WROCŁAW DOCTORAL SCHOOL OF INSTITUTES
OF POLISH ACADEMY OF SCIENCES

List of doctoral projects available for the academic year 2022/2023

INTiBS PAN
WROCŁAW

Wrocław 2022

Chemistry/Physics

Supervisor: Przemysław Dereń, prof. (p.deren@intibs.pl)
Auxiliary Supervisor: Bartosz Bondzior, dr

Subject: ***Preparation by levitation of amorphous binary compounds such as Al_2O_3 and ternary compounds such as $LaAlO_3$ doped with rare-earth and transition metal ions, achieving nano-glass ceramics from amorphous samples, and an examination of the spectroscopic properties of the samples obtained.***

Discipline: Chemistry/Physics

Description: : The synthesis of glasses is limited to materials in which there is a network of ions that form the structure of such a glass, so most often silicate or borate glasses are known. Two-component oxides such as Al_2O_3 or ternary $LaAlO_3$ cannot be obtained in an amorphous form, because any contact with the vessel (crucible) or the plate on which the molten material will be poured will cause crystallization. To obtain an amorphous sample of the materials mentioned above, a special melting technique must be used without contact with any container or surface. The levitation method is suitable for this. In the flow of inert gas, the material will levitate, the temperature of which will be raised to around 2000°C employing CO_2 laser radiation. The rapid stopping of the laser radiation will cause very rapid cooling of the material which will be solidified in amorphous form. This material will be doped with lanthanide ions. The new optical materials thus obtained will be tested as to their ability to be used as active elements of lasers and temperature sensors. In the next research step, by heating these materials, the appearance of Al_2O_3 or $LaAlO_3$ nanocrystals in this material will be initiated. The spectroscopic properties of these new glass ceramics will also be studied.

Additional information: The doctoral student must have the skills necessary to work in a chemical laboratory, know the basics of working in a spectroscopy laboratory and know the level of English language that allows for independent writing of publications.

Supervisor: Przemysław Dereń, prof. (p.deren@intibs.pl)
Auxiliary Supervisor: Karol Lemański, dr

Subject: ***Synthesis of $Lu_xLa_{1-x}PO_4$ and $Ca_9Y_xLa_{1-x}(PO_4)_7$ polycrystals (where x = 1 : 0), doped with Pr^{3+} and/or Nd^{3+} ions and investigations of the UV emission of these samples excited by visible light.***

Discipline: Chemistry/Physics

Description: The objective of the doctoral thesis will be to develop the synthesis of LuxLa1-xPO4 and Ca9YxLa1-x(PO4)7 (where x=1:0) polycrystals doped with Pr3+ and/or Nd3+ ions and to study the UV emission excited by up-conversion, that is to say with a light whose photon energy is lower than the energy of the emitted photons. The transitions between the configuration of 5d and 4f electrons will be studied.
The emission thus obtained can be used for surface disinfection, sterilization or to support the treatment of neoplastic tumors. For sterilization with this radiation to be effective, the emission must take place in the UV-C range, that is to say between 100 and 200 nm. The biggest challenge will be to obtain this emission with a low density of excitation radiation. Success will depend on the morphology of the samples and the sensitizers used. The doctorate will therefore consist of both work in the chemical laboratory and spectroscopic research.

Additional information: The doctoral student must have the skills necessary to work in a chemical laboratory, know the basics of working in a spectroscopy laboratory and know the level of English language that allows for independent writing of publications.
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 hydrogen generation.***

Discipline: Chemistry

Description: Hydrogen is one of the promising renewable and clean energy source alternatives for fossil fuels. The catalytic thermochemical method has a high potential to play a prominent role in commercial hydrogen production, providing that appropriate active, stable, and cheap catalysts are developed.
The proposed doctoral project's main aim is to develop novel, nanostructured catalysts dedicated to hydrogen generation. Multi-component 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 support, etc.), nanosized active phase with uniform particle size distribution (cheap transition metals in mono- or bimetallic configurations), and appropriate strongly basic promoter necessary to improve the catalyst activity, coke-resistivity, and stability at elevated temperatures. 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 on their chemical properties. The hydrogen generation activity of obtained catalysts will be checked in the water-gas-shift (WGS) reaction ($CO+H2O \rightarrow CO2+H2$). 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: 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, D.Sc. (dr hab.) (l.marciniak @intibs.pl)

Subject: ***Luminescence thermometry based on temperature-induced phase transition in materials doped with Ln3+ ions.***

Discipline: Chemistry

Description: The aim of this Ph.D. thesis is to find and understand the correlation between host material composition and dopant ion concentration and the thermometric properties of phosphors that can find applications in luminescence thermometry with high relative sensitivity and low temperature resolution.

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

Subject: ***Synthesis and studies of novel organic-inorganic multifunctional hybrid perovskites.***

Discipline: Chemistry

Description: Organic-inorganic hybrids have been the subject of intense studies in recent years due to their functional properties such as ferroelectric, photovoltaic, photoluminescent, switchable dielectric and nonlinear optical. One of the most famous group are those crystallizing in a 3D perovskite type structure of general formula ABX3 (A= organic cation; B= metal cation such as Pb2+, Mn2+, Cd2+ etc.; X= halide, formate, cyanide) but lower-dimensional perovskites also attract increasing interest. The may advantage of the low-dimensional perovskites is their large structural diversity, which allows broad tunability of their properties. For instance, change of dimensionality form 3D to 2D, 1D or 0D may lead to appearance of broadband photoluminescence (including white) and/or polar order. The aim of PhD student will be search for novel perovskite hybrids exhibiting linear (efficient photoluminescence) and nonlinear optical properties, ferroelectric and switchable dielectric properties. Single crystals of these compounds will be grown using various methods and studies will be performed using IR, Raman and optical spectroscopes (as a function of temperature and pressure) as well as other experimental methods (dielectric spectroscopy, X-ray diffraction, differential scanning calorimetry).

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: 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: ***"Preparation and studies of biocompatible materials with theranostics' properties for precision biomedical applications"***

Discipline: Chemistry

Description: The main aim of the PhD thesis is to design and to obtain a novel multifunctional biomaterial based on nanosized phosphate compounds including apatite structure doped and co-doped with rare earth ions (RE3+) and p-, d-block ions of the periodic table loaded with bioactive molecules closed in the obtained biodegradable polymers for tissue regeneration including critical bone and nerve defects as well as drug delivery system.
In the proposed system, the biodegradable polymer will serve as a supporting base - scaffold that could be adjusted to the size and/or volume of a defect site. The obtained system will be biodegradable polymer matrix in which phosphate compounds modified by bioactive molecules could be closed, giving opportunity for application in personalized medicine.

Supervisor: Artur Bednarkiewicz, prof. (a.bednarkiewicz@intibs.pl)

Subject: ***Photon avalanche in Pr3+, Tm3+, Ho3+ sensitized by Yb3+ ions.***

Discipline: Physics

Description: The photon avalanche emission that occurs in phosphors doped with lanthanide ions is characterized by a highly nonlinear relationship between the intensity of luminescence and the intensity of laser excitation. These properties open up a huge field of new applications, e.g. in imaging below the diffraction limit, the construction of ultrasensitive biosensors, temperature measurements, etc. Most known avalanche materials use one type of admixture (e.g. Tm3+ ions), but the presence of admixtures of other ions (e.g. Yb3+) should strengthen (sensitize) the avalanche behavior of individual avalanching Tm3+, Pr3+, Ho3+ ions. The research will concern the verification of this hypothesis and will consist in measurements of spectroscopic properties (emission/excitation spectra, times of luminescence build-up and decay, dependence of luminescence intensity as a function of excitation power) and imaging of nanoparticles co-doped with the above-mentioned ions.
Requirements: general knowledge of photophysical processes in lanthanide ions, knowledge of the basics of photonics, spectroscopy, lasers, software (Matlab, LabView, etc.), the construction of optical and opto-electronic systems. Good knowledge of English, fascination with applied science.

Additional information: The studies will be realized with NCN OPUS research project **Sensitized Photon Avalanche Emission in lanthanide doped colloidal core-shell nanoparticles: novel materials for superresolution imaging (SPA).** LINK

Supervisor: Artur Bednarkiewicz, prof. (a.bednarkiewicz@intibs.pl)

Subject: ***Luminescent nanoparticles doped with lanthanide ions for 4 colour Resonant Energy Transfer (RET) biosensing.***

Discipline: Physics

Description: DNA sequencing has become an indispensable tool in clinical diagnosis and life scien¬ces, for example in biotechnology, evolutionary research or in genetic profiling of microorganisms. Current single-molecule DNA sequencing techniques, however, suffer from several disad-vantages that can be circumvented by employing the unique photo¬physical features of novel lanthanide doped luminescent nanomaterials (LnNP) which (1) efficiently emit short-wave-length light under NIR exci¬ta¬tion (2) LnNP are very photostable and do not blink. (3) LnNP emit multiple narrow emission bands under single wavelength excitation, such that a single luminescent nanoparticle can be used as a donor for FRET to four different acceptor dyes, which are required to identify individual dNTPs. The research will focus on the verification of this hypothesis and will consist in measurements of spectroscopic properties (emission/excitation spectra, times of luminescence build-up and decay, dependence of luminescence intensity as a function of excitation power) and imaging of nanoparticles co-doped with the above-mentioned ions.

Requirements: general knowledge of photophysical processes in lanthanide ions, knowledge of the basics of photonics, spectroscopy, lasers, software (Matlab, LabView, etc.), the construction of optical and opto-electronic systems.

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" (realization within a program NCN PRELUDIUM BIS3) addresses a fundamental problem related to experimental investigations of Weyl and Dirac quasiparticles. The magnetostriction in a nonmagnetic semimetal results from the interaction between the electron and elastic degrees of freedom in a crystal, and thus it is determined by the change of the charge-carrier density in an intense magnetic field. Furthermore, for a multiband material with multivalley structure, this directional dependent thermodynamic quantity is greatly enhanced due to a band overlap and an electron redistribution between the bands at the switching-on of magnetic field. The main research task is intended to study relativistic quasiparticles in topological semimetals using the magnetostriction as an experimental probe. Her are proposed 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. A second intention, which constitutes the main experimental challenge of the project, is to explore effect of uniaxial stress on the magnetostriction. A study of magnetostrictive effects when the enclosed nodes will be tuned under uniaxial tension to the Fermi level may disclose new physics. In a wider context, the observation of large and strongly anisotropic length changes under magnetic fields can be relevant for future Weyltronic devices, since strained thin-films might be realized using a magnetostrictive stress.

Additional information: Sample preparation. Performing measurements of angular-dependent magnetostriction on a 3He/4He dilution refrigerator. Experiments on uniaxial-stress dilatometer. Data analysis. Participation and then main contribution in preparing manuscripts. Poster and oral presentations at the conferences. Basic knowledge of solid state physics. Some experience in experimental physics.

Supervisor: Przemysław Dereń, prof. (p.deren@intibs.pl)
Auxiliary Supervisor: Karol Lemański, dr

Subject: ***Synthesis of $LiY_xLa_{1-x}F_4$ and $BaY_{2x}La_{2(x-1)}F_8$ polycrystals (where x = 1:0), doped with Pr^{3+} and/or Nd^{3+} ions and investigations of the UV emission of these samples excited by visible light.***

Discipline: Physics/Chemistry

Description: The objective of the doctoral thesis will be to develop the synthesis of polycrystals LiYxLa1-xF4 and BaY2xLa2(x-1)F8 (where x=1:0) doped with Pr3+ and/or Nd3+ ions and to study the UV emission excited by upconversion, i.e. light whose photon energy is lower than the energy of the emitted photons. The transitions between the configuration of 5d and 4f electrons will be studied.
The emission thus obtained can be used for surface disinfection, sterilization or to support the treatment of neoplastic tumors. For sterilization with this radiation to be effective, the emission must take place in the UV-C range, that is to say between 100 and 200 nm. The biggest challenge will be to obtain this emission with a low density of excitation radiation. Success will depend on the morphology of the samples and the sensitizers used. The doctorate will therefore consist of both work in the chemical laboratory and spectroscopic research.

Additional information: The doctoral student must have the skills necessary to work in a chemical laboratory, know the basics of working in a spectroscopy laboratory and know the level of English language that allows for independent writing of publications.
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: Detlef Hommel, prof. (d.hommel@intibs.pl)
Auxiliary Supervisor: Edyta Piskorska-Hommel, dr

Subject: ***Study of the doping element concentration influence on the electronic structure of the wide-gape GaN-based semiconductors.***

.

Discipline: Physics/Chemistry

Description:
Nitrides-III are the base materials for opto- and high-power electronics. Their functionality can be expanded by engineering the bandgap (doping) of AlN, GaN, and InN compounds. The key parameter in these compounds is the electronic structure. The knowledge of the electronic structure of these materials will influence the improvement of the current devices based on the materials mentioned above. Synchrotron techniques based on the absorption phenomenon, such as XAS and UARPES, are proposed to study the electronic structure of the GaN-based wide-gape semiconductors.
The study will consist of growth using epitaxial methods (MBE / MOVPE) and characterization or only characterization of GaN-based semiconductor structures.
The growth of semiconductor structures will be performed in the epitaxy laboratory of the Institute of Low Temperature and Structure Research Polish Academy of Sciences or/iand of the Łukasiewicz Research Network - Port Polish Center for Technology Development in Wroclaw. The use of synchrotron techniques will be carried out on the SOLARIS synchrotron in Krakow.

Requirements: - knowledge of the topics related to the interaction of X-rays with matter
- English language skills enabling the presentation of scientific results in written and oral form
- experience with research equipment
- master degree in physics, chemistry, material sciences, or a related field
- knowledge of electron spectroscopy techniques or X-ray absorption spectroscopy methods
- experience with the synthesis and preparation of the materials
- knowledge of synchrotron methods, beamline components and research equipment will be beneficial.

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

Subject: ***Quantum tunneling of vibrational excitations in thermal conductivity of selected materials.***

Discipline: Physics

Description: The proposed thesis aims to help develop a comprehensive experimental-theoretical universal approach to describe the thermal conductivