List of doctoral projects available for the academic year 2025/2026

Wrocław 05.08.2025

Chemistry/Physics

Supervisor: Małgorzata Małecka, D. Sc. (dr hab.) (m.malecka@intibs.pl)

Subject: ***Self-regeneration in highly dispersed $Ce_{1-x}M_xO_{2-y}$ (M - transition metal) nanoparticles anchored in porous oxide materials***

Discipline: Chemical sciences

Description: The main research goal of the project is to design active oxidation catalyst with a hierarchical 3D structure based on modified CeO_2. Porous oxide materials, including mesoporous silica (MCM-41, SBA-15 and others), are extremely interesting carriers of a highly dispersed active phase. However, active particles such as pure and doped cerium oxides have excellent reversible reduction-oxidation capabilities of cerium ions and oxygen transport in the ceria lattice. The combination of these advantages may lead to the development of highly active catalysts. The possibility of self-regeneration of the active phase gives hope for the creation of a so-called "intelligent catalyst" with the desired properties.
Work in the laboratory will be carried out on the basis of wet chemistry methods. The samples prepared in this way will be characterized by the following techniques: TEM, SEM, EDX, XRD, IR, RAMAN, N_2 adsorption-desorption, TG, catalytic oxidation tests. The candidate is expected to be involved in laboratory work and to expand his knowledge.

Supervisor: Jan Jańczak, Prof. (j.janczak@intibs.pl)

Subject: ***Functionalization of metallophthalocyanines***

Discipline: Chemical sciences

Description: Metal (II) phthalocyanines (for example MgPc, ZnPc, MnPc, FePc, CoPc), although they have been known for several decades, are still of great interest due to their various applications. The properties of metallophthalocyanines of the transition metals, as representatives of the metallophthalocyanine family with the metal at +2 oxidation state, differ significantly from magnesium and zinc phthalocyanine (Mg, d0, Zn, d10) due to the electronic structure of the central ion (Mn^{2+} (Ar)$3d^5$; Fe^{2+}, (Ar)$3d^6$, Co^{2+}, (Ar)$3d^7$). The aim of the work will be to obtain and characterize new functionalized metallophthalocyanines by axial coordination of N- and O-donor ligands, their crystallization, performing diffraction measurements on single crystals and carrying out their structural analysis, as well as investigating their optical properties in the so-called "therapeutic window". In addition, performing DFT calculations of the geometry of the obtained derivatives and TD-DFT calculations and correlation with experimental UV-Vis spectra.

Supervisor: Rafael de Lima Oliveira, D. Sc. (dr hab.) (r.oliveira@intibs.pl)

Subject: ***Confinement of metal nanoparticles in doped porous carbonaceous materials and their application in catalysis***

Discipline: Chemical sciences

Description: Hydrogenation and oxidation of organic compounds correspond to essential reactions in the chemical industry. Traditionally, these reactions are done by stoichiometric amounts (or excess) of toxic reagents such as sodium borohydride as a reduction agent, or potassium permanganate as an oxidizing agent, resulting in processes with low selectivity and the generation of a lot of waste. Thus, these traditional processes are environmentally and economically unsuitable. The use of supported catalysts emerged as an alternative for producing valuable chemicals more sustainably.

The project's main goal is to develop a new class of doped porous carbonaceous materials using diverse techniques such as hard template techniques and post-activation processes. We are also interested in using waste such as glycerol (a by-product of biodiesel synthesis) as a carbon precursor. After the synthesis of the carbon materials, metal nanoparticles (NPS) or clusters will be deposited in this structure, aiming for a strong interaction between the metal NPS and the carbon materials, creating a synergy between them. These materials will be characterized by many different projects, such as microscopies (TEM and SEM), N_2 physisorption, XRD, XPS, and XAS.

The prepared materials will be used as catalyst candidates for the oxidation reactions (such as selective oxidation of alcohols and alkenes), hydrogenation reactions (CO_2 or biomass compounds), and hydrogen transfer reactions.

Supervisor: Rafael de Lima Oliveira, D. Sc. (dr hab.) (r.oliveira@intibs.pl)

Subject: ***Synthesis of metal clusters on doped carbon materials using MOF as precursor***

Discipline: Chemical sciences

Description: Metal-organic frameworks (MOFs) are highly porous materials composed of metal ions or clusters coordinated to organic ligands. They are known for their exceptional surface area and tunable porosity, making them useful for a variety of applications, including gas storage, separation, and drug delivery.

MOFs can be synthesized in various ways and can include a wide range of metal ions (like zinc, copper, or iron) and organic linkers (such as carboxylates or phosphonates). The unique combination of their structural properties allows researchers to design MOFs for specific tasks, tailoring their chemical and physical properties for optimal performance.

MOF has some limitations related to low stability, which limits their application in catalysis, especially when high pressure, temperature, and the presence of oxidizing or reducing agents are needed. Thus, some researchers suggest the carbonization of these structures, aiming for their use as a catalyst.

There are many different ways to prepare carbon materials using MOFs as the precursor, such as direct carbonization, carbonization of MOF with co-precursor, and carbonization of MOF with acid wash. The goal of this project is to synthesize a group of carbonaceous materials where metal clusters or nanoparticles will be immobilized on these carbonaceous structures. Herein, earth-abundant metal oxides such as cobalt, iron, nickel, or copper. These materials will be characterized by many different techniques, such as microscopies (TEM and SEM), N_2 physisorption, XRD, XPS, and XAS.

The prepared materials will be used as catalyst candidates for the oxidation reactions (such as selective oxidation of alcohols and alkenes), hydrogenation reactions (CO_2 or biomass compounds), and hydrogen transfer reactions.

Supervisor: Jacek Ćwik, D. Sc. (dr hab.) (j.cwik@intibs.pl)

Subject: ***The influence of modifying composition on the structural, magnetic and magnetocaloric properties of $R(Ni_{1-x}Al_x)_2$ solid solutions, where R represents selected rare earth elements***

Discipline: Physical sciences

Description: Hydrogen is rapidly becoming a preferred type of fuel, however, its liquefaction using today's vapor-compression technology is energy consuming and expensive. Magnetic cooling based on the magnetocaloric effect (MCE) is an energy-efficient and environmentally friendly alternative, but improvements in refrigerants are crucial for its success. This method can be implemented across a broad temperature range, from ultra-low to a few hundred Kelvin temperatures. The ideal magnetic refrigerant exhibits consistent magnetocaloric properties across system's operating temperature range. The proposed dissertation will include medium- and high-magnetic field studies, intermetallic lanthanide compounds with Laves phase structure, i.e. $R(Ni_{1-x}Al_x)_2$ (where R - selected lanthanides and $0.0 \leq x \leq 1.0$) aimed at proposing a multilayer magnetocaloric material for cryogenic applications. The selected starting compounds that are the basis for the proposed solid solutions exhibit second-order magnetic phase transitions and are characterized by large reversible magnetocaloric effect values in the cryogenic temperature range due to special properties associated with high localized magnetic moments originating from the incompletely filled 4f-electron shell of rare earth atoms, while selected Ni and Al atoms in these compounds remain in a non-magnetic state. The conducted research will allow for the proposal of magnetic refrigerants that could be used in multilayer materials characterized by a sufficiently high and constant MCE value over a wide temperature range.

Supervisor: Karol Lemański, D. Sc. (dr hab.) (k.lemanski@intibs.pl)

Subject: ***Synthesis and study of spectroscopic properties of polycrystalline perovskites converting infrared radiation into visible light***

Discipline: Physical sciences

Description: The scientific objective of the doctoral research is to investigate the processes of upconversion emission, for the selected inorganic polycrystals doped with rare earth ions. In most cases, these will be micro or nano-sized perovskite crystals, but for comparative purposes, other crystals could be also synthesized and studied. Radiation upconversion is a process in which two (or more) low-energy photons incident on an optical medium cause a high-energy photon to be emitted. This means that when a given material is irradiated with infrared light, invisible to the human eye, visible light will be obtained. An important issue for this research is to describe the mechanisms of upconversion of radiation for the obtained perovskites doped with lanthanide ions and to analyze other spectroscopic properties that have a significant impact on the luminescence and on the potential applications of the investigated samples. Due to their properties, some materials showing upconversion have already found many new applications, including in biophotonics or medicine, where they are used, among others, in photodynamic therapy against cancer. The research possess fundamental importance in the field of spectroscopy and nanotechnology.

Supervisor: Paweł Głuchowski, D. Sc. (dr hab.) (p.gluchowski@intibs.pl)
Auxiliary Supervisor: Mykhailo Chaika, dr.

Subject: ***Development of Cr^{4+}-based nanoceramic materials for passive Q-switching***

Discipline: Physical/Chemical sciences

Description: The excellent performance of Nd^{3+}:YAG lasers has driven increased demand for efficient Cr^{4+}:YAG saturable absorbers. Cr^{4+}:YAG single crystals have been commercially available since the late 1980s, indicating significant optimization of their fundamental properties. However, it is still difficult to claim that their performance as saturable absorbers is entirely satisfactory.

LiF single crystals exemplify the true potential of high-quality materials for passive Q-switching. In contrast, Cr^{4+}:YAG suffers from several inherent limitations, including residual absorption, the presence of Cr^{4+} ions in multiple tetrahedral sites, and strong nonradiative relaxation pathways. These parasitic effects are most likely associated with distortions in the Cr^{4+} tetrahedral sites. Therefore, developing new materials for passive Q-switching requires a deeper understanding of these structural and spectroscopic phenomena.

One promising direction for future research is the application of external pressure to modify the local structure of the optical centers. Pressure can alter the cation sites' symmetry and physical dimensions. In the case of the $(CrO_4)^{6-}$ optical center, such structural changes can affect the energy level positions of the chromium ions and modify their spectral splitting, thereby influencing the material's optical properties.

Nanoceramic materials offer precise control over microstructural parameters, enabling systematic investigation of how tetrahedral site symmetry and size affect optical behavior. The PhD student will be responsible for synthesizing nanopowders for nanoceramic preparation and characterizing their structural and spectroscopic properties.

Supervisor: Łukasz Marciniak, Prof. (l.marciniak@intibs.pl)

Subject: ***Inorganic phosphors doped with lanthanide ions for applications in thermal history markers***

Discipline: Chemical sciences

Description: Structural changes observed in inorganic materials doped with lanthanide ions under a change in annealing temperature can significantly modify the spectroscopic properties of such materials. This effect can be used to design luminescent thermal memory tags with high sensitivity and a wide thermal operating range. The goal of the PhD student's work will be to synthesize such inorganic materials and analyze their spectroscopic properties in order to understand the mechanisms of thermally induced structural changes occurring in these materials. This work will enable the intentional design of luminescent markers with predefined sensing parameters.

Supervisor: Rafał Wiglusz, Prof. (r.wiglusz@intibs.pl)

Subject: ***Design, preparation, and investigation of new biomaterials intended for tissue engineering***

Discipline: Chemical Sciences

Description: The main objective of the dissertation is to design and develop a smart biocomposite based on three-dimensional (3D) hydrogels (e.g., poly(ethylene glycol) (PEG or PEO), poly(propylene oxide) (PPO) and aliphatic polyesters such as poly(glycolide) (PGA), as well as polysaccharides - e.g., cellulose derivatives. Cellulose derivatives - and their biocomposites as a specific scaffold for dispersed nanosized phosphates doped with metal ions (e.g., lithium (I) ions) for tissue engineering applications.

The obtained biocomposites will be used in further stages of the PhD thesis to evaluate regenerative and proliferative properties of nerve cells, such as olfactory cells. In addition, the work will undertake the task of reconstructing the damaged neuronal pathway. The work will focus on obtaining nanosized phosphates doped with various ions, e.g., lithium(I), dispersed in a hydrogel carrier, and evaluating its effect on olfactory cells to stimulate limited nerve regenerative properties and neuronal growth and consequently restore the sense of smell.

