

The 3rd Serbian Conference on Materials Application and Technology - SCOM

BOOK OF ABSTRACTS

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SCOM 2024

**The 3rd Serbian Conference on Materials
Application and Technology**

BOOK OF ABSTRACTS

Belgrade, Serbia, 16th - 18st of October 2024

Dear Colleagues and Friends,

It is our great pleasure to welcome you to the second Serbian Conference on Materials Application and Technology - SCOM2024. The conference is jointly organized by the Society for Science Development of Serbia and the Vlatacom Research and Development Institute. With a focus on cutting-edge materials design, fabrication, and integration as well as ground-breaking materials-based technologies, SCOM2024 is the new home for all materials-related technological research. This conference will highlight the most recent advancements in the field of materials technology and application aiming to bridge the gap between researchers working on materials and technology users. Energy, healthcare, electronics, optics, microfluidics, sensors, food safety, and other topics will be covered. This year, four tutorial lectures, four invited lectures, and nine oral presentations on the following topics will be given: Nanomaterials, Biomaterials, Optical and Photonic Materials, Materials for energy production and storage, Chemo/Bio/Physical Engineering, Photocatalysis, Green technologies, Sensor materials and technologies, Materials synthesis and processing.

We anticipate that SCOM2024 will be fruitful in terms of scientific exchange and that it will strengthen existing collaborations among participants while also fostering future ones. We would like to thank various organizations for their financial assistance.

Organizers of the SCOM2024 wish you a nice time during the conference in Belgrade!

Conference Chairperson

Prof. Dr. Miroslav D. Dramićanin

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Upconversion Luminescence in Rare-Earth Doped Oxyfluoride Materials

Anatolijs Šarakovskis, Guna Kriekē
Institute of Solid State Physics, University of Latvia
anatolijs.sarakovskis@gmail.com

Fluoride composites, particularly those doped with rare-earth ions, have emerged as highly efficient upconversion materials due to their low phonon energy, which significantly reduces non-radiative losses. These materials enable the absorption of multiple low-energy photons, typically in the near-infrared region, and emission of higher-energy photons in the visible or ultraviolet regions. Fluoride-based hosts, such as NaYF₄, are widely explored for their high upconversion efficiency, making them promising candidates for applications in bio-imaging, energy harvesting, and photonics.

The upconversion properties of fluoride materials, often doped with lanthanide ions such as Er³⁺, Yb³⁺, and Tm³⁺, have led to their exploration in diverse applications. In the field of bio-imaging, their bright emissions in the visible region are utilized for high-contrast imaging and diagnostics. In energy harvesting, these materials are being developed for solar energy upconversion, enhancing the efficiency of photovoltaic systems by converting infrared light to usable energy. Additionally, they find use in environmental sensing and lighting technologies, where their efficient luminescence can be applied for low-energy lighting solutions and pollutant detection.

Within this class of materials, transparent oxyfluoride glass ceramics represents an important subclass that combines the structural and thermal stability of oxide glasses with the superior optical properties of fluoride nanocrystals. These materials are synthesized through controlled crystallization, where fluoride nanocrystals precipitate within an oxide glass matrix. The resulting phase-separated structure allows for improved mechanical and chemical durability, while retaining the advantageous low phonon energy of the fluoride phase, crucial for efficient upconversion processes.

Recent advancements in tailoring the glass network structure and optimizing the nanocrystal size and distribution have further enhanced the upconversion efficiency of these materials, expanding their potential for cutting-edge applications. In my talk I will present general overview and recent results from our group on upconversion luminescence in oxyfluoride composites particularly on synthesis, structure and optical properties of transparent oxyfluoride glass ceramics.

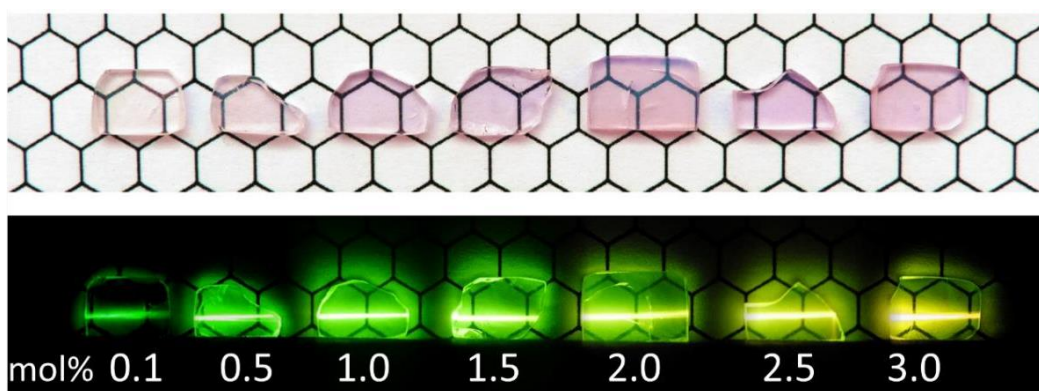


Fig. 1 Upconversion luminescence in transparent oxyfluoride glass ceramics with NaYF₄: Er³⁺ nanocrystals under 980 nm excitation

