crystallinity, and electron–hole recombination rate. The interactions between the prepared matrix of waste glass, TiO_2, Fe_2O_3 or g-C_3N_4 lead to the formation of new mixed-phase compounds with lower band gaps. The band gap shifts to a lower value, and the composite starts to utilize visible light more effectively by which we can meet the growing demand to manage industrial waste and water pollution in a sustainable way.

Keywords: alkali activation, glass ceramics, organic pollutants, photocatalysis, upcycling of waste glass, water treatment.

Acknowledgment:

This item is a part of dissemination activities of project FunGlass.
This project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 739566.
The authors also gratefully acknowledge the financial support from the projects APVV-23-0352 and VEGA 1/0110/23, the Alexander Dubček University of Trenčín, and the Internal Grant Scheme within the Project D16_2024.

Development of photoactive/conductive oxide electrodes by additive manufacturing techniques for photo/electrocatalytic reaction

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ABSTRACT

In the 21st centuries, the increasing energy consumption and environmental issues are the two primary challenges confronting modern societies. To address these problems, researchers' attention is focused on renewable sources of energy. Hydrogen production via photoelectrochemical and electrochemical water splitting is an ideal way to mitigate the ever-escalating energy and environmental problem. Moreover, the fabrication of stable, cost effective, and highly conductive electrode is crucial for energy conversion and storage applications. Recently, metal oxide-based electrodes have been attracting significant attention as a low cost and stable electrode materials. In this work, we will report the development of oxide electrodes using additive manufacturing techniques, specially Fused Deposition Modeling (FDM) and Direct Ink Writing (DIW). The industrial waste (red/brown mud) is a byproduct of aluminium production, which is notable for its substantial iron oxide content and comparatively lower levels of other oxides. Initially, the red mud, which is highly alkaline in nature, will be employed as the primary precursor. Subsequently, waste glass and binders of varying compositions will be incorporated to form a slurry. This prepared slurry will be directly utilized for Direct Ink Writing (DIW) to print the working electrode. In contrast, for Fused Deposition Modeling (FDM), filaments will first be developed, and their mechanical strength will be assessed. The prepared filament will then be used to print the 3D working electrode. The fabricated 3D working electrode will undergo extensive characterization, including X-ray diffraction for phase composition analysis, scanning electron microscopy (SEM), and X-ray photoelectron spectroscopy (XPS) for surface morphology examination. The successfully prepared 3D electrodes will serve as the working electrode in a three-electrode cell configuration using the ECS Solartron Analytical instrument. All electrochemical measurements will be conducted in a 1 M KOH alkaline solution. This study aims to explore new avenues for transforming industrial waste, such as waste glass and red/brown mud, into value-added products applicable in the fields of energy conversion and storage.

Keywords: direct ink writing, energy conversion, fused deposition modeling, hydrogen production, upcycling of waste, water splitting.

Acknowledgment:

This item is a part of dissemination activities of project FunGlass.
This project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 739566. The authors also acknowledge the financial support from the Slovak Grant Agency of the Ministry of Education, Science, Research and Sport, VEGA 1/0110/23.

Design and fabrication of multifunctional optical coatings for solar cell cover glasses using HC-PECVD and PVD

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ABSTRACT

The performance of solar cells is limited by the optical and environmental limitations of their cover glasses. Despite this, during outdoor performance, its efficiency decreases between 2-30%, which is driven primarily by reflection losses, thermal degradation, encapsulant degradation, and surface soiling. This highlights the need for advanced solar cell cover glass coatings that can offer high transmittance, UV shielding, and IR reflectance to enhance overall cell performance and lifespan.

We propose two optimized bi-layer antireflective coating (AR) stacks tailored for silicon (operating range 400-1100 nm) and CdTe/perovskites (400-900 nm) based solar cells. This bi-layer coating was fabricated using a low-temperature hollow-cathode plasma-enhanced chemical vapor deposition (HC-PECVD) and physical vapor deposition (PVD) process, enabling precise control over film uniformity and scalability on large-area substrates.

The first layer consists of ZnO, which was optimized from Al-doped ZnO and ZnSn PVD targets by varying process conditions such as O_2/Ar gas flow rate and power. The optimized process conditions were selected based on UV absorption, visible transmittance, layer thickness and chemical composition. The second layer, SiO_2, process conditions were optimized through varying base pressure, Ar/O_2 gas ratio, SiH_4 concentration, and power in the HC-PECVD process. Optical simulations using CODE and OTF Studio Software were performed using experimentally obtained refractive index and film thickness to design a double-layer coating tailored for silicon and perovskite/CdTe solar cells, considering their operating wavelength ranges. These layer stacks were fabricated using a hybrid PVD and PECVD system with a thickness control accuracy of ± 1 nm achieved by monitoring the deposition rate of each layer.

The simulation results well matched the experimental results, demonstrating good visible transmittance (≥ 94 % in the 400-1100 nm range and ≥ 98% in the 400-900 nm range), excellent UV protection (99% UVB blocking), and a considerable increase in the IR reflectance (up to 25%). The coating demonstrated excellent mechanical durability, as confirmed by wet rub and dry brush tests, and showed strong environmental stability under UV exposure, Cleveland, humidity cycling and bronzing tests. To further improve surface properties, a hydrophobic thin layer of SiO_xC_y was deposited using TMDSO precursor, and Ar/N_2 gas ratio using PECVD process, achieving a water contact angle above 100°. These multifunctional coatings show strong potential in next-generation photovoltaic technologies that can offer robust and highly efficient solar module designs.

Keywords: Antireflection coatings, Solar cell cover glasses, PVD, PECVD, Hydrophobic coatings

Acknowledgment: This work has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101120555, Project CLiCAM.

This item is a part of dissemination activities of project FunGlass.
This project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 739566.

