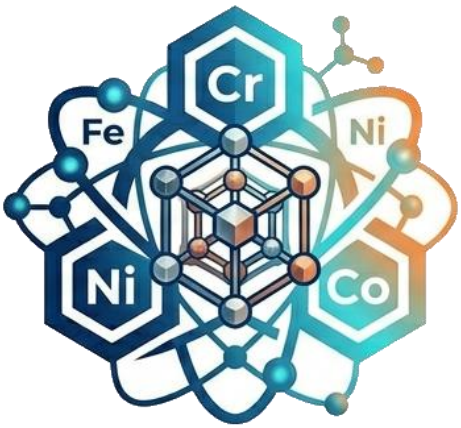
# BOOK OF ABSTRACTS

**17-18 September 2026, Wroclaw, Poland**




# ICTMA 2026

## 1st International Conference on Transition Metal Applications

Bridging fundamental science and technological innovation in transition metal systems

**1st International Conference on**
**Transition Metal Applications (ICTMA 2026)**
**September 17th – 18th, 2026, Wrocław, Poland**

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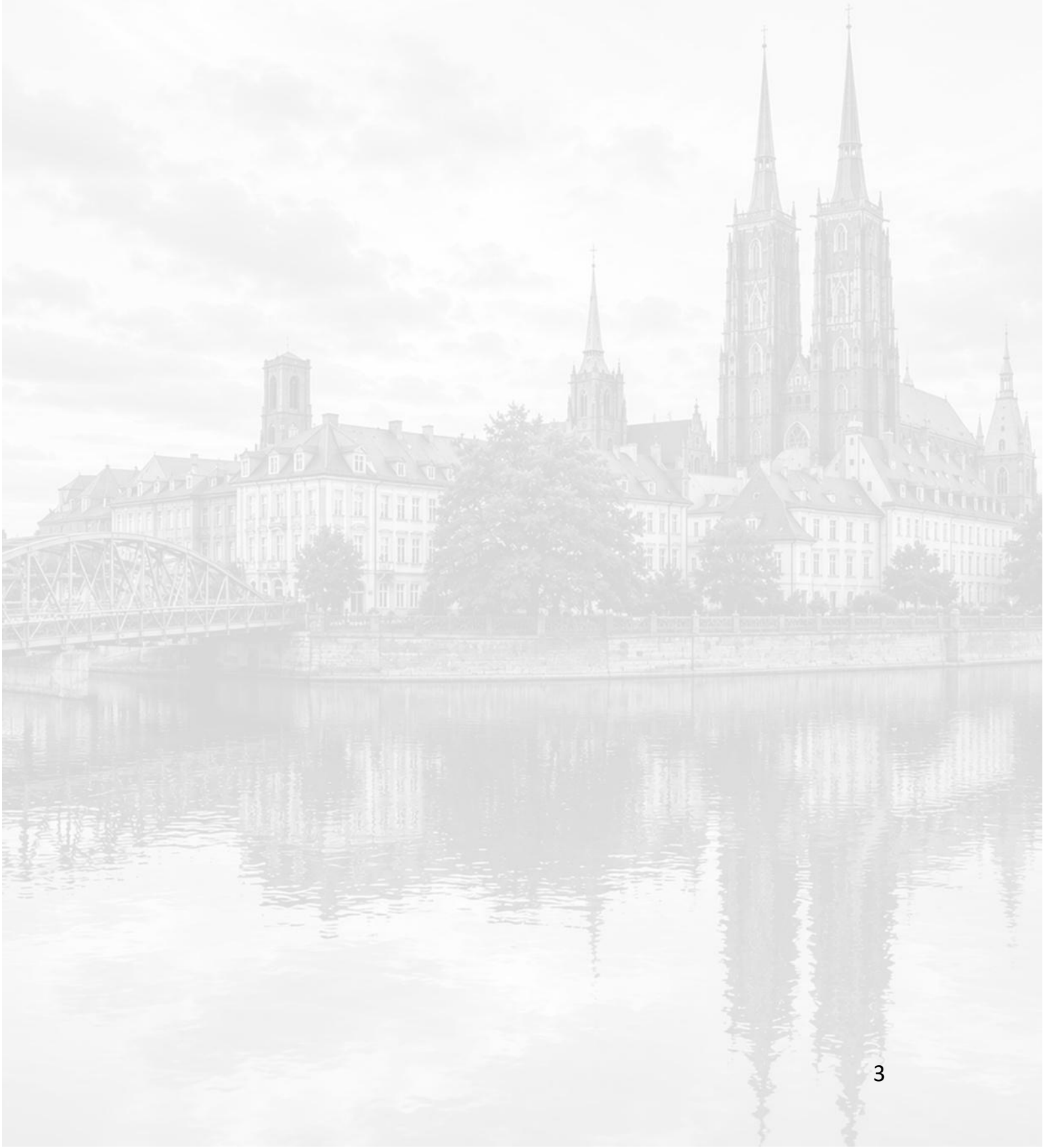

# 1st International Conference on Transition Metal Applications (ICTMA 2026)

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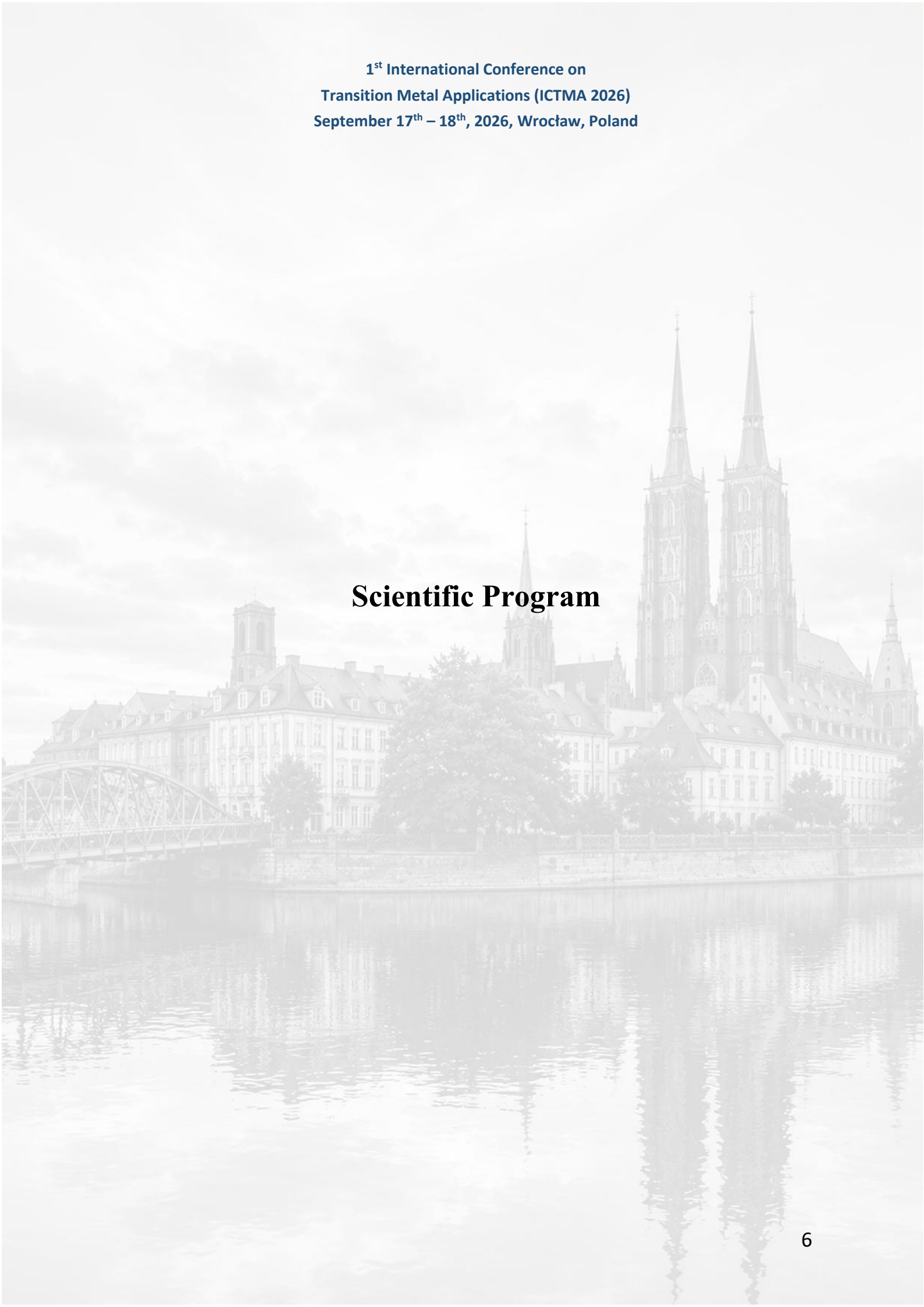
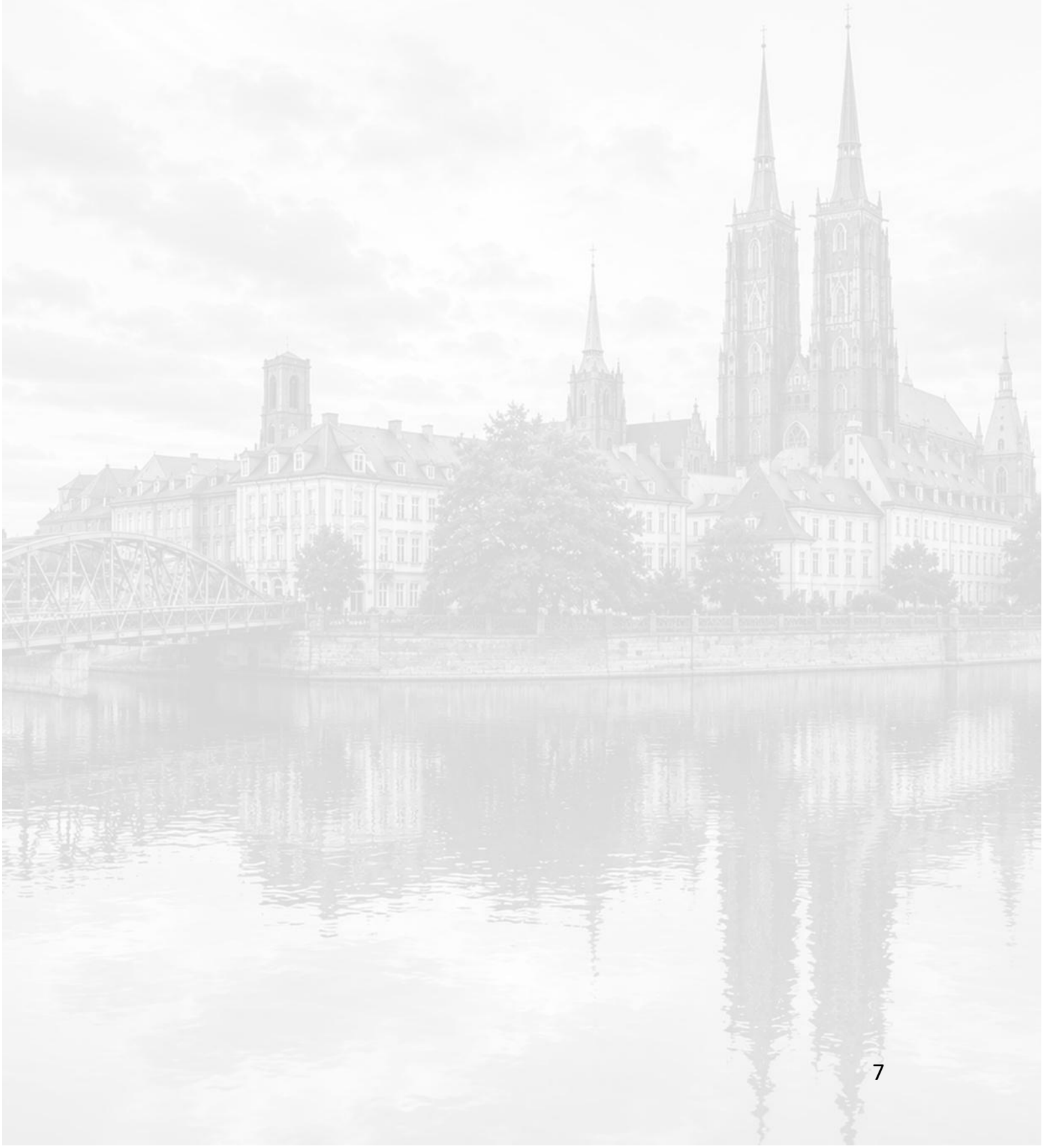


# Scientific Program



| 1st Day<br>17 September 2026 (Thursday) | | |
|---|---|---|
| 09:00 – 09:50 | Registration & Welcome Coffee | |
| 09:50 – 10:00 | Opening Ceremony | |
| Chair (Mykhailo Chaika ) | | |
| 10.00 - 10.30 | Stanislav Balabanov | Growth and doping technologies of zinc chalcogenide gain media for mid-infrared lasers |
| 10.30 - 10.45 | Maciej Kowalczyk | $Cr^{2+}$:ZnS/Se gain crystals for ultrastable and ultrafast mid-IR laser sources |
| 10.45 - 11.00 | Karolina Suliga | Exploiting the Cr:ZnS gain medium's electro-optic properties for laser phase stabilization |
| 11:00 – 11:30 | Coffee Break | |
| Chair (Sergii Ubizskii) | | |
| 11.30-12.00 | Juraj Kajan | Possibilities of the Horizontal Directed Crystallisation (HDC) growth method for sapphire, Re:YAG and eutectic ceramics |
| 12.00 - 12.15 | Yuliia Rumiantseva | HPHT sintering of optically transparent $LiGa_5O_8$ ceramic |
| 12.15 - 12.30 | Yaroslav Zhydachevskyy | Tuning the crystal structure, optical band gap and persistent luminescence performance of $Cr^{3+}$-doped $LiGa_5O_8$ spinel by adding aluminum and indium |
| 12.30 - 12.45 | Anastasiia Karabut | Impact of excess lithium on the persistent luminescence and thermoluminescence behavior of undoped and $Cr^{3+}$-actived $Li_{1+x}Ga_5O_8$ spinel |

| | | |
|---|---|---|
| 12.45 - 13.00 | Akash Shankar Padole | Synthesis, structural and luminescence properties of new high-entropy perovskites $(La_{1/3}Gd_{1/3}Y_{1/3})_{1-x}M_xAlO_{3-\delta}:Mn^{4+}$ (M = Ca, Sr) |
| 13:00 – 14:30 | Lunch Break | |
| Chair (Yaroslav Zhydachevskyy ) | | |
| 14.30-14.45 | Ihor Syvorotka | Growth and optical properties of YAG:$Cr^{4+}$ single crystalline epitaxial films |
| 14.45-15.00 | Mykhailo Chaika | The feature of $Cr^{4+}$ doped $Y_3Al_5O_{12}$ transparent ceramic spectroscopic properties |
| 15.00 - 15.15 | Paweł Kubica-Cypek | Optical Properties and Potential Applications of Monochiral SWCNTs Isolated via Conjugated Polymer Extraction |
| 15.15 – 15:30 | Andrzej Dzienia | Tuning Near-Infrared Luminescence in Single-Walled Carbon Nanotubes through Conjugated Polymer Extraction and Covalent Defect Engineering |
| 15:30 – 16:00 | Coffee Break | |
| 16:00 – 17:30 | Poster session | |
| 20:00 – 23:00 | Dinner & Networking<br>**Młoda Polska Bistro & Pianino**<br>**Plac Solny 4, Wrocław** | |

| 2nd Day<br>18 September 2026 (Friday) | | |
|---|---|---|
| Chair (Jan Hostaša) | | |
| 9.30 - 10.00 | Nadiia Rebrova | Ultraviolet Luminescence of Praseodymium-Doped Wide-Bandgap Phosphors: Spectroscopic Properties, Luminescence Mechanisms, and Applications |
| 10.00 - 10.15 | Przemysław Dereń | The factors that make the upconversion phosphor efficient |
| 10.15 - 10.30 | Vitalii Boiko | Understanding the role of defects in the persistent luminescence of $ZnGa_2O_4$ spinels |
| 10.30 - 10.45 | Sergii Ubizskii | The powder synthesis and ceramics sintering of substituted spinel compositions as matrix for optical applications |
| 10.45 - 11.00 | Oleh Vovk | Study of the single crystal of $Na_3Cr_3(PO_4)_4$ phosphate with 2D superstructure |
| 11:00 – 11:30 | Coffee Break | |
| Chair (Paweł Głuchowski) | | |
| 11.30-12.00 | Karol Bartosiewicz | Structure-dependent near-infrared luminescence of $Fe^{3+}$ in single and eutectic oxide crystals |
| 12.00 - 12.15 | Anton Markovskyi | Dual-Layer YAG:Cr/YAG:Ce Ceramics: Fabrication and Temperature-Dependent Luminescence |
| 12.15 - 12.30 | Andrii Shyichuk | Dodecahydrogen uranium: an icosahedral high-spin f-electron superatom with potential for quantum information applications |
| 12.30 - 12.45 | Bernardo Tavares | Interfacial dynamics and process bottlenecks in the fabrication of transition metal-coated diamond powders via HFCVD for magnetic hyperthermia |

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|---|---|---|
| 12.45 - 13.00 | Wiesław Stręk | Modelling of laser-induced white emission of graphene |
| 13:00 – 14:30 | Lunch Break | |
| Chair (Przemysław Deren ) | | |
| 14.30-14.45 | Vojtěch Nečina | Transparent ceramics by cold sintering process: Dream or reality? |
| 14.45-15.00 | Jan Hostaša | Stabilizing $Cr^{4+}$ in Cr:YAG transparent ceramics by MgO |
| 15.00 - 15.15 | Rémy Boulesteix | Role of fluorine on the elaboration and optical properties of RE:$Y_2O_3$ transparent ceramics (with RE = $Ho^{3+}$, $Er^{3+}$, $Tm^{3+}$) |
| 15.15 – 15:30 | Nathan Kerkad | Transparent $Al_2O_3$:$Cr^{3+}$ ceramics manufactured by Spark Plasma Sintering: correlations between microstructure, doping content and optical properties |
| 15:30 – 16:00 | Coffee Break | |
| Chair (Rémy Boulesteix) | | |
| 16.00 - 16.15 | Pawel Gluchowski | Low-dimensional materials for sustainable energy conversion |
| 16.15 - 16.30 | Dominika Czekanowska | Composition-controlled PMS activation over Cu-Co Tungstates for photocatalytic degradation of Acetaminophen |
| 16.30 - 16.45 | Oleksii Bezkrovnyi | Ru/Ceria-Based Catalysts for Important Environmental Reactions |
| 16.45 - 17.00 | Astita Dubey | Transition Metal-Doped bismuth ferrite Nanoparticles for Catalysis |
| 17.00 - 17.30 | Closing Conference and final remarks | |

**Poster session**

| Code | Presenting author | Title |
|---|---|---|
| **P1** | Beata Barszcz | The peculiarities of emission spectra in $Cr^{3+}$:YGG nanocrystals |
| **P2** | Katarzyna Hałubek-Głuchowska | Influence of Energy Transfer on the Luminescence Properties of $Cr^{3+}$:YGG Ceramics |
| **P3** | Weronika Bodylska-Maj | Luminescence properties of $Cr^{4+}$:YAG nanocrystals |
| **P4** | Pawel Gluchowski | Concentration-Dependent Emission Spectra in $Cr^{3+}$:GGG Transparent Nanoceramics |
| **P5** | Ihor Zavaliy | Raney-type Ni-Co-Fe nanostructured catalysts for efficient hydrogen production by hydrolysis of sodium borohydride |
| **P6** | Dominika Czekanowska | Spectroscopic Properties of $Cr^{3+}$:$Al_2O_3$ Nanoceramics with Highly Disordered Local Structure |
| **P7** | Mark Vovsianiker | Point defects in YAG ceramics induced by $SiO_2$ and MgO sintering additives. A first-principles study |
| **P8** | Olena Fesenko | Comparative Evaluation of the Antibacterial Activity of Dental Nanophotopolymer Composites Modified with Silver Nanoparticles and Graphene Oxide |
| **P9** | Olena Fesenko | Vibrational Spectroscopic Study of MXene-Based Hybrid Nanosystems |
| **P10** | Olena Fesenko | $Fe_3O_4$ Nanohybrids Modified with Pt, Ag and Au for Surface-Enhanced Molecular Spectroscopy |

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|---|---|---|
| **P11** | Olena Fesenko | IR AND RAMAN SPECTROSCOPY OF $Eu_xNd_{1-x}S$_ SOLID SOLUTIONS |
| **P12** | Malwina Janiak | Spectroscopic and Luminescence Properties of $Pr^{3+}$-Doped $ACaF_3$ (A = K, Rb, Cs) Fluorides. |

# INVITED LECTURES

**Dr. Stanislav Balabanov**

**Ludwig-Maximilians-Universität München**

Dr. Stanislav Balabanov is a Senior Scientist at the Crystal Laboratory, Chair of Experimental Physics — Laser Physics, Ludwig-Maximilians-Universität München (LMU), Garching, Germany. He has more than 20 years of research experience in the field of optical ceramics and advanced functional polycrystalline materials.

His research has focused on the development of optical ceramics and ceramic–ceramic nanocomposites, including rare-earth oxide-based materials, through the development of nanopowder synthesis and precursor technologies, powder processing and consolidation, and advanced sintering methods. His expertise also includes diffusion bonding of optical materials and the investigation of their structural, optical, laser, magneto-optical, mechanical, and thermophysical properties. He has led research teams involved in the development of a broad range of new materials and processing methods, several of which were reported for the first time.

Dr. Balabanov is the co-author of 163 scientific publications and 10 patents, with an h-index of 25. His current research is primarily focused on zinc chalcogenide-based optical materials, with particular emphasis on their synthesis, processing, consolidation, and optical and functional properties for laser and other photonic applications.

# Growth and doping technologies of zinc chalcogenide gain media for mid-infrared lasers

**Stanislav Balabanov[1,2]*, Alexander Weigel[1,2,3], Ferenc Krausz[1,2,3]**

[1] *Fakultät für Physik, Ludwig-Maximilians-Universität München (LMU), Garching, Germany*
[2] *Max Planck Institute of Quantum Optics (MPQ), Garching, Germany*
[3] *Center for Molecular Fingerprinting (CMF), Budapest, Hungary*
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Chromium- and iron-doped zinc chalcogenides ($Cr^{2+}$:ZnS/ZnSe and $Fe^{2+}$:ZnS/ZnSe) are established gain media for solid-state lasers operating in the mid-infrared (2–5 μm) spectral range. Their broad absorption and emission bands, large stimulated emission cross-sections, wide wavelength tunability, and favorable thermo-mechanical properties enable continuous-wave, pulsed, and ultrashort-pulse laser operation. In particular, $Cr^{2+}$:ZnS/ZnSe are often regarded as the mid-infrared analogues of Ti:sapphire.

Despite the maturity of these laser systems, further improvement of their performance remains closely tied to the quality of the active material and the methods used for its fabrication. This work presents an overview of current approaches to the fabrication and doping of zinc chalcogenides, including melt growth, vapor-phase crystal growth, chemical vapor deposition, and hot pressing of transparent ceramics. The advantages and limitations of both in-growth doping and post-growth diffusion are discussed.

Particular attention is paid to the relationship between fabrication technology, microstructure, and laser performance. The influence of residual mechanical stress, scattering centers, dopant distribution, and dopant charge state on the optical and laser properties of the active media is considered. A comparison of existing fabrication routes shows that no method simultaneously provides optimal optical quality, scalability, and process complexity. The review identifies the key technological bottlenecks common to existing fabrication routes and discusses possible approaches to overcoming them.

The presentation concludes with the Global Initiative: Protecting Health project as an example of an emerging large-scale application of $Cr^{2+}$-doped zinc chalcogenide lasers. The project employs field-resolved infrared fingerprinting spectroscopy based on ultrashort mid-infrared laser pulses for early blood-based disease diagnostics. Owing to its scale and demanding laser-source requirements, it is expected to become a major driver for the further development of $Cr^{2+}$-doped zinc chalcogenide gain media for biomedical photonics.

**Dr. Juraj Kajan**

**University of Žilina**

Eng. Juraj Kajan, PhD. – has been working in the field of crystal growth research using horizontal crystallization since 2014, when he was a young student at the time. At the engineering level, his work was dedicated to the topic "Design of a pyrometer movement mechanism for measuring high temperatures", which was used to measure the temperature of the heater and the melt in the crystallizer. His dissertation dealt with the topic "Research into the possibility of increasing the dimensions of the thermal node of a device used for growing single crystals using the horizontal crystallization method". Today, his primary focus is on growing doped YAG single crystals via HDC method . He works as the head of the department at the University of Žilina in Žilina and CTO at AT crystals company.

# Possibilities of the Horizontal Directed Crystallisation (HDC) growth method for sapphire, Re:YAG and eutectic ceramics

**Juraj Kajan[1,2]*, Tomáš Gregor[1,2], Štefan Medvecký[2]**

[1] *Institute of Competitiveness and Innovations, University of Žilina, Univerzitná 8215, 010 26 Žilina, Slovakia*
[2] *AT Crystals s.r.o., Rosinská cesta 9, Žilina 010 08, Slovakia*
**Juraj.Kajan@fstroj.uniza.sk*

The Czochralski growth method is the most developed and the most commonly used technology for industrial growth of YAG single-crystals doped with rare earth elements. The development enabled stable production of high-quality crystals for solid-state lasers. However, its main defect — the ingot's core "bulk defect"—visible in the cross-section, significantly limits the usability of the crystal and the ability to obtain high-dimension laser elements— such as slabs and disks. Further disadvantages of the industrial implementation of this method also include high cost of the crystal production process due to the use of expensive iridium and stabilized zirconia ceramic in the design of Czochralski crystal growth system (growth furnace).

The method of Horizontal Directed Crystallization (HDC), which was essentially developed for production of laser single-crystals related to the family of yttrium aluminum garnets, allows to obtain ingots in the form of plates, which is the most suitable shape for the manufacture of slab and disk laser elements.

The melting zone in the HDC method moves along the length of the container throughout the process, which is achieved by local melting of the loaded raw material — this approach allows continuous feeding (recharge) of the melt with raw components and dopants. Using a specific raw material distribution method to fill the container, it is possible to compensate for the components with selective vaporization in vacuum and/or to grow crystals with a specific dopant (gradient) distribution.

Despite the general presence of defects in the bulk single-crystal, good-quality plates with dimensions of 100 × 80 × 10 mm were successfully extracted from the defect-free part of the Yb:YAG crystal bulk with dimensions of 100 × 200 × 25 mm, grown by AT Crystals' first generation HDC method. Today, with the second-generation production capabilities, AT Crystals is on a stable production, achieving dimensions of over 170 x 300 x 35 mm for YAG, Yb:YAG [1], which translates to around 120 x 120 x 20 mm high optical quality slabs. For Sapphire, AT Crystals arrive at bulk dimensions in crystallographic axis C of 230 x 300 x 45mm and A axis 220×400×50 mm [2]. Also, the eutectic ceramic material has been grown in large dimensions up to 317 × 220 × 35 mm[3].

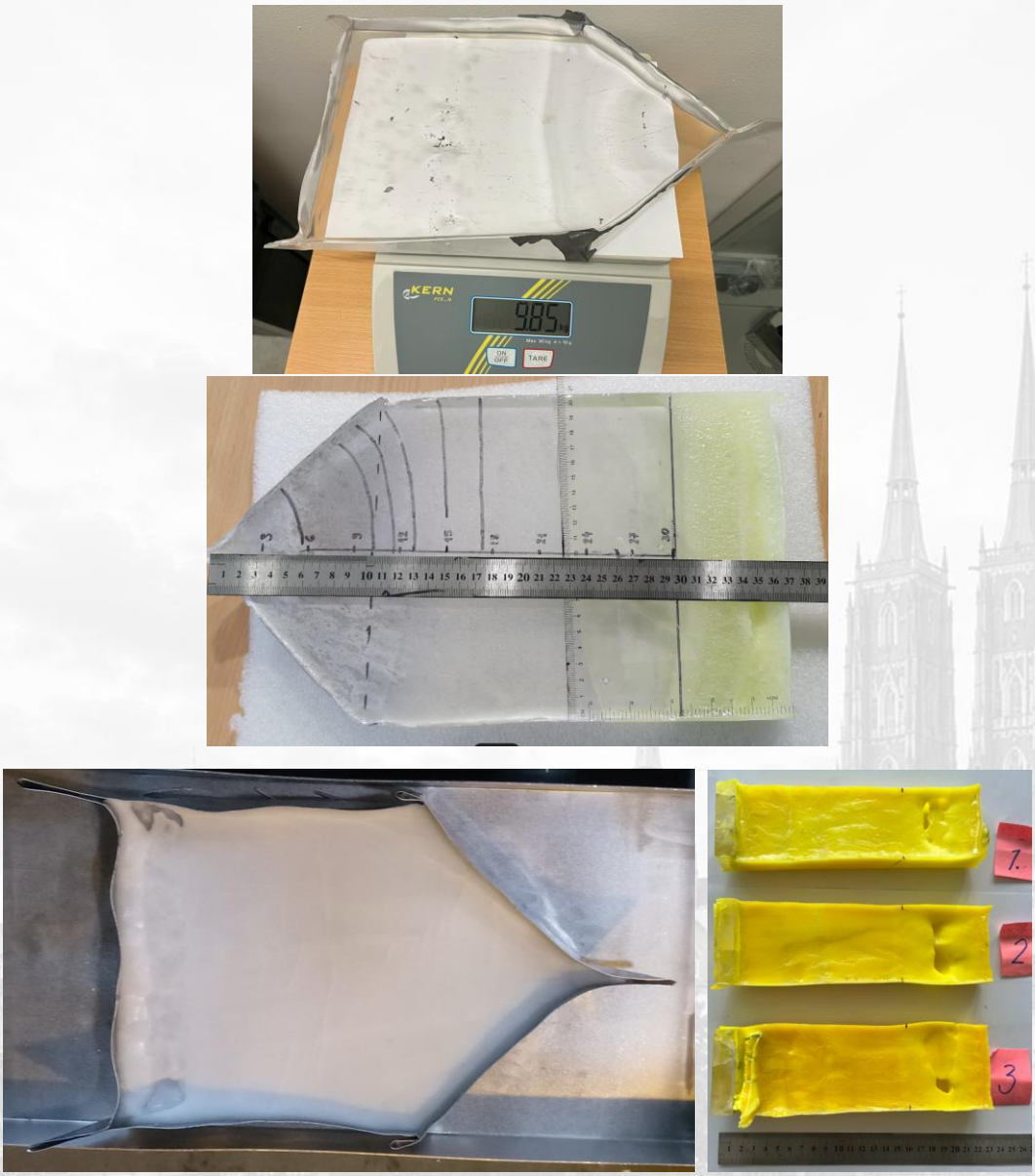


*Fig. 1: Sapphire, YAG crystal and eutectic ceramic grown via HDC method.*

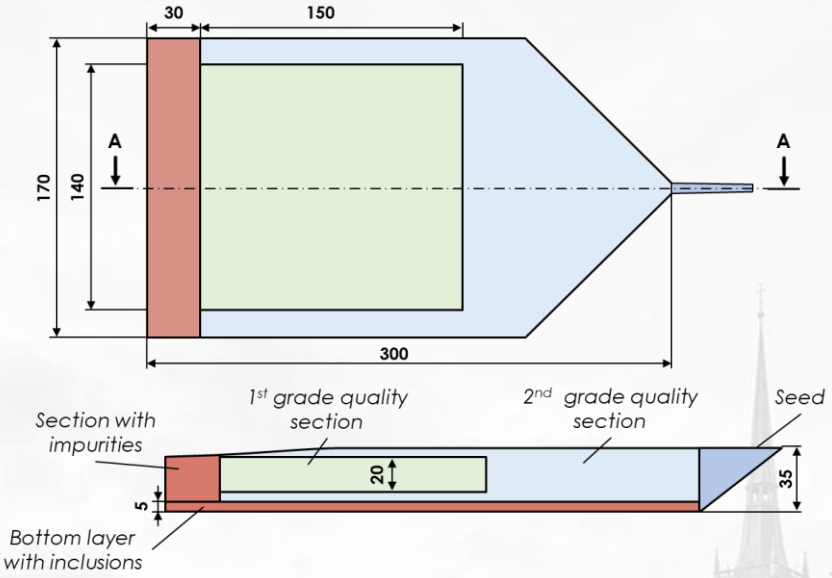


*Fig. 2: Dimensions of the container that hosts the crystal and the different sections regarding quality grade of the YAG crystal*

**Acknowledgements**
Funded by the EU Next Generation EU through the Recovery and Resilience Plan for Slovakia under the project No. 09I0503V0200065. Also authors would like to thank for the financial support for the European Union under the HORIZON.1.2 – Marie Skłodowska-Curie Actions (MSCA), topic HORIZON-MSCA-2023-SE-01 – MSCA Staff Exchanges 2023 program, the project titled - "Cr4+:YAG/Polymer nanocomposite as alternative materials for Q-switched lasers: properties, modeling, and applications – ALTER-Q" - Project number 101182995.

**References**
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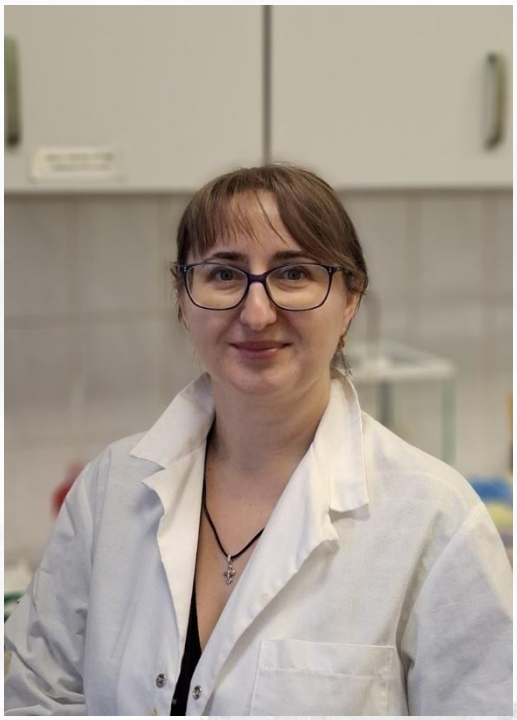
2. J Kajan et al., 2024 J. Phys.: Conf. Ser. 2931 012026
3. Kajan J, et al., Crystals. 2024; 14(10):858. https://doi.org/10.3390/cryst14100858

**Dr. Nadiia Rebrova**

**Institute of Low Temperature and Structure Research,**

**Polish Academy of Science**



Dr. Nadiia Rebrova is a materials scientist specializing in luminescent and scintillation materials, with particular expertise in rare-earth-doped phosphors, upconversion luminescence, persistent luminescence, and optical thermometry. She received a Master's degree in Chemistry from V.N. Karazin Kharkiv National University (Ukraine), and in 2018 defended her PhD n Materials Science at the Institute of Scintillation Materials of the National Academy of Sciences of Ukraine.

Since 2022, she has been working at the Institute of Low Temperature and Structure Research of the Polish Academy of Sciences in Wrocław, where her research focuses on the discovery and characterization of novel ultraviolet-emitting phosphors, particularly $Pr^{3+}$-activated materials for UVC upconversion, persistent luminescence, and photonic applications.

Dr. Rebrova has authored more than 50 peer-reviewed scientific publications in leading journals, including Inorganic Chemistry, Journal of Physical Chemistry C, Journal of Materials Chemistry C, Dalton Transactions, and other. She is the principal investigator of several research projects funded by the National Science Centre (Poland) and international facilities, including DESY (Germany).

Her scientific achievements have been recognized with the President of Ukraine Prize for Young Scientists (2018). She is also an inventor and co-inventor of several patents in the fields of luminescent and scintillation materials.

Research interests: luminescent materials, scintillators, rare-earth spectroscopy, upconversion processes, persistent phosphors, optical thermometry, crystal growth, and advanced inorganic synthesis

# Ultraviolet Luminescence of Praseodymium-Doped Wide-Bandgap Phosphors: Spectroscopic Properties, Luminescence Mechanisms, and Applications.

**Nadiia Rebrova[1]*, Alexander Grippa[2], Patrycja Zdeb-Stańczykowska[1], Andriy Pushak[3], Malwina Janiak[4], Anatoliy Voloshinovskii[3], Przemysław J. Dereń[1]**

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*[2]Institute for Scintillation Materials, National Academy of Sciences of Ukraine, Nauki Avenue, 60, 61001, Kharkiv, Ukraine.*
*[3]Ivan Franko National University of Lviv, 8 Kyryla i Mefodiya St, 79005, Lviv, Ukraine.*
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In recent years, trivalent praseodymium ions ($Pr^{3+}$) have attracted considerable attention from researchers as activators for phosphors, lasers, and scintillators. This interest is primarily due to the unique electronic structure of $Pr^{3+}$ in wide-bandgap host materials [1]. The ion possesses low-lying excited 4f5d states, as well as several metastable levels in the $4f^2$ configuration, providing access to a wide range of radiative transitions. Emission from 4f5d states is characterized by short decay times, typically on the order of tens of nanoseconds, making $Pr^{3+}$-doped materials particularly attractive for scintillation applications requiring fast response and high temporal resolution. In contrast, radiative transitions from the metastable $^1D_2$, $^3P_0$, and $^3P_1$ levels of the $4f^2$ configuration lead to visible emission and are therefore of significant interest for solid-state laser systems, as well as for red and orange phosphor components in light-emitting diodes (LEDs).
At the same time, increasing attention is being paid to the development of efficient ultraviolet (UV) phosphors for applications in sterilization, disinfection, phototherapy, and modern optoelectronic devices. In this regard, wide-bandgap materials activated by $Pr^{3+}$ ions represent a particularly promising class of UV phosphors [2]. This talk will discuss the technological potential of praseodymium-activated materials. Particular attention will be paid to persistent luminescence and vis-to-ultraviolet upconversion luminescence, with an emphasis on the mechanisms governing these processes and the factors influencing their efficiency.

**Acknowledgements**
This work was supported by the National Science Centre of Poland (NCN) under grants No. UMO-2021/41/B/ST5/03792 and UMO-2025/57/B/ST4/00594, for which the authors express their sincere gratitude.

**References**
1. A.M. Srivastava, J Lumin 129 (2009) 126–129
2. M.D. Dramićanin, Nanomaterials 15 (2025) 562

**Dr. Karol Bartosiewicz**

**Institute of Physics, Czech Academy of Sciences**

Dr. Karol Bartosiewicz is an accomplished physicist and chemist specializing in luminescent, scintillating, and photoconversion materials, with expertise in advanced materials science and crystal growth. Born on July 23, 1989, in Poland, he began his research career at the University of Wrocław, where he worked as a University Research Assistant in the Faculty of Chemistry from 2012 to 2013, gaining experience in the synthesis and characterization of novel luminescent materials.

In 2013, he joined the Marie Curie Initial Training program within the European Network on Luminescent Materials in Prague, developing expertise in energy transfer, luminescence quenching, defect engineering, and optically active garnet single crystals. He later served as an Assistant Professor at Tohoku University's Institute for Materials Research in Japan, conducting research on crystal growth and scintillation processes.

From 2019 to 2024, he was an Assistant Professor at Kazimierz Wielki University in Bydgoszcz, Poland. Since September 2024, he has been an MSCA Postdoctoral Fellow and EU-funded Principal Investigator at the Institute of Physics of the Czech Academy of Sciences in Prague. His current research focuses on oxide single-crystal growth, advanced luminescent and scintillating materials, innovative crystal-growth methods, and material optimization.

# Structure-dependent near-infrared luminescence of $Fe^{3+}$ in single and eutectic oxide crystals

**K. Bartosiewicz[1*], Y. Smortsova[2], R. Tomala[3], M. Szymczak[3], V. Babin[1], D. Szymański[3], Y. Zhydachevskyy[4], Ł. Marciniak[3], G. Bai[5], A. Yoshikawa[6]**

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Near-infrared luminescent materials are widely studied for spectroscopy, imaging, sensing, and radiation-related applications. Among transition-metal ions, $Fe^{3+}$ ions are of particular interest because they emission is strongly influenced by local coordination, crystal-field strength, and the structural characteristics of the host lattice [1]. In the present work, $Fe^{3+}$ ions luminescence was investigated in $Y_3Ga_5O_{12}$ single crystals and $Y_3Ga_5O_{12}$-$Ga_2O_3$ eutectic heterostructures. The single and eutectic crystals were grown from the melt by the micro-pulling-down method. Structural characterization confirmed the formation of a eutectic microstructure composed of two immiscible phases, namely $Y_3Ga_5O_{12}$ garnet and β-$Ga_2O_3$. The influence of phase constitution and microstructural arrangement on the near-infrared emission of $Fe^{3+}$ in eutectic crystals was therefore examined. In $Y_3Ga_5O_{12}$ single crystals, the $Fe^{3+}$ near-infrared luminescence remains weak, whereas the eutectic material provides a larger number of available Fe incorporation sites. Vacuum-ultraviolet spectroscopy under synchrotron radiation revealed differences in the band-gap-related excitation processes and in the excitation dynamics associated with $Fe^{3+}$ luminescence. Photoluminescence measurements showed only minor concentration quenching, efficient excitation in the blue spectral range compatible with commercial blue LEDs, and pronounced thermometric performance with a maximum relative sensitivity of 9.3 % $K^{-1}$. The results demonstrate that $Fe^{3+}$ luminescence in these materials depends strongly on phase composition, local crystallographic environment. $Y_3Ga_5O_{12}$ single crystals and $Y_3Ga_5O_{12}$-$Ga_2O_3$ eutectics therefore represent two complementary material forms for studying $Fe^{3+}$ near-infrared luminescence and for developing blue-LED-excitable phosphors and multifunctional optical materials [2].

**Acknowledgements**
This research was funded by the GIMRT program of the Institute for Materials Research, Tohoku University (Proposal No. 202412-RDKYA-0503) and by the European Union Horizon Europe research and innovation programme under the Marie Skłodowska-Curie Actions COFUND, Physics for Future.

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2. P. Wang, M. S. Che Kurboniyon, et al., ACS Appl. Mater. Interfaces 18 (14), 20752-20762.

# ORAL PRESENTATIONS

# $Cr^{2+}$:ZnS/Se gain crystals for ultrastable and ultrafast mid-IR laser sources

**Maciej Kowalczyk***

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Transition-metal-doped II–VI chalcogenides such as chromium-doped zinc sulfide and selenide ($Cr^{2+}$:ZnS, $Cr^{2+}$:ZnSe) are currently the most promising active laser materials for direct generation of ultrashort pulses in the mid-infrared spectral region. This band is critical for several important applications including spectroscopy, biomedicine, environmental sensing, and strong-field science [1]. $Cr^{2+}$:ZnS/Se gain media, sometimes termed the "Ti:sapphire of the mid-infrared", can be pumped by widely available erbium- or thulium-doped lasers, emit ultrabroadband radiation around the wavelength of 2.3 μm, and thus enable generation of ultrashort pulses down to durations equivalent to a mere few cycles of the electric field [2].

In this work, I will present our recent advances in employing $Cr^{2+}$:ZnS/Se gain crystals for the development of ultrafast and ultrastable mid-IR laser sources. I will report on the development of oscillators producing ~30 fs pulses (Fig. 1a) [3], which can be spectrally broadened to cover more than an optical octave (Fig. 1b) and compressed to single-cycle durations [4]. The quadratic nonlinear properties of the $Cr^{2+}$:ZnS/Se crystals allow generation of harmonics and help to achieve record-low-noise laser operation. I will describe how we employed for the first time the electro-optic properties of these media for laser stabilization [5]. Finally, I will focus on nonlinear conversion of the $Cr^{2+}$:ZnS/Se laser radiation towards the long-wavelength mid-IR band [6], and its applications in spectroscopy [7].

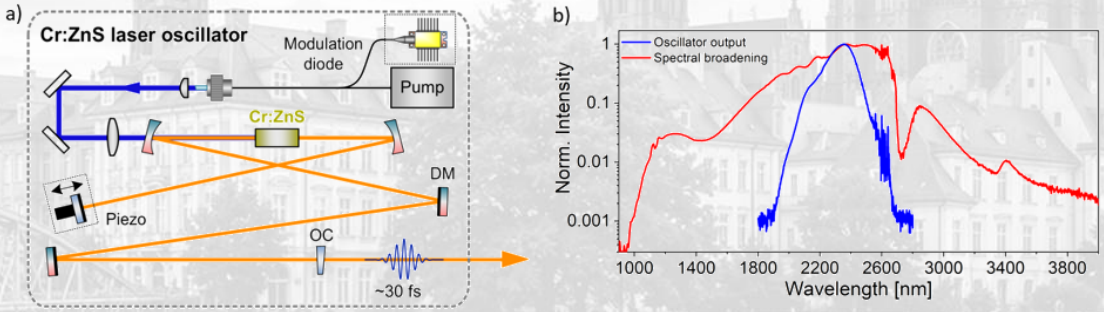


*Fig.1 (a) Experimental setup of the $Cr^{2+}$:ZnS laser producing femtosecond pulses; (b) optical spectrum emitted directly from the $Cr^{2+}$:ZnS laser and after subsequent spectral broadening in a nonlinear $TiO_2$ medium.*

**Acknowledgements**

The project "Ultrastable pulsed lasers covering the spectral range from near to far infrared" (FENG.02.02-IP.05-0069/23) is carried out within the First Team programme of the Foundation for Polish Science, co-financed by the European Union under the European Funds for Smart Economy 2021-2027 (FENG).

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# Exploiting the Cr:ZnS gain medium's electro-optic properties for laser phase stabilization

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Optical frequency combs (OFCs) are indispensable tools for precision metrology, attosecond science, spectroscopy, and optical clocks, however they require stable phase control. While numerous stabilization techniques have already been developed [1], none have exploited the laser gain medium itself. In this work, we demonstrate a novel stabilization approach based on the electro-optic modulation of chromium-doped zinc sulfide (Cr:ZnS), a material that combines excellent laser gain characteristics with voltage-controlled birefringence. Our results show that the electro-optic behavior known for ZnS [2] is preserved in Cr:ZnS, enabling the gain crystal to perform simultaneously as an intracavity polarization modulator. The method was implemented in a 97 MHz Kerr-lens mode-locked Cr:ZnS oscillator [3] (Fig. 1a) operating at a central wavelength of 2300 nm.

Successful stabilization was demonstrated, confirming the feasibility of a gain-medium-based electro-optic method. Frequency response measurements of the crystal showed a stable response in frequencies up to 1 MHz (Fig 1b, pink trace), but revealed an electro-optic relaxation effect [4] that limits the effective modulation bandwidth at low frequencies. Additionally, we compared the electro-optic modulation performance of polycrystalline Cr:ZnS used in the laser with that of its monocrystalline counterpart (Fig. 1b, purple trace). These results establish Cr:ZnS as a multifunctional optical material that simultaneously provides laser gain and electro-optic control, opening new possibilities for compact and ultrastable frequency comb stabilization architectures.

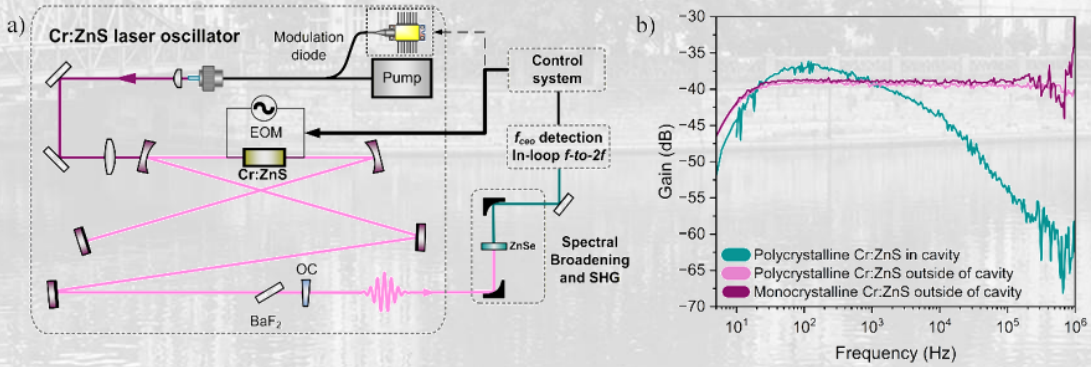


*Fig. 1 a) Experimental setup for phase stabilization of Cr:ZnS laser b) Frequency response of monocrystalline Cr:Zns (purple) and polycrystalline Cr:ZnS to modulation inside the laser cavity (turqoise) and outside (pink)*

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# Sintering of optically transparent $LiGa_5O_8$ ceramic

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Transparent lithium gallate spinel ($LiGa_5O_8$) is an emerging ultra-wide-bandgap oxide semiconductor that has recently attracted interest due to its reported p-type conductivity and potential applications in optoelectronics, photonics, and luminescent devices. However, the preparation and characterization of dense bulk $LiGa_5O_8$ ceramics remain largely unexplored. In this work, transparent $LiGa_5O_8$ ceramics were fabricated by the high-pressure high-temperature (HPHT) pressing technique using both nanocrystalline powders synthesized by the citrate sol-gel method and microcrystalline powders obtained through a conventional solid-state reaction route. The influence of powder characteristics and sintering parameters on the structural, optical, and mechanical properties of the resulting ceramics was systematically investigated. X-ray diffraction analysis confirmed the formation of a single-phase cubic spinel structure in both precursor powders and HPHT-sintered samples. The evolution of powder morphology with calcination temperature revealed progressive crystallization and grain growth, while HPHT processing of microcrystalline powders led to a grain-refinement effect attributed to pressure-induced particle fragmentation. Dense ceramics with relative densities up to 98.3% of the theoretical value were obtained under pressures of 7.8 GPa and temperatures between 664 and 740 °C. Mechanical characterization demonstrated high hardness values of approximately 9.6-11.8 GPa and Young's moduli of 236-273 GPa. Analysis of elastic parameters, including the Poisson ratio and Pugh criterion, indicated a mixed ionic-covalent bonding character, in good agreement with theoretical estimates based on Pauling ionicity. The calculated plasticity parameter ($\delta_p$ = 0.62-0.67) suggests an unusually high resistance to brittle failure for an oxide ceramic. Optical measurements showed that transparency strongly depends on the balance between sintering temperature and dwell time, with optimal transparency achieved for samples processed at the highest temperature and shortest sintering duration. These results demonstrate that HPHT pressing is an effective route for producing highly dense and optically transparent $LiGa_5O_8$ ceramics, providing a foundation for future investigations of their electronic, optical, and functional properties.

**Acknowledgments**
This work was supported by the "Development of a technology for manufacturing ceramic targets and depositing PVD coatings on them using magnetron sputtering method" project, which was funded by the Ministry of Science and Higher Education for the Łukasiewicz Research Network – Krakow Institute of Technology. It was also supported by the Polish National Science Centre (project no. 2024/53/B/ST11/01108), the Ministry of Education and Science of Ukraine (project no. DB/GALIO 0125U001768), the ENR Project of EUROfusion Program (Grant Agreement No. 101052200), and the SE MSCA HORIZON project ALTER-Q (Grant Agreement No. 101182995).

# Tuning the crystal structure, optical band gap and persistent luminescence performance of $Cr^{3+}$-doped $LiGa_5O_8$ spinel by adding aluminum and indium

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The possibility of tuning the optical band gap, crystal structure and persistent luminescence performance of $Cr^{3+}$-doped $LiGa_5O_8$ spinel by partially replacing Ga with Al and/or In has been studied extensively. For this purpose, a series of $Cr^{3+}$-doped $Li(Ga_{1-x-y}Al_xIn_y)_5O_8$ ($x = 0…0.5$; $y = 0…0.1$) microcrystalline phosphors were synthesized using a conventional solid-state reaction method and characterized by powder X-ray diffraction and luminescence techniques. The DFT-based electronic structure calculations were carried out for the same $Li(Ga_{1-x-y}Al_xIn_y)_5O_8$ compositions, and the results were compared with the experimental ones. Based on the studies performed, the mechanism of Al and In incorporation into the $LiGa_5O_8$ spinel structure, as well as the tuning of the crystal lattice parameters, local structure of $M^{3+}$ ($M$ = Ga, Al, In) cations and optical band gap of the material have been established. The multicenter structure and the broadening of the local structural disorder of the octahedrally coordinated $Cr^{3+}$ centers observed in this case have been confirmed by the high-resolution, low-temperature photoluminescence measurements. Band gap engineering through alterations in the chemical composition of the $LiGa_5O_8$ spinel, as well as the depth of the native point defects responsible for charge trapping, allows for the efficient tuning of the thermoluminescent and persistent luminescent properties of $Li(Ga_{1-x-y}Al_xIn_y)_5O_8:Cr^{3+}$ phosphors. Thus, the room-temperature persistent luminescence performance of the phosphors modified by the addition of Al and annealing in an oxygen-free atmosphere was increased threefold compared to the pristine $LiGa_5O_8:Cr^{3+}$ phosphor synthesized under the same conditions.

**Acknowledgements**

The work was supported by the Polish National Science Centre (project no. 2024/53/B/ST11/01108), the Ministry of Education and Science of Ukraine (project DB/GALIO no. 0125U001768), and the European Research Executive Agency (HORIZON-MSCA-2023-SE-01 Project no. 101182995). The authors gratefully acknowledge Polish high-performance computing infrastructure PLGrid (HPC Centre: ACK Cyfronet AGH) for providing computer facilities and support within the computational grant no. PLG/2024/017683.

# Impact of excess lithium on the persistent luminescence and thermoluminescence behavior of undoped and $Cr^{3+}$-activated $Li_{1+x}Ga_5O_8$ spinel.

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Lithium-gallium spinel ($LiGa_5O_8$) activated with rare-earth (RE) or transition metal (TM) ions is a well-established crystalline phosphor exhibiting long-lasting persistent luminescence (PersL), thermally stimulated luminescence (TSL) and mechanoluminescence (ML) properties. In particular, when activated with $Cr^{3+}$-doped $Li_{1+x}Ga_5O_8$ spinel displays intensity persistent luminescence in the deep red spectral region centered about 700 nm. In contrast, undoped $LiGa_5O_8$ spinel exhibits a strong broad-band intrinsic photoluminescence (PL) in the violet-blue spectral region near 400 nm, but only weak PersL at room temperature. The radiation storage capabilities responsible for the PersL, TSL and ML of the material are associated with intrinsic point defects as well as cation antisites, cation and oxygen vacancies that are highly probable in this spinel compound (see e.g. [1]). In our recent works, we demonstrated that partial substitution of Ga by Al and/or In enables tuning of the optical band gap, crystal structure, and persistent luminescence performance of $Cr^{3+}$-doped $LiGa_5O_8$ spinels [2]. The present study aims to go further and to get a better insight into the nature of the intrinsic point defects responsible for the charge trapping and their targeted modification with the purpose of improving the PersL and TSL properties of the material. Specificallly, the impact of lithium excess on the PersL and TSL properties of the $Li_{1+x}Ga_5O_8$-based phosphors has been investigated in detail. To this end, several series of $LiGa_5O_8$-based compounds with varying Li/Ga ratios. Both nominally undoped samples and $Cr^{3+}$-activated compositions were prepared by the solid-state reaction method and comprehensively characterised using powder XRD and luminescence techniques. The results demonstrate that the modification of the $LiGa_5O_8$ host lattice by the Li excess has a high potential for tuning and improving the PersL and TSL properties of undoped and $Cr^{3+}$-doped material. Most notably, the introduction of excess lithium enables the development of an efficient blue-emitting persistent phosphor based on the undoped $Li_{1+x}Ga_5O_8$ spinel.

**Acknowledgements**

The work was supported by the Polish National Science Centre (project no. 2024/53/B/ST11/01108), the Ministry of Education and Science of Ukraine (project DB/GALIO no. 0125U001768).

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# Synthesis, structural and luminescence properties of new high-entropy perovskites $(La_{1/3}Gd_{1/3}Y_{1/3})_{1-x}M_xAlO_{3-\delta}:Mn^{4+}$ (M = Ca, Sr)

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High-entropy oxides exhibit high structural stability due to configurational entropy, which stabilises single-phase solid solutions containing multiple cations at the same crystallographic sites. Their tunable structural, electronic, and other application-relevant functional properties make them promising materials for catalysis, functional ceramics, and optical technologies [1].

High-entropy perovskites with nominal composition composition $(La_{1/3}Gd_{1/3}Y_{1/3})_{1-x}M_xAlO_{3-\delta}$:0.1%$Mn^{4+}$ ($x$ = 0, 0.05, 0.1; $M$ = Ca, Sr) were synthesised by sol-gel and solid-state reaction methods. In the sol-gel route, aqueous solutions of the corresponding metal nitrates and citric acid were mixed and evaporated at 80 °C. The obtained gels were calcined at 300 and 450 °C, followed by sequential heat treatment at 800, 900, 1000 and 1100 °C for 4 h, and at 1300 and 1500 °C for 5 h. The solid-state synthesis was carried out from simple oxide micropowders, thoroughly ground in an agate mortar and synthesised at 1300, 1500 and 1600 °C with intermediate grinding. To study the effect of reducing annealing, selected samples were annealed in high vacuum at 1000 °C for 2 h.

DTA/TG analysis of the $(La_{1/3}Gd_{1/3}Y_{1/3})AlO_3:Mn^{4+}$ gel shows that the main weight losses are related to decomposition of metal nitrates and combustion of organic components, while crystallisation occurs up to about 1000 °C. XRD analysis after each annealing stage confirmed that a single-phase perovskite structure of $(La_{1/3}Gd_{1/3}Y_{1/3})_{1-x}M_xAlO_{3-\delta}:Mn^{4+}$ can be obtained by the sol-gel route after heat treatment at 1000 °C. For the unsubstituted material, the perovskite phase is already formed at 800 °C, whereas the Ca- and Sr-containing compositions require temperatures above 900 °C. Rietveld refinement was performed in the orthorhombic Pbnm space group, and the obtained lattice parameters agree with literature data for related $RAlO_3$ compounds [2].

Photoluminescence (PL) and photoluminescence excitation (PLE) studies of the materials obtained by both synthesis routes revealed the characteristic $Mn^{4+}$ emission in the red spectral range at about 700 nm.

The studied materials revealed thermally stimulated luminescence (TSL) after UV light exposure, similar to that observed previously for $Y_{1-x}Gd_xAlO_3:Mn^{4+}$ and $Gd_{1-x}La_xAlO_3:Mn^{4+}$ phosphors [3]. The solid-state samples showed much higher radiation storage ability than the sol-gel samples, as evidenced by stronger TSL and persistent luminescence (PersL) intensity. The luminescence behaviour indicates that chemical composition and synthesis conditions influence the formation and stability of charge-trapping centres. In particular, divalent cation substitution ($Ca^{2+}$, $Sr^{2+}$) and annealing procedures affect the density and depth of traps, and therefore the intensity and duration of the luminescent emission. These results show how synthesis parameters and cation distribution govern energy storage and release processes in $Mn^{4+}$-doped high-entropy perovskites.

**Acknowledgements**
The work was supported by the Polish National Science Centre (project no. 2024/55/B/ST7/02680) and by the National Research Foundation of Ukraine (project no. 2025.07/0218).

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1st International Conference on
Transition Metal Applications (ICTMA 2026)
September 17th – 18th, 2026, Wrocław, Poland

# Growth and optical properties of YAG:$Cr^{4+}$ single crystalline epitaxial films

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Chromium-doped yttrium aluminum garnet ($YAG^{4+}$) is an important functional material for passive Q-switching of Nd lasers operating near 1.064 μm [1]. Liquid phase epitaxy (LPE) provides an attractive alternative to bulk $YAG^{4+}$ crystals, allowing direct growth of a saturable absorber layer on a Nd substrate and providing improved control over the thickness and spatial distribution of $Cr^{4+}$ centers.

The $YAG^{4+}$ epitaxial films were grown on (100)-oriented YAG substrates by isothermal LPE from a supercooled $PbO–B_2O_3$-based solution. The MgO was introduced into the melt as a charge compensator promoting stabilization of chromium in the $Cr^{4+}$ state. The growth temperature was 990–1050 °C. Depending on melt supercooling and film thickness, different surface growth regimes were observed. At low supercooling, $\Delta T < 20$ °C, tangential growth resulted in mirror-like surfaces even for films with thicknesses up to 150 μm. Increasing supercooling led to a transition toward mixed and kinetically controlled growth accompanied by the formation of growth hillocks.

A particular feature observed for sufficiently thick films grown in the high-supercooling regime was the formation of hollow-core growth hillocks on the (100) surface. This morphology is unusual for epitaxial garnet films. Growth and spiral hillocks in garnets have conventionally been associated mainly with singular {110}-type surfaces, whereas their formation on (100)-oriented epitaxial garnet films has not been reported [2]. The present observation represents the first identification of conditions leading to hollow-core hillock formation in (100)-oriented epitaxial garnet films.

Optical characterization at 1064 nm demonstrated strong $Cr^{4+}$-related absorption. Moreover, spatially resolved measurements revealed substantially higher lateral uniformity of the absorption coefficient in the epitaxial $YAG^{4+}$ film compared with a bulk $YAG^{4+}$ single crystal. The epitaxial film also exhibited a considerably higher absorption coefficient. These results demonstrate that control of LPE growth conditions enables simultaneous optimization of surface morphology, film thickness, and spatial uniformity of $Cr^{4+}$ optical centers, which is important for reproducible passive Q-switching and other photonic applications.

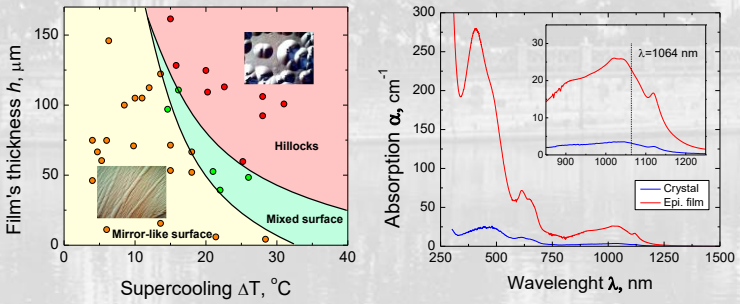


*Fig. 1. Surface morphology map and optical absorption spectra of crystal and film.*

**Acknowledgements**
The work was supported by the European Research Executive Agency (HORIZON-MSCA-2023-SE-01 project No. 101182995).

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# Low-temperature luminescence of $Cr^{4+}$-doped $Y_3Al_5O_{12}$ transparent ceramic

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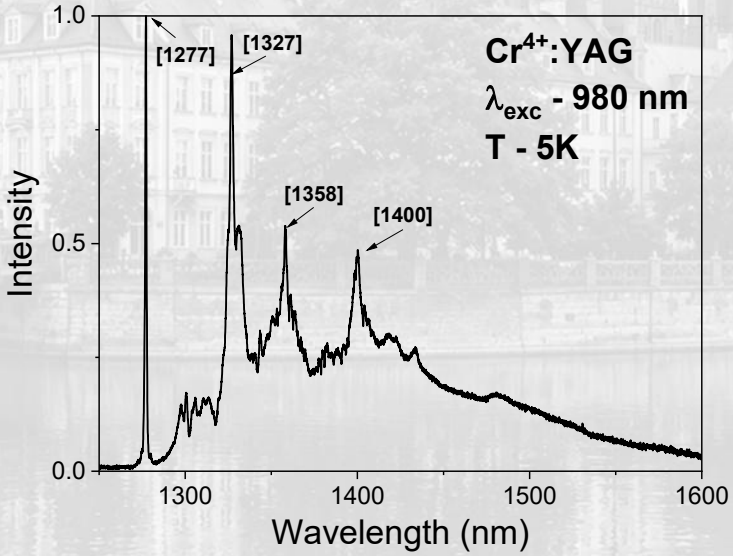
Over the last few decades, $Cr^{4+}$:YAG has been widely used as a laser host material. The unique properties of this material arise from the splitting of $Cr^{4+}$ energy levels in the crystal field of a distorted tetrahedron with $D_{2d}$ symmetry. This crystal field splitting provides both advantages and disadvantages, including the presence of multiple $Cr^{4+}$ emission centers. These centers can reduce the laser performance of $Cr^{4+}$ ions. The nature of these emission centers might be related to the orientation of $Cr^{4+}$ along specific crystallographic axes, differences in charge compensation mechanisms, or possible misinterpretation of the crystal field splitting components of the $Cr^{4+}$ ions. This work focuses on the spectroscopic properties of $Cr^{4+}$:YAG transparent ceramic. Absorption, excitation, and emission spectra were measured over a temperature range from 5K to 300K. Low-temperature absorption spectra reveal sharp and narrow lines corresponding to partially allowed transitions from the ground state to the crystal field splitting components of $^4T_2$ energy level. The shape of the excitation spectra was found to be independent of the monitored emission wavelength, indicating that $Cr^{4+}$ emission originates from the lowest excited state. Low-temperature emission spectra exhibit a sharp and narrow ZPL, accompanied by the vibronic sidebands extending up to ~2000 $cm^{-1}$. Both absorption and emission spectra of the lowest excited state at low temperature consist of a doublet, with a splitting of 28 $cm^{-1}$. The temperature dependence of the spectroscopic parameters of this doublet is reported. Based on the obtained results, possible explanations of its origin are proposed [1].




*Emission spectra of the Cr4+:YAG transparent ceramic measured at λexc – 980 nm and T – 5K*

**Acknowledgements**

This work was supported by the Polish National Science Center, grant: OPUS 23, UMO-2022/45/B/ST5/01487.

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# Optical Properties and Potential Applications of Monochiral SWCNTs Isolated via Conjugated Polymer Extraction

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Single-walled carbon nanotubes (SWCNTs) are single sheets of graphene rolled into cylindrical structures. Chirality describes the orientational vector of the graphene lattice upon rolling, which fundamentally dictates whether an SWCNT behaves as a metallic or semiconducting material. This structure-property relationship renders distinct nanotube species highly attractive for diverse applications. However, the direct, selective synthesis of individual chiralities remains challenging and economically unviable, necessitating the use of polydisperse chiral mixtures in both fundamental research and technological applications.

The isolation of semiconducting single-walled carbon nanotubes (s-SWCNTs) with high chiral and enantiomeric purity is a cornerstone of next-generation carbon photonics. Conjugated polymer extraction (CPE) has proven to be an efficient sorting method, capable of achieving monochiral purity through the optimization of conventional polymer characteristics. While early systematic studies by Mayor and Kappes established foundational libraries of fluorene and carbazole copolymers, such as PFO, PFDD, PFTD, F8BT, and PFO-BPy, recent advancements have primarily shifted toward degradable backbones for polymer-free SWCNT recovery or specialized enantiomeric resolution. Despite these developments, a comprehensive re-evaluation of how core backbone modifications dictate monochiral selectivity remains lacking in the literature. Furthermore, we demonstrated that achieving high selectivity is not only a matter of chemical composition but is critically dependent on the macromolecular parameters of the polymers.

The relative abundance of individual chiralities can be quantified using optical absorption spectroscopy (UV-Vis-NIR) and photoluminescence excitation-emission mapping. Beyond fundamental characterization, we highlight the potential of monochiral SWCNTs as tunable optical materials. Their narrow, structure-dependent optical transitions make them promising candidates for applications in nanoscale photonics, optical sensing, bioimaging, and related technologies that require precisely defined photonic responses.

**Acknowledgements**

The authors gratefully acknowledge financial support from the National Science Centre, Poland (under the SONATA programme, Grant agreement UMO-2024/55/D/ST11/02962) and Metropolis GZM, Poland (under Metropolitan Science Support Fund, Grant agreement No. RW/25/2026).

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# Tuning Near-Infrared Luminescence in Single-Walled Carbon Nanotubes through Conjugated Polymer Extraction and Covalent Defect Engineering

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The creation of tunable, bright, and robust near-infrared (NIR) emitters remains a central challenge in modern photonics and telecommunications. Although transition-metal-doped systems have received considerable attention, single-walled carbon nanotubes (SWCNTs) functionalized with luminescent $sp^3$ defects have emerged as a promising, metal-free alternative for deep-NIR applications. Here, we provide an overview of our recent progress in tailoring the optical properties of SWCNTs by combining conjugated polymer extraction (CPE) with covalent defect engineering. The methodology combines chirality-selective isolation, organic radical chemistry, and advanced optical spectroscopy. We begin by examining the isolation of high-purity monochiral fractions of SWCNTs (e.g., (6,5), (7,5), and (7,3)) by means of CPE. Special attention is given to the structure of fluorene-based polymers and to the optimization of the macromolecular parameters that control the selective isolation of the desired chiralities, showing distinct pristine fluorescence signatures.
Second, we show that the optical properties can be modified after extraction by means of covalent defect engineering. Instead of depending on the stochastic formation of defects, we use a specially designed library of benzoyl peroxide (BPO) derivatives and other radical precursors. By systematically altering the electronic features of the substituents, as measured by the Hammett constants, and their steric properties, we can exert deterministic control over both defect density and the depth of the optical trap. This method allows accurate fine-tuning and substantial red-shifting of the defect-induced photoluminescence ($E_{11}$*) into the telecommunication window.
Through comprehensive spectroscopic characterization, we elucidate the structure-property relationships governing these luminescent nanomaterials. Ultimately, this presentation will showcase how integrating scalable polymer-assisted sorting with precise radical chemistry provides a robust, chemically intuitive toolbox for designing the next generation of tunable NIR photonic materials.

**Acknowledgements**

The author gratefully acknowledge financial support from the National Science Centre, Poland (under the SONATA programme, Grant agreement UMO-2024/55/D/ST11/02962) and Metropolis GZM, Poland (under Metropolitan Science Support Fund, Grant agreement No. RW/25/2026).

# The factors that make the upconversion phosphor efficient

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The upconversion phenomenon has been studied and utilized since the 1960s. While it is often considered a disadvantage in optical fiber telecommunications, it has found numerous valuable applications, including document and banknote security, infrared sensing, bioimaging, and medicine. Upconversion is most commonly used to convert low-energy infrared photons into visible light. However, achieving efficient conversion to higher-energy ultraviolet radiation, particularly in the UVC range used for disinfection, remains a significant challenge.
In this lecture, I will discuss the fundamental limitations of the upconversion process and highlight the key factors that determine its efficiency. Special attention will be given to the requirements for achieving effective visible-to-UVC upconversion and its potential applications.

**Acknowledgements**

This work was supported by the National Science Centre of Poland (NCN) under grants No. **UMO-2021/41/B/ST5/03792**.

# Understanding the role of defects in the persistent luminescence of $ZnGa_2O_4$ spinels.

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$ZnGa_2O_4$ (ZGO) spinels doped with transition metals with emission in the near-infrared (NIR) range are of interest for their promising applications across various fields, including biovisualisation. The presence of different types of defects can lead to luminescence quenching. By contrast, structural inversion can be a source of persistent luminescence (PersL) [1]. In our previous investigation, ZGO obtained by hydrothermal synthesis followed by calcination at 750°C exhibited the best PersL, maintaining an average particle size around 20 nm [2], which is important for subsequent applications. Calcination at higher temperatures improves photoluminescence but decreases PersL. It can be concluded that calcination at lower temperatures eliminates quenching-related defects, while calcination at higher temperatures further improves the structure by reducing the number of trapping centres.

In the present work, ZGO nanoparticles doped with transition metals (Fe and Cr) were synthesised by the hydrothermal method with parameters optimised earlier [2]. The synthesised samples were characterised by both structural and spectroscopic methods. Additionally, based on Raman and thermoluminescence data, the presence of antisite defects in the obtained samples was analysed. Undoped and codoped samples were analysed by optical spectroscopy, particularly in the deep UV range, to evaluate defects related to oxygen vacancies. Electronic structure calculations of a set of iron- and chromium-related point defects in ZGO crystals were carried out using the DFT band-periodic CASTEP method within the super-cell approach. The results of the calculations are compared with experimental data from optical spectroscopy and structural characterisation of the synthesised samples.

**Acknowledgements**

This work was supported by the Polish National Science Centre, grant Nr: 2024/08/X/ST5/00392 (VB) and grant Nr. 2022/45/B/ST5/01487 (MC) and the NEPHEWS programme under Grant Agreement No. 101131414 from the EU Framework Programme for Research and Innovation Horizon Europe. Parts of this research were conducted at PETRA III, P66 Superlumi, proposal ID: I-20250937 EC.

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# The powder synthesis and ceramics sintering of substituted spinel compositions as matrix for optical applications

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Optical transparency from the UV to IR range of the spectrum, along with other attractive properties of $MgAl_2O_4$ spinel, accounts for its widespread use as an optical material for lasers, optical windows, phosphors etc. The crystal structure of $MgAl_2O_4$ spinel is formed by densely packed oxygen atoms, which form a rigid structural framework with tetrahedral and octahedral voids, the number of which exceeds the number of cations occupying them. This feature determines the high mobility of cations and, in particular, the high radiation resistance of spinel compounds and their ability to recover from damage after intense irradiation and/or thermal treatment. The substitution of cations in the spinel compound modifies the features of the spinel-type crystal structure of the nominally pure composition, as well as its properties a=as matrix for optically active dopant to tune their optical properties.

This work is devoted to study a possibility of useful substitutions of spinel and attempts to produce transparent ceramics from them by high-pressure high-temperature (HPHT) sintering of nano- and micro-powders synthesized by various methods and annealed in the range from 800 to 1200 °C in air. We have found that only Zn substitution forms a solid solution $Mg_{1-x}Zn_xAl_2O_4$ across the entire range of $x$ = 0…1. Accurate estimates of the crystal structure parameters showed that $MgAl_2O_4$ initially crystallises with an inverted cation distribution and becomes normal with increasing annealing temperature, unlike $ZnAl_2O_4$, which crystallises immediately with normal ordering. Other substituting cations retain the cubic structure of spinel only at a limited level of substitution. The results of a comparative study of the optical properties of the ceramic materials obtained, in particular their behaviour under irradiation with 12.5 MeV electrons up to a fluence of $10^{17}$ $cm^{-2}$, as well as a comparison with single-crystal spinel are presented.

**Acknowledgments**
The study has been carried out within the framework of the EURO*fusion* Consortium, funded by the European Union via the Euratom Research and Training Programme (GA No 101052200), as well as the ALTER-Q project funded by the European Union via SE MSCA Horizon-Europe Program (GA No 101182995). This work was co funded too by the Polish Ministry of Science and Higher Education within the project “Development of a technology to produce transparent spinel for optical applications” (No. 602430).

1st International Conference on
Transition Metal Applications (ICTMA 2026)
September 17th – 18th, 2026, Wrocław, Poland

# Study of the single crystal of $Na_3Cr_3(PO_4)_4$ phosphate with 2D superstructure

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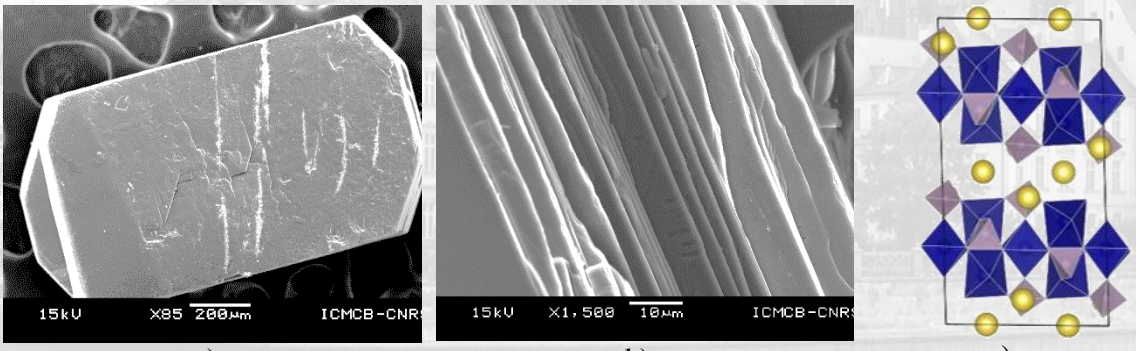
$Na_3Cr_3(PO_4)_4$ phosphate has been synthesised and described by XRD in 1980 [1], but at that time it didn't attract interest. Nowadays, this substance has gained new attention due to the searching new high-voltage materials based on the $Cr^{4+}/Cr^{3+}$ redox couple for the rechargeable sodium battery [2], as well as materials with multiferroic and magnetoelectric properties [3].
The single crystals of $Na_3Cr_3(PO_4)_4$ were obtained from a flux melt based on $Na_2MoO_4$-$Na_2Mo_2O_7$ at 1200 °C - 1000 °C. The crystal structure was established by powder and single-crystal XRD.
The morphology was studied by SEM, chemical composition was proven by EDS. Optical absorption was measured by DRS, and magnetic properties were investigated on a SQUID magnetometer up to 8 T at subhelium temperatures.
It was established that $Na_3Cr_3(PO_4)_4$ belongs to the monoclinic space group "C2/c" cell paramiters: a=19.7074(15), b= 6.3331(4), c= 10.4173(8), β= 92.187(4). The crystal consists of layers of two kinds of octahedra with $Cr^{3+}$ inside and tetrahedra with $P^{5+}$ combined by the corners. The $Na^+$ ions are located in the interlayer space. The layers are perpendicular to the [100] direction, which also results in layer morphology. The absorption spectra confirm that Cr ions take place in two different octahedra. Magnetic properties of the single crystal are different in normal and along directions to the layers.




a) b) c)

*SEM images of the single crystal of $Na_3Cr_3(PO_4)_4$ a),its layered 2D structure b), crystal cell c)*

**Acknowledgements**
This work was supported by the project "Multiphos", ANR France. O.V. gratefully acknowledge the financial support of the PAUSE Program.

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# Dual-Layer YAG:Cr/YAG:Ce Ceramics: Fabrication and Temperature-Dependent Luminescence

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Transparent dual-layer phosphor ceramics based on $Ce^{3+}$-doped YAG (YAG:Ce, 1 at.% $Ce^{3+}$) and $Cr^{3+}$-doped YAG (0.10–0.25 at.% $Cr^{3+}$) were successfully fabricated as promising color-conversion media for next-generation solid-state lighting. The ceramics were prepared using a freeze-granulation technique followed by uniaxial pressing, cold isostatic pressing, and high-temperature reactive vacuum sintering, resulting in dense, highly transparent, and well-bonded layered structures with controlled dopant distribution and phase purity (Fig.1 a,b). This processing route enables the formation of dual-layer architectures in which $Ce^{3+}$ and $Cr^{3+}$ active layers are spatially separated, allowing independent control of yellow and red emission components.
The dual-layer architecture is particularly attractive for high-power LED and laser-driven white-light sources, where ceramic phosphor converters provide superior thermal and mechanical stability compared with conventional phosphor-in-silicone composites [1]. The $Cr^{3+}$ layer extends the emission spectrum toward longer wavelengths, compensating for the red deficiency of YAG:Ce and increasing the color rendering index (CRI) from approximately 62 to 71 while maintaining high thermal stability. The $Cr^{3+}$ emission exhibited excellent resistance to thermal quenching for all compositions, with $T_{1/2}$ values of 652, 654, 654, and 655 K and activation energies of 0.48, 0.50, 0.47, and 0.43 eV for $Cr^{3+}$ concentrations of 0.10, 0.15, 0.20, and 0.25 at.%, respectively.

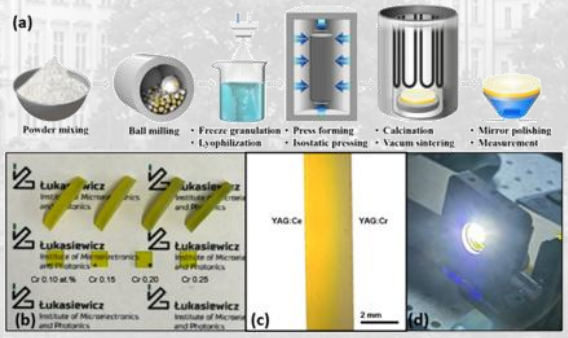


*Fig. 1. Fabrication process of dual-layered YAG:Ce/YAG:Cr ceramics (a); photographs of YAG:Ce/YAG:Crx (x = 0.10–0.25 at.%) transparent ceramics (b); cross-section showing distinct YAG:Ce and YAG:Cr layers (c); the operation of the YAG:Ce/YAG:Cr converter in an LED setup (d).*

**Acknowledgements**
This work was supported by the National Science Centre Poland (NCN) MINIATURA Grant No. 2024/08/X/ST5/00814.

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# Dodecahydrogen uranium: an icosahedral high-spin f-electron superatom with potential for quantum information applications

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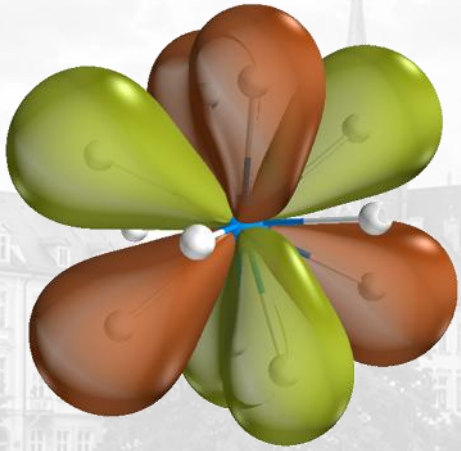
A new icosahedral superatom UH12 is reported and analyzed using post-Hartree-Fock multiconfigura-tional methods. A RASSCF/CASPT2/RASSI/SINGLE_ANISO workflow is employed to determine the electronic energy levels and magnetic properties. Superatomic characteristics such as orbital topologies and shell filling order are discussed. The high hydrogen-to-uranium ratio and potential for optically stimulated decomposition make UH12 interesting in the context of hydrogen storage. The molecule is magnetically isotropic, its electric-dipole transition oscillator strengths vanish, while its lowest electro-nic transitions fall in the THz and infrared ranges. The lowest heptet manifold exhibits crystal-field splitting into a 1+3+3 pattern, as expected from icosahedral symmetry. In turn, the interlevel gaps within these crystal-field triplets are below 100 GHz (1-3 cm-1). The molecule is magnetically isotropic at low fields, while its levels exhibit higher-order Zeeman anisotropy that becomes significant around 2 Tesla. These properties suggest potential applications in quantum computing, quantum communication, and quantum memory, including qubit- and qudit-based architectures.



*A superatomic f-orbital of $UH_{12}$, $B_{2u}$ symmetry*

# Interfacial dynamics and process bottlenecks in the fabrication of transition metal-coated diamond powders via HFCVD for magnetic hyperthermia

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Magnetic nanoparticle-mediated hyperthermia requires robust carriers capable of shielding active magnetic phases while maintaining therapeutic heat generation [1]. This study evaluates a hot-filament chemical vapor deposition (HFCVD) route aimed at fabricating double-encapsulated diamond/transition-metal/diamond composite particles. Monocrystalline diamond powders in 0.5–1 μm and 10–20 μm fractions were subjected to vibration-assisted thermal evaporation of iron (Fe), nickel (Ni), and tungsten (W), followed by a secondary HFCVD step targeting a boron-doped diamond overgrowth at substrate temperatures between 750°C and 800°C. Morphological and structural evaluation revealed that the choice of transition metal critically dictates the interfacial carbon phase and coating viability. Iron and tungsten interlayers preserved faceted, microcrystalline diamond-related growth, whereas nickel proved fundamentally incompatible. This is attributed to the thermal reduction of Ni, which promoted active carbon dissolution, complete suppression of $sp^3$ nucleation, and the formation of disordered graphitic carbon [2].

While metallic retention was confirmed across all samples, conformal encapsulation was prevented by particle shadowing and localized agglomeration, yielding discontinuous metal-rich regions. Furthermore, preliminary alternating magnetic field (AMF) screening (80 kHz, 5.1 mT) indicated detectable thermal responses, peaking in Fe-containing composites. The synthesis of continuous metal-diamond hybrid architectures is severely constrained by transition metal mobility and metal-catalyzed graphitization during high-temperature CVD. Future process optimization will prioritize dynamic powder fluidization to eliminate shadowing and quantitative magnetic phase analysis to definitively separate core hyperthermia performance from environmental thermal artifacts.

**Acknowledgements**

This work was developed within the scope of the project CICECO-Aveiro Institute of Materials, UID/50011/2025 (DOI 10.54499/UID/50011/2025) & LA/P/0006/2020 (DOI 10.54499/LA/P/0006/2020) & UID/PRR/50011/2025 (DOI 10.54499/UID/PRR/50011/2025), financed by national funds through the FCT/MCTES (PIDDAC). Miguel Neto acknowledges FCT for the research contract 2023.07806.CEE CIND/CP2840/CT0030 (DOI 10.54499/2023.07806.CEECIND/CP2840/CT0030). Bernardo L. Tavares acknowledges FCT for the PhD Research Scholarship 2025.00641.BDANA, funded by national funds under the Program Portugal 2030. European project Alter-Q (Grant Agreement number: 101182995) is acknowledged.

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# Modelling of laser-induced white emission of graphene

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Laser-induced broadband white emission was observed in several inorganic compounds and is preceded by multiphoton-induced ionization, giving access to broadband visible light [1,2]. It is characterized by an excitation threshold, an exponential increase of emission intensity with excitation power, a saturation plateau, and an ejection of hot electrons giving access to efficient photocurrent [3,4]. In the present work, we propose an empirical model of laser-induced broadband emission and discuss its practical applications in lighting, photocurrent, and photocatalysis

**Acknowledgements**
This work was supported by the Polish National Science Center, grant: OPUS 23, UMO-2022/45/B/ST5/01487.

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# Transparent ceramics by cold sintering process: Dream or reality?

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Fabrication of transparent ceramics remains rather expensive due to the high processing temperatures and the relatively high product defect rate. Even higher temperatures are required in the context of single crystal fabrication; additionally high dopant concentrations can lead to phase separation. The cold sintering process (CSP) offers an enticing route for low-temperature densification of ceramics. To date, several ceramic systems (primarily fluorides) have been successfully prepared in transparent form. While these achievements are remarkable, they should be treated with caution. A detailed understanding of the densification mechanisms is still largely absent. Moreover, expanding this success to other ceramic system (particularly oxides) remains a major challenge.

The present contribution addresses the key challenges through experimental data obtained by in-situ dilatometry and microstructural observations, providing a realistic assessment of the potential of CSP for the fabrication of transparent ceramics. This is specifically addressed for materials relevant to transition metals doping ($CaF_2$ and $Y_2O_3$).


*Sample of transparent $CaF_2$ ceramics prepared by cold sintering process at 400 °C.*

**Acknowledgements**

This publication was created thanks to the equipment acquired as part of the project No. CZ.02.01.01/00/22_012/0005292 within the Jan Amos Komensky Operational Program co-funded by the European Union.

# Stabilizing $Cr^{4+}$ in Cr:YAG transparent ceramics by MgO

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The presented work dealt with the production of $Cr^{4+}$:YAG ($Cr^{4+}$-doped yttrium aluminum garnet) transparent ceramics. The main applications of Cr:YAG are in lasers, as saturable absorbers for Q-switching of Nd:YAG and Yb:YAG-based solid state lasers, or as absorbing cladding to suppress Amplified Spontaneous Emission and parasitic oscillations. The energy level structure and the corresponding broad absorption bands in the 1 μm region are characteristic of $Cr^{4+}$ ions occupying tetrahedral sites in the crystal structure of YAG [1]. However, the thermodynamically stable state of Cr in YAG under standard conditions is $Cr^{3+}$, subsituting $Al^{3+}$ ions in the crystalline structure. Therefore, the as-sintered Cr:YAG ceramics contain predominantly trivalent chromium ions, and the ceramist's task is to find a way to convert them – by the use of co-dopants, specific thermal treatments, or, most likely, both, while maintaining a good optical quality of the material. An optimal co-dopant should therefore also have the have function of a sintering aid, which allows the full densification of the material, removing the sources of light scttering [2].
The ceramics presented in this work were produced by reactive vacuum sintering of a mixture of oxide powders constituting the Cr:YAG ($Cr_2O_3$, $Y_2O_3$, $Al_2O_3$), and MgO added in the role of both sintering aid and charge compensator. We will illustrate how the relation between the quantity of $Cr_2O_3$ and MgO determines the fraction of $Cr^{4+}$ ions in the material and will also comment on the limits of use of MgO.

**Acknowledgements**
Work performed in the frame of the CeMiLAP2 Research Project. The project is co-funded by the Italian Ministry of Defence in the frame of the National Military Research Program 2019 managed by the National Armaments Directorate under the contract n. 8731, prop. A2018.059.A special thanks goes to the personnel of the National Armaments Directorate and the Territorial Technical Office of Naples of the Directorate of Air Armaments and Airworthiness.

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# Role of fluorine on the elaboration and optical properties of RE:$Y_2O_3$ transparent ceramics (with RE = $Ho^{3+}$, $Er^{3+}$, $Tm^{3+}$)

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In recent years, advances in ceramic processing technologies have enabled the large-scale fabrication of these materials in the form of transparent polycrystalline components with tailored compositions, such as $Sc_2O_3$, $Y_2O_3$, or $Lu_2O_3$ doped with various luminescent ions including $Ho^{3+}$, $Yb^{3+}$, and $Nd^{3+}$, depending on the targeted laser wavelength [1-3]. More recently some studies have also highlighted the interest in developing magneto-optical transparent ceramics like $Ho_2O_3$, $Tb_2O_3$ or $Tb_{1-x}Lu_xO_3$ as Faraday rotators in high power lasers [4]. As a result, ceramic technology offers several major advantages for the production of innovative solid-state laser materials, including the capability for high-volume production of components in a wide range of sizes, as well as the fabrication of new compositions that are hardly achievable using current single-crystal growth techniques.

This study focuses on the development of manufacturing processes for laser ceramics derived from the $RE_2O_3$ sesquioxide family, where RE represents elements of rare-earth family like $Lu_2O_3$ and $Y_2O_3$ doped with luminescent ions such as $Ho^{3+}$, $Er^{3+}$ and $Tm^{3+}$. In this work, the role of fluorine doping on the microstructural and spectroscopic properties of Ho:$Y_2O_3$ transparent ceramics was firstly investigated. The ceramics were fabricated by adding $YF_3$ powders to the primary composition, then sintered using either a rapid sintering technique (Spark Plasma Sintering, SPS) or Hot Isostatic Pressing (HIP). As a result, fluoride appears to promote grain growth and porosity elimination, regardless of the sintering method. Spectroscopic study shows that limited F doping (4500 ppm $YF_3$) has no significant influence on the absorption and emission spectral profiles of $Ho^{3+}$ ions, but it increases the luminescence lifetimes of the $^5I_7$ and $^5I_6$ manifolds giving rise to emission at 2 µm and 3 µm, respectively, especially for ceramics produced by a post-HIP treatment.

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# Transparent $Al_2O_3:Cr^{3+}$ ceramics manufactured by Spark Plasma Sintering: correlations between microstructure, doping content and optical properties

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In the 1960s, a ruby single crystal (corundum-structured $Al_2O_3$:Cr) was used as the gain medium in an early solid-state laser prototype [1]. Today, this material remains widely used in high-power lasers and as a synthetic gemstone in jewellery. Compared to their single-crystal counterparts, polycrystalline α-$Al_2O_3$-based ceramics exhibit outstanding (thermo-)mechanical, chemical, and thermal properties. Furthermore, they can be doped with transition metals at contents above beyond the corresponding solubility limits observed in single crystals. However, due to the birefringent hexagonal structure of α-$Al_2O_3$, high transparency requires a fine microstructure with very small grain sizes [2]—a prerequisite for applications demanding high optical quality lasers [3]. Additionally, very low residual porosity level (< $10^{-2}$%–$10^{-4}$%) is needed in order to reach transparency in α-$Al_2O_3$-based ceramics [2]. To meet these two objectives, chromium-doped alumina ceramics were manufactured using Spark Plasma Sintering (SPS) that is a well method to enable rapid, full densification and the production of fine-grained ceramics. In this study, the doping level was varied between 0.1% and 0.5% $Cr^{3+}$ to investigate its influence on both sintering behavior and the optical properties of the sintered specimens by SPS. Increasing the $Cr^{3+}$ content progressively shifts the maximum densification rate toward lower temperatures without significantly affecting the final relative density. Chromium thus acts as a sintering aid promoting the densification of $Al_2O_3$ ceramics. Nevertheless, chromium contents above approximately 0.3 mol% promote a finer but more chemically heterogeneous microstructure and lower optical transmission. This result appears to be due to local Cr-rich regions of the type $Cr_xAl_{2-x}O_3$ phase acting as scattering centers. The ceramics so-obtained are transparent whatever the amount of $Cr^{3+}$, with an optimum of transparency 40% at 800 nm around 0.2at.% of $Cr^{3+}$ ions, as illustrated in Figure 1.


*Photograph of 10-mm-diameter $Al_2O_3$:Cr ceramic samples containing 0.1 to 0.5 molar percent chromium, arranged in descending order of chromium content from left to right (0.5 molar percent on the right and 0.1 molar percent on the left). The samples were sintered using the SPS method at 1,400 °C for 15 minutes under a pressure of 130 MPa.*

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# Low-dimensional materials for sustainable energy conversion

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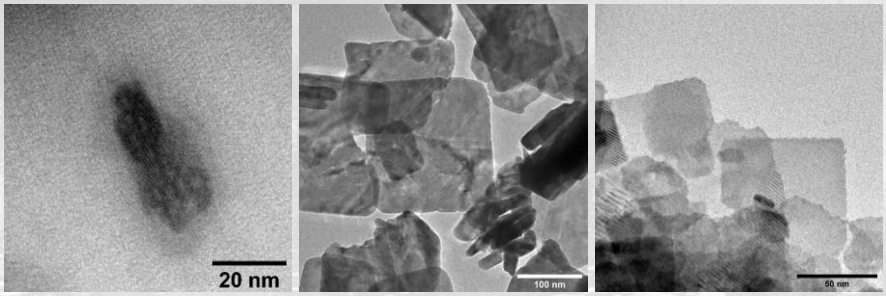
Low-dimensional materials have emerged as promising platforms for next-generation energy conversion technologies due to their unique structural, electronic, optical, and surface properties. One-dimensional (1D) carbon-based nanostructures, including carbon dots, combine strong and tunable light absorption, high photostability, efficient charge transport, and versatile surface chemistry. These characteristics make them attractive components of photocatalytic systems, where they can promote charge separation, broaden light harvesting, and enhance the efficiency of solar-driven energy conversion. Two-dimensional (2D) materials offer complementary advantages arising from their atomic-scale thickness, high specific surface area, tunable electronic structures, and efficient interactions with light and charge carriers. Particular attention is given to integrating 2D materials into coatings, heterostructures, and active membranes, where their unique properties can be exploited to improve charge transfer, catalytic activity, selectivity, and overall system performance.

This work provides a comparative overview of recent advances in the design, synthesis, characterization, and application of 1D and 2D materials for sustainable energy technologies. The discussion focuses on the relationship between low-dimensional structure, surface properties, charge-transfer mechanisms, and functional performance, while highlighting current challenges related to material stability, scalability, and integration into practical devices. Finally, emerging strategies combining 1D and 2D architectures are discussed as a promising route toward multifunctional materials with enhanced efficiency and broader applicability.




*1D structures of carbon dots (left)) and 2D structures of $WO_3$ (middle) and $Bi_2WO_6$ (right) used for energy conversion*

**Acknowledgements**

This work was supported by European Commission grant: HORIZON-MSCA-2022-SE-01-01 – MSCA Staff Exchanges 2022 Piezo2D (project number 101131229)

# Composition-controlled PMS activation over Cu-Co Tungstates for photocatalytic degradation of Acetaminophen

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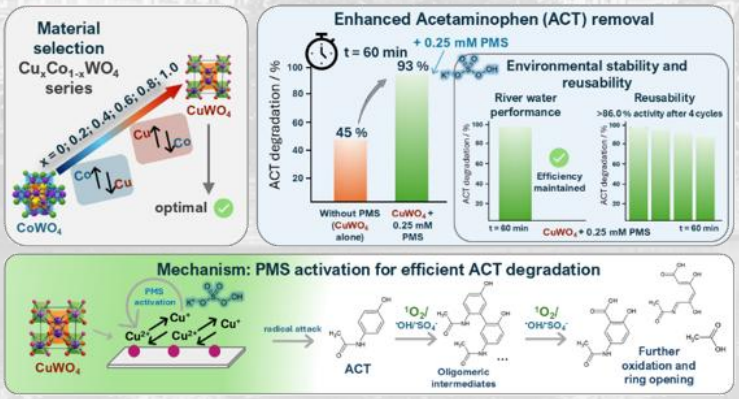
Transition-metal tungstates offer tunable electronic structures and redox-active sites for advanced oxidation processes. Here, a hydrothermally synthesized $Cu_xCo_{1-x}WO_4$ (x = 0, 0.2, 0.4, 0.6, 0.8, 1.0), series was evaluated for solar-driven acetaminophen degradation. Correlating phase composition, hydration, surface chemistry, and charge transport with reactivity identified $CuWO_4$ as the optimal composition. It removed ~45% of acetaminophen within 60 min without an oxidant, while only 0.25 mM peroxymonosulfate (PMS) increased removal to >95%. Co substitution generally reduced activity by increasing structural disorder, charge-carrier recombination, and charge-transfer resistance. Calcination revealed a trade-off between improved bulk charge transport and the loss of surface hydroxyl and defect sites involved in PMS activation. Scavenger experiments suggested that singlet oxygen and/or catalyst-mediated electron transfer dominate the process, whereas radical species play secondary roles. PMS also redirected persistent oligomeric intermediates toward ring opening and lower-molecular-weight products. These findings demonstrate how transition-metal composition and surface redox chemistry govern efficient, low-dose PMS activation.




*$CuWO_4$ selection from the $Cu_xCo_{1-x}WO_4$ series and its performance, stability, and proposed mechanism in PMS-assisted solar ACT degradation.*

**Acknowledgements**
The studies were funded from the European Union under the HORIZON.1.2 – Marie Skłodowska-Curie Actions (MSCA), topic HORIZON-MSCA-2022-SE-01-01 – MSCA Staff Exchanges 2022 grant agreement No 101131229 „Piezoelectricity in 2D-materials: materials, modeling, and applications – Piezo2D".

# Ru/Ceria-Based Catalysts for Important Environmental Reactions

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Ru/Ceria-based materials have been extensively used as multifunctional catalysts for a wide range of environmentally important reactions, such as CO oxidation, $C_3H_8$ oxidation, ammonia decomposition, Water Gas Shift Reaction, Methane Steam reforming etc. Among them, in our study we focused on the $C_3H_8$ (as model Volatile Organic Compound) oxidation reaction and Methane Stem Reforming for $H_2$ production. The catalytic activity and stability of ceria-based catalysts are primarily attributed to the reversible $Ce^{4+}/Ce^{3+}$ redox transition in ceria. This process determines the ability of ceria-based catalysts to transport oxygen to the active sites, an essential step in the Mars-van Krevelen (MvK) reaction mechanism. Furthermore, strong metal–support interactions at the ceria–metal nanoparticle (M NP) interface significantly influence the charge state of the M NPs, which is crucial for both the MvK and Langmuir–Hinshelwood (LH) reaction mechanisms, while the relatively low cost of cerium dioxide makes it an attractive material for industrial applications. Special attention was paid to investigating the chemical state of the catalysts using *in situ* methods to gain new and valuable insights into the fundamental processes occurring in operating M/ceria catalysts [1-4]. This knowledge is essential for the development of new, highly effective catalysts for important environmental reactions. The key factors responsible for the deactivation of Ru/ceria-based catalysts were investigated and discussed. A new approach to inhibit coke formation was also proposed [5].

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# Transition metal doped bismuth ferrite nanoparticles for catalysis

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$BiFeO_3$ (BFO) combines visible light absorption with ferroelectric polarization and piezoelectricity, but its catalytic performance is constrained by carrier recombination and composition sensitive surface chemistry. This contribution examines how 5 mol% Mn or Co substitution at the Fe site, together with aliovalent Bi-site substitution, regulates the ferroic, electronic, and interfacial properties of sol-gelderived BFO nanoparticles (NPs) [1-6]. Ba/Mn codoping retained the rhombohedral R3c ferroelectric phase while modifying the spin cycloid and spin canting [1]. A composition containing 1 mol% Ba and 5 mol% Mn was photocatalytically optimal, completely degrading methyl orange and rhodamine B within 25 and 60 min, respectively, under UV-visible irradiation at pH 2.2 [2]. Subsequent screening of $Ag^{+}$, $Ca^{2+}$, and $Dy^{3+}$ revealed an approximately threefold activity enhancement for the best compositions. Dy-doped NPs were most active under light alone, whereas highly piezoresponsive Ag-doped NPs benefited especially from 40 kHz ultrasonication, supporting a piezoelectric contribution to charge separation and surface redox chemistry [3]. Immobilizing Ag/Mn-codoped BFO on graphene oxide (GO) reduced agglomeration and enabled complete dibutyl phthalate degradation within 2.5 h under UV irradiation; GC-MS identified the transformation pathway [4]. The same compositional strategy improved alkaline hydrogen evolution: Dy-doped BFM exhibited the lowest overpotential among the investigated oxides, associated with reduced charge-transfer resistance, favourable porosity, surface dopant sites, oxygen vacancies, and microstrain [5]. In the Co-substituted series, A-site co-doping narrowed the visible light band gap, while the Gd-containing composition combined the strongest piezoresponse with the highest piezophotocatalytic activity [6]. Across these reactions, polarization is important factor but the overall catalytic performance emerges from its interplay with light absorption, carrier separation, accessible surface area, interfacial charge transfer, and defect/oxidation-state chemistry. These structure-property relationships provide a basis for designing polarization active BFO ferrocatalysts that couple light and mechanical energy for pollutant degradation and hydrogen evolution.

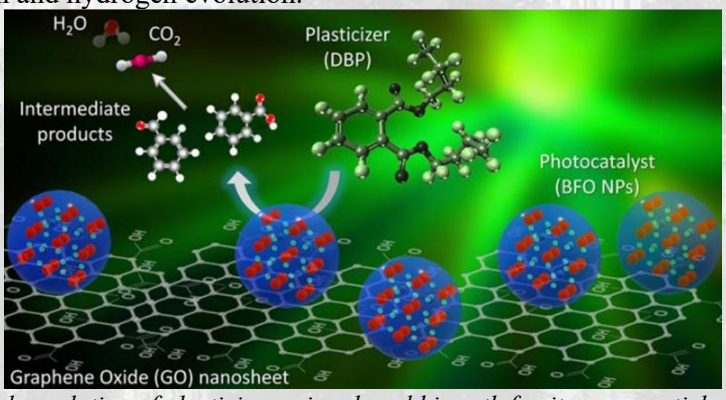


*Figure 1: Photodegradation of plasticizer using doped bismuth ferrite nanoparticles and graphene oxide nanocomposites. [4].*

**Acknowledgements**

All authors highly acknowledge DFG funding and DAAD-PRIME funding for this work.

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# POSTER PRESENTATIONS

# The peculiarities of emission spectra in $Cr^{3+}$:YGG nanocrystals

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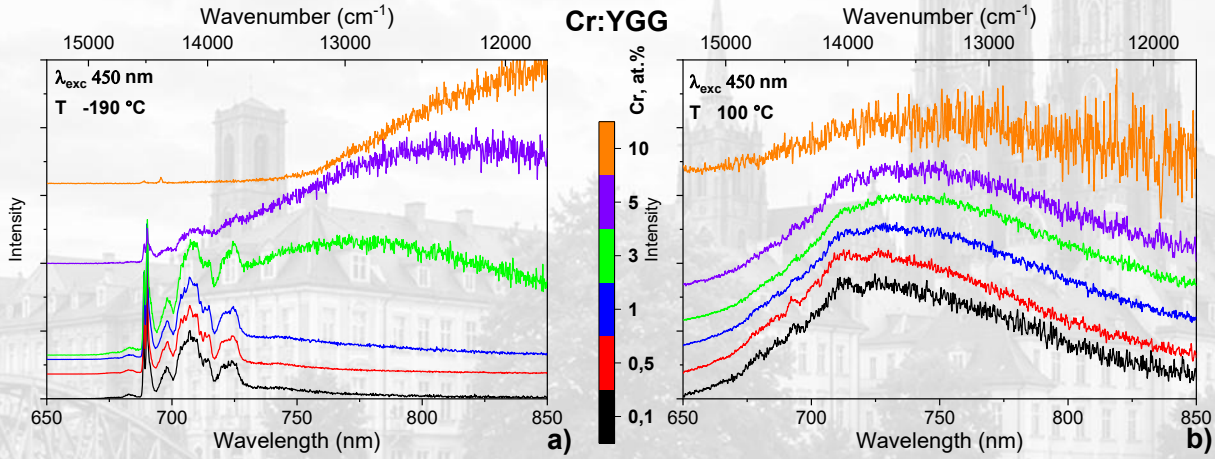
$Cr^{3+}$-doped phosphors are widely used for their tunable luminescence, but performance variations highlight the need for further investigation into their spectroscopic behavior. Cr-doped phosphors play an important role in daily life. $Cr^{3+}$-doped garnets are one of the best light converters for NIR LEDs. This application potential relies on the spectroscopic characteristics of $Cr^{3+}$ ions, such as the spectral position and emission intensity. One of the challenges encountered in this context is the variability in the properties of Cr-doped phosphors, even for the same chemical composition. Investigating these irregularities will help to improve their functional characteristics [1].
The present work focuses on the study of the spectroscopic properties of $Cr^{3+}$:YGG nanopowders, focusing on energy transfer between ions in different crystal field environments. The concentration of $Cr^{3+}$ ions varied from 0 to 30 at. % [2]. Excitation, emission, and luminescence decay curves were collected in the temperature range of − 190 °C to 500 °C. It was shown that increasing the concentration of $Cr^{3+}$ ions caused a redshift in the emission spectra. The detected features were explained by the energy transfer process between $Cr^{3+}$ ions in octahedral sites with different local crystal field strengths.




*Emission spectra of $Cr^{3+}$ ions in $Cr^{3+}$:YGG nanocrystals measured at $\lambda_{exc}$ – 450 nm and a) T – -190 °C, b) T – 100 °C.*

**Acknowledgements**
This work was supported by the Polish National Science Center, grant: OPUS 23, UMO-2022/45/B/ST5/01487.

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# Influence of Energy Transfer on the Luminescence Properties of $Cr^{3+}$:YGG Ceramics

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Cr-doped materials find applications as NIR LEDs, solid-state lasers, luminescent thermometry, etc. However, the presence of parasitic processes, such as energy transfer, can reduce the performance of such devices. One such process is the energy-transfer "chain" phenomenon, in which the absorbed energy by one ion is transferred among multiple $Cr^{3+}$ ions before being emitted or transferred to a luminescence quenching centre. This phenomenon can also induce changes in the emission spectra.

It was shown earlier that an increase in $Cr^{3+}$ concentration led to a redshift of the emission of $Cr^{3+}$:YGG nanocrystals, while the crystal field strength remains nearly unchanged [1]. These changes were observed at low temperatures, whereas at room temperature the emission spectra remain similar. This behavior has been attributed to the energy-transfer "chain" phenomenon. The presence of $Cr^{3+}$ ions in a weak crystal field among interacting ions promotes emission from these sites, resulting in a redshifted emission.

The proposed energy transfer chain phenomenon was used to explain changes in $Cr^{3+}$ emission in nanopowders [1] and nanoceramics [2]. However, the observed patterns could be attributed to the inhomogeneous microstructure of the investigated nanomaterials. Therefore, it remains unclear whether similar behavior occurs in bulk materials. If the proposed hypothesis is valid, a similar pattern should be observed in bulk materials with the same compositions [1].

In this work, we present a detailed study of the spectroscopic properties of $Cr^{3+}$:YGG ceramics doped with 0-5 at.% of $Cr^{3+}$. It was shown that increasing the $Cr^{3+}$ concentration results in a redshift of the emission spectra, consistent with earlier results for the nanopowders of the same compositions [1]. These spectral changes are interpreted in terms of energy transfer between $Cr^{3+}$ ions occupying octahedral sites with different local crystal-field strengths. The results support the existence of multiple inequivalent $Cr^{3+}$ centers in the YGG ceramic and indicate that excitation energy migration between them plays an important role in shaping the overall luminescence spectra.

**Acknowledgements**
This work was supported by the Polish National Science Center, grant: OPUS 23, UMO-2022/45/B/ST5/01487.

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# Luminescence properties of $Cr^{4+}$:YAG nanocrystals

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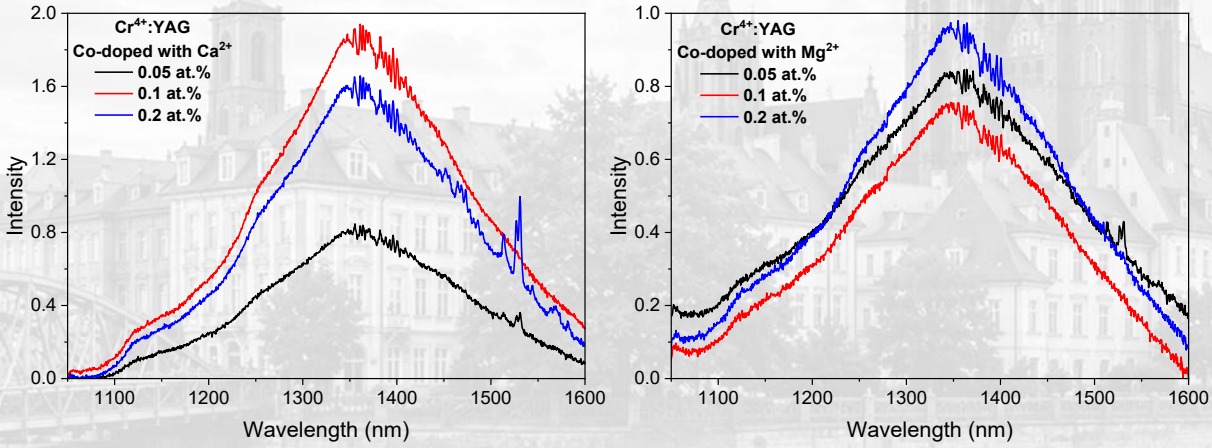
$Cr^{4+}$-doped $Y_3Al_5O_{12}$ is used as a CW laser that operates from 1.2 µm to 1.7 µm or as saturable absorbers for NIR lasers operating from 0.7µm to 1.1 µm [1]. The YAG crystal is cubic (space group Ia3d), with eight formula units in a unit cell. Its general structure can be written as $[C_3][A_2][D_3]O_{12}$, where "C," "A," and "D" denote cation sites in dodecahedral, octahedral, and tetrahedral coordination positions. The "A" and "D" sites are occupied by the $Al^{3+}$ ions, while the Y ions occupy the "C" site [2]. As a single dopant, Cr is incorporated into YAG as a trivalent $Cr^{3+}$ in the "A" site. $Cr^{3+}$ to $Cr^{4+}$ ion valence transformation requires co–doping with divalent ions such as $Ca^{2+}$ or/and $Mg^{2+}$ in the YAG lattice [1]. $Cr^{4+}$ ion formation occurs in both octahedral and tetrahedral sites, where the latter is responsible for laser properties.
$Cr^{4+}$:YAG is typically produced in the form of single crystals, transparent ceramics, or epitaxial films. In contrast, $Cr^{4+}$:YAG nanopowders have received comparatively little attention. In this work, $Cr^{4+}$:YAG nanopowders were synthesized via the Pechini process at 900 °C. Structural and morphological analyses (XRD, TEM) confirmed the formation of nanocrystalline YAG. The recorded emission spectra were consistent with $Cr^{4+}$ emissions in the garnet host. No significant difference in the emission spectral shape was detected between $Ca^{2+}$ - and $Mg^{2+}$ - co-doped samples. In some samples, emission lines attributed to $Er^{3+}$ were also observed, which may originate from trace impurities in the yttrium precursor.




*$Cr^{4+}$:YAG emission spectra collected at $\lambda_{exc}$ – 980 nm and T – 295K.*

**Acknowledgements**

This work was supported by the Polish National Science Center, grant: OPUS 23, UMO-2022/45/B/ST5/01487.

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1st International Conference on
Transition Metal Applications (ICTMA 2026)
September 17th – 18th, 2026, Wrocław, Poland

# Concentration-Dependent Emission Spectra in $Cr^{3+}$:GGG Transparent Nanoceramics

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In recent years, Cr-doped garnets have attracted a lot of attention due to their unique properties. Interpretation of spectroscopic properties of $Cr^{3+}$ ions in garnets is difficult due to the variation of the crystal field strength over a large range, resulting in the presence of $Cr^{3+}$ ions in octahedral sites with different local crystal field strengths. This is also relevant for nanostructured materials such as $Cr^{3+}$-doped nanopowders. Despite the large number of works, a lot of questions remain concerning the luminescence properties of $Cr^{3+}$ ions in nanomaterials.

In the present work [1], we report the study of the optical properties of $Cr^{3+}$:GGG nanoceramics synthesized by the high isostatic pressure (HIP) method at relatively low temperature. Cr:GGG nanoceramics doped with 0.1 at.%, 0.2 at.%, and 0.3 at.% of chromium ions were obtained.

. The synthesized nanoceramics consist of crystallites with an average size of 17 nm and an average lattice parameter of ~12.40 Å. High-temperature emission spectra show the presence of at least four different $CrO_6$ optical active centers in Cr:GGG nanoceramics. The presence of satellites of R-lines confirms uniform distribution of local crystal fields around different chromium ions. The change in the concentration of $Cr^{3+}$ ions does not influence the room-temperature optical properties of Cr:GGG nanoceramics. Excitation and emission spectra, and lifetimes were the same for the investigated samples. No difference in the calculated Racah parameters was detected for different $Cr^{3+}$ concentrations.

The low-temperature emission spectra depend on the chromium content, and the increase in $Cr^{3+}$ concentration caused an increase in the ratio of broadband $^4T_{2g}(^4F)$ emission intensity to overall $Cr^{3+}$ emission. At the same time, no difference was detected in the peak position and width of $^4T_{2g}(^4F) \rightarrow {}^4A_{2g}(^4F)$ broadband emission. The difference in the low-temperature emission spectra was explained by the energy transfer between chromium ions in sites with different local crystal field strength. $Cr^{3+}$ ions in the low crystal field site have a higher probability of emitting photons rather than transferring the excitation energy to the nearby $Cr^{3+}$ ions. The increase in concentration of $Cr^{3+}$ ions caused an increase in the energy transfer between $Cr^{3+}$ ions, thus increasing the ratio of emission intensity of $Cr^{3+}$ ions in low crystal field to the total luminescence.

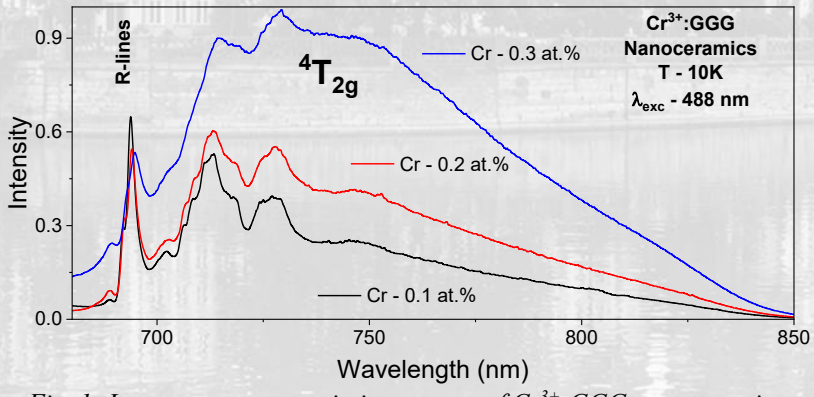


*Fig. 1: Low-temperature emission spectra of $Cr^{3+}$:GGG nanoceramics.*

**Acknowledgements**

This work was supported by the Polish National Science Center, grant: OPUS 23, UMO-2022/45/B/ST5/01487.

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# Raney-type Ni-Co-Fe nanostructured catalysts for efficient hydrogen production by hydrolysis of sodium borohydride

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Hydrolysis of sodium borohydride ($NaBH_4$) is considered a promising approach for portable and on-demand hydrogen production [1]. The development of efficient and low-cost catalysts remains a key challenge for the practical implementation of this technology. Among transition-metal-based catalysts, Raney-type materials attract considerable attention due to their high surface area, simple preparation route, low cost and magnetic separability [2].

In this work, nanostructured Raney-type catalysts based on Ni, Co and Fe were synthesized by selective leaching of aluminum from precursor *M*–Al alloys. Monometallic (Ni, Co and Fe), bimetallic ($Ni_{50}Co_{50}$, $Ni_{50}Fe_{50}$, $Co_{50}Fe_{50}$) and trimetallic ($Ni_{33.3}Co_{33.3}Fe_{33.3}$) compositions were prepared and investigated as catalysts for hydrogen generation from alkaline $NaBH_4$ solutions.

The obtained powders consisted of agglomerated particles with sizes of approximately 10-40 μm and contained less than 5 wt.% residual Al after leaching. X-ray diffraction analysis revealed the formation of nanocrystalline metallic phases with crystallite sizes ranging from 4 to 8 nm. Nitrogen adsorption measurements showed specific surface areas of 50-75 $m^2\ g^{-1}$.

The catalytic performance strongly depended on the chemical composition of the catalyst. Among the investigated samples, the trimetallic $Ni_{33.3}Co_{33.3}Fe_{33.3}$ catalyst demonstrated the highest activity, providing a hydrogen generation rate of 2100 mL $min^{-1}$ $gcat^{-1}$. The hydrolysis rate increased linearly with increasing $NaBH_4$ concentration in the range of 0.1-1.0 mol $L^{-1}$, whereas increasing the solution pH from 11 to 14 resulted in only a 15% decrease in catalytic activity. Temperature-dependent measurements yielded an activation energy of 17.7 kJ $mol^{-1}$ indicating favorable reaction kinetics.

The obtained results demonstrate a pronounced synergistic effect between Ni, Co and Fe in Raney-type nanostructures and identify the $Ni_{33.3}Co_{33.3}Fe_{33.3}$ composition as a highly efficient catalyst for hydrogen generation from alkaline sodium borohydride solutions.

**Acknowledgements**

This work was supported by the National Research Foundation of Ukraine under the projects "Development of efficient processes and devices for decarbonization and hydrogen generation by catalytic hydrolysis of $NaBH_4$" (No. 2025.07/0315).

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# Spectroscopic Properties of $Cr^{3+}$:$Al_2O_3$ Nanoceramics with Highly Disordered Local Structure

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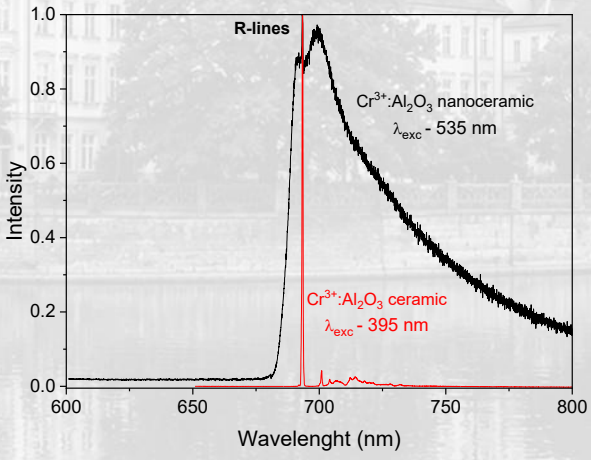
$Cr^{3+}$ (ruby) is a well-established laser material characterized by efficient and thermally stable $Cr^{3+}$ luminescence. Conventional ruby exhibits narrow R-line emission originating from the $^2E_g \rightarrow {}^4A_{2g}$ transition, whereas modification of the local crystal-field environment can lead to substantially broader emission. In this work, we investigate the spectroscopic properties of $Cr^{3+}$ nanoceramics synthesized by cold isostatic pressing at 8 GPa and 770 K and compare them with conventional transparent ceramics.

The nanoceramics exhibit an unusual broadband luminescence extending from approximately 675 to 850 nm, accompanied by narrow R-lines centered near 693 nm. The broadband component is attributed to the $^4T_{2g} \rightarrow {}^4A_{2g}$ transition, while the R-lines originate from $Cr^{3+}$ ions in more regular crystal-field environments. The coexistence of these emissions indicates a broad distribution of local structural configurations, consistent with the highly disordered microstructure of the nanoceramics. Temperature-dependent spectra remain largely unchanged over the investigated range, apart from a variation in the relative R-line intensity around 80–120 K.

Luminescence decay measurements further confirm the presence of multiple $Cr^{3+}$ optical centers. At 5 K, the decay is described by three components with lifetimes of 0.15, 1.0, and 3.7 ms. The shortest-lifetime contribution increases from approximately 56% at 5 K to 82% at 280 K. These results demonstrate that structural disorder in ruby nanoceramics provides an effective approach for tailoring $Cr^{3+}$ emission toward broadband and potentially tunable laser applications.

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**Acknowledgements**
This work was supported by the Polish National Science Center, grant: OPUS 23, UMO-2022/45/B/ST5/01487. This work was supported by NAWA Joint research projects between Poland and France, PHC Polonium, Project No. BPN/BFR/2024/1/00013/U/00001.

1st International Conference on
Transition Metal Applications (ICTMA 2026)
September 17th – 18th, 2026, Wrocław, Poland

# Point defects in YAG ceramics induced by $SiO_2$ and MgO sintering additives. A first principle study.

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To produce high-quality laser ceramics, various sintering additives are commonly employed. In YAG ceramics, tetraethyl orthosilicate and $SiO_2$ are widely used as sintering aids. Recent experimental studies have demonstrated the potential of MgO as an effective additive that suppresses grain growth in YAG ceramics. In several studies, MgO was used in combination with $SiO_2$ or TEOS. In Ref. [1], it was found that YAG ceramics sintered with $SiO_2$ and MgO additives at equal atomic concentrations of Si and Mg contained a large number of residual pores that strongly scattered incident light, rendering the ceramics nearly opaque. In contrast, ceramics sintered with an excess of either $SiO_2$ or MgO exhibited significantly higher optical quality, particularly those enriched with silicon.

In this work, we present the results of a comprehensive first-principles investigation of Si and Mg doping in YAG. Density functional theory (DFT) calculations were performed using the approach developed in Refs. [2–5]. We calculated the formation energies and equilibrium concentrations of point defects in Si-doped, Mg-doped, and Si–Mg co-doped YAG as functions of the sintering conditions.

Our main findings are as follows. The solubilities of Si and Mg in YAG differ by up to two orders of magnitude depending on the growth conditions. Silicon exhibits higher solubility under $Al_2O_3$-rich conditions, whereas magnesium is more soluble under $Y_2O_3$-rich conditions. Si doping increases the concentrations of Al and Y vacancies by up to six orders of magnitude while suppressing the concentration of oxygen vacancies. Substitutional $Si_{Al}^{\bullet}$ defects show a strong tendency to form complexes with both Al and Y vacancies. As a result, an unexpected effect is observed: at high Si concentrations, the populations of free (not bound in complexes) Al and Y vacancies decrease despite the overall increase in vacancy production.

Mg doping suppresses the formation of Al and Y vacancies while increasing the concentration of oxygen vacancies by up to four orders of magnitude. In Mg-doped samples grown under strongly reducing conditions, charge transfer between point defects leads to an increase in the concentration of positively charged oxygen vacancies, $V_O^{\bullet}$ ($F^+$ centers), during cooling. In samples grown under oxidizing conditions, an increase in the concentration of electrically neutral $Mg_{Al}^{\times}$ defects (in addition to $Mg_{Al}'$ defects) upon cooling is predicted.

For Si–Mg co-doping, we predict a pronounced minimum in the concentrations of all vacancy species when the atomic concentrations of Si and Mg are equal. This effect arises because $Si_{Al}^{\bullet}$ and $Mg_{Al}'$ defects mutually compensate each other's charge. These defects also exhibit a tendency to form electrically neutral complexes. However, at Si and Mg concentrations of approximately 0.1 at.%, defects not bound in complexes remain predominant.

**Acknowledgements**
M.Vovsianiker acknowledges support from the Scholarship of the National Academy of Sciences of Ukraine for Young Scientists.

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# Comparative Evaluation of the Antibacterial Activity of Dental Nanophotopolymer Composites Modified with Silver Nanoparticles and Graphene Oxide

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Controlling bacterial growth is an important objective in the development of polymer-based dental restorative materials. Incorporating functional nanofillers into photopolymerisable resins offers opportunities to introduce antibacterial properties while tailoring the characteristics of the resulting composites. This study focuses on silver nanoparticles (Ag NPs) and graphene oxide (GO) as modifiers of dental nanophotopolymer composites, with particular attention to the comparison of modified and unmodified formulations.

Two photopolymerisable resin matrices were developed using Bis-EMA, Bis-GMA, TEGDMA, HEMA, and UDMA as monomer components. The resulting photopolymer nanocomposites were characterised using infrared (IR) spectroscopy, Raman spectroscopy, and microscopy. Their antimicrobial properties were also investigated, comparing composites containing Ag NPs and/or GO with corresponding unmodified materials to assess the influence of nanofiller incorporation.

Silver nanoparticles synthesised from silver nitrate ($AgNO_3$) exhibited pronounced antibacterial activity against the model microorganism Lactobacillus plantarum. The inhibitory effect was observed across the entire investigated concentration range, including low concentrations. These findings support the potential of Ag NPs as antibacterial components of dental photopolymer formulations.

Graphene oxide was considered as a complementary carbon-based modifier because of its reported antimicrobial mechanisms, including interactions with bacterial membranes and oxidative processes, together with its potential contribution to polymer reinforcement. Evaluating formulations containing these nanofillers individually and in combination provides a basis for further optimisation of composite composition and antibacterial functionality.

**Acknowledgements**

The research was conducted within the initiative research project “Development of polymer nanocomposites with metallic and carbon nanoparticles for biomedical and functional applications,” funded by the Ministry of Education and Science of Ukraine following the state assessment of the institution’s research performance and Horizon Europe Piezo2D project.

# Vibrational Spectroscopic Study of MXene-Based Hybrid Nanosystems

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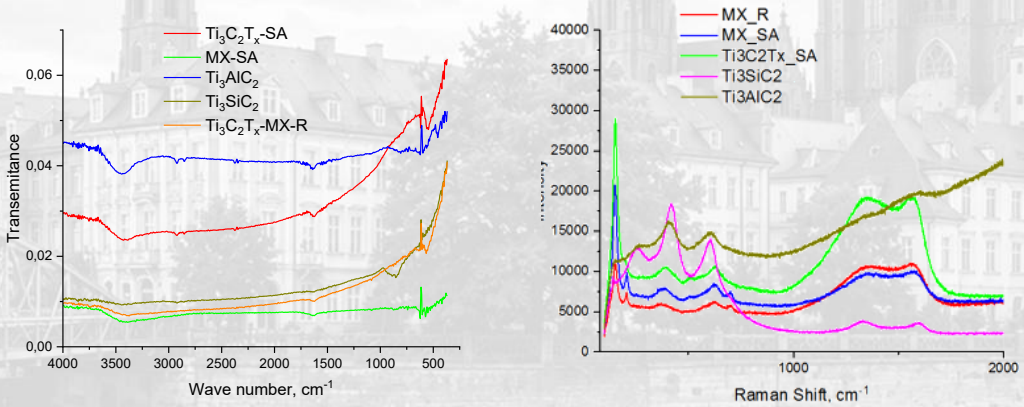
Amid the rapid development of nanotechnology and functional materials, the design of systems with tunable optical, electronic, and physicochemical properties remains a key challenge in materials science. Such materials are of considerable interest for applications in sensing, photonics, flexible electronics, and bioengineering. Hybrid nanomaterials that combine the advantages of two-dimensional structures with functional organic or inorganic components are particularly promising. MXenes, a family of two-dimensional transition-metal carbides and nitrides, have attracted considerable attention due to their high electrical conductivity, versatile surface chemistry, mechanical flexibility, and ability to form hybrid structures with various functional components. In this work, the vibrational properties of MXene-based materials were investigated using Fourier-transform infrared (FTIR) and Raman spectroscopy. The studied samples included $Ti_3C_2T_x$-SA, MX-SA, $Ti_3AlC_3$, $Ti_3SiC_2$, and $Ti_3C_2T_x$-MX-R.

The FTIR spectra exhibit a broad absorption band in the 3600–3200 $cm^{-1}$ region, which can be assigned to O–H stretching vibrations of surface hydroxyl groups and adsorbed or interlayer water molecules. The band near 1650–1600 $cm^{-1}$ is primarily associated with H–O–H bending vibrations of water. Absorption features in the 1500–1000 $cm^{-1}$ region may be related to vibrations involving oxygen- and fluorine-containing surface terminations, while bands below 800 $cm^{-1}$ are associated with vibrations of the Ti–C framework, Ti–O bonds, and surface functional groups of $Ti_3C_2T_x$ MXene.




The Raman spectra of the investigated samples reveal broad vibrational bands and distinct features, particularly in the low-wavenumber region below 1000 $cm^{-1}$. The MX-R and MX-SA samples exhibit broadly similar spectral characteristics, including bands near 200–300 $cm^{-1}$ and broader contributions at higher Raman shifts. The $Ti_3C_2T_x$-based samples show more pronounced differences in spectral profiles, including broad features in the 1000–1600 $cm^{-1}$ region. These variations in band positions, widths, and intensities reflect differences in the composition, structural organization, and surface functionalization of the investigated materials.

The obtained results demonstrate the sensitivity of IR and Raman spectroscopy to the structural and chemical characteristics of MXenes and highlight the potential of MXene-based hybrid nanosystems for the development of advanced functional materials for sensing, photonic, etc. applications.

**Acknowledgements**

This work is funded by the National Science Foundation of Ukraine (grants No. 2025.07/0400 “Vibrational–Electronic Processes in MXene-Based Hybrid Nanosystems”).

# $Fe_3O_4$ Nanohybrids Modified with Pt, Ag and Au for Surface-Enhanced Molecular Spectroscopy

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Magnetite-based nanohybrids offer a platform for combining magnetic functionality with enhanced molecular spectroscopy. This study examines $Fe_3O_4$–Pt, $Fe_3O_4$–Ag and $Fe_3O_4$–Au systems for surface-enhanced Raman scattering (SERS) and surface-enhanced infrared absorption (SEIRA), using thymine and glycine as model biomolecules.

Ag- and Au-containing nanohybrids were prepared by chemical precipitation, while Pt-containing systems were obtained by rotational corrosion dispersion. Characterisation employed X-ray diffraction, electron microscopy, UV–Vis, FTIR and Raman spectroscopy [1,2]. Electrical measurements additionally examined Pt-dependent changes in dielectric behaviour and conductivity [3].

Metal modification enabled vibrational signal enhancement while retaining the magnetic properties of $Fe_3O_4$. $Fe_3O_4$–Au enhanced glycine spectra, whereas $Fe_3O_4$–Ag and $Fe_3O_4$–Pt supported thymine detection. Spectral changes indicated that enhancement depends on molecular orientation and interfacial binding. Glycine adsorption involved carboxylate groups; thymine coordination predominantly involved nitrogen on Ag-containing surfaces and carbonyl groups on Pt-containing surfaces.

The findings highlight the importance of both electromagnetic enhancement and chemical adsorption, with chemical interactions particularly relevant to Pt-containing nanohybrids. These results support the development of substrates for molecular identification and biosensing.

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# IR AND RAMAN SPECTROSCOPY OF $Eu_xNd_{1-x}S_2$ SOLID SOLUTIONS

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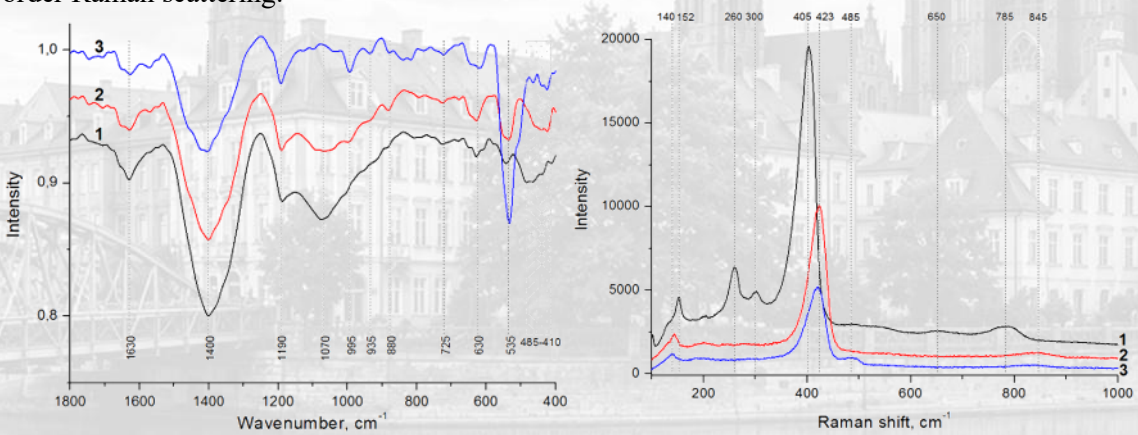
The vibrational properties of $Eu_{0.1}Nd_{0.9}S_2$, $Eu_{0.6}Nd_{0.4}S_2$, and $Eu_{0.9}Nd_{0.1}S_2$ were studied by infrared (IR) and Raman spectroscopy. The spectra show broadly similar vibrational patterns for all compositions, while changes in band positions and intensities are observed with increasing Eu content, indicating modification of the local structural environment without formation of a completely different dominant phase.

The IR spectra contain bands near 1630 and 1400 $cm^{-1}$, attributed mainly to adsorbed water and carbonate-containing or residual precursor species. Broad features in the 1190–630 $cm^{-1}$ region may originate from vibrations of the anion sublattice, local structural distortions, and surface species. A distinct band near 535 $cm^{-1}$, most pronounced for $Eu_{0.9}Nd_{0.1}S_2$, is assigned to S–S vibrations, while the ~485–410 $cm^{-1}$ region contains additional lattice-related modes.

The dominant Raman band for all samples occurs in the ~400–425 $cm^{-1}$ region and is attributed to Ln–S (Eu–S and Nd–S) vibrations. With increasing Eu content, this mode shifts by about 18 $cm^{-1}$ toward higher wavenumbers, reaching ~423 $cm^{-1}$ for $Eu_{0.9}Nd_{0.1}S_2$. In this Eu-rich sample, an additional Raman mode near 485 $cm^{-1}$ corresponding to S–S vibrations is observed, consistent with the IR band near 535 $cm^{-1}$. Weak bands near 785 and 845 $cm^{-1}$ are likely associated with second-order Raman scattering.




*IR and Raman spectra of solid solutions $Eu_{0,1}Nd_{0,9}S_2$ (1), $Eu_{0,6}Nd_{0,4}S_2$ (2) and $Eu_{0,9}Nd_{0,1}S_2$ (3).*

Thus, increasing Eu content leads to systematic changes in the vibrational spectra while preserving the overall spectral pattern. The shift of the Ln–S mode and the appearance of pronounced S–S vibrations in the Eu-rich composition indicate changes in the local bonding environment caused by Eu/Nd substitution. The composition-dependent vibrational properties of Eu–Nd sulfide materials may be of interest for their potential application in optoelectronic, photonic, and functional semiconductor devices

**Acknowledgements**

The work was financed by US National Academy of Science and Office of Naval Research in the framework of IMPRESS-U program under STCU project 7138 “Two-Dimensional Nanosheets of Magnetic Lanthanide Chalcogenide”.

# Spectroscopic and Luminescence Properties of $Pr^{3+}$-Doped $ACaF_3$ (A = K, Rb, Cs) Fluorides.

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The search for novel luminescent materials capable of emitting across a wide spectral range, from ultraviolet (UV) to infrared (IR), remains an important area of research due to their potential for numerous technological applications [1]. Among rare-earth ions, $Pr^{3+}$ is particularly attractive because of its ability to generate emissions throughout nearly the entire optical spectrum. The emission behavior of $Pr^{3+}$ strongly depends on the crystal host, which determines the relative position of the $4f^15d^1$ excited state with respect to the $4f^2$ excited levels and the conduction band. As a result, a variety of optical phenomena can be observed. In hosts where the 4f5d state lies below the $^1S_0$ level, luminescence is dominated by interconfigurational $4f^15d^1 \rightarrow 4f^2$ transitions, making such materials promising candidates for ultraviolet phosphors, scintillators, and upconversion luminescent systems. Conversely, when the 4f5d state is located above the $^1S_0$ level, emission is governed primarily by intraconfigurational 4f → 4f transitions, enabling efficient photon cascade processes [2].
Perovskite fluorides $ACaF_3$ (A = K, Rb, Cs) activated with rare-earth ions such as $Eu^{2+}$, $Yb^{3+}$, $Gd^{3+}$, $Nd^{3+}$, $Dy^{3+}$, $Sm^{3+}$, and $Ce^{3+}$ have been extensively investigated owing to their attractive luminescent properties. However, $Pr^{3+}$-doped members of this family have received comparatively little attention. In the present study, $ACaF_3:Pr^{3+}$ (A = K, Rb, Cs) phosphors were synthesized by the conventional solid-state reaction method. Their luminescence behavior in the ultraviolet and visible spectral regions was examined and compared. Furthermore, the potential of these materials for practical applications is discussed.

**Acknowledgments:** This work was supported by the National Science Centre (NCN), Poland, through the OPUS 29 project (grant no. **UMO-2025/57/B/ST4/00594**).

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# Participant List