SYNCHROTRON RADIATION AND EXCITATION LUMINESCENCE SPECTROSCOPY OF WIDE BANDGAP MATERIALS

V. Pankratov

*Institute of Solid State Physics, University of Latvia, Riga, Latvia, vpank@latnet.lv;
vladimirs.pankratovs@cfi.lu.lv*

After its discovery in 1946/47, it took about 15 years until synchrotron radiation (SR) was systematically used for spectroscopy. From that time many spectroscopic methods under SR excitations have been developed. However, the tuneability of SR and its inherent well-defined time structure makes it particularly well suited for time-resolved luminescence studies. Nevertheless, the first pioneering work was published only in 1970 reporting the luminescence spectroscopy experiments under SR excitations. The measurements were performed at TANTALUS storage ring (Wisconsin, USA). Afterwards, luminescence activities at other synchrotron centers around the world started. Since 1970 luminescence spectroscopy experiments have been carried out for instance at Tokyo synchrotron (Japan), at synchrotron center of Lebedev Physical Institute (Moscow, USSR), at ACO storage ring (Orsay, France), MAXLAB (Lund, Sweden), UVSOR (Okazaki, Japan) and others. However, the most successful and significant luminescence experiments under SR were performed at SUPERLUMI setup. The SUPERLUMI endstation was constructed and developed as a user facility in 1981 at DORIS III storage ring of HASYLAB at DESY (Hamburg, Germany) and it was a flagship experiment for three decades [1, 2].

In the present lecture, after brief introduction about SR the pioneering luminescence experiments are illustrated. The exciting development is demonstrated presenting highlights for the whole period from the beginning to the present day. The highlights are taken from fields like exciton self-trapping, inelastic electron–electron scattering, cross luminescence, or probing of nanocluster properties with luminescence spectroscopic methods. More technological aspects play a role in present day's experiments, like quantum cutting in rare-earth-doped insulators.

Next, a few ideas concerning the future development of luminescence spectroscopy with SR will be sketched. The main attention will be paid to the new luminescence setup – FINESTLUMI [3] that was installed in 2019 on the Finnish-Estonian beamline (FinEstBeAMS) [4,5] of the 1.5 GeV storage ring at MAX IV Laboratory (Lund, Sweden). Currently, this setup along with new SUPERLUMI beamline at DESY synchrotron in Hamburg (Germany) are actively utilizing by many user groups within and outside of Europe. The recent experiments as well as the recent significant results [6-10] obtained at FINESTLUMI for novel luminescence materials and prospective scintillators will be demonstrated and discussed. Special attention will be paid on the analysis of excitation spectra in vacuum ultraviolet (VUV) and soft X-rays (XUV) spectral range where multiplication of electronic excitation processes occur. The role of these processes in the luminescence efficiency in heavily irradiated scintillator crystals will be elucidated.

Finally, the advantages of luminescence spectroscopy under synchrotron radiation excitations will be demonstrated considering several examples based on relevant luminescent and scintillator materials.

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**COMPUTATIONAL AND INFORMATICS APPROACHES IN CERAMICS
AND METAL SCIENCE**

Isao Tanaka

*Department of Materials Science and Engineering, Kyoto University, Kyoto, 606-8501, Japan
Nano Research Lab., JFCC, Nagoya 456-8587, Japan*

The abstract will be provided by the author upon request at tanaka@cms.mtl.kyoto-u.ac.jp

OPTICAL NANOMATERIALS FOR BIOMEDICAL APPLICATIONS

Riccardo Marin

*Nanomaterials for Bioimaging Group (NanoBIG), Universidad Autónoma de Madrid (UAM),
28049 Cantoblanco, Madrid, Spain
Institute for Advanced Research in Chemical Sciences (IAdChem), UAM, 28049 Cantoblanco,
Madrid, Spain
Instituto Nicolas Cabrera (INC), UAM, 28049 Cantoblanco, Madrid, Spain*

The abstract will be provided by the author upon request at riccardo.marin@uam.es

Bismuth-Sensitized Eu^{3+} Luminescent LED Technology for Effective Indoor Plant Growth

Sanja Kuzman, Bojana Milićević, Katarina Milenković, Jovana Periša, Miroslav D. Dramićanin
Centre of Excellence for Photoconversion, Vinča Institute of Nuclear Sciences - National Institute of the Republic of Serbia, University of Belgrade, Belgrade, Serbia, sanjaculubrk@gmail.com

