WROCŁAW DOCTORAL SCHOOL OF INSTITUTES
OF POLISH ACADEMY OF SCIENCES

List of doctoral projects available for the academic year 2024/2025

INTiBS PAN
WROCŁAW

Wrocław 27.05.2024

Chemistry/Physics

Supervisor: Dariusz Kaczorowski, prof. (d.kaczorowski@intibs.pl)
Auxiliary Supervisor: Grzegorz Chajewski, dr.

Subject: ***Unconventional superconductivity and magnetic ordering in Ce-Pd-In and Ce-Pt-In dense Kondo systems.***

Discipline: Physical sciences

Description: Since the spectacular discovery of the phenomenon in 1979, advanced experimental and theoretical studies on heavy-fermion superconductivity have continued to be at the very forefront of modern condensed matter physics. This is due to the special character of the superconducting state, which cannot be described in terms of the conventional theory of superconductivity, as well as due to a variety of unusual physical behavior observed in the normal state. The microscopic nature of all these anomalous phenomena originates from strong electronic correlations in metallic systems bearing localized magnetic moments. In recent years, significant progress has been made in understanding the fundamental mechanisms responsible for the simultaneous presence of magnetism and superconductivity (by a number of decades considered as entirely antagonistic). In consequence, the scenarios of competition, coexistence or sometimes even interplay of the two cooperative phenomena have been recognized. Nevertheless, a consistent universal theory of the heavy-fermion superconductivity that might account for all its intriguing aspects is still lacking. Furthermore, new experimental discoveries in the field often result in identification of novel scientific challenges.

The ternary Ce-Pd-In and Ce-Pt-In systems comprise several phases crystallizing with diverse crystal structures, including a few prototype ones. Some of them have been found to exhibit the coexistence of superconductivity and magnetic ordering. Amidst those materials, especially interesting are dense Kondo compounds with multiple Ce atoms sites in their crystallographic unit cells.

In this doctoral work, we intend to investigate comprehensively a few representatives of this unique family of Ce-based heavy-fermion superconductors. The research will be carried out on high-quality single-crystalline specimens in wide ranges of temperature, magnetic field and hydrostatic pressure, employing a variety of modern bulk and local-probe research techniques. We expect that successful accomplishment of this PhD project will significantly contribute to the general understanding of the emergence of magnetism and superconductivity in strongly correlated electron systems.

Supervisor: Jan Janczak, prof. (j.janczak@intibs.pl)

Subject: ***Stereochemistry and properties of metallophthalocyanine derivatives.***

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, d^0, Zn, d^{10}) due to the electronic structure of the central ion (Mn^{2+} (Ar)$3d^5$; Fe^{2+}, (Ar)$3d^6$, Co^{2+}, (Ar)$3d^7$). Therefore, the aim of the work will be to obtain and characterize new complexes of metal phthalocyanines with additional axially coordinating N and O-donor ligands in the crystalline form as well as perform their structural analysis. In addition, the physicochemical characterization of the obtained metallophthalocyanines especially in the therapeutic window should be performed. Moreover, DFT calculations of the geometry of the obtained derivatives and TD-DFT calculations as well as correlation with the experimental UV-Vis spectra should be performed.

Supervisor: Mirosław Mączka, prof. (m.maczka@intibs.pl)

Subject: ***Synthesis, lattice dynamics and tunable ferroelectric and optical properties of multilayered hybrid perovskites.***

Discipline: Chemical sciences

Description: Organic-inorganic hybrids have been the subject of intense studies in recent years due to their functional properties. One of the most important group of hybrid perovskites constitute lead halides since these compounds are attractive photovoltaic materials. These compounds are also promising materials for optical applications (for instance light-emitting diodes, LEDs). In recent years there is growing interest in synthesis of perovskite structures built up from two- or trilayered slabs separated by sheets composed of organic cations. These compounds have advantages of both three-dimensional (for instance good photovoltaic performance) and two-dimensional perovskites (efficient emission and good chemical stability, especially to moisture). The aim of PhD student will be synthesis and single-crystal growth of novel multilayered hybrid perovskites exhibiting linear (efficient photoluminescence) and nonlinear optical properties (second harmonic generation, efficient two-photon absorption) as well as ferroelectric and switchable dielectric properties. These obtained compounds will be studied using infrared, Raman and optical spectroscopes. Additional x-ray diffraction, dielectric, and nonlinear optical studies will be performed in cooperation with other research groups from our Institute as well as from Wrocław University of Technology.

Additional information: The doctorate will be implemented as part of a project led by prof. Mirosław Mączka: " Synthesis, lattice dynamics and tunable ferroelectric and optical properties of multilayered hybrid perovskites ", NCN OPUS 25 grant no. 2023/49/B/ST5/00119) at the Division of Optical Spectroscopy (INTiBS PAN) in Wrocław.

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

Subject: ***Optical manometry based on the luminescence kinetics of Mn^{4+} ions.***

Discipline: Chemical sciences

Description: The aim of the work will be to create a library of luminescent materials that can be used in lifetime-based thermometry and to build a semi-empirical model enabling predefined design of thermometers with precisely defined sensory properties, taking into account relative sensitivity, operating temperature range and absolute sensitivity. As part of this PhD thesis, work will be carried out to determine the impact of the crystal field strength on the thermal depopulation of the 2E level of Mn^{4+} ions. The electronic configuration of these ions ($3d^3$) is the reason for the extraordinary sensitivity of their spectroscopic properties to changes in the crystal field intensity caused by changes in the stoichiometry of the material. Such modifications enable to change the spin-orbit coupling between levels 2E and 4T2, influencing the depopulation kinetics of level 2E. Hence thermometric performance of this kind of sensors can be very smoothly modify by optimizing the composition of the host material. The PhD student will be responsible for both the synthesis of luminescent materials and the characterization of their luminescent properties. Based on the results obtained, the thermometric parameters of the analyzed systems will be determined via the machine learning module.