Europium-activated Molybdate Phosphors with enhanced thermal stability for near-UV-excited LED applications

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ABSTRACT

Phosphor-converted white LEDs (pc-WLEDs) excited by near-ultraviolet (NUV) light are considered promising for advanced lighting and display technologies. However, they often suffer from thermal quenching, leading to reduced efficiency at elevated temperatures. In this study, Eu^{3+}-doped $CaLaLiMoO_6$ phosphors were synthesized via a high-temperature solid-state reaction route and investigated for their potential use in NUV-pumped pc-WLEDs.
The composition $CaLa_{0.89}LiMoO_6$:$0.11Eu^{3+}$ exhibited strong red emission under NUV excitation. X-ray diffraction (XRD) confirmed the formation of a nearly single-phase orthorhombic structure with minor secondary phases. Scanning Electron Microscopy (SEM) revealed relatively uniform grain size and dense surface morphology, indicating controlled crystal growth. Photoluminescence (PL) emission spectra, recorded under NUV excitation (270–410 nm), showed intense red emission with a dominant peak at ~614 nm, corresponding to the hypersensitive $^5D_0 \rightarrow {}^7F_2$ electric dipole transition of Eu^{3+} ions in a low-symmetry crystal field environment. This confirms that the host lattice efficiently absorbs NUV photons and transfers energy to Eu^{3+} ions, resulting in radiative emission.
This red-emitting phosphor is intended to be combined with complementary blue and green components under NUV excitation to achieve full-spectrum white light. The current focus is on enhancing the thermal stability of the red phosphor by investigating the effects of electron-phonon coupling, crystal field environment, and dopant-host interactions, with the aim of achieving zero thermal quenching. Further optimization is expected to improve key performance metrics such as quantum efficiency, CRI, and CCT in the white LED system.This work contributes to the development of robust red phosphors as essential components in thermally stable, high-color-quality pc-WLEDs for high-power lighting applications.

Keywords: Zero Thermal Quenching, Phosphors, Photoluminescence, pc-WLEDs, Thermal Stability, Solid-State Reaction

Acknowledgment:

This research is a part of dissemination activities of project FunGlass.
This project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 739566.

Effect of SPS processing on the microstructure and photoluminescence of Rare-Earth doped YAG ceramic materials

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ABSTRACT

This study investigates the optimization of Spark Plasma Sintering (SPS) parameters namely temperature, pressure, heating rate, and dwell time for the fabrication of high-density Ce^{3+}-doped yttrium aluminum garnet (Ce:YAG) ceramics. Ce:YAG is a well-established phosphor material with efficient 5d–4f luminescence, thermal stability, and widespread use in solid-state lighting, particularly in phosphor-converted white LEDs (pc-WLEDs). Achieving high optical quality in Ce:YAG ceramics requires full densification and controlled microstructure, as residual porosity and excessive grain growth can impair both mechanical and photoluminescent properties.

In present work, Ce:YAG precursor was prepared by homogenization of the appropriate oxides via planetary ball milling and subsequently spray-dried to produce spherical granules with uniform particle size and favorable packing behaviour. The granulated powders were sintered by SPS at 1450–1650 °C under 60 MPa, with **varied dwell times.** SPS was selected for its ability to achieve rapid densification at relatively low temperatures and short durations, thereby minimizing undesirable grain coarsening and preserving optical functionality.

The sintered ceramics were characterized by X-ray diffraction (XRD), scanning electron microscopy (SEM), and bulk density measurements to evaluate phase purity, microstructure, and densification behavior. Photoluminescence (PL) spectroscopy was employed to assess the optical response of Ce^{3+} ions and to correlate luminescent efficiency with microstructural evolution.The results demonstrate the critical role of SPS parameters in tailoring both structural and optical properties of Ce:YAG ceramics, offering valuable insights for the development of advanced phosphor materials for solid-state lighting applications.

Keywords: Ceramic Materials, Microstructure, Optical properties, Photoluminescence, SPS.

Acknowledgment:

This item is a part of dissemination activities of project FunGlass.
This project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 739566.

Persistent luminescence and mechanoluminescence of bismuth-doped germanates

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ABSTRACT

Polycrystalline materials with ultraviolet (UV) photoluminescence (PL), persistent luminescence (pPL), and mechanoluminescence (ML) have attracted significant attention due to their wide range of applications, including stress sensing, phototherapy, anti-counterfeiting, germicidal treatment, photocopying, lighting, etc. [1-2]. Among various host lattices, germanates are considered promising candidates for accommodating activator ions (e.g., Bi^{3+}, Tm^{3+}, Pr^{3+}, …), owing to their relatively low synthesis temperatures, superior thermal stability, and favourable luminescence performances [3,4]. Compared to rare-earth ions, bismuth ions have gained considerable attention as versatile activators in inorganic phosphors, offering tunable, broadband emissions in UV/NIR regions, due to their multiple valence states and diverse ligand states [5]. These properties render Bi^{3+} suitable for multifunctional applications, such as stress sensing, anti-counterfeiting, phototherapy, and diagnostics.

In this work, two Bi-doped germanate phosphors, $NaY_{1-x}Bi_xGeO_4$ ($NYGOB_x$) and $K_4SrGe_3O_9:Bi^{3+}$, were synthesized via the conventional solid-state reaction. $NYGOB_x$ phosphors ($0.0 \leq x \leq 4.0$ mol%) exhibit both near-UV/blue mechanoluminescence (ML) under mechanical stimulation, and long-lasting persistent photoluminescence (pPL) across NUV (~415 nm) region, attributed to the Bi^{3+} center. The optimal $NYGOB_{1.5}$ sample showed strong emission with a PLQY of 46%. In addition, Bi^{3+}-doped $K_4SrGe_3O_9$ showed broadband UVA emission peaking at 353 nm (FWHM ~46 nm) under 304 nm excitation (Fig. 1). These results reveal the versatility of bismuth doping in developing rare-earth-free, broadband UV/NUV-emissive materials for emerging photonic applications.

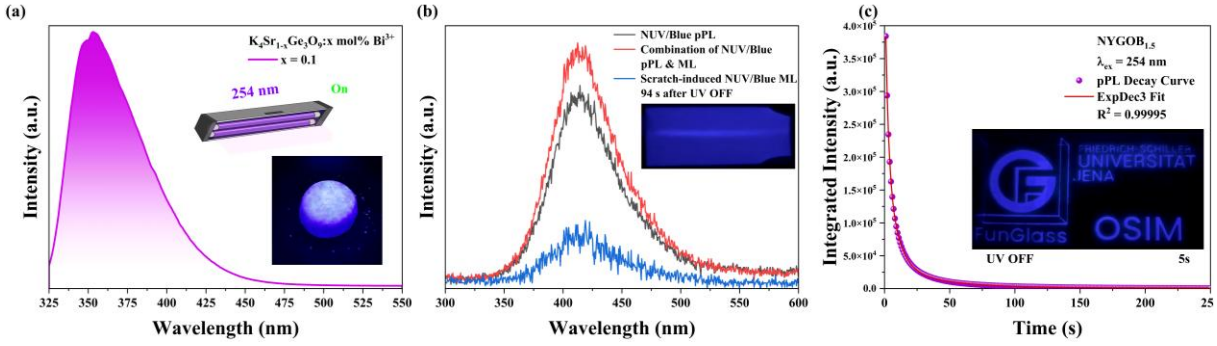

Fig. 1 (a) PL emission spectrum of the $K_4SrGe_3O_9$:0.1mol%Bi^{3+} material under UV light excitation, **(b)** pPL/ML emission spectra of the $NaYGeO_4$:1.5mol%Bi material (the inset shows the photograph of scratch-induced ML), **(c)** The corresponding pPL decay curve after illumination by a 254 nm UV lamp for 1 min (the inset shows the photograph of pPL at 5s after irradiation cease).