This report focuses on developing bismuth-sensitized Eu^{3+} luminescent LED technology to improve indoor plant growth. The design of energy-efficient, water-resistant, tunable-emitting LED systems that optimize plant growth in controlled environments, such as greenhouses and vertical farms to meet the growing global demand for sustainable food production. The development of suitable phosphors that can absorb blue or UV light and emit tunable blue-red light has evolved into an imperative in crop production. By selecting the appropriate host, the emission spectra of Bi^{3+} - Eu^{3+} co-activated luminescent materials can be fine-tuned to achieve blue-red double emission, effectively aligning with the absorption spectra of plant photoreceptors (Photosynthetically Active Radiation (PAR) spectrum) such as cryptochrome and phytochrome. Among various classes of inorganic host materials, fluoride-based phosphors exhibit numerous outstanding properties, including a broad optical transmission range, anionic conductivity, low phonon energy, high resistivity, and reduced nonradiative relaxation of excited states, which enhances radiative emission. Our results show that Eu^{3+} -doped BaYF_5 and SrF_2 exhibit around 200% enhancement of red emission originating from Eu^{3+} . In addition, $\text{SrF}_2:\text{Eu}^{3+}$, Bi^{3+} phosphor has a tunable blue-red emission, and the highest red/blue emission portion (40.8:59.2) was found for the sample $\text{SrF}_2:10\text{Eu}20\text{Bi}$. For the inorganic phosphor synthesis, we use traditional solvothermal and solvothermal microwave-assisted synthesis techniques, while the LED fabrication includes selected phosphor, mixed with a ceramic binder and placed on top of a 275 nm near-UV chip.

The findings have far-reaching implications for the future of indoor farming, promising increased agricultural efficiency, lower energy costs, and a reduced carbon footprint. Through continuing collaboration with industry stakeholders, we aim to scale up this technology and create an ongoing impact on sustainable agriculture.

BACTERIAL NANOCELLULOSE: FROM BACTERIA TO BREAKTHROUGH BIOMATERIALS

Vuk Filipović, Marijana Ponjavić, Sanja Jeremić, Jasmina Nikodinović-Runić
*Institute of Molecular Genetics and Genetic Engineering, University of Belgrade, Belgrade,
Serbia, vukan87@yahoo.com*

Recent advances in natural resource exploration have driven the development of high-performance biomedical materials using green chemistry, in order to minimize adverse effects on the environment. Bacterial nanocellulose (BNC), a sustainable material obtained from bacteria, offers exceptional properties like high mechanical strength, crystallinity, biodegradability, and tunable surface chemistry. Its biocompatibility makes it valuable in medicine and pharmacy. In our study, BNC was utilized for controlled drug delivery of actinomycin D. The structure of BNC was significantly modified by oxidation using TEMPO, in order to adjust the release kinetics. Oxidized BNC showed improved chemical and physical properties, and enhanced compound release control. In another project, we developed a two-step process to produce edible BNC, obtained from lignocellulose coming from wood waste, functionalized by the adsorption of black raspberry extract using simple soaking. This approach converts plant biomass as a highly abundant renewable resource is converted into high-value-added sustainable product.

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IMAGING TECHNIQUES FOR AEROSPACE RESEARCH USING LUMINESCENT MATERIALS

Benoit Fond

*Department of Aerodynamics, ONERA, the French Aerospace Lab, Paris Saclay University,
92190 Meudon, France, benoit.fond@onera.fr*

The motion of aircraft and space vehicles involve complex fast flows, whether those are the external flows around the vehicle or the very hot internal flows through the combustion engine. Advanced simulations are key to improving vehicle performance, but they need to be adjusted and improved using experimental data. For this, models of the vehicles are placed in wind tunnels, mimicking flight conditions. Two key quantities to measure are the model surface pressure, which is the mark of the flow on the vehicle and the temperature which indicates areas of intense heat exchange between the model and the flow. Many models are difficult to instrument with pressure probes and thermocouples. In addition, those flows are inherently three dimensional. For these reasons, imaging techniques are necessary.

In this talk we will show how the luminescence properties of optically active materials can be exploited to derive 2D pressure and temperature maps.

Many compounds with temperature dependent luminescence properties can be used for thermometry, but for robust measurements, inorganic phosphors are preferred thanks to their low photo degradation and their thermochemical stability.

For pressure sensing, oxygen quenching in phosphorescent metal organic compounds such as metal porphyrins is exploited. However, the luminescence of those compounds is also highly temperature sensitive so that obtaining reliable pressure information requires the simultaneous measurement of temperature. Ongoing research in this direction will be discussed.

EUROPIUM-DOPED MOLYBDATES FOR LUMINESCENCE THERMOMETRY

Tamara Gavrilović*, Aleksandar Ćirić, Mina Medić, Vesna Đorđević, Zoran Ristić, Jovana Periša, Željka Antić, and Miroslav Dramićanin

Vinča Institute of Nuclear Sciences – National Institute of the Republic of Serbia, University of Belgrade, P.O. Box 522, Belgrade 11001, Serbia

*corresponding author email: tashichica@gmail.com

A set of Eu^{3+} doped molybdates, $\text{Y}_{2-x}\text{Eu}_x\text{Mo}_3\text{O}_{12}$ ($x = 0.04; 0.16; 0.2; 0.4; 0.8; 1; 1.6; 2$), was synthesized using a solid-state technique and their properties studied as a function of Eu^{3+} concentration. X-ray diffraction showed that replacing Y^{3+} with larger Eu^{3+} resulted in a transformation from orthorhombic (low doping concentrations) through tetragonal (high doping concentrations), reaching monoclinic structure for full replacement in $\text{Eu}_2\text{Mo}_3\text{O}_{12}$. The intensity of typical Eu^{3+} red emission slightly increases in the orthorhombic structure then rises significantly with dopant concentration and has the highest value for the tetragonal $\text{Y}_2\text{Mo}_3\text{O}_{12}:80\text{mol}\% \text{Eu}^{3+}$ (YMO80Eu). Further, the complete substitution of Y^{3+} with Eu^{3+} in monoclinic $\text{Eu}_2\text{Mo}_3\text{O}_{12}$ leads to decreased emission intensity. Lifetime follows a similar trend, it is lower in the orthorhombic structure, reaching slightly higher values for the tetragonal structure and showing a strong decrease for monoclinic $\text{Eu}_2\text{Mo}_3\text{O}_{12}$.

Temperature-dependent emission spectra of YMO80Eu were recorded in the 300 to 650 K range upon 405 nm LED excitation. Using temperature-dependent emission spectra, luminescence thermometry is performed by i) read-out based on a principal component analysis (PCA) and ii) traditional luminescence intensity ratio (LIR) method from thermally coupled $^5\text{D}_0$ and $^5\text{D}_1$ energy levels of Eu^{3+} . Obtained values indicate PCA's superiority, approximately three times better resolution, and more than double the accuracy of LIR is found.

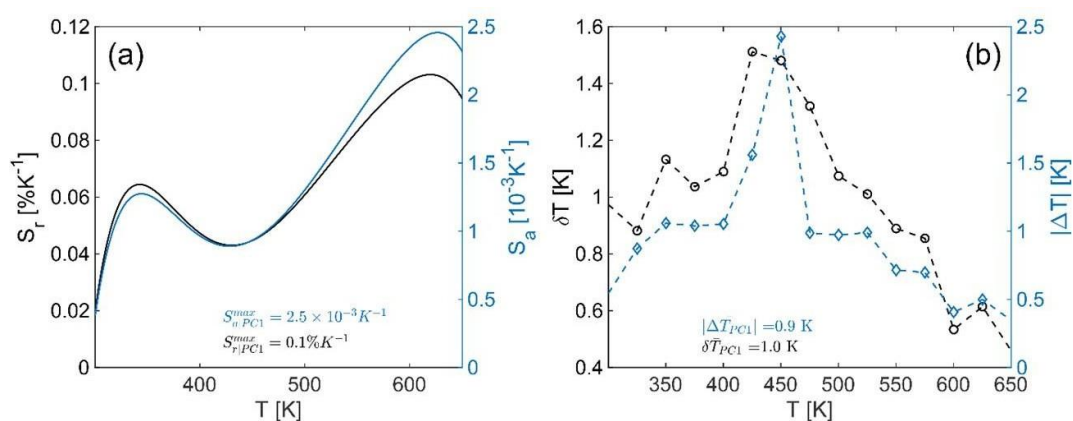


Figure 1. PCA thermometry parameters of YMO80Eu probe: (a) Absolute and relative sensitivities, (b) accuracy and resolution.

NEW PROGRAM IN VLATACOM INSTITUTE FOR LASER SYSTEMS DEVELOPMENT – THE NEED FOR NEW MATERIALS

Miroslav Perić^a, Novak Stanojević^a, Teodora Pavličević^a, Dragana Perić^a, Marko Krstić^b,
Jasna Crnjanski^b, Dejan Gvozdić^b

^a*Vlatacom Institute, Belgrade, Serbia*

^b *Department of Microelectronics and Technical Physics, Faculty of Electrical Engineering,
University of Belgrade,*

In this paper we present the new development program in Vlatacom Institute for laser systems. The main objective of this program is development of various laser based devices like laser obstacle removals with high safety, target designators, controllable beam direction long range laser range finders and gated imaging in SWIR range. For these applications we present the basic block diagrams of the systems and their components like mirrors, lenses, active fibres, cooling system, mechanical mounting elements etc. We present the needs for new materials for them.

Thin-film/Coating electrolysis printer

Aleksandar Ćirić, Mina Medić, Željka Antić, Miroslav D. Dramićanin

Centre of Excellence for Photoconversion, Vinča Institute of Nuclear Sciences - National Institute of the Republic of Serbia, University of Belgrade, Belgrade, Serbia

We present a novel invention designed to revolutionize electrochemical surface treatment methods, including anodization and plasma electrolytic oxidation (PEO), which have been used for over a century. This invention overcomes key challenges in these traditional processes and offers an innovative approach to creating and repairing coatings on metal surfaces.

Anodization typically operates at low voltages, forming thin oxide layers, while PEO produces thicker, ceramic coatings applicable to a broader range of metals, including steel. Both methods are widely used for protective, mechanical, thermal, and chemical barrier coatings. However, existing techniques require large electrolytic baths, leading to inefficiencies in chemical usage, and difficulties arise when parts need repairs or are welded into place. Transporting parts to repair facilities and re-immersing them in baths is costly and time-consuming.

Our invention replaces the need for large baths with a localized electrochemical cell that can apply coatings directly to any shape or size, even on-site. This eliminates the need for part removal, making the process more efficient and less wasteful. The technology has been tested successfully and includes an automated pumping system for chemicals. It has reached Technology Readiness Level (TRL) 4 and is poised to advance further with industrial collaboration. Additionally, this technology offers a breakthrough in the production of luminescent sensor coatings without the need for binders. These coatings, commonly used in temperature or oxygen sensing in aerospace and other industries, are now produced with superior adhesion, uniformity, and thermal contact, surpassing current sprayed-on methods. The invention can also create luminescent QR codes and signs, which can glow in the dark, providing durable, high-performance alternatives to existing printed coatings.

We are actively seeking industrial partners to advance the technology to TRL 7 and beyond, focusing on applications in aerospace, automotive industries, and companies involved in luminescent sensor technologies and signage production. This invention promises to be a game-changer in electrochemical processes, offering significant cost savings, scalability, and versatility.

Our goal is to bring this technology to market, making electrochemical coating processes more efficient, flexible, and commercially viable across multiple industries.

Acknowledgement

This research was supported by the Innovation Fund of the Republic of Serbia, project grant TTF 1168, Technology transfer fund for Thin-film/coating printer based on electrolysis of valve metals.

IMMOBILIZATION OF ENZYME PEROXIDASE ON FUNCTIONALIZED MAGNETITE NANOPARTICLES

Katarina Isaković, Valentina Nikšić, Miljana Dukić, Vesna Lazić

Vinča Institute of Nuclear Sciences – National Institute of the Republic of Serbia, University of Belgrade, Centre of Excellence for Photoconversion, Belgrade, Serbia.

The Fe₃O₄-based hybrid nanomaterials with different functional groups (amino or carboxyl) were prepared, followed by a study of their influence on the immobilization of the peroxidase enzyme. A new synthetic method for modifying the surface of TiO₂ with amino and carboxyl groups was established, utilizing the interfacial charge transfer complex (ICT) formation between the surface of magnetite and salicylic type of ligand (5-aminosalicylic acid (5-ASA)) and catecholate type of ligand (caffeic acid (CA)). FTIR analysis confirmed the successful binding of 5-ASA and CA ligands to the magnetite surface. The efficiency of covalent enzyme immobilization on both types of functionalized materials was evaluated through enzyme activity assays, showing that the material functionalized with amino groups achieved better results than the one modified with carboxyl. Preliminary results of peroxidase activity monitoring indicated that both materials preserved excellent activity even after 5 cycles, with a minor decrease in activity over time, while demonstrating significant catalytic performance.

It was concluded that both materials improve the activity of the enzyme peroxidase and can be used across multiple cycles, as their magnetic characteristics allow easy separation from the reaction mixture and reusability. This finding highlights their potential for practical applications in biocatalysis, particularly regarding the importance of reusability and efficiency.

ELECTROPHORETIC DEPOSITION OF Pr³⁺- DOPED Y₂SiO₅ FOR ANTIMICROBIAL APPLICATIONS

Milica Maričić*, Maxim Ivanov, Andjela Rajčić, Željka Antić, Katarina Isakovic, Vesna Lazić, Zoran Ristić and Miroslav D. Dramićanin

Centre of Excellence for Photoconversion, Vinča Institute of Nuclear Sciences - National Institute of the Republic of Serbia, University of Belgrade, P.O. Box 522, Belgrade 11001, Serbia

**msekulic@vinca.rs*

This study optimizes electrophoretic deposition of the Pr³⁺-doped Y₂SiO₅ (YSO_Pr) powders into thin films for antimicrobial applications. The research is driven by the fact that Pr³⁺-doped materials, when excited by blue light, can show upconversion in the ultraviolet (UVC) range known for germicidal efficiency. For this, single-phase Y₂SiO₅ doped with 0.5 mol% Pr³⁺ was synthesized using a Pechini-type polymerized complex route, based on polyesterification between citric acid (CA) and ethylene glycol (EG). Before deposition, the obtained sample was ball-milled to ultra-fine powder and dispersed in isopropanol. Controlled electrophoretic deposition of the YSO_Pr powder resulted in the uniform film deposited onto a conductive aluminum substrate. Initial antimicrobial tests were done on gram-positive (*Staphylococcus aureus*) and gram-negative bacteria (*Escherichia coli*), and fungi (*Candida albicans*). The characterization of both as-synthesized and ball-milled precursor powder and deposited thin film was conducted using X-ray diffraction, scanning electron and optical microscopy, photoluminescence spectroscopy, and antimicrobial efficiency tests.

Keywords: Y₂SiO₅; Pr³⁺; electrophoretic deposition; UVC emission; antimicrobial efficiency.

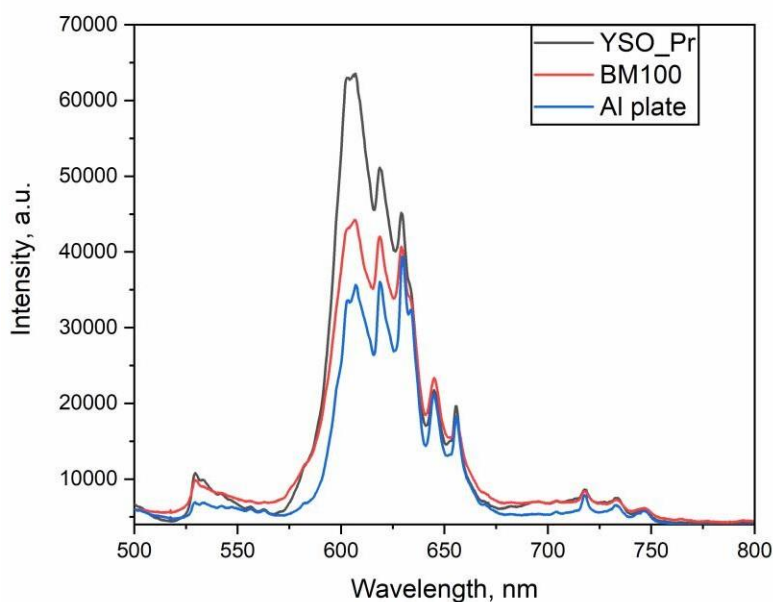


Figure 1. Emission spectra of Y₂SiO₅, recorded at $\lambda_{ex}=450\text{nm}$

NI-P-BASED POWDER ALLOYS AS POTENTIAL ELECTROCATALYSTS FOR OXYGEN EVOLUTION REACTION

Milica M. Vasić^a, Tomáš Žák^b, Biljana Šljukić^a, Dragica M. Minić^a

^a*University of Belgrade, Faculty of Physical Chemistry, Studentski trg 12-16, 11000 Belgrade, Serbia, mvasic@ffh.bg.ac.rs*

^b*Institute of Physics of Materials CAS, Žitkova 22, 616 62 Brno, Czech Republic*

Amorphous alloys have been studied for more than 60 years due to various advantageous characteristics that these materials possess, including favorable mechanical, magnetic, electrical and chemical properties, resulting from their isotropic structure. The alloys in powder forms can be easily compacted into different shapes, can have versatile composition and high specific surface area. Ni-P-based amorphous alloys are exceptional because of their good corrosion resistance and mechanical properties, (non) magnetic and catalytic behavior.

The oxygen evolution reaction (OER) is considered as a common and very important anodic process in aqueous solutions. For development and large scale application of new clean energy sources, further progress in research of the low-cost materials with good electrocatalytic performance for OER is required. In this work, Ni-P-based powder alloys with different composition and microstructure (amorphous/nanocrystalline) were studied as potential electrocatalysts for OER. The alloy samples were prepared by simple chemical reduction route. The microstructure and thermal stability of the Ni-P-based powder samples were examined by using XRD, DTA and electron microscopy techniques. The study of electrochemical behavior and OER performance of the alloy samples was performed in 0.1 M KOH, and included application of linear sweep and cyclic voltammetry, chronoamperometry and electrochemical impedance spectroscopy. The Ni-P-based powder alloys examined in the work demonstrated promising electrocatalytic activity for OER, dependent on the alloy microstructure. Addition of small amount of Fe to the alloy composition noticeably improved the OER electrocatalytic performance of the material, while good anti-corrosion properties were retained.

SYNTHESIS OF VARIOUS RUBIDIUM AND CESIUM YTTRIUM FLUORIDE STRUCTURES DOPED WITH Eu^{3+}

Katarina Milenković, Vesna Đorđević, Ivana Zeković, Bojana Milićević, Miroslav D. Dramićanin

Centre of Excellence for Photoconversion, Vinča Institute of Nuclear Sciences - National Institute of the Republic of Serbia, University of Belgrade, Belgrade, Serbia, katarina.milenkovic@vinca.rs

Lanthanide-doped nanoparticles function as host-guest systems, where rare earth ions are randomly integrated into the host lattice, acting as dopants that enable optical activity. Nanoscale particles present numerous advantages over bulk materials, including increased packing density, accelerated preparation times, reduced light scattering, customizable surface properties, and the ability to control particle shape and size. Among potential host materials, fluoride matrices stand out due to their low phonon energies (between 300 and 500 cm^{-1}) and excellent transparency in the targeted spectral region.

The structural chemistry of alkali rare fluorides is complex, with several known stoichiometries and crystal structures. The literature identifies five main stoichiometric groups: A_3ReF_6 , AReF_4 , ARe_2F_7 , $\text{ARe}_3\text{F}_{10}$, and A_2ReF_5 (where $\text{A} = \text{Li, Na, K, Rb, Cs}$; $\text{Re} = \text{Y, La-Lu}$). The diversity of structures arises from variations in the sizes of alkali and rare earth ions, as well as the synthesis conditions used. Although fluoride systems with Na and Li have received extensive study, there is a significant gap in our understanding of systems with K, Rb, and Cs.

In this study, we synthesized CsY_2F_7 , RbY_2F_7 , $\text{CsY}_3\text{F}_{10}$, and $\text{RbY}_3\text{F}_{10}$ doped with Eu(III) ions using a microwave-assisted solvothermal method. This method offers rapid and uniform heating, which drastically reduces synthesis time while increasing reaction rates and yields. By varying the precursors ratio, temperature, reaction time, solvents ratio and addition of complexing agent we produced two different Rb and Cs systems. X-ray diffraction measurements reveal that CsY_2F_7 and RbY_2F_7 crystallize in an orthorhombic structure with the Pnna (52) space group, whereas $\text{CsY}_3\text{F}_{10}$ and $\text{RbY}_3\text{F}_{10}$ exhibit a cubic symmetry with the Fm-3m (225) space group. Under excitation at a wavelength of 393 nm, the emission spectra of CsY_2F_7 and RbY_2F_7 show a dominant europium emission peak at around 611 nm, whereas $\text{CsY}_3\text{F}_{10}$ and $\text{RbY}_3\text{F}_{10}$ reveal prominent Eu^{3+} emission peaks in the orange, red, and deep-red regions of the spectrum at 592 nm, 620 nm, and 700 nm, respectively.

The findings of our study suggest that these fluoride-based nanomaterials possess significant potential for applications in the development of LEDs for agricultural purposes, security labeling, and latent fingerprint detection.

APPLICATION OF ZnO-MODIFIED LNTO CERAMICS IN DESIGN OF MICROWAVE DIELECTRIC RESONATORS IN LTCC TECHNOLOGY

Dalibor L. Sekulić^a, Radoš R. Raonić^b, Ondrej Bošák^c, Marian Kubliha^c, Roman Yatskiv^d
Tamara B. Ivetić^b

^a*University of Novi Sad, Faculty of Technical Sciences, Department of Power, Electronic and Telecommunication Engineering, Trg Dositeja Obradovića 6, Novi Sad, Serbia, dalsek@uns.ac.rs*

^b*University of Novi Sad, Faculty of Sciences, Department of Physics, Novi Sad*

^c*Faculty of Materials Science and Technology, Slovak University of Technology, Trnava*

^d*Institute of Photonics and Electronics, Czech Academy of Sciences, Prague*

With the rapid development of wireless communications in the last few decades, the synthesis of dielectric ceramics with optimal characteristics in the microwave frequency range attracts attention because these materials are important for the design of passive microwave devices such as resonators and antennas [1, 2]. Here we present our latest results of the successful synthesis and comprehensive characterization of a low-temperature (900°C) sintered lithium-niobium-titanium-oxide (LNTO) composite ceramics modified with ZnO, which possess microwave properties desirable for the fabrication of dielectric resonators in LTCC technology. Using SEM and XRD techniques, structural analysis confirmed the densely packed structure of the synthesized *M*-phase LNTO ceramics consisting of anisotropic rod- and plate-shaped grains. Raman spectra at room temperature showed a much lower number of vibration modes than group theory predicts, because the LNTO structure consists of only two basic building blocks (NbO₆ and TiO₆ octahedral) that exhibit weak interactions. A detailed analysis of the electrical conductivity and impedance response indicated the high bulk resistivity of the ZnO-modified LNTO composite ceramics possessing NTCR characteristics and can be mainly attributed to the grain boundary effect. In general, increasing the content of ZnO as a functional additive from 0 wt. % to 5 wt. % in the prepared LNTO ceramics led to a higher density, and thus to better microwave characteristics and higher temperature stability. Accordingly, the obtained results showed that the prototype cylindrical dielectric resonator, based on 5 wt. % ZnO-modified LNTO composite ceramics and directly excited by a microstrip line, possesses optimal microwave performance with a dielectric constant of 58 and a parameter $Q \times f = 43856$ GHz at resonant frequency of 9.85 GHz, and the temperature coefficient of the resonant frequency of about -14 ppm/°C [3]. Moreover, we believe that the synthesized composite ceramics with unique microwave characteristics in the X-frequency band can be used for the design of dielectric resonator antennas.

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CHALLENGES AND PERSPECTIVES OF HETEROGENEOUS PHOTOCATALYSIS FOR WATER TREATMENT

Tamara B. Ivetić

University of Novi Sad Faculty of Sciences, Department of Physics, Trg Dositeja Obradovića3, 21000 Novi Sad, Serbia, tamara.ivetic@df.uns.ac.rs

Heterogeneous photocatalysis is an excellent example of a sustainable and attractive advanced oxidation process that can simultaneously solve energy and environmental problems. Therefore, its application has recently achieved significant progress in many fields, such as energy production, chemical engineering, medicine/biochemistry, agriculture, and others [1]. However, despite many advantages such as process simplicity, reusability, and non-toxicity, its application in water treatment still faces many challenges due to cost and time efficiency, which prevents its practical application on a larger scale [2]. Enormous efforts have been made to increase the efficiency and reduce the cost of photocatalytic water treatment through charge carrier separation mechanisms [3,4], increasing visible light absorption using nanotechnology, or using magnetic separation techniques to remove the catalyst after its use in photocatalysis [5]. Also, additional environmental pollution during this process increases the interest in applying green chemistry approaches in synthesizing semiconductor photocatalysts [6]. Here, the basic facts about heterogeneous photocatalysis for water treatment, strategies to overcome the shortcomings with examples of ZnO-based photocatalysis, and future perspectives in this field with special reference to natural water remediation are presented.

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ALKALI-MODIFIED CELLULOSE NANOCRYSTAL AEROGELS: ADVANCED HYDROPHILIC SEPARATORS FOR HIGH- PERFORMANCE SUPERCAPACITORS

Daniel M. Mijailović^a, Patrick A. C. Gane^{a,b}, Katarina Dimić-Mišić^b, Monireh Imani^b, Dušica B. Stojanović^a, Petar S. Uskoković^a

^a*University of Belgrade, Faculty of Technology and Metallurgy, Karnegijeva 4, 11120 Belgrade, Serbia, dmijailovic@tmf.bg.ac.rs*

^b*Department of Bioproducts and Biosystems, School of Chemical Engineering, Aalto University, FI-00076 Aalto, Finland*

The growing demand for energy conversion and storage technologies, such as supercapacitors, batteries, and fuel cells, is being driven by the global shift towards low-carbon and sustainable energy solutions. As a result, it has become increasingly important to develop high-performance, renewable materials to replace traditional ones in these systems. This study presents an innovative strategy for designing and fabricating advanced conductive separators for supercapacitors, which is based on the interaction between alkali ions and cellulose nanocrystals (CNC). The modified CNC, treated with potassium ions, demonstrates superior performance compared to conventional glass microfiber separators. This enhancement is evident in both mechanical properties and ionic conductivity. The inherent hydrophilicity and porous structure of the material allow for efficient potassium ion transport, which plays a key role in enhancing supercapacitor performance. With high mass loading electrodes, the supercapacitor devices achieve a specific capacitance of up to 80 F/g at a scan rate of 10 mV/s in Swagelok cells. Additionally, the device maintains capacitance retention of 95% over 1000 continuous charge-discharge cycles. These findings show the potential of this novel CNC-based material to serve as a sustainable, high-performance component in energy storage systems. By offering both safety and efficiency, it represents a promising alternative for renewable energy storage technologies and contributing to the development of low-carbon energy solutions.