Additional information: The doctorate will be implemented as part of a project (NCN OPUS) led by prof. Łukasz Marciniak at the Division of Biomedical Physico-Chemistry (INTiBS PAN) in Wrocław.

Supervisor: Łukasz Marciniak, prof. (l.marciniak@intibs.pl)
Auxiliary Supervisor: Karolina Elżbieciak-Piecka, dr.

Subject: ***Novel materials based on lignin from biomass with enhanced luminescent activity.***

Discipline: Chemical sciences

Description: Nowadays, phosphors are ubiquitous in our daily lives from the lighting industry to remote temperature sensors and biological markers. Therefore, the possibility of producing low-cost, biocompatible, environmentally friendly phosphors from biomass is particularly important from an economic and environmental perspective. The goal of this project is to develop a method for producing high-intensity carbon luminescent dots from lignin. The proposed solution will enable the development of efficient and low-cost luminophores with controlled emission properties. The application potential of the produced materials will be verified for their use in the production of remote temperature and pressure sensors.

Additional information: The doctorate will be implemented as part of a project (NCN OPUS) led by prof. Łukasz Marciniak at the Division of Biomedical Physico-Chemistry (INTiBS PAN) in Wrocław.

Supervisor: Leszek Kępiński, prof. (l.kepinski@intibs.pl)
Auxiliary Supervisor: Karolina Ledwa, dr.

Subject: ***Nanostructured catalysts for CO_2 thermochemical valorization.***

Discipline: Chemical sciences

Description: Global warming due to anthropogenic greenhouse gas emissions is our generation's greatest challenge. Carbon dioxide, which is by far the most significant contributor to global warming, is currently considered a promising prospective for potential applications as a raw material for the production of fine chemicals, like hydrocarbons, alcohols, ethers, etc.
The proposed thesis aims to develop well-defined, highly active nanostructured heterogeneous catalysts dedicated to CO_2 hydrogenation into more valuable chemicals. The catalysts will be composed of a high surface area support with well-defined 3D geometry (e.g., amorphous mesoporous support with uniform ordered pores, various types of 3D hierarchical flower-like supports, etc.) as well as optimized chemical composition and structure, and nanosized active phase with uniform particle size distribution (cheap transition metals in mono- or bimetallic configurations). Obtained systems will be characterized using a wide range of experimental methods (electron microscopy, X-ray diffraction, NMR, FTIR, Raman spectroscopy, XPS, gas adsorption, etc.) to find how the catalyst structure, chemical architecture, and geometry influence their chemical properties. Then, the catalytic activity and selectivity of the catalysts will be checked in the appropriate CO_2 hydrogenation process, depending on the chosen active phase activity. An essential step to elucidate the catalysts' behavior at reaction conditions will be in situ investigations (e.g., in situ TEM and in situ DRIFTS), which are planned to be performed in collaboration with other institutions.

Supervisor: Leszek Kępiński, prof. (l.kepinski@intibs.pl)
Auxiliary Supervisor: Rafael de Lima Oliveira, dr.

Subject: ***Metal nanoparticles confined in doped porous carbonaceous materials and their application in catalysis.***

Discipline: Chemical sciences

Description: Hydrogenation and oxidation of organic compounds are essential reactions in the chemical industry. Traditionally, these reactions are conducted 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 much waste. Thus, these traditional processes are environmentally and economically unsuitable. Supported catalysts emerged as an alternative for producing valuable chemicals more sustainably. The project's primary goal is to develop a new class of doped porous carbonaceous materials synthesized using diverse techniques, such as the hard template method or the post-activation of carbons. Waste materials such as glycerol (a by-product of biodiesel synthesis) will be used as a carbon precursor. Metal nanoparticles (NPS) will be deposited in the structure of the carbon materials, aiming for a strong interaction between the metal NPS and the carbon materials, creating a synergy between them. The materials will be characterized using various techniques such as electron microscopy (TEM and SEM), N_2 physisorption, XRD, XPS, and XAS. The prepared metal/carbon materials will be tested as catalysts for the oxidation reactions (such as selective oxidation of alcohols and alkenes), hydrogenation reactions (CO_2 or biomass compounds), and hydrogen transfer reactions.

Supervisor: Adam Pikul, prof. (a.pikul@intibs.pl)
Auxiliary Supervisor: Grzegorz Chajewski, dr. or Orest Pavlosiuk, dr.

Subject: ***Unconventional Superconductivity, Complex Magnetism and Nontrivial Topology in van der Waals U-Te systems.***

Discipline: Physical/Chemical sciences

Description: The objective of this dissertation is to identify and elucidate the distinctive physical properties of several uranium tellurides. These compounds are derivatives of uranium telluride, a recently discovered unconventional superconductor. In contrast, they possess a layered structure and are van der Waals materials, which have also been the subject of condensed matter physics due to the potential for exotic magnetic states, superconductivity, and the formation of so-called topologically nontrivial states. The discovery of the latter was awarded the 2016 Nobel Prize in Physics, which has made van der Waals materials an attractive object of research due to their potential applications in electronics, particularly in quantum computers.