Keywords: Bi-doped germanate; Persistent Luminescence; Photoluminescence; Mechanoluminescence; Ultraviolet (UV).

Acknowledgment:

This item is a part of dissemination activities of project FunGlass. This project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 739566. The financial support by the Slovak Grant Agency, VEGA No. 1/0476/22 is gratefully acknowledged.

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Phase-dependent luminescence in multicomponent ceramics: A study of pyrochlore and defect fluorite systems in RE2Zr2O7 ceramics

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ABSTRACT

Rare-earth zirconates ($RE_2Zr_2O_7$) are promising for luminescent applications due to their thermal stability, radiation resistance, and ability to host various RE^{3+} activator ions, making them suitable for extreme environments such as lighting, sensing, and optoelectronics. Structurally, $RE_2Zr_2O_7$ ceramics can form either an ordered pyrochlore or a disordered defect fluorite structure. The pyrochlore phase, with its symmetric cation and anion ordering, is preferred for luminescence due to its stable local environments around activator ions.

To investigate the effects of structural phases on luminescence, both conventional and multicomponent $RE_2Zr_2O_7$ were synthesised using the combustion method. The present work focuses on how these structural differences, along with the incorporation of multiple rare-earth elements (high-entropy approach), affect the luminescent properties of $RE_2Zr_2O_7$ ceramics.

Results confirmed that the pyrochlore phase exhibits more intense luminescence in comparison to the defect fluorite structure. However, the relationship between phase structure and luminescent behaviour becomes more complex with the introduction of the high-entropy concept, where multiple rare-earth elements occupy the same crystallographic site. Multicomponent approach broadens the distribution of local environments around the luminescent centres. In the pyrochlore phase, such increased chemical complexity can degrade luminescence efficiency by introducing additional structural disorder and enhancing non-radiative decay pathways. Conversely, the defect fluorite phase, which is already characterised by significant intrinsic disorder, can benefit from the high-entropy strategy. In this case, the incorporation of multiple rare-earth ions led to a local stabilisation of more favourable environments for emission, which enhanced luminescence output despite the overall disordered nature of the matrix.

Keywords: $A_2Zr_2O_7$ Ceramic, Defect Fluorite, High Entropy Ceramic, Luminescence, Multicomponent Ceramic, Pyrochlore

Acknowledgment:

This item is a part of dissemination activities of project FunGlass.
This project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 739566.

This work has received funding from the Horizon Europe research and innovation programme GlaCerHub under grant agreement No. 101087154. CzechNanoLab project LM2023051, funded by MEYS CR, is gratefully acknowledged for the financial support of the measurements/sample fabrication at CEITEC Nano Research Infrastructure.

Study of optical properties of Er^{3+}, Yb^{3+} and Li^{+} doped yttrium-aluminate glasses with YAG composition

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ABSTRACT

Aluminate glasses with a composition corresponding to yttrium aluminium garnet ($Y_3Al_5O_{12}$, YAG), doped with Er^{3+} ions, are promising materials for laser and luminescent applications. Their potential is enhanced by several key properties, including excellent mechanical strength, thermal stability, and chemical resistance. Optically, these materials are notable for their ability to emit radiation in the green (525–567 nm) and red (625–725 nm) spectral regions.

The incorporation of Yb^{3+} ions can enhance this emission through efficient absorption and subsequent energy transfer to Er^{3+} ions. An alternative strategy involves the addition of Li^{+} ions, which, when incorporated into the glass matrix, can lower the phonon energy and reduce non-radiative losses.

One of the primary challenges in producing aluminate glasses is the high melting temperature (~2000 °C) and the necessity for rapid quenching (~1000 °C/s). To address these challenges, a combination of the Pechini sol-gel method and flame synthesis was employed in this study. Using this approach, glass microspheres with a YAG-based composition (62.5 mol% Al_2O_3 and 37.5 mol% Y_2O_3), doped with 0.75 mol% Er_2O_3 and varying amounts of Yb_2O_3 (0 and 10 mol%) and Li_2O (0 and 8 mol%), were successfully prepared.

X-ray diffraction (XRD) analysis revealed a predominantly amorphous structure, characterised by a broad amorphous hump. Weaker diffraction maxima at 2θ values of 18°, 33°, 41°, 46°, and 55° indicated partial crystallisation, corresponding to the formaion of YAG phase. Scanning electron microscopy (SEM) images showed spherical, fully melted microspheres. Most particles exhibited smooth surfaces without visible signs of crystallisation, though a minor fraction of crystalline or partially crystalline particles was present.

Differential thermal analysis (DTA) revealed a single exothermic peak in all samples, with peak temperatures ranging from 916 °C to 930 °C. Post-DTA XRD analysis confirmed the formation of the YAG phase, indicating that the exothermic effect corresponds to crystallisation. Samples containing Li^{+} ions exhibited improved thermal stability, as evidenced by a shift in the crystallisation temperature.

The optical properties of the microspheres were examined under excitation wavelengths of 378 nm and 980 nm. A significant enhancement in green emission intensity was observed for Li^{+}-doped glasses under 378 nm excitation. Glasses doped with Yb^{3+} showed increased red emission, particularly under 980 nm excitation.

Keywords: alumina glasses, sol-gel, flame synthesis, fluorescence, luminescence, rare earth ions

Impact of phase composition on the optical properties of high-entropy ceramics

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ABSTRACT

High-entropy oxides (HEOs) based on rare-earth zirconates are promising candidates for optical applications due to their compositional flexibility and structural tunability. This study explores the influence of phase composition—specifically pyrochlore ($A_2B_2O_7$) versus defect fluorite structures—on the up-conversion photoluminescence behavior of multi-cation systems containing Y, Lu, Gd, La, Yb, and Er on the A-site, and Zr, Ti on the B-site.

To favor pyrochlore formation, partial substitution of Zr^{4+} with smaller Ti^{4+} ions was used to increase the average cation radius ratio (Ra/Rb). Powders were synthesized via solution combustion, followed by calcination in a conventional furnace and spray drying. Optical activation was achieved by co-doping with Yb^{3+} and Er^{3+} (5:1 ratio), while other rare-earth cations acted as optically inactive hosts to attain entropy stabilization.

Under near-infrared excitation, visible emissions were observed in the green (~550 nm) and red (~660 nm) regions, corresponding to Er^{3+} transitions facilitated by Yb^{3+} sensitization. The emission intensity and spectral features found to be strongly dependent on to the structural phase and dopant concentration, with quenching effects observed at higher Yb/Er levels.

Keywords: defect fluorite, high-entropy oxides, photoluminescence, pyrochlore, rare-earth ceramics, up-conversion

Acknowledgment:

This item is a part of dissemination activities of project FunGlass.
This project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 739566.

Nano-structured luminescent materials for non-contact optical thermometry application

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ABSTRACT

Accurate measurement of temperature is essential in many domains, such as industrial operations, biomedical examinations, and environmental monitoring. Traditional temperature sensors, including thermocouples, resistance temperature detectors (RTDs), and infrared sensors, often encounter difficulties in hostile environments due to electromagnetic interference, slow responding times, and material degradation. These issues need for the development of specialized temperature sensing systems that provide high sensitivity, stability, and non-contact measuring features.

Optical thermometry has emerged as an attractive option, especially fluorescence intensity ratio (FIR)-based sensing, owing to its capability to operate in electromagnetically and thermally harsh environments. Compared to intensity, wavelength, and bandwidth-based approaches, FIR-based sensing offers great precision and dependability due to its ability to adjust to spectrum fluctuations and external interruptions.

In this study, novel oxyfluoride glass OxG and glass-ceramic OxGC systems were synthesized via the melt-quenching method, with a base composition of $55SiO_2–22.5KF–22.5ZnF_2$. These compositions were carefully selected to facilitate controlled crystallization of fluoride nanocrystals within the glass matrix. With appropriate heat treatment, controlled crystallization led to the precipitation of $KZnF_3$ nanocrystals within the glass matrix. The study emphasises lanthanide-doped systems, particularly with $Er^{3+}$and Tm^{3+}, to create temperature-sensitive luminescence, enhancing luminescence efficiency by reducing non-radiative losses. The impact of composition and thermal treatment on the nucleation and development of these nanocrystals is examined to improve transparency, mechanical stability, and luminescent characteristics.

This study examines the optical properties of the OxG and OxGC system, specifically emphasising the up-conversion process under near-infrared (NIR) excitation. The temperature-dependent luminescence behaviour is investigated for its usefulness in high-sensitivity optical thermometry. The sensitivity of thermally coupled and non-thermally coupled levels is compared with previous literature to optimize performance.

Keywords: Crystallization, Luminescence, Optical Thermometry, Up-conversion, Oxyfluoride, Rare-Earth Ions.

Acknowledgment:

This research is conducted as a part of dissemination activities of the FunGlass project. This project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 739566 VEGA project 1/0844/21 and VEGA 1/0045/24

Tailored disorder: engineering high-entropy oxides for next-generation thermal barrier coatings

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ABSTRACT

In this work, a series of high-entropy $(5RE_{0.2})_2(Zr_{0.5}B_{0.5})_2O_7$ (RE = La, Sm, Eu, Gd, Yb, Tm, Er, Dy, Y; B = Ce and Hf) oxides with fluorite and pyrochlore structures were synthesized via the conventional solid-state reaction method and evaluated as promising thermal barrier coating (TBC) materials. Compared to yttria stabilized zirconium YSZ (2.2--2.9 $W \cdot m^{-1} \cdot K^{-1}$, 10.5× 10^{-6} K^{-1}) and single-component zirconates (1.7--2.2 $W \cdot m^{-1} \cdot K^{-1}$, 9--11 × 10^{-6} K^{-1}), which are conventional top layer materials for TBC applications, high-entropy oxides exhibit larger thermal expansion coefficients and lower thermal conductivities (1.12--1.64 $W \cdot m^{-1} \cdot K^{-1}$, 10.55--11.82 × 10^{-6} K^{-1} at 1000°C). The results show that the thermal conductivity gradually decreases with decreasing r_A/r_B cation radius ratio due to the increased randomness of the oxygen vacancies and lattice anharmonicity. The enhanced effective scattering of phonons via multi-scale defects results in the lowest thermal conductivity (1.12 $W \cdot m^{-1} \cdot K^{-1}$) for the $(La_{0.2}Sm_{0.2}Eu_{0.2}Gd_{0.2}Yb_{0.2})_2(Zr_{0.5}Ce_{0.5})_2O_7$ sample. In addition, the $(La_{0.2}Sm_{0.2}Eu_{0.2}Gd_{0.2}Yb_{0.2})_2(Zr_{0.5}Ce_{0.5})_2O_7$ sample has a larger thermal expansion coefficient (11.82 × 10^{-6} K^{-1}) due to lower average electronegativity difference between the cations and anions of its corresponding compounds. The sintering resistance, an essential property of thermal barrier coatings, increases with increasing ionic radius ratio (R_A/R_B). In ordered pyrochlore structures, oxygen vacancy clusters induce local strain, which stabilizes grain boundaries and enhances resistance to sintering. As R_A/R_B decreases, the ordered pyrochlore structure transitions into a disordered defect fluorite phase, accelerating the sintering process. This increased structural disorder facilitates defect formation and lowers the migration barrier for oxygen vacancies, further promoting sintering. These insights offer valuable guidance for the design of advanced high-entropy oxide materials aimed at next-generation thermal barrier coatings (TBCs).

Keywords: High-entropy oxide, Thermal barrier coating (TBC), Thermal conductivity, Thermal expansion coefficient.

Acknowledgment:

This item is a part of dissemination activities of project FunGlass.
This project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 739566.

Ultra-fast high temperature sintering (UHS) of fluorite-structured high-entropy CeO_2-δ·$(RE,La,Sm,Y)_2O_3$ [RE = Gd, Nd] oxides

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ABSTRACT

From among several advancements in the sintering of ceramics, ultrafast high-temperature sintering (UHS), introduced in 2020, has revolutionized the sintering process by drastically reducing overall processing time from hours to a few seconds. In this work, single-phase high entropy fluorite $CeO_{2-\delta}$·$(RE,La,Sm,Y)_2O_3$ [RE =Gd, Nd] powder was synthesized by combustion synthesis and subsequently consolidated using UHS. The chemical uniformity and phase purity of the sintered specimens was confirmed by X-ray diffraction (XRD), and energy dispersive X-ray spectroscopy (EDX). Though optimizing the conditions of UHS (current and dwell time), dense samples (relative density > 95%) with nanometric grains and minimal porosity were prepared. The high heating rates achieved in UHS suppressed grain coarsening and ensured phase stability. Sintering in argon induced reduction of Ce^{4+} to Ce^{3+}, which was confirmed by X-ray photoelectron spectroscopy (XPS). This *in-situ* reduction creates oxygen vacancies in the fluorite structure, significantly enhancing ionic conductivity. These properties make the material a promising candidate for solid oxide fuel cells and oxygen sensors. The work highlights the UHS as a rapid, efficient method for fabricating high-entropy ceramics, advancing their potential in energy applications.

Keywords: High-entropy oxides, Ultra-fast high-temperature sintering, Microstructure, Ionic conductivity

Preparation of HEO materials with spinel structure and important magnetic properties

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ABSTRACT

The exceptional physicochemical, optical, thermal, and magnetic properties of high-entropy oxides (HEOs) have currently drawn a lot of interest [1,2]. HEOs finds applications in various fields, such as catalysts, lithium-ion batteries, dielectric and electromagnetic materials, and in the fabrication of corrosion-resistant batteries and coatings [3,4]. Among HEOs, ferrites with a cubic spinel structure (Fd-3m) are especially valued for their multifunctional properties such as magnetism, photocatalytic, and dielectric behavior [5]. This work investigates the influence of Mg^{2+} and Zn^{2+} substitution and sintering temperature on the structure and magnetic behavior of spinel-type HEOs. Based on the available literature, precursor materials with two compositions $(Al_{0.2}Co_{0.2}Cr_{0.2}Ni_{0.2}Fe_{0.2}Zn_{0.2})_3O_4$ and $(Al_{0.2}Co_{0.2}Cr_{0.2}Ni_{0.2}Fe_{0.2}Mg_{0.2})_3O_4$ were prepared by solid-state synthesis using high-purity oxides, followed by cold-pressing (CP) and cold isostatic pressing (CIP). To investigate the effect of sintering temperature on magnetic properties, all prepared green compacts were sintered in the air at 1223 K for 6 hours, and two selected samples from both compositions were sintered at 1423 K for 6 hours. Phase composition and magnetic properties have been investigated by XRD and SQUID methods. The prepared samples had a single-phase spinel structure. M-H curves of all samples indicated that all samples exhibited ferromagnetic or ferrimagnetic behavior. The measured values of M, Mr, and Hc of the prepared soft magnetic materials were mainly influenced by the heat treatment conditions; the influence of composition was less pronounced. Further analysis of both magnetic and structural properties is required to better understand the influence of heat treatment as well as the influence of Zn and Mg addition.

Keywords: High-entropy oxide, Magnetic properties, Sintering

Acknowledgment:

This item is a part of dissemination activities of project FunGlass.
This project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 739566.

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Effect of lanthanum incorporation on phase stability and optical properties of high-entropy aluminium garnet

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ABSTRACT

Yttrium aluminium garnet (YAG) is a widely used ceramic material in photonic applications, commonly serving as a host for doping with luminescent rare-earth (RE) ions. The present study deals with the fabrication of high-entropy (HE) version of YAG, where careful compositional design is essential to prevent reduction in luminescence efficiency caused by concentration quenching or non-radiative energy transfers.
This work aims to evaluate the possibility of La incorporation into HE garnet matrix, as its low interaction with other RE ions makes it a potentially beneficial component in terms of photoluminescence (PL). Er^{3+}/Yb^{3+} co-doped $RE_3Al_5O_{12}$ powders (RE = Lu, Y, Gd, La) with progressively increasing concentration of La (5–20 mol.%) were synthesised via combustion. After calcination at 1000–1600 °C, phase composition was analysed using X-ray diffraction and optical properties using PL spectroscopy. The distribution of elements was determined using energy dispersive X-ray spectroscopy on bulk samples obtained after sintering in air at 1650 °C for 4 h.
The formation of high-entropy $(Er_{0.01}Yb_{0.2}Lu_{0.2}Y_{0.34}Gd_{0.2}La_{0.05})_3Al_5O_{12}$ was confirmed after calcination at 1000 °C. However, the stability of the compound was compromised due to the large ionic radius of La, and partial decomposition into a perovskite and β-alumina phase was observed above 1080 °C. The content of secondary phases increased proportionally to the concentration of La present in the samples, which coincided with a significant enhancement in PL emission intensity in the green spectral region.

Keywords: aluminium garnet, high-entropy ceramics, combustion synthesis, lanthanum, photoluminescence

Acknowledgment:

This item is a part of dissemination activities of project FunGlass.
This project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 739566 and programme GlaCerHub under grant agreement No 101087154. Brno City Municipality is acknowledged for the financial support through Brno Ph.D. talent programme and CzechNanoLab project LM2023051, funded by MEYS CR, is gratefully acknowledged for the financial support of the measurements/sample fabrication at CEITEC Nano Research Infrastructure.

Influence of mixing time on the properties of porous glass ceramics, prepared from waste glass-based geopolymer-like materials

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ABSTRACT

The construction industry significantly contributes to CO2 emissions, with the production of ordinary Portland cement (OPC) alone accounting for about 8% of these emissions. Tackling this issue requires developing innovative sustainable building materials and processes. This environmental challenge necessitates creating more sustainable building materials and production methods. One promising strategy involves utilizing silica-rich inorganic waste, such as waste glass and waste refractories, in conjunction with alkaline activators to produce geopolymers and alkali-activated materials (AAMs). When waste glass is dissolved in an alkaline solution, it forms aluminosilicate gels that decompose and release gases during thermal treatment, promoting the formation of porous glass-ceramics. Such materials hold significant potential for functional applications in lightweight construction, including thermal and acoustic insulation. In this study, the impact of mixing waste fiberglass with alkali solutions, both with and without the addition of an alumina-silica-zirconia (AZS) refractory mixture, on the mechanical and physical properties of the resulting materials was examined. The powders were blended with an alkali solution (NaOH or KOH) at concentrations of 3–8 M, with mixing durations of 10 minutes, 1 hour, and 2 hours. The prepared suspensions were cured at 60 °C for 24 hours and subsequently stored under ambient conditions. The highest compressive strength was observed in samples prepared with an 8 M alkali solution and mixed for 2 hours. In contrast, a notable reduction—over 50%—in strength was recorded for samples mixed for only 10 minutes. Thermal treatment at 800 °C and 1000 °C demonstrated that prolonged mixing times, particularly at higher alkali concentrations (6 M and 8 M), resulted in denser, less porous glass-ceramics. The 3 M samples produced highly porous and lightweight glass-ceramics. These findings suggest that by optimizing both alkali concentration and mixing time, it is possible to engineer waste glass-based alkali-activated materials into lightweight glass-ceramics with adjustable porosities and enhanced strength. Such materials are promising candidates for lightweight construction applications, including aggregate production, thermal insulation, and acoustic dampening.

Keywords: alkali activation, geopolymers, porous glass ceramics, waste glass

Acknowledgment:

This item is a part of dissemination activities of project FunGlass.
This project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 739566.

Greener, safer, and stronger: plasma ion-exchanged pharmaceutical glass vials for precision drug delivery dosing

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ABSTRACT

This study introduces the groundbreaking synergistic influence of plasma and ion-exchange treatment (P-IET), conducted under varying conditions (450°C and 500°C for 2, 12, and 24 h), preceded by a few seconds of pre-plasma treatment using a mixed air-argon gas approach. P-IET is a cost-effective, innovative, long-lasting, and industrially scalable process designed to improve the performance of Type I borosilicate glass across a variety of pharmaceutical packaging forms and structures. This treatment produces a durable hydrophilic surface, as confirmed by FTIR analysis, which shows a broad and intense OH group peak at ~3350 cm^{-1}, along with significant structural changes that demonstrate enhanced water-attractive properties. Furthermore, P-IET significantly lowers water contact angles on the glass's inner surface, amplifying its hydrophilicity. These improvements are crucial for water-based drug formulations, facilitating efficient and waste-free drug delivery by enabling complete withdrawal and precise dosing—critical features and requirements for contemporary and modern pharmaceutical applications. Beyond hydrophilicity, P-IET also significantly enhances the mechanical strength of glass by generating a robust compressive layer, hence doubling its resistance to crushing loads by 2124 ± 21 N (e.g., at 500°C for 24h) compared to untreated standard vials available on the market today (1157 ± 91 N). Moreover, P-IET sterilizes the glass surface by removing biological contaminants and microorganisms, organic residues and improves chemical durability by reducing Na and K ion leach-out, thus assuring long-term chemical stability under various pH conditions. Notably, these are achieved without changing the colour or transparency of the glass with preserving its aesthetic or functional integrities. The proposed transformative technology effectively tackles critical challenges in pharmaceutical packaging by introducing a greener, safer, and more efficient solution. It facilitates complete drug withdrawal with precise dosing and boasts exceptional mechanical and chemical resistance. P-IET is establishing new standards related to type I borosilicate glass and is promoting the development of innovative drug delivery systems characterized by their unique reliability and sustainability.

Keywords: Plasma-Ion exchange treatment (P-IET), hydrophilicity enhancement, mechanical strength, pharmaceutical packaging, chemical durability, type I borosilicate containers.

Acknowledgment:

This item is a part of dissemination activities of project FunGlass.
This project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 739566.

Enhancement of corrosion resistance of eco-friendly epoxy-silica composite coatings

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ABSTRACT

Today 75% of all the epoxy polymers in the world are made with bisphenol A (BPA) and represent severe environmental issues while slowing down the transition to a more sustainable solution. Our research is part of the effort to reverse this trend and to replace BPA with an environmentally friendly alternative in a green epoxy coating based on vanillin alcohol diglycidyl ether (DGEVA), a wood lignin derivative. In this way, instead of relying on BPA, wood lignin with its own excellent barrier and adhesion properties and due to the durable metal oxide-polymer bonds can be used to further increase the lifetime of the coating. As a follow-up to this research, the performance of a composite coating prepared in our previous work is further improved by incorporating MXene nano-sheets to serve as carriers for inhibitors. The key is to functionalize the MXene surface with ZIF-8 (zeolitic imidazolate framework-8) nanoparticles grown in situ. This type of complex modification not only maintains the original properties of MXene nano-sheets but also endows them with other functions, and as a result, it is a promising carrier for inhibitors in the composite coating. Electrochemical impedance spectroscopy (EIS) was used to test the passive/active inhibition efficiency of the reinforced intact coatings. The Nyquist diagrams demonstrated that the total resistance of the coating with ZIF8-modified MXene sheets is significantly improved compared to the blank sample and the coatings with only MXene or ZIF-8 nanoparticles.

Keywords: Nano-carrier, Ti3C2 MXene, Metal organic framework, Smart self-healing, Corrosion, Biobased epoxy coating

Acknowledgment:

This item is a part of dissemination activities of project FunGlass. This project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 739566.

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Structural and biological study of bismuth- doped boron containing bioactive glasses for biomedical applications

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ABSTRACT

Bioactive glasses (BGs) are well-known for their superior bioactivity and ability to release therapeutic ions for biomedical applications. In particular, borate bioactive glasses attract attention due to their rapid apatite ability formation in the physiological body fluids [1]. Various therapeutic ions have been introduced through compositional doping to endow BGs with distinctive properties. Bismuth (Bi) has previously been added into silicate 45S5 BG as a contrast agent to enhance X-ray absorption or radiopacity [2]. In this study, Bi was incorporated into the borate 1393-B3 BGs, to enhance potential radiopacity and antibacterial properties making them attractive as an alternative for biomedical applications.
1393-B3 BG was synthesized through the melt-quenching technique [3] with nominal composition in wt. % of 56.6 B_2O_3 , 18.5 CaO, 11.1 K_2O, 5.5 Na_2O, 4.6 MgO, and 3.7 P_2O_5 . Afterwards, Bi_2O_3 was included in the with progressive additions of BG of 5, 10, and 20 wt. % through the same synthesis technique. Inductively coupled plasma optical emission spectroscopy (ICP-OES) confirmed the agreement among the theoretical and experimental composition. The amorphous nature of all BGs was confirmed by X-ray diffraction (XRD). The BGs chemical structure was followed using Fourier-transform infrared (FTIR) and Raman spectroscopies. The results showed characteristic bands of borate glass, including peaks corresponding to trigonal and tetrahedral boron units. The characteristic temperatures of BGs samples were studied using differential thermal analysis (DTA). Glass transition (T_g) and crystallization ($T_{c)}$ temperatures decreased when Bi_2O_3 content was increased, as a possible result of the glass network modification. The bioactivity of the glasses was studied by following the apatite formation ability after immersing them in Kokubo's simulated body fluid (SBF). The apatite crystallization in the BGs surface after 1, 3, and 7 days were investigated by FTIR, XRD, and scanning electron microscopy (SEM). The results showed evidence of the deposited appetite in all samples after 1 day of immersion. Moreover, ion concentration of all SBF solutions after filtration was measured by (ICP-OES). Osteoblasts MG-63 cell viability tests were performed by indirect approach and mitochondrial metabolic activity evaluation using WST-8. The relative cell viability demonstrated an extract concentration-dependent response, with higher extract concentrations showing reduced viability, particularly in glasses with higher bismuth content. Notably, the sample with 5 wt. % Bi_2O_3 exhibited the highest relative cell viability at lower extract concentrations, indicating an interesting balance between bioactivity and cytocompatibility. The combined analysis and results in this work support the potential use of Bi-doped 1393-B3 in biomedical applications. Further investigations are planned to evaluate their radiopacity and antibacterial properties.

Keywords: 1393-B3, Bioactivity, Bismuth, Borate bioactive glass, Radiopacity, Therapeutic ions.

Acknowledgment:

This item is a part of dissemination activities of project FunGlass.
This project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 739566.

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Influence of nitrogen incorporation on the structure–property correlation in alkali-free bioactive glasses

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ABSTRACT

Bioactive glasses (BG), such as 45S5 Bioglass®, contain CaO, Na_2O, and P_2O_5 components, which are widely used in bone tissue engineering. BGs could form a hydroxycarbonate apatite layer in bio-environments, promoting strong bonding with natural bones. However, the high amount of Na_2O (typically exceeding 20 mol%) leads to a more pronounced crystallization tendency and possible cytotoxicity due to the rapid release of Na^+ ions. To address these issues, researchers have focused on the development of alkali-free BGs that exhibit controlled degradation rates while maintaining bioactivity [1]. Recent studies also have shown that Si_3N_4 could be a promising material due to its superior mechanical properties and osteo-integration as a nitrogen source[2].
This research investigates the incorporation of nitrogen into alkali-free BGs via Si_3N_4 addition, which could enhance their mechanical properties. This could be explained by the three-fold coordination of nitrogen anions compared to the two-fold coordination of oxygen anions [3]. In the first step, alkali-free BGs powder is melted in air between 1500-1550 °C, following the formulations developed by *Pablos-Martín et al* [4]. Subsequently, 90 wt.% of the resulting glass powder was mixed with 10 wt.% silicon nitride (Si_3N_4) powder and re-melted at the same temperature in an N2 atmosphere. The resultant glasses will be characterized by a variety of analytical techniques, including X-ray diffraction, X-ray fluorescence, scanning electron microscopy, and differential thermal analysis.

Keywords: Alkali-free bioactive glasses, Mechanical properties, Nitrogen incorporation.

Acknowledgment:

This item is a part of dissemination activities of project FunGlass. This project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 739566.

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Mechanistic study on the biological activity of ZIF-8 and propolis-loaded ZIF-8

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ABSTRACT

Bacterial infection has been known as a major public health threat. The progress in nanotechnology resulted in the development of effective and antibiotic-independent antibacterial agents in biomedical applications. Metal-organic frameworks (MOFs) as a class of nanoporous materials has become the center of interest due to their potential in combating bacterial infection as well as ability to drug delivery. However, the biocompatibility issues often arise from metal cation release from MOF structures. Thus, a deep understanding of the mechanisms behind the antibacterial effect and cytotoxicity helps the effective and safe application of MOFs in the biomedical field.

In this study, the antibacterial and biocompatibility features of ZIF-8 nanoparticles, a Zn-based MOF, was investigated, focusing on the mechanism of toxicity for bacteria and cells. Additionally, loading the ZIF-8 particles with ethanolic extract of *propolis* enhanced their functionality by endowing with phytotherapeutic effects and improving both antibacterial and compatibility properties. Nanoparticles (Z: ZIF-8 and ZP: *propolis* loaded ZIF-8) were synthesized through a rapid room temperature method and were characterized via various identification methods. The sustained and gradual Zn^{2+} release profile of both Z and ZP nanoparticles under dynamic conditions in Tris-HCl buffer solution was confirmed using inductively coupled plasma optical emission spectroscopy (ICP-OES). While characterizations showed limited evidence of *propolis* in the ZP particles, diffuse reflectance spectroscopy and UV-Vis obtained from post-synthesis aqueous dispersion confirmed partial retention, likely through physical entrapment. *Propolis* also slightly changed crystal morphology, reducing aggregation and enhancing porosity, as shown by scanning electron microscope and nitrogen adsorption-desorption diagrams. Moreover, pH sensitivity of nanoparticles, which plays a crucial role in balancing cytocompatibility and antibacterial efficacy, was proved through the UV-Vis spectroscopy. The particles remain more stable under physiological pH conditions, while a decrease in pH, mimicking an infected environment, induces particle degradation, leading to increased Zn ion release and enhanced antibacterial activity.

Antibacterial properties were validated through various complementary assays, revealing significant inhibition of bacterial growth in the concentration of 250 and 500 $\mu g.mL^{-1}$. Although the exact mechanism of toxicity has not been fully demonstrated and several crucial factors are involved, Zn ion infiltration and oxidative membrane damage are considered the main and primary mechanisms explaining the antibacterial behavior of Zn-based nanoparticles [1,2]. The ICP-OES results showed the minimum release of 50 and 119 ppm Zn ion from both particles into the bacterial growth media at the concentration of 250 and 500 $\mu g.mL^{-1}$. The greater effectiveness against *S. aureus* compared to *E. coli* suggested that the absence of an outer membrane in Gram + bacteria enhances ion permeability and causes more intracellular disruptions. Also, a significant reduction in the metabolic activity of *S. aureus* was observed with ZP compared to Z particles, while no notable difference was found against *E. coli*, suggesting a synergistic effect of *propolis* with ZIF-8 that enhances antibacterial efficacy against *S. aureus*. This finding is consistent with literature reports that *propolis* is generally more effective against Gram + bacteria [3].

Literature also demonstrated moderate biocompatibility of ZIF-8 nanoparticles with no toxicity up to the concentration of 30 $\mu g.mL^{-1}$ and higher concentration of ZIF-8, led to more Zn ion release resulting in the reactive oxygen species (ROS) production and oxidative stress, followed by DNA fragmentation and cell apoptosis [4]. Both synthesized particles showed neither cytotoxicity nor genotoxicity on the MC3T3 cells at the concentration of 100 $\mu g.mL^{-1}$, indicating greater

biocompatibility of obtained particle compared to the reports.
As a future direction, incorporation of these nanoparticles into hydrogels is proposed to enhance the targeted release of *propolis* while minimizing direct contact with cells, offering a promising route for safer biomedical applications.

Keywords: Antibacterial properties; Biomaterials; Metal-organic frameworks (MOFs); Nanomaterials; *Propolis*; ZIF-8.

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Synthesis of upconversion nanoparticles via core-shell-shell engineering strategy for enhanced photodynamic therapy applications

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ABSTRACT

Photodynamic therapy (PDT) has sparked significant interest of scientific community as a non-invasive treatment for malignant diseases, such as cancer; however, its efficacy is restricted by poor tissue penetration of excitation light and inefficient photosensitizer delivery [1]. Recent advances in rare-earth-doped upconversion nanoparticles (UCNPs) can address these challenges by converting low-energy near-infrared photons (700-1100nm) into higher-energy emissions to activate photosensitizers [2-4]. Herein, we develop a core-shell-shell engineering approach to synthesize advanced UCNPs with optimized luminescence and biocompatibility for enhanced PDT. The core-shell-shell structure consists of a $NaYbF_4$:Tm^{3+}/Er^{3+} for efficient upconversion, an intermediate shell of $NaYF_4$ for preventing surface quenching, and an outer functional mesoporous silica shell for covalent photosensitizer grafting.
Structural and optical characterization will be conducted by various advanced techniques, including X-ray photoelectron spectroscopy (XPS), transmission electron microscopy (TEM), scanning electron microscopy (SEM), Photoluminescence (PL), X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FT-IR) and UV-Vis spectroscopy.

Keywords: Photodynamic therapy, photosensitizer, core-shell-shell structure

Acknowledgment:

This item is a part of dissemination activities of project FunGlass.
This project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 739566.

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Debinding dynamics of organic molecules in glass powder DLP printing for transparent structures

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ABSTRACT

Vat-photopolymerization 3D printing of glass powder via viscous flow sintering offers a promising approach for creating complex, optically transparent multioxide functional structures[1]. This process requires the formulation of a printable slurry by blending glass powder with photocurable resins and other organic additives. Post-printing, an effective debinding step is crucial to eliminate organic residues, which can affect the optical clarity of the final glass product. Critical thermal parameters such as debinding temperature, heating rate, and holding time govern the polymer-to-powder interactions during this stage. In this study, we investigate the debinding dynamics of organic constituents in digital light processing (DLP) of low sintering-temperature glass powders, with a focus on achieving high transparency structures.
Thermogravimetric analysis (TGA) was conducted on the resin to determine the temperature (~600 °C) required for its complete removal. TG-DTA analysis indicated that Barium Crystallin Glass (BCG), provided by RONA, a.s. Slovakia, exhibits a glass transition temperature (T_g) of ~510°C. The relatively high T_g minimizes the risk of premature sintering of glass particles before the burn-out of organic binders[1]. Hence, the debinding temperature (T_{db}) suitable for complete removal of organic components must be lower than T_g ($T_{db} < T_g$) to ensure effective organic residues elimination prior to the onset of glass softening. However, for BCG glass, achieving complete carbon removal has proven challenging, as T_{db} exceeds T_g. To address this issue, debinding at approximately 500°C with extended holding time is currently being investigated. These findings highlight the importance of aligning the resin removal temperature with the glass transition temperature to achieve optical transparency. Additionally, gas release during debinding was also found to be influenced by the internal gas pathways within the printed structure. To examine this effect, geometries such as cubic, gyroid, and diamond were evaluated for their effectiveness in facilitating gas escape. Among these, the gyroid structure was identified as the most effective in enabling organic gas release, making it most suitable for transparent glass fabrication.

Keywords: Debinding dynamics, DLP printing, optically transparent glass.

Acknowledgment:

This item is a part of dissemination activities of project FunGlass.
This project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 739566.

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Advanced MTES-modified silazane coating with enhanced durability and corrosion resistance properties

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ABSTRACT

Polysilazane is an attractive candidate of coating materials due to its good adhesion properties to most substrates and its great potential to be modified and to obtain tailored properties for a variety of applications [1] [2]. In this work, the hybrid coating based methyltriethoxysilane (MTES) and poly(methylvinyl)silazane (Durazane 1800) was synthesized by sol-gel route to improve corrosion resistance and lifetime of stainless steel substrate. The MTES/polysilazane solution was synthesized using tetra-n-butylammonium fluoride (TBAF) and n-butyl acetate (NBTA), and was deposited on stainless steel by dip coating method. The structure and thermal stability of hybrid sol were investigated by Fourier transform infrared (FTIR) spectroscopy and thermogravimetric analysis (TGA). FTIR studies demonstrated that the incorporation of MTES to polysilazane backbone the integrity of polysilazane was preserved. Based on Field emission electron microscopy (FESEM) analysis, crack-free, smooth, and homogenous hybrid coatings were obtained on stainless steel. The corrosion resistance of MTES/polysilazane and polysilazane coatings are studied by electrochemical impedance spectroscopy (EIS) and potentiodynamic polarization techniques. The results confirmed that the synthesized hybrid coatings can be a good option to improve the corrosion resistance of the stainless steel substrate in 3.5 wt% NaCl solution.

Keywords: Polysilazane, corrosion, stainless steel, hybrid thin films, sol-gel chemistry

Acknowledgment:

This item is a part of dissemination activities of project FunGlass. This project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 739566.
This project is part of dissemination activities of the MICINN project TED2021-131258B-I00. Funding from Horizon project EverGlass, No. 101129967 is acknowledged. The authors also gratefully acknowledge the financial support from the projects VEGA 1/0242/23 and APVV 22-0070.

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From Glass Melting Furnaces to Monitoring: Corrosion and Ultrasonic Non-Destructive Evaluation of AZS Refractories in Contact with Barium Cristallin Glass

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ABSTRACT

In glass manufacturing, furnaces are the heart of the industry. These furnaces are lined with fused cast Al_2O_3-ZrO_2-SiO_2 (AZS) refractories, which are critical for withstanding the high temperatures and harsh conditions of the glass melting process. However, prolonged exposure to molten glass leads to severe corrosion, reducing the furnace lifespan and operational efficiency. Therefore, in this study, we focused on a comprehensive investigation of the corrosion mechanisms and nondestructive evaluation of AZS refractories in contact with barium cristallin glass. A modified ASTM C621-09 static corrosion test was conducted at 1480°C for 72 hours to simulate glass tank conditions and assess the performance of various refractory compositions. The corroded samples were measured for glass line and half-down corrosion, followed by detailed microstructural characterization using SEM, EDS, and XRD to assess the degradation depth and phase evolution. The results indicate that corrosion involves the diffusion of alkalis from the glass melt into the refractory and the dissolution of Al_2O_3 from the refractory into the melt, leading to the erosion of the boundary layer of the refractory. In addition to conventional testing methods for evaluating refractory wear, this study employs ultrasonic nondestructive testing (NDT) techniques for the first time in the glass industry to assess internal degradation, cavities, and voids in operational glass furnace refractories. This research enhances the understanding of the fused-cast AZS refractory wear mechanisms in contact with barium cristallin glass. It also highlights the need for improved corrosion methods and broader adoption of NDT techniques to assess refractories.

Keywords: AZS refractory materials; barium cristallin glass; refractory wear, corrosion; static testing methods; NDT.

Acknowledgement:

This item is a part of dissemination activities of project FunGlass. This project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 739566 and This publication was funded by the Alexander Dubček University of Trenčín and the Internal Grant Scheme within the Project: Sheeraz Khan: D11_2024 - Development of dynamic corrosion test of refractory materials used in glass manufacturing.