WROCŁAW DOCTORAL SCHOOL OF INSTITUTES
OF POLISH ACADEMY OF SCIENCES

List of doctoral projects available for the academic year 2023/2024

INTiBS PAN
WROCŁAW

Wrocław 2023

Chemistry/Physics

Supervisor: Marek Daszkiewicz, D.Sc. (dr hab.) (m.daszkiewicz@intibs.pl)
Auxiliary Supervisor: Elżbieta Wojaczyńska, D,Sc. (dr. hab., prof. P.Wr).

Subject: ***Synthesis, structural studies and properties of chiral guanidinated 2-azabicycloalkanes as potential chemotherapeutics.***

Discipline: Chemistry

Description: The aim of the doctoral thesis is to synthesize a series of new, chiral 2-azabicycloalkanes substituted with the guanidinium group. The synthesis of heterocyclic, enantiopure compounds in a crystalline form is required for crystal structure determination. The crystals will be examined using X-ray diffraction at different temperature (100-400 K) and high pressure conditions by means of diamond anvil cell. Experimental results are juxtaposed with in-silico data especially with regard to the phase stability. A series of second harmonic generation tests are planned. The nature and proved activity of such a group of compounds prompt us to check them in biological tests as well.

Supervisor: Marek Daszkiewicz, D.Sc. (dr hab.) (m.daszkiewicz@intibs.pl)

Subject: ***Anisotropy of intermolecular interactions in crystals at extreme conditions.***

Discipline: Chemistry

Description: The aim of the doctoral thesis is to synthesize a series of organic and organic-inorganic compounds in the crystalline of biological importance. In the crystal structure, the molecules should interact with each other by various types of interactions including hydrogen bonds, stacking interactions, halogen-halogen etc. Changes of the systems of intermolecular interactions will be monitored using X-ray diffraction at different temperature (100-400 K) and high pressure conditions. Indicatrices of thermal expansion and compressibility will be determined. Mechanical properties of the crystals will be correlated with the crystal packing and network of intermolecular interactions..

Supervisor: Przemysław Dereń, prof. (p.deren@intibs.pl)

Subject: ***Synthesis of aluminosilicates and silicates doped with Pr3+ and/or other lanthanide ions and examination of the UV emission of these samples excited by visible light..***

Discipline: Chemistry

Description: The objective of the doctoral thesis will be to develop the synthesis of polycrystalline aluminosilicates and silicates doped with Pr3+ and/or other lanthanide ions and to study the UV emission induced by up-conversion, i.e. i.e. with light with a photon energy lower than the emission photon. Transitions between 5d and 4f electronic configurations as well as within the 4f configuration will be studied.
The UV emission thus obtained can be used for surface disinfection, sterilization or to support the treatment of cancerous tumors. For sterilization to be effective with this radiation, the emission must take place in the UV-C range, that is to say between 200 and 280 nm. The biggest challenge will be to achieve upconversion with low-density of excitation radiation. Success will depend on the morphology of the samples and the dopants used. The doctorate will therefore include both work in the chemical laboratory and spectroscopic research..

Additional information: The doctorate will be implemented as part of a project led by prof. Przemysław Dereń: "Phosphors for UVC LEDs: self-disinfecting surfaces", OPUS grant no. 2021/41 / B / ST5 / 03792) at the Optical Spectroscopy Department (INTiBS PAN) in Wrocław, The planned scholarship is PLN 5,000 gross per month..

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

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

Discipline: Chemistry

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

Subject: ***Nanostructured catalysts for thermochemical CO2 valorization.***

Discipline: Chemistry

Description: Global warming due to anthropogenic emissions of greenhouse gases is the greatest challenge of our generation. Carbon dioxide, which is by far the largest 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 main aim of the proposed thesis is to develop well-defined, highly active nanostructured heterogeneous catalysts dedicated to the hydrogenation of CO2 into more valuable chemicals. Synthesized 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.), 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 obtained catalysts will be checked in the appropriate CO2 hydrogenation process, depending on 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, in situ DRIFTS), 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: Chemistry

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 much 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 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 microscopies (TEM and SEM), N2 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 (CO2 or biomass compounds), and hydrogen transfer reactions.

Supervisor: Radosław Lisiecki, D.Sc. (dr. hab.) (r.lisiecki@intibs.pl)
Auxiliary Supervisor: Paweł Głuchowski, dr.

Subject: ***Synthesis and study of photocatalytic properties of 2D structures and their hybrids.***

Discipline: Chemistry

Description: The main goal of the PhD thesis is to obtain 2 dimensional structures and hybrids based on these materials in order to achieve the synergistic effect of the catalytic properties of individual structures. It is planned to obtain structures like: graphene, h-BN, TiO2, C3N4, MXene etc., which already themselves have catalytic properties and combine them into hybrids, in which it will be possible to transfer electrons between individual structures supporting process of photodegradation of organic compounds in water. One of the aspects that will be studied in particular will be to study the impact of phosphorescence, on increasing the efficiency of the photocatalysis process. Phosphorescent hybrids will be used in the process of photodegradation of drugs (e.g. carbamazepine), their derivatives (e.g. 4-(2-nitrophenyl)pyridine) or pesticides (e.g. glyphosate).
The 2 dimensional structures will be synthesized using hydrothermal, solvothermal, precipitation, electrochemical exfoliation, mechanosynthesis and thermal decomposition methods. Special attention will be paid to the development of scalable methods for obtaining catalysts. The produced structures will be characterized structurally and morphologically (XRD, Raman, IR, SEM/TEM, XPS), spectroscopically (absorption, luminescence, lifetime of carriers) and chemically (time and rate of decomposition of organic compounds, chemical and photostability over time). Attempts will also be made to mobilize the studied structures in the form of thin layers for their easier use in future applications..

Supervisor: Anna Łukowiak, D.Sc. (dr. hab.) (a.lukowiak@intibs.pl)
Auxiliary Supervisor: Marzena Fandloch, dr.

Subject: ***Novel COF@bioglass platforms for biomedical applications.***

Discipline: Chemistry

Description: The aim of this study is to synthesize new materials containing bioactive glass particles and covalent organic frameworks (COFs). COFs are crystalline porous organic structures with a unique molecular architecture and large specific surface area. They are composed of light elements (e.g., H, B, C, N, and O) linked by covalent bonds, and this favors their biodegradability and biocompatibility, indicating their potential in biomedical applications. A pioneering approach of the research will be to combine COFs with biomaterials, in particular bioactive glass. This will lead to advanced functional systems supporting bone tissue regeneration with desirable properties superior to individual components.
The dissertation will include the development of methods for the synthesis of composites of selected COFs and bioactive glass particles. The structural, spectroscopic, and textural characterization of the systems will be performed by using, e.g., XRD, MAS NMR, IR/Raman spectroscopy, TEM/SEM imaging, and nitrogen sorption. The next steps of the planned research concern: (i) determining the effect of the new composites on biocompatibility and bioactivity in vitro; (ii) using them as carriers for selected compounds, e.g., with anticancer or antibacterial properties. The gained knowledge will enable the design of new nanoplatforms for biomedical applications.

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

Subject: ***Hierarchical Ce1-xMxO2-y systems (M - transition metal) as catalysts for oxidation reactions.***

Discipline: Chemistry

Description: The main research goal of the project is to design active oxidation catalyst with a hierarchical 3D structure based on modified CeO2. Hierarchical materials are very interesting from a catalytic point of view because of their 3D structure and interesting pore characteristics. In addition, the active supports, which are 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 with the red-ox properties of cerium oxide materials could lead to the development of highly active catalysts. The multitude of possibilities to interfere with the 3D structure and microstructure of such material gives hope for obtaining a "tailor-made" catalyst for a selected chemical reaction.
Work in the laboratory will be carried out on the basis of wet chemistry methods and hydro(solwo)thermal techniques. The samples prepared in this way will be characterized by the following techniques: TEM, SEM, EDX, XRD, IR, RAMAN, N2 adsorption-desorption, TG, catalytic oxidation tests. The candidate is expected to be involved in laboratory work and to expand his/her knowledge.

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

Subject *Luminescence thermometry based on first-order structural phase transition.* (2 positions)

Discipline: Chemistry/Physics

Description: The PhD thesis will be carried out within the framework of the NCN Opus 2022/45/B/ST5/01629 project entitled "Luminescent thermometry based on first-order structural phase transition". As part of its implementation, inorganic luminescent materials doped with lanthanide ions and exhibiting a first-order structural phase transition will be designed. The possibility of exploiting changes in the spectroscopic properties of phosphors observed under temperature changes makes it possible to develop luminescent thermometers. With the remote temperature readout offered by such thermometers, it is possible to thermally image, for example, biological systems or mechanical components in a manner with reduced invasiveness. In order to increase the reliability and accuracy of temperature reading using luminescent thermometers, materials and solutions are being sought to achieve high relative sensitivity while maintaining high emission brightness. To meet these requirements, this project proposes a new and unique solution based on the use of lanthanide ion-doped phosphors in which a temperature-induced first-order structural phase transition is observed. This effect, associated with a change in point symmetry around the lanthanide ion, significantly affects the configuration of its energy levels and thus its spectroscopic properties. Therefore, in the temperature range around the phase transition temperature, the observed spectacular changes in the shape of the emission spectrum make it possible to develop a ratiometric luminescence thermometer with high sensitivity. The project plans to develop luminescent thermometers operating in different temperature ranges by optimizing the composition of the host material, dopant ion concentration and nanoparticle size. The ongoing research will provide important information on the influence of the first-order structural phase transition on the spectroscopic properties of nanoscale lanthanide ion-doped luminophores. The potential of the obtained results is expected to go far beyond luminescence thermometry.
The doctoral student's tasks will include the synthesis of the described materials, their structural and morphological characterization, and the study of spectroscopic properties over a wide temperature range in order to determine the thermometric parameters of the developed thermometers. In addition, the doctoral student will be responsible for the analysis of the obtained results, preparation of scientific publications and presentation of research results at scientific conferences in the form of posters and oral presentations.

Additional information: The Ph.D. thesis will be carried out within the framework of the NCN Opus 2022/45/B/ST5/01629 project entitled "Luminescent thermometry based on first-order structural phase transition**.** The planned scholarship is PLN 5,000 gross per month.

Supervisor: Mirosław Mączka, prof. (m.maczka@intibs.pl)
Auxiliary Supervisor: Dagmara Stefańska, dr.

Subject: ***Mechanisms of energy transfer processes occurring in inorganic phosphors doped with Eu2+ ions and selected optically active ions.***

Discipline: Chemistry

Description: Broadband emission of Eu2+ ions is highly desirable for generating white light in LED systems. Supplementing the emission of Eu2+ ions by co-doping the material with selected optically active ions can be an interesting way to obtain white light with a high CRI. The aim of the doctoral thesis will be to investigate and understand the mechanisms of energy transfer processes occurring in materials doped with Eu2+ ions and co-doped with lanthanide and transition metal ions. The tasks of the Ph.D. student will include developing a method for the synthesis of selected compounds using wet and dry chemistry techniques and optimizing the process of reducing Eu3+ ions to Eu2+. The structural characterization of obtained samples will be carried out using research techniques such as XRD powder diffraction and Raman spectroscopy. The morphology of the obtained materials will be verified using a transmission electron microscope (TEM). The spectroscopic characterization of the obtained phosphors will include measurements of the emission spectrum, excitation, luminescence kinetics, temperature stability, and quantum efficiency. The Ph.D. student will know the measurement techniques and the acquired theoretical knowledge will allow for the interpretation of the obtained results. The results of the research will be published in good scientific journals and presented at scientific conferences.

Supervisor: Włodzimierz Mista, 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: Chemistry

Description: This thesis focuses on the development of a hydro/solvothermal method and or microwave-assisted synthesis for the rapid synthesis of good quality copper benzene-1,3,5-tricarboxylate (Cu-BTC referred also 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), N2 (77K) physisorption analysis, CO2 and H2 volumetric adsorption, termo-programmed reaction (TPR-H2, TPD-MS, TPO), Raman, IR spectroscopy and by catalytic activity (CO oxidation, PROX).

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

Subject: ***Synthesis, characterization and catalytic activity of selected perovskites ($LaMO_3$; M= Mn,Co, Fe…) doped with noble metals.***

Discipline: Chemistry

Description: This thesis focuses on the preparation and characterization of perovskite materials (LaMO3; M=Mn, Co, Fe…). The following preparation methods will be used: sol-gel citrate methods, solvothermal methods / microwave-assisted, nano casting technique using mesoporous SBA-15 silica materials as a template. The perovskite structures ABO3 can incorporate ions of various sizes and charges showing great flexibility of composition. Moreover, substitutions of ions into the A- and/or B-sites forming A1-xA'xB1-yB'yO3 or deviation from ideal stoichiometry resulted in altering the electronic properties and also catalytic activity of the perovskites. Therefore the effect of substituting additional different metal cations (Ce+4, Ca+2, …) in A and/or B sites of perovskite cells on catalytic activity will be investigated. Therefore the incorporation of selected noble metals into perovskite lattice will be studied. Exposing the catalyst to oxidizing and reducing atmosphere resulted in the recovery of the high dispersion of noble metals and the excellent stability of the perovskite structure.
As prepared perovskite samples will be characterized by: XRD, SEM–EDS, HRTEM, thermal analysis (TG), N2 (77K) physisorption analysis, thermo-programmed reaction (TPR-H2, O2-TPD-MS, TPO), Raman and FTIR spectroscopy and catalytic activity for CO, VOC, and soot oxidation.

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

Subject: ***Design, preparation and investigation of new block copolymer hydrogels intended for tissue engineering.***

Discipline: Chemistry

Description: The main aim of the PhD thesis is to design and develop an intelligent biocomposite based on the intelligent three-dimensional (3D) printed block copolymer 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 nanophosphates doped with metal ions (e.g. lithium (I) ions) dispersed inside it.
The obtained biocomposites will be used in further stages of the project to evaluate regenerative and proliferative properties for 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 nanophosphates doped with various ions, e.g., lithium(I), dispersed in a block copolymer 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: Artur Bednarkiewicz, prof. (a.bednarkiewicz@intibs.pl)

Subject: ***New anti-Stokes luminescent labels and multicolour FRET for DNA sequencing***

Discipline: Physics

Description: The objective of the project is to study a 4 color FRET with lanthanide doped luminescent nanoparticles as donors for its potential use in DNA sequencing by synthesis. First, a wide range of appropriate luminescent colloidal nano-/micro-materials will be synthesized and characterized in terms of structure, morphology and fundamental spectral properties. Next, these materials will be versatilely characterized, searching for suitable features (e.g. anti-Stokes emission, efficient transfer to selected acceptors). For the latter, a dedicated optical setup for temperature and excitation power dependent spectra and luminescence kinetics studies will be developed using fluorescence microscope, temperature chamber, photon counters etc. to automate some routine measurements. Simultaneously dedicated optical instruments will be developed to study the most promising materials for time-resolved 4CH FRET recording and analysis.
Tasks:

- Characterization of temperature and excitation power dependent properties of colloidal nano-/micro-particles
- Design, construction and testing of new optical systems (photon counting with PMT, automation of spectral and kinetic studies of colloidal nanoparticles, development of single nanoparticle fluorescence microscope based)
- Data analysis, modelling, writing reports and scientific publications.

Requirements: Basic experience with design and optimization of optical instruments (e.g. fluorescence, confocal microscopes, optical setups)

- Some experience in optical spectroscopy (fluorescence, biospectroscopy) and knowledge of spectral instrumentation (spectrographs, cameras, microscopes, PMT/APD photodetectors, photodetection techniques)
- Experience in lasers and optoelectronics
- Experience in software development (C/C++, LabView, Matlab, Office, Origin, Python etc.) and potentially electronic circuits development
- Very good skills in spoken and written English
- Outstanding motivation for research, reliability, independence, teamwork skills, creativity, high personal culture,

Additional information: The PhD thesis will be carried out within the framework of NCN OPUS WAVE-UNISONO „Novel anti-Stokes lanthanide-doped nanoparticles and multicolor FRET mechanisms for single-molecule DNA sequencing (LantaSEQ)”. The planned scholarship is PLN 5,000 gross per month.

Supervisor: Tomasz Cichorek, prof. (t.cichorek@intibs.pl)

Subject: ***Detection of relativistic fermions in topological semimetals with magnetostriction.***

Discipline: Physics

Description: A research project Detection of relativistic fermions in topological semimetals with magnetostriction addresses a fundamental scientific problem related to experimental investigations of Dirac and Weyl quasiparticles: First-principles calculations and angle-resolved photoemission spectroscopy measurements can point towards new materials with nontrivial band topology. However, other experimental signatures of relativistic fermions are often subtle and indirect, since in these materials conventional, massive charge carriers exist as well. Hence, new experimental methods for determining the relativistic character of the quasiparticles are highly desirable to set the stage for investigations of their relevance for electronic applications.
The main research task is intended to study relativistic quasiparticles in topological semimetals using the magnetostriction as an experimental probe. It is planned to perform comprehensive investigations of the angle-dependent field-induced length change of selected representative topological semimetals with bulk band crossings sufficiently close to the Fermi energy, and hence giving rise to robust gapless electronic excitations. The second intention, which constitutes the main experimental challenge of the project, is to explore effect of uniaxial stress on the magnetostriction. Because this thermodynamic quantity is sensitive to the position of the Fermi level, it is planned to study magnetostrictive effects when the enclosed nodes will be tuned under uniaxial tension to the Fermi level, and thus to search for new physics.

Additional information: The PhD thesis will be carried out within the framework of NCN Preludium-Bis-3 project „Detection of relativistic fermions in topological semimetals with magnetostriction.)". The planned scholarship is PLN 5,500 gross per month.

Supervisor: Tomasz Cichorek, prof. (t.cichorek@intibs.pl)

Subject: ***Constraints on the order parameter in candidate chiral superconductors from local magnetization measurements.***

Discipline: Physics

Description: In the past years, the revealed significance of the topological nature of certain superconducting states has attracted great interest in condensed matter physics because of its potential application for topological fault-tolerant quantum computation. A promising platform for topological superconductivity and emergent Majorana quasiparticles are chiral superconductors – bulk topological materials with finite angular momentum Cooper pairs circulating around a unique chiral axis, thereby spontaneously breaking time-reversal symmetry. Such unique properties, attractive from the viewpoints of basic and applied science, triggered tremendous efforts for searching for topological superconductivity. However, naturally occurring candidate materials are scarce and the realization of chiral superconductivity is still under intensive debate.
The main research task is intended to investigate the temperature dependence of the field of first flux penetration of leading candidate materials for chiral superconductivity utilizing a new innovative micro-Hall-probe magnetometry with a high spatial resolution. Measurements of the lower critical field Hc1 are planned down to temperatures as low as 0.007 K, since investigations deep in the superconducting state can validate or rule out a subset of possible superconducting order parameters. Effect of uniaxial stress will be also explored, since unconventional superconducting order parameters are inherently connected to the symmetry of the underlying crystal lattice that can be reduced under strain. The additional goal is to verify the presence of considerable multiband effects that can put severe constraints on the order parameter(s) of a superconductor with finite angular momentum.

Additional information: The PhD thesis will be carried out within the framework of NCN Opus 23 project „Constraints on the order parameter in candidate chiral superconductors from local magnetization measurements”. The planned scholarship is PLN 4,000 gross per month.

Supervisor: Przemysław Dereń, prof. (p.deren@intibs.pl)

Subject: ***Synthesis by levitation of amorphous binary compounds, e.g. Al2O3 and ternary compounds, such as LaAlO3, doped with rare earth and transition metal ions followed by the preparation of nanoceramics and the study of the spectroscopic properties of the obtained samples.***

Discipline: Physics/Chemistry

Description: Obtaining glasses is limited to materials in which there is a network of ions forming the structure of the glass, typically silicate or borate glasses. However, classical methods cannot be used to obtain glasses of oxides such as Al2O3 or ternary compounds like LaAlO3, as any contact with the container or surface will cause crystallization. To obtain amorphous samples of these materials, a special melting technique without any contact with containers or surfaces is required. The levitation method is suitable for this purpose. In this method, the material is levitated in an inert gas flow, and the temperature is raised to approximately 2000℃ using CO2 laser radiation. Stopping the laser rapidly cools the material at a rate of around 600℃/min, resulting in a frozen amorphous form. Our plan is to obtain these materials doped with lanthanide ions. The newly obtained optical materials will be examined for their potential use as active elements in lasers and temperature sensors. In the subsequent research phase, heating these materials will induce the formation of Al2O3 or LaAlO3 nanocrystals within the material, and their spectroscopic properties will also be examined.

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

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

Discipline: Physics

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, and the results will be published in the most prestigious scientific journals and presented at major scientific conferences.

Supervisor: Adam Pikul, D.Sc.(dr hab.) (a.pikul@intibs.pl)

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

Discipline: Physics/Chemistry

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: Rafał Wiglusz, prof. (r.wiglusz@intibs.pl)
Auxiliary Supervisor: Adam Watras, dr.

Subject: ***Novel fluoride and oxyfluoride materials for use in bioimaging and thermal sensing.***

Discipline: Physics

Description: The main goal of the thesis is to design, prepare and study physicochemical properties of fluoride (LnF3) and oxyfluoride materials (LnOF, Ln4O3F6), where Ln = La-Lu, doped and co-doped with rare-earth ions for use in bioimaging and thermal sensing. Since both the bioimaging and thermal sensing is based on specific energy transfers inside or between different optically active ions, this thesis will be devoted to study the energy transfer mechanisms in the LnF3, LnOF and Ln4O3F6 matrices. The energy transfer including up-conversion phenomenon and the down-conversion processes will be studied. All samples will be prepared using a wet-chemistry methods such as modified Pechini's method, co-precipitation and microwave assisted hydrothermal method, which allow to tailor the final size of nanoparticles and minimize the particle agglomeration effects. For evaluation of crystal structure and morphology the X-ray powder diffraction and electron microscopy both SEM (Scanning Electron Microscopy) and TEM (Transmission Electron Microscopy) techniques will be used. Detailed structural properties will be obtained by FT-IR (Fourier-Transform Infra-Red) and Raman spectroscopy. The spectroscopic characterization will involves such measurements like absorption spectra in UV-VIS-NIR region, emission and excitation spectra in UV-VIS-NIR region, kinetics of luminescence measured with different excitation and at wide range of temperatures. Selected samples will be prepared for use in bio-imaging and temperature sensing...

Supervisor Tomasz Zaleski, D.Sc. (dr hab.) (t.zaleski@intibs.pl)

Subject: ***Influence of gauge potentials and topology on phase transitions of bosons in optical lattice.***

Discipline: Physics

Description: Optical lattices, which are recently of great interest to researchers, are periodic structures formed from the intersection of counter-propagating laser beams. They allow for trapping of atoms cooled to very low temperatures and observation of quantum phenomena characteristic for the solid state physics (hence the name "quantum simulators").
The PhD student's task will be to theoretically analyze the properties of ultracold bosons in an optical lattice. The doctoral student will begin his work by familiarizing himself with simple models describing the behavior of solids and mastering the methods of statistical thermodynamics. Then, expanding his research workshop, he/she will move on to more complicated models and techniques and the use of appropriate approximations. As a result, he/she will learn to determine the properties of the Bose-Hubbard model using advanced methods of quantum field theory and will be prepared to conduct research in the project.
The dissertation will be devoted to the analysis of various properties of the Bose-Hubbard model, e.g., excitations of quasiparticles in bands with trivial and non-trivial topology, transport properties in geometry-constrained lattices in the presence of gauge potentials, or the role of dissipation in the formation and nature of ordered states.
Participation in the project includes a 5-month research internship at the Institute for Theoretical Physics, Technical University Berlin, for which the PhD student will be eligible for NAWA funding.

Additional information: The research and dissertation will be carried out within the framework of the research project: “Influence of gauge potentials and topology on phase transitions of bosons in optical lattice " (No 2020/39/O/ST3/01148) carried out under the contract awarded by the National Science Center.
The PRELUDIUM BIS doctoral scholarship will be paid a maximum of 4 years in the monthly amount of:

- 5000 PLN (the amount will be reduced by the cost of mandatory social security contributions, etc., about 24%) until the month in which the doctoral student's mid-term evaluation at the doctoral school was conducted,
- 6000 PLN (the amount will be reduced by the cost of mandatory social security contributions, etc., about 24%) after the month in which the student's mid-term evaluation at doctoral school was conducted.

Biology

Supervisor: Ewa Brzozowska, D.Sc. (dr hab.) (ewa.brzozowska@hirszfeld.pl)

Subject: ***Bacteriophage tail proteins – characterization of their tertiary structure and biological function.***

Description: Bacteriophage tail proteins are thought to play a structural role. However, they are involved in recognition and adhesion to bacterial cells, and the hydrolytic activity of bacterial polysaccharides. They can be used as antibacterial agents and prevent biofilm formation by slime polysaccharide destruction. There are some Tail Tubular Proteins characterized as polysaccharide depolymerases in the literature. However, their mechanism of action is still unknown. Therefore the concept of the study will concern tertiary structure solving using mostly crystallography methodology. Selected phage proteins will be produced on a large scale, purified, and used to set crystallization (co-crystallization with sugar compounds will be also included). Moreover, proteins will be characterized in terms of their hydrolytic activity and antibacterial features. Methods: molecular biology – design of genetic constructs and plasmids production, proteins biochemistry - proteins production in bacterial expressing system, proteins purification and analysis (purity, stability, homogeneity), functional assays – enzymatic activity, biofilm formation, inhibition, and degradation, bactericidal activity determination, microbiology – bacteria cultivation and cell components fractionation, crystallography – proteins crystallization tertiary structure solving based on X-ray diffraction.

Additional information: The study will be performed in cooperation with dr Anna Pyra (University of Wrocław) who specializes in proteins crystallography.

Supervisor: Dariusz Danel, D.Sc. (dr hab.) (dariusz.danel@hirszfeld.pl)
Auxiliary Supervisor: Piotr Fedurek, dr

Subject: ***The relationship between Toxoplasma gondii infection and social integration in chacma baboons.***

Description: The prevalence of *Toxoplasma gondii* (TG) in wildlife reaches up to 70-80%. Previous studies on primates and other group living mammals have shown that TG infections affects social behaviour and dominance rank acquisition of an individual. The aim of this project is to determine the extent to which behavioural changes resulting from TG infection and parasite load, in general, affect the social network integration of chacma baboons (ChB). The research will be conducted on the Swebeswebe Wildlife Estate, Limpopo Province, South Africa. The research protocol will include collecting blood and faecal samples and behavioural data (to assess social integration) in two ChB troops, followed by Immunochromatographic (IC) tests for IgG and IgM markers of TG. The results of this project will not only help to understand better how toxoplasmosis influences the social behaviour of its host but critically determine the degree to which changes in aggression and affiliative behaviour resulting from TG infection influence an individual's social integration in the group. Overall, this study will provide new insights into understanding the degree to which parasite-host interactions are associated with social dynamics in group-living animals, including humans.

Additional information: The successful candidate will (ideally) have a background in either zoology, primatology, veterinary or animal behaviour as well as international fieldwork/relevant laboratory experience in collecting and testing animal biological samples.
The project will be co-supervised by dr Piotr Fedurek (Anthropology Department IITD PAN) who has got a vast experience in studying social network integration in human and non-human primates. The study will be conducted in collaboration with dr Richard McFarland (Nottingham Trent University, United Kingdom), the director of the Swebeswebe Primate Research Project where the data collection will be conducted.

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

Subject: ***The effect of phages on the production of specific antibodies.***

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 consitutes 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 on mice 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 important data on the effects of phage therapy on humoral immune responses.

Supervisor: Sławomir Kozieł, prof. (slawomir.koziel@hirszfeld.pl)

Subject: ***Polymorphisms of dopaminergic genes: DRD4, DRD2, COMT and DAT1 and risk taking behaviour. Study of Polish soldiers taking part in combat missions.***

Description: The aim of the study is an assessment of relationship between frequencies of certain polymorphisms of dopaminergic genes and risk taking behaviour. There are many reports showing association between polymorphism of DRD4 gen with some personality traits like novelty seeking. Other studies have indicated relationship between long allele of DRD4 with such risk taking behaviour like gambling and financial risk. However, there is a lack of research reporting association between such behaviour and polymorphisms in other dopaminergic genes. There is also no any data showing relationship between those polymorphisms and risk behaviour exposing human life. Proposed study will be based on comparison of frequencies of polymorphisms in three groups: (1) soldiers taking part and (2) not taking part in combat missions and (3) control group of males, who are not soldiers

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

Subject: ***The use of artificial intelligence (AI) algorithms to detect off-target mutations after using base editors.***

Description: CRISPR/Cas9 (Clustered regularly interspaced short palindromic repeats/ CRISPR-associated protein 9) is a revolutionary gene-editing tool, allowing for precise targeting of DNA sequences. CRISPR/Cas9 comprises two main components: a short guide RNA (gRNA) molecule and Cas9 nuclease protein. A breakthrough came with the discovery of Base editors (BEs) - a modified CRISPR/Cas9 system with partially deactivated Cas9 nuclease and attached cytosine or adenine deaminase subunits. Base editors can facilitate chemical single-nucleotide transitions of cytosine to thymine (C to T) or adenine to guanine (A to G) within targeted sequence without introducing dangerous double-strand DNA breaks and needing an external template. To date, all CRISPR/Cas9-based systems (including base editors) have been shown to introduce unwanted, off-target Cas9-dependent mutations resulting from partial complementarity of used gRNA to other, non-targeted sequences. Moreover, Cas9-independent genome-wide deaminations in the DNA of edited cells have been described in sequences with no gRNA complementarity, with the exact mechanism of their occurrence yet to be elucidated.
The project aims to develop a method of searching for potential off-target mutations using artificial intelligence algorithms.

Additional information: Graduate of biotechnology, bioinformatics or a related field with knowledge of artificial intelligence (AI) programming techniques.

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

Subject: *Control of the Epsiloproteobacterial cell cycle.*

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 Epsilonproteobacterota: *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.

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 (anna.pawlik@hirszfeld.pl)

Supervisor: Joanna Rossowska, D.Sc. (dr hab.) (joanna.rossowska @hirszfeld.pl)

Subject: *Modified extracellular vesicles as a tool for anti-cancer immunotherapy.*

Description: Extracellular vesicles (EVs), i.e. nanoparticles surrounded by a phospholipid membrane with a size of 30 to 200 nm, secreted by cells into the intercellular space, have been described as an essential player in the intercellular communication process. Depending on the cell of origin, the EV content varies greatly. They have been described as critical mediators of several biological processes associated with tumor cell migration, modulation of cell functions, and induction of inflammation or suppression. Due to their biocompatibility, stability and high ability to penetrate the tumor microenvironment, they are considered as a tool for anti-tumor therapy. The research aims at evaluating the anti-tumor activity of EVs isolated from genetically modified endothelial cells overexpressing pro-inflammatory interleukins and shRNA for TGF-B1 or interleukin 10, with particular emphasis on their ability for induction of anti-tumor immune response, angiogenesis normalization and metastasis prevention. The research will be conducted using conventional and 3D cell culture models in vitro, and in vivo models as well. Methods such as flow cytometry, confocal and electron microscopy, size-exclusion chromatography, western blot, and RT-PCR will be used to evaluate the activity of modified EVs. The obtained results may be of great importance when designing anti-cancer therapies using modified exosomes.

Medicine

Supervisor: Katarzyna Bogunia-Kubik, prof. (katarzyna.bogunia-kubik@hirszfeld.pl)
Auxiliary Supervisor: Joanna Wielińska, dr.

Subject: ***Involvement of NK cells in rheumatoid arthritis.***

Description: The aim of the project is to analyse natural killer (NK) cells isolated from patients with rheumatoid arthritis (RA) in the context of their diverse repertoire of cell surface receptors at different times after the implementation of biological treatment with TNF-alpha inhibitors.
We aim to concentrate on NK cells population and their characteristics in RA patients in the context of extracellular vesicles (EVs).
We propose a comprehensive research including analysis and comparison of NK cell frequency and phenotype, polymorphism and expression of NK-related genes, muti-omic approach to characterise RA-EVs and assessment of their effect on NK cells in *in vitro* culture experiments followed, NK cell functional characteristics including secreted cytokines levels.

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

Subject: ***Revealing the mechanism involved in infection fever as a potential anti-cancer therapy***

Description: In our previous studies on Meltome Atlas (Jarząb et al, Nature Meth, 2020) we have observed that cancer cells are more sensitive to heat treatment than their healthy counterparts. Due to those reasons, we are planning to investigate the association and mechanism of cancer cell death in a response to infectious fever caused by microbes. We will evaluate the anti-tumor efficacy of hyperthermia on *in vitro* model using human cancer cell lines and primary cells, accompanied by *ex vivo* studies of the clinical material isolated from patients. Subsequently we will move to mice model and will evaluate the efficacy of bacterial cell components in inducing fever and its development by using implanted temperature microchips. To investigate the mechanism of action we will employ proteomics, which will allow to monitor changes in cancerous and healthy cells on molecular level in multi-omics scale

Additional information: Keywords: cancer research, cell culture, mice studies, microbiology, proteomics, bioinformatics.
Cooperation with Technical University of Munich.

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

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

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.