The research methodology will entail the synthesis and characterization of high-quality uranium telluride monocrystals, their exfoliation (similar to that used to obtain graphene), and a comprehensive study of their physical properties under extreme conditions (i.e., low temperatures, strong magnetic fields, and high pressure). The dissertation will be carried out in collaboration between two leading research centers in Poland (in Wroclaw and Krakow) and two analogous centers in the Czech Republic (in Prague and Ostrava). Each country will have one experimental and theoretical group.

Additional information: No medical contraindications to work with radioactive isotopes.

Supervisor: Adam Pikul, prof. (a.pikul@intibs.pl)
Auxiliary Supervisor: Grzegorz Chajewski, dr. or Orest Pavlosiuk, dr. or Maria Szlawska, dr.

Subject: ***Thermal expansion and magnetostriction of uranium intermetallic compounds a potential advanced next-generation nuclear fuel.***

Discipline: Physical/Chemical sciences

Description: Construction of nuclear reactors based on advanced nuclear fuels is one of the conditions for effective decarbonization of the world energy industry. The most commonly used fuel in modern nuclear power plants is semi-conducting uranium dioxide, which (although relatively cheap and easy to produce) is not free from defects and limitations in its use. Problems include swelling and cracking of fuel rods and their low thermal conductivity which is a consequence not only of the burning of uranium dioxide but also of its physical and chemical properties. Therefore, a new generation of nuclear fuels referred to as ATF (accident tolerant fuel) is being searched for i.a. among uranium intermetallic compounds. The proposed PhD thesis will support this search at the level of basic research. Its aim will be to synthesize and study physical properties of selected uranium intermetallic compounds and to attempt to relate these properties to magnetism of the 5f electrons of uranium. The research will consist of growing monocrystals of several carefully selected compounds and their physical characterization mainly through thermal expansion and magnetostriction measurements. Part of the experiments will be carried out in France and the USA (as part of an ongoing collaboration of the supervisor), and the results obtained will be published in specialized journals and presented at international scientific conferences.

Additional information: The condition of admission to work with radioactive isotopes is positive qualification by a doctor of occupational medicine (medical examinations will be conducted at the expense of INTiBS PAN).

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 $Dy(Ni_{1-x}Al_x)_2$ and $Tb(Ni_{1-x}Al_x)_2$ solid solutions.***

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. A magnetic material in multilayer form, which will include individual solid solutions, will allow to obtain a material with unchanged high enough MCE values over a wide temperature range.

Supervisor: Artur Bednarkiewicz, prof. (a.bednarkiewicz@intibs.pl)
Auxiliary Supervisor: Aleksandra Pilch-Wróbel, dr.

Subject: ***Investigation of the influence of composition, size, and chemical architecture of Tb- and Eu-doped nanoluminophores on the efficiency of energy transfer to an organic acceptor.***

Discipline: Physical sciences

Description: Due to the long excited-state lifetimes, Tb^{3+} and Eu^{3+} ions have been investigated in the form of chelates and complexes for use in time-resolved, sensitive biodetection and bioimaging. The goal of this work is to develop, model, and characterize the spectral and time-resolved properties of new luminescent inorganic colloidal nanocrystals doped with Tb^{3+}, Eu^{3+}, or both Tb^{3+} and Eu^{3+}. The impact of concentration and chemical architecture on energy transfer efficiency (such as Förster resonance energy transfer, FRET) to organic acceptors on the surface will be verified. Additionally, a time-resolved measurement method using a sensitive camera and microscope will be developed.

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

Subject: ***Design, preparation, and investigation of hydrogel materials intended for tissue engineering.***

Discipline: Chemical sciences

Description: The main aim of the PhD thesis is to design and develop an intelligent 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) and their biocomposites as a specific scaffold for nanosized phosphates doped with metal ions (e.g. lithium (I) ions) dispersed inside it.
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)

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

Discipline: Physical/Chemical 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 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 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, the kinetics of luminescence measured with different excitation and at 77 and 300 K.

Fabrication of nanoceramics will be performed using the low-temperature, high-pressure (LTHP) sintering technique. Before sintering, pellets will be formed from the powder and coldly pressed in a cylindrical cell under a pressure of 0.8 GPa. Pellets of a diameter of 4 mm and height of about 2 mm will be prepared in this way.

Supervisor: Włodzimierz Miśta, D.Sc. (dr hab.) (w.mista@intibs.pl)

Subject: ***Synthesis, characterization and catalytic activity of graphitic carbon nitride (g-C_3N_4) - based hybrid nanomaterials doped with metals.***

Discipline: Chemical Sciences

Description: The work will concern methods of preparation of hybrid materials based on g-C_3N_4/nanocarbon components (GR, CNT) doped with metals. The synthesis of carbon nitride involves the thermal condensation of organic precursors, such as melamine, urea, dicyanodiamide. For high surface area materials hard (silica: SBA-15) and soft templates (P-123, Triton X-100) will be used. Due to its physical properties, it is a suitable carrier for active phases (e.g. metals). Due to the fact that it is a semiconductor with a small bandgap (2.7 eV), it can catalyze several environmentally important photodegradation reactions of organic pollutants, as well as to produce hydrogen in the photoreduction reaction of water splitting with the participation of sunlight.
The obtained materials will be characterized using the following methods: XRD, SEM-EDX, HRTEM, thermal analysis (TG), nitrogen adsorption (77 K), thermoprogrammed methods (TPR-H2, TPO-MS, TPD-MS), Raman spectroscopy, IR, UV-VIS, luminescence and testing of catalytic activity (CO oxidation, photocatalytic water decomposition).