Supervisor: Rafał Wiglusz, Prof. (r.wiglusz@intibs.pl)

Auxiliary supervisor: Adam Watras, dr.

Subject: ***Nanosized mixed fluorite-structured optically active compounds as potential materials for thermal imaging and pressure sensors***

Discipline: Physical sciences

Description: The main aim of the PhD thesis is to synthesize fluoride nanosized compounds mixed systems with the chemical formula $X_{1-x}Z_xF_2$ (where X, Z = Ca^{2+}, Sr^{2+} ions) doped and co-doped with lanthanide ions in the form of nanosized materials and ceramics. The structural and luminescence properties of the obtained materials will be compared to each other depending on the desired application. Potential applications of nanomaterials as thermal agents and nanosized ceramics for pressure sensing will be studied.

The most crucial aspect of the PhD thesis is to investigate how the composition and synthesis method of $X_{1-x}Z_xF_2$ mixed systems doped and co-doped with rare earth ions influence the clustering phenomenon. It is well known that clusters of rare earth ions are created in fluorite-type materials and greatly impact their physicochemical properties.

For the evaluation of the crystal structure and morphology of the obtained materials, the X-ray powder diffraction and electron microscopy, both SEM (Scanning Electron Microscopy) and TEM (Transmission Electron Microscopy) techniques will be used. Additionally, an EDX (Energy-Dispersive X-ray spectroscopy) measurement will be performed to get the exact data on phase composition. Detailed structural properties will be obtained by FT-IR (Fourier-Transform Infra-Red) and Raman spectroscopy. Both techniques will give information about the type and energy of vibrations in the obtained materials.

The spectroscopic characterization will involve such measurements as absorption spectra in the UV-VIS-NIR region, emission and excitation spectra in the UV-VIS-NIR region measured at 77 and 300 K, and the kinetics of luminescence measured with different excitation and at 4, 77, and 300 K.

Supervisor: Andrzej Jeżowski, Prof. (a.jezowski@intibs.pl)
Auxiliary supervisor: Daria Szewczyk, dr.

Subject*: Effect of defects, pressure and chemical composition on quantum tunneling of vibrational excitations in thermal properties of selected materials*

Discipline: Physical sciences

Description: The proposed thesis aims identify the possible effect of defects, pressure and chemical composition on diffusional thermal conductivity. The research is based on developing a comprehensive experimental-theoretical universal approach to describe the thermal conductivity κ(T) of solids, based on the multilateral verification of the concepts and predictions of the recently introduced theory of thermal conductivity [Simoncelli-Marzari-Mauri, Nature Physics (2019) https://doi.org/10.1038/s41567-019-0520-x]. With original methods it is expected to find manifestations of quantum tunneling in thermal conductivity according to experimental data. The methodology includes a) the study of isochoric thermal conductivity of disordered molecular crystals, amorphous materials and composites; b) measuring the isobaric thermal conductivity coefficient of highly anisotropic molecular crystals; c) analysis and systematization of literature data with subsequent computer processing on the temperature dependences of the thermal conductivity of complex crystals and amorphous materials. Additional topic targeted in the thesis will be demonstration of the correlation between the boson peak frequency and thermal conductivity of selected systems. Combination of studies on thermal conductivity and heat capacity should result in obtaining universal mutual dependencies.

Supervisor: Piotr Solarz, D. Sc. (dr hab.) (p.solarz@intibs.pl)
Auxiliary Supervisor: Radosław Lisiecki, D. Sc. (dr hab.)

Subject: *Investigation and interpretation of energy transfer processes in Pr+Ce+Pr systems*

Discipline: Chemical sciences

Description: The aim of the research is the synthesis, observation and interpretation of the phenomenon of energy transfer in Pr+Ce+Pr systems, discovered by Aleksander Łempicki in the 1970s. Determination of the effect of temperature on the process. The subject of the research will be inorganic materials. Such systems can convert high-energy radiation into red light, needed by both plants and animals for normal life.