Supervisor: Włodzimierz Miśta, D.Sc. (dr hab.) (w.mista@intibs.pl)

Subject: ***Synthesis, characterization and catalytic activity of metal-organic framework HKUST-1 with encapsulated selected noble metals.***

Discipline: Chemical sciences

Description: This thesis focuses on developing a hydro/solvothermal method and/or microwave-assisted synthesis for the rapid synthesis of good quality copper benzene-1,3,5-tricarboxylate (Cu-BTC also referred to as HKUST-1) with high yield under mild preparation conditions. Different synthesis conditions and activation methods were studied to understand their influence on the properties of HKUST-1. An additional attempt will be made to in situ synthesis/ immobilization of HKUST-1 in macro-/mesoporous silica/nickel monoliths for continuous flow catalysis with low-pressure drop.
As synthesized MOF will be activated by encapsulation of selected noble metals (Au, Pt, Pd, …). Interactions between metal nanoparticles (NPs) and metal–organic frameworks (MOFs) in their composite forms have proven to exhibit beneficial properties, such as enhanced catalytic performance through synergistic effects. As prepared hybrid MOF materials will be characterized by: XRD , SEM–EDS, HRTEM, thermal analysis (TG), N_2 (77 K) physisorption analysis, CO_2 and H_2 volumetric adsorption, termoprogrammed reaction (TPR-H2, TPD-MS, TPO), Raman, IR spectroscopy and by catalytic activity (CO oxidation).

Supervisor: Edyta Piskorska-Hommel D.Sc. (dr hab.) (e.piskorska@intibs.pl)
Auxiliary Supervisor: Dominika Majchrzak, dr., Sieć Badawcza Łukasiewicz – PORT Polski Ośrodek Rozwoju Technologii

Subject: ***Chemical surface modification of group-III nitrides for sensitivity improvement of open gate sensors.***

Discipline: Physical/Chemical sciences

Description: Nitrides are polar materials with large internal piezoelectric fields, making them ideal for open-gate sensors. These sensors are poised to play a crucial role in various applications, from environmental monitoring to medical diagnostics. For example, AlGaN/GaN HEMT-based biosensors and pH sensors have been employed in food analysis, medical diagnosis, and chemical research laboratories. The use of HEMT as a biosensor has also been demonstrated for detecting c-erbB-2 protein, as well as glucose, MIG, C-erbB-2, KIM-1, and PSA, and in the development of ion sensors.
Chemical surface modification of GaN is a powerful technique for enhancing the functionality of open-gate sensors. By tailoring the surface properties, sensors can achieve higher sensitivity, selectivity, and stability. The choice of modification method and functionalization agents depends on the specific application and the target analytes to be detected.
The aim of the PhD work is to prepare group-III nitride compounds using epitaxial methods such as Metal Organic Vapour Phase (MOVPE) and Molecular Beam Epitaxy (MBE), choose an appropriate chemical surface modification method, surface chemical and electronic analysis using X-ray Photoemission Spectroscopy (XPS), surface morphology analysis using Atomic Force (AFM) and Scanning Electron Microscopy (SEM), and structural study using X-ray Diffraction (XRD) and synchrotron radiation -based technique X-ray absorption Spectroscopy.

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

Subject: ***Synthesis and explanation of energy transfer in Pr-Ce systems.***

Discipline: Physical/Chemical sciences

Description: The aim of this work is to explain the energy transfer processes in Pr-Ce systems. Knowledge of these phenomena was initially documented in the 1970s. However, it is not clear to this day.
What is known is that in the presence of cerium ions, praseodymium ions do not show emission from 3P0 levels. All emissions come from the 1D2 level of praseodymium.
This is not a trivial problem and a PhD student is expected to have basic mathematical analysis skills. It is expected that the doctorate will result in the publication of about 7 works, which will open up his further career. In the first period, the doctoral student will be able to choose about 3 inorganic compounds on which he will be able to conduct his research. The works are expected to be published in the best journals.

Supervisor: Marek Drozd, prof. (m.drozd@intibs.pl)
Auxiliary Supervisor: Vasyl Kinzhybalo, dr.

Subject: ***Investigation of the Spectroscopic Properties of Guanidine Complexes as Functional Hybrid Materials.***

Discipline: Chemical sciences

Description: Hybrid organic-inorganic guanidine compounds are studied and obtained mainly as new molecular complexes with strictly defined properties. Among this group of compounds, ferroic materials exhibiting phase transitions and being generators of the second harmonic are being searched for. The first stage of the work will be the synthesis of completely new molecular complexes containing the guanidine cation, in which the main interactions are hydrogen bonds of different strengths and geometry. For the newly obtained complexes, the structure will be determined using diffraction methods (X-ray). The main method used for property measurements will be vibrational spectroscopy with particular emphasis on infrared spectroscopy and Raman spectroscopy. The combination of the results of X-ray methods and vibrational spectroscopy will allow to select potential second harmonic generators (complexes without a macroscopic center of symmetry) from the group of studied compounds. These materials are widely used in laser technology as well as optoelectronics in the broadest sense. For all obtained materials, tests will be carried out using differential scanning calorimetry. These studies will determine the occurrence of possible phase transitions. On their basis, it will be possible to initially select materials with ferroic properties, i.e. ferroelectrics or ferroelastics. Experimental research will be supplemented by quantum-mechanical calculations concerning equilibrium structures, theoretical vibrational spectra as well as first- and second-order hyperpolarizability.

Biology

Supervisor: Małgorzata Cebrat, D.Sc. (dr hab.) (malgorzata.cebrat@hirszfeld.pl)

Subject: ***The criteria of functional heterozygosity of Apis mellifera complementary sex determiner gene.***

Discipline: Biological sciences

Description: Csd gene is responsible for sex determination in honey bees: individuals heterozygous for csd are females, whereas hemi- or homozygous are males. The goal of the project is to establish the criteria for functional heterozygosity (ability to form females) of CSD proteins. This will involve examining the interaction of CSD potentially-specifying domains using a luciferase complementation assay. Based on recently published results, it is anticipated that identical (or nearly identical) PSDs will interact, while significantly differing ones will not. A set of mutated PSDs, varying in the length of HVRs, RS-domains, P-domains, and single amino acid substitutions, will be created to identify the minimal requirements for "functional difference" (abrogation of interaction in the assay). The PSD pairs will then be tested in the context of the full-length CSD protein for their functionality in governing sex-specific fem transcripts in an established *in vitro* model.

Methods: Molecular cloning, DNA sequencing, mutagenesis, gene expression analysis, cell culture and transfection. Genetic material will be obtained from honey bees. No infectious materials will be used.

Additional information: Since part of the research involves honey bee sampling in the field, it is highly recommended that prospective PhD students are not allergic to honey bee venom.

Supervisor: Marcin Czerwiński, prof. (marcin.czerwinski@hirszfeld.pl)

Subject: ***Functions and evolution of ceramide synthase and ceramide glucosyltransferase, enzymes fundamental for glycosphingolipid synthesis.***

Discipline: Biological sciences

Description: Glycosphingolipids are membrane-bound molecules commonly found in most animals. They are synthesized by an arsenal of enzymes and the central steps – sphingosine addition and subsequent glucosylation – are catalyzed by highly evolutionarily conserved proteins: ceramide synthase (CerS) and ceramide glucosyltransferase (UGCG). Activities of these enzymes were only investigated in well-known eukaryotes, such as plants, animals and fungi. This project aims to investigate activity of these enzymes in evolutionarily relevant groups, such as Ancyromonadida, Ichthyosporea and Choanoflagellata. The purpose of the research is to understand the functions glycosphingolipids played in ancient eukaryotic history. The research is expected to be broadly relevant as the origins of basic biological processes may inform their understanding in humans. Methodology will involve ancestral protein reconstruction and expression in mammalian systems, enzyme kinetics and characterization of reaction products.

Methods: Protein production in HEK293 cells and CHO-Lec2 cells, protein production in bacterial cells, fluorimetry and spectrophotometry, mass spectrometry of proteins, sugars and lipids, liquid chromatography, bioinformatic phylogeny reconstruction, molecular cloning. Other possible methods are culturing eukaryotes and SPR/calorimetry.

Supervisor: Andrzej Gamian, prof. (andrzej.gamian@hirszfeld.pl)
Auxiliary Supervisor: Anna Jarząb, dr. (anna.jarzab@hirszfeld.pl)

Subject: ***Bacterial Meltome Atlas and its use in the assessment of bacterial sensitivity to temperature in the context of infectious fever.***

Discipline: Biological sciences

Description: Microorganisms have fascinated scientist since the ancient times. On one hand they are considered to be an etiological agent of infectious diseases, on the other hand, they have been also recognized as a natural microsystem helping to reduce environmental pollutants or building up humans' immunity. In our laboratory, we want to utilize proteomics (Thermal Proteome Profiling) to focus on the microorganisms surveillance in the context of infectious fever by measuring their viability to heat and investigating the influence of heat on the bacterial proteins by proteomics. In addition, we will assess the immune response to bacteria weakened by different temperature treatment. Elevating body temperature by microbial infection and letting it run represents promising concept in anti-bacterial therapies and goes beyond standard pharmacological treatment by using fever reducing drugs and antibiotics. The general outcome and the result of our work will be the proteome/meltome database, which will constitute the extension for existing Meltome Atlas [Jarzab A, et al, Nature Meth. 2020] resource available at [https://meltomeatlas.proteomics.wzw.tum.de/master_meltomeatlasapp/].

Methods: Methods used in the project: proteomics, bioinformatics, biochemical, microbiological, analytical methods.
Organisms used in the study: bacterial cell culture, mammalian cell culture on cell lines.

Additional information: Project will be based on a collaboration with Technical University of Munich.

Supervisor: Ewa Jończyk-Matysiak, D.Sc. (dr hab.) (ewa.jonczyk-matysiak@hirszfeld.pl)

Subject: ***Immunomodulatory effect of phages on gastrointestinal tract epithelium.***

Discipline: Biological sciences

Description: The purpose of the studies is the determination of the possible phage interactions with epithelial cells of the gastrointestinal tract (i.e. inducing or inhibiting the secretion of β-defensins in well-differentiated epithelial cell lines e.g. Caco-2 (intestinal) treated with phage preparations is planned to study:
- cell differentiation and polarization, forming a monolayer that mimics the *in vivo* environment;
- asses specific pathways involved in tested phage transcytosis;
- the functional integrity of the epithelial barrier by measuring transepithelial electrical resistance (TEER);
- the potential impact of purified preparations of selected bacteriophages on the secretion of β-defensins e.g. hBD-2 *in vitro* by various epithelial cell lines, as well as the murine cells. The effect will be evaluated in ELISA assay enabling qualitative and quantitative assessment of the effect. Moreover, factors with proven stimulating effect on defensin (i.e.hBD-2) production in human cells e.g. TNF-α or other will be compared to the studied effect of phage interactions will also be used.
The planned works are of practical importance.

Methods: Phage interactions with epithelial cells in cell culture will be studied (using e.g., ranswell inserts) to allow differentiation and polarization, forming a monolayer that mimics the in vivo environment). Well-differentiated epithelial cell line, such as Caco-2 (intestinal) will be used.
Inhibitor studies - using pharmacological inhibitors to block specific pathways involved in transcytosis, such as: chlorpromazine (clathrin-mediated endocytosis inhibitor), filipin (caveolae-mediated endocytosis inhibitor), monensin (vesicular trafficking inhibitor).
Assessing the functional integrity of the epithelial barrier by measuring transepithelial electrical resistance (TEER) before and after phage exposure.
The induction of production cytokines in ELISA assay will be checked.
Mice models of phage application by different routes, cells will be isolated from animals.

Supervisor: Marta Kaszowska, D.Sc. (dr hab.) (marta.kaszowska@hirszfeld.pl)

Subject: ***Effective carbohydrate antigens for OPS-based glycoconjugate vaccines.***

Discipline: Biological sciences

Description: The goal is identification of the effective carbohydrate antigens for OPS-related glycoconjugate vaccines. Glycoconjugates are naturally processing by APCs and present on their surfaces by MHCII. These carbohydrate structures determine the strength of the binding to the TCR receptor on T cells. The magnitude of this strength consequently determines the level of immunity response for glycoconjugates. To this time it has not been definitely indicated how is a processing and presentation mechanism of OPS-related glycoconjugates.

Manipulation of the size and character of the attached polysaccharides could be used to enhance yielding optimal T cell help and booster responses. Such T cells might help more effectively boost the antibody response to subsequent exposure to a glycoconjugate vaccines.

The understanding of mechanisms governing glycoconjugate processing and presentation is crucial for the creation of the new generation of glycoconjugate vaccines whose chemical and physical properties are specially designed to enhance immunogenicity markedly.

The project's results should help to better understand how OPS-related glycoconjugate work and possibly learn how to fully exploit their potential as glycoconjugate vaccines.

The identification of the minimal effective carbohydrate antigens to elicit safe and protective immune response against a specific pathogen remains a challenge in the development of glycoconjugate vaccines.

Methods: Methods of research

1. Isolation and structural analyses of antigens for glycoconjugate vaccines preparation (preparative electrophoresis, SDS-PAGE and protein and sugar colometric assays HPLC, MALDI-TOF MS, ESI-MSn, 2D NMR spectroscopy).

2. Kinetic of bindings (surface plasmon resonance, SPR).

3. Identification of carbohydrate epitopes of OPS-related glycoconjugates. (STD NMR/trNOESY NMR).

4. Analysis of OPS-based glycoconjugates processing and presentation pathways by confocal microscopy.

5. Analysis of OPS-based glycoconjugates processing and presentation pathways by antigen presenting cells and cell differentiation by flow cytometry.

6. Identification of carbohydrate fragments from OPS-based glycoconjugates which are presented by MHCII (UHPLC and mass spectrometry methods).

7. *In vitro* stimulation of primary CD4+ T cells.

8. Isolation of carbohydrate-specific CD4+ T cell clones (Tcarbs cells).

Generation T cell hybridomas.

Additional information: The project is interdisciplinary for a PhD candidate who likes challenges.

Supervisor: Jolanta Łukasiewicz, prof. (jolanta.lukasiewicz@hirszfeld.pl)

Subject: ***Decoding the Klebsiella novel O/K loci into chemical O/K antigen structures and their biological relevance – towards better adjustment of bactericidal therapies and epidemiological studies.***

Discipline: Biological sciences

Description: *Klebsiella pneumoniae (Kp)* causes dangerous infections, such as sepsis, urinary tract infections, or infections leading to impaired liver function. The species is characterized by an alarming worldwide multidrug resistance. Its major virulence factors is O antigen (lipopolysaccharide, LPS) seen as a good candidate for promising therapeutic strategies based on active or passive immunization. For such therapy to be effective, it is necessary to have complete knowledge about O antigens, their occurrence and diversity.
For years, *Kp* was perceived as the species characterised by little diversity of O antigens. 12 O serotypes have been identified, distinguishing Kp from other Gram-negative bacteria. Five of them were described in detail in the Laboratory of Microbial Immunochemistry and Vaccines (O1v2, O2v2, O3a, O3b, O13) leaded by Jolanta Łukasiewicz, including the effect of insertion sequences in genes for switch between O1/O2v2 to O1/O2v1 phenotype. However, open-source bioinformatics tools for *Klebsiella* O and K antigen coding sequences, such as Kaptive, indicate higher variability. Depending on the report, estimated variability ranges 2.4 to 17% of non-typeable strains in various collections of *Kp* clinical isolates.
The project concerns a group of clinical isolates selected as nontypeable based on the variability of gene regions coding O and K antigens. Additionally, it is planned to investigate the susceptibility of strains with new serotypes O and K to the action of complement - a mechanism of the innate response of the human immune system.
In 2017, the World Health Organization (WHO) classified multidrug-resistant *Kp* isolates as priority 1. Critical, taking into account the availability of drugs effective in preventing such infections. If newly developed therapies based on O and LPS and K antigens are to be effective, expanding knowledge about the structures and diversity of O serotypes is a necessary condition.

Methods: Microbiology, microbial cultures in fermenters, preparative and analytical chemistry of carbohydrates and proteins, immunoassays, flow cytometry, TEM/SEM microscopy, NMR spectroscopy, ESI and MALDI mass spectrometry, flow cytometry, and bioinformatics of *K. pneumoniae* genomes, particularly O loci responsible for O antigen biosynthesis.

Additional information: By implementing the project's objectives, society will gain an advantage in knowledge about possible significant changes in the distribution of O/K serotypes among isolates causing infections, e.g. as a result of antigenic drift.

Supervisor: Anna Pawlik, D.Sc. (dr hab.) (anna.pawlik@hirszfeld.pl)

Subject: ***Control of the Campylobacterial cell cycle.***

Discipline: Biological sciences

Description: The bacterial cell cycle, i.e., the growth and division rate, is controlled and coordinated with environmental conditions. Nutrient availability or stress (e.g., thermal, oxidative) determines the bacterial cell cycle. Harsh conditions may even determine cell death. Bacteria sense the environmental conditions and respond appropriately to optimise growth; under some conditions, they may modify the cell cycle and transform into a dormant state. The project aims to identify pathways of environmental signal sensing, its transmission and targets affecting the cell cycle of selected pathogenic species belonging to *Campylobacteria: Helicobacter pylori, Campylobacter jejuni and Arcobacter butzleri*. Surprisingly, their cell cycle has hardly been studied. The results of proposed studies may not only fill the knowledge gap on their cell cycle but also be necessary for future work on antibiotic therapy targeting these species for which new antibiotics are urgently needed.

Methods: Molecular microbiology techniques, including bacterial mutagenesis, transcriptomic, proteomic, metabolomic, ChIP-seq or ChIP-qPCR, and protein-DNA interaction studies, are planned to be employed.
H. pylori, C. jejuni, and A. butzleri are infectious bacteria (category 2 pathogens).
Work with genetically modified microorganisms (GMM II) is planned.

Additional information: Representative review articles:
Dawan, J.; Ahn, J. Bacterial Stress Responses as Potential Targets in Overcoming Antibiotic Resistance. *Microorganisms* 2022, 10, 1385. https://doi.org/10.3390/microorganisms10071385
Liselot Dewachter and others, An integrative view of cell cycle control in Escherichia coli, FEMS Microbiology Reviews, Volume 42, Issue 2, 2018, Pages 116–136, https://doi.org/10.1093/femsre/fuy005
In case of any questions, don't hesitate to get in touch with Anna Pawlik
More information about the laboratory or supervisor may be found at:
https://hirszfeld.pl/en/structure/laboratories/laboratory-of-molecular-biology-of-microorganisms/
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Supervisor: Joanna Wietrzyk, prof. (joanna.wietrzyk@hirszfeld.pl)
Auxiliary Supervisor: Mateusz Psurski, dr. (mateusz.psurski@hirszfeld.pl)

Subject: ***CRISPR-mediated gene therapy as a novel approach to overcome drug-resistance in cancer.***

Discipline: Biological sciences

Description: The drug resistance in tumors often results from changes in genes expression indirectly related to the chemotherapy agent metabolism. Initial studies have shown that knocking out genes such as spermidine N1-acetyltransferase (SAT1) or argininosuccinate synthase 1 (ASS1) using the CRISPR technique resulted in a decrease in resistance to cisplatin in selected bladder cancer cell lines (both initially sensitive and resistant). Similar effects can be expected for other genes and cytostatic drugs. The effective implementation of the above observations is promising, therefore, the **aim of the research** will be to identify genes susceptible to modification using the CRISPR technique, the modulation of which will impact the therapeutic efficacy of cytostatic drugs. The project is part of a comprehensive research aimed at developing new drug-resistant cancer models (both in vitro and in vivo), as well as methods for selective drug delivery (e.g., through ultrasonographic targeting).

Methods: The methodological scope of the research envisaged in the project will include the derivation of model cell lines resistant to selected cytostatic drugs (with primary focus on lung, breast, colon, and bladder cancers cell lines), which will be further characterized for morphological, biochemical, and drug resistance traits using a variety of techniques including fluorometry, luminometry, cytometry, and microscopic analysis. Further work will involve obtaining and comprehensively characterizing a series of cell lines with modified expression of selected genes based on literature research and our own findings. To achieve this, the full range of available techniques in molecular biology and cell research will be utilized in the laboratory. The obtained cell lines will be utilized in extensive studies on combined therapies, incorporating gene therapy based on CRISPR modification methods as one of their crucial components.
Neither animal testing nor testing using infectious material is planned.

Additional information: The auxiliary promoter in this project will be Mateusz Psurski, PhD, who specializes in drug discovery.

Medicine

Supervisor: Andrzej Górski, prof. (andrzej.gorski@hirszfeld.pl)

Subject: ***Effect of phage administration on specific antibody production.***

Discipline: Medical sciences

Description: Recent studies have revealed that phage administration induces the appearance of phage-specific antibodies and our work has allowed for elucidation of their possible influence on the outcome of phage therapy. However, there are no data available on the effect of phage on the production of antibodies to other specific antigens. Thus, there is no data on the effect of phage administration on vaccination, production of autoantibodies etc. which constitutes a significant scientific and clinical gap.
Therefore it is of great importance to assess whether phages may inhibit humoral responses to a specific antigen. The effect of phage on antibody production will be evaluated in a mouse model (anti-SRBC plaques). Purified phage preparations specific to G+ or G- bacteria will be administered using different routes and different timing of SRBC administration. The results should provide original and completely novel data on the effects of phage administration on humoral immune responses.

Methods: Mice and purified phages will be used.

Supervisor: Łukasz Łaczmański D.Sc. (dr hab.) (lukasz.laczmanski@hirszfeld.pl)

Subject: ***Prediction of Pharmacological Treatment Impact on Bladder Cancer Cells Using Neural Networks and SCS Transcriptomic Data.***

Discipline: Medical sciences

Description: The project aims to develop a predictive model based on deep neural networks (DNN) using single-cell transcriptomic data (SCS) to predict cancer cell response to pharmacological treatment. This innovative approach leverages SCS to study the genotype and phenotype of cancer subclones, aiding in personalized oncology therapies. The methodology involves analyzing SCS data to understand tumor heterogeneity and identify gene expression patterns correlated with treatment response. The model will be validated using clinical and experimental data, potentially impacting personalized medicine and therapeutic strategies.

Methods: Single-cell RNA sequencing (SCS), deep neural networks (DNN), transcriptomic data analysis, model validation using clinical datasets. No tests on animals or infectious materials will be used. Clinical data for the project will be obtained during the implementation of a project funded by the Medical Research Agency – OncoSCNC.

Additional information: Graduates in biology, biotechnology, or bioinformatics with practical skills in data analysis and programming in R and Python are eligible to apply for this PhD program.

Supervisor: Izabela Nowak, Dr.Sc. (dr. hab.) (izabela.nowak@hirszfeld.pl)

Subject: ***Association of selected miRNAs with susceptibility to endometriosis and its severity.***

Discipline: Medical sciences

Description: Endometriosis is a debilitating gynecological disease defined as the presence of endometrial cells in an abnormal or ectopic location outside the uterine cavity. Most affected sites are the pelvic peritoneum, ovaries, uterosacral ligaments. Common symptoms of endometriosis are: painful periods and ovulation, severe pelvic cramping, pain during sex, urination and bowel pain. Disease occurs in approximately 10-15% of reproductive aged women. The aim of this project is to investigate the role of selected microRNAs as negative regulators of expression of the genes encoding proteins engaged in HLA class I antigen processing - TAP1, TAP2 as well as HLA class I. The expression of miRNAs related to the inflammatory response will also be analyzed. Expression of miRNA will be analyzed by Real-Time PCR in blood plasma and tissue sections after laparoscopy. This expression will be correlated with protein expression in tissues obtained from laparoscopy and tested in immunohistochemistry.

Methods: Real-time PCR, immunohistochemistry.
Only human material will be used: blood and tissue sections after laparoscopy.

Supervisor: Egbert Piasecki D.Sc. (dr hab.) (egbert.piasecki@hirszfeld.pl)
Auxiliary Supervisor: Marta Sochocka, dr. (marta.sochocka@hirszfeld.pl)

Subject: ***The effect of periodontal disease treatment on systemic inflammatory markers, oral microbiome composition, and change the trajectory of cognitive functions in Alzheimer's disease.***

Discipline: Medical sciences

Description: The overarching goal of this project is to evaluate if the treatment of periodontal disease (PeD) will improve immune response of peripheral immune cells, reduce the pro-inflammatory burden in men and women with Alzheimer's disease (AD), and evaluation if PeD treatment may also improve quality of life, cognitive performance, and behavioural changes.

SIGNIFICANCE/INNOVATION
• Peripheral immune cells activation/immune response in AD and comorbid PeD diagnosis may represent a biomarker of the impact on the brain and has not been previously explored, also in relation to the patient's sex.
• The evaluation of PeD as a source of inflammatory challenge that can contribute to worse cognitive performance, behavioral abnormalities, and diminished quality of life in AD has not been thoroughly investigated yet.
• The integration of immunological, microbiological, and clinical measures (change in the quality of life, behavioral symptoms, and cognitive performance), along with measures of PeD parameters is novel and can provide a comprehensive understanding of the impact of PeD on the progression of AD in men and women.

• The focus on how PeD treatment can impact on peripheral immune cells, modulate systemic immune responses and improve cognitive performance, behavioral symptoms, and quality of life is novel and can have an immediate impact on the clinical management of patients with AD (men and women).

STUDY DESIGN

Observational study phase: 104 older adults with mild or moderate AD divided in 2 groups: AD and diagnosis of PeD (AD+PeD, n=52) and AD without PeD diagnosis (comparison group, n=52).
PeD intervention phase: 52 participants with AD+PeD will be randomly assigned to 2 groups: PeD treatment (n=26) or Standard of Care (SoC, n=26). The ratio of men/women in each group will be 1:1. Blood, plasma and saliva samples will be taken before (T0), after 3 months (T3, post-treatment time-point) and 6 months (T6, study endpoint) of PeD treatment.

LABORATORY ANALYSES

Blood, plasma and saliva samples will be taken before (T0), after 3 months (T3, post-treatment time-point) and 6 months (T6, study endpoint) of PeD treatment to investigate: peripheral immune cells activation (level of innate immunity), cytokine production by activated PBLs, plasma biomarkers, oral microbiome changes, bioinformatics analysis of microbiome.

Methods:

1. Cell culture.
2. Virus titration and propagation (vesicular stomatitis virus, VSV).
3. Immune cells isolation and purifying.
4. Biological test of a level of innate immunity (PBLs).
5. Light microscopy/inverted light microscope.
6. Enzyme Immunoassay (ELISA).
7. Multiplex immunoassay.
8. High-throughput sequencing based on the NGS technique.
9. Analysis of marker gene-based microbiome sequencing data (Quantitative Insights Into Microbial Ecology, QIIME2)

Animals: no
Infectious material: human blood and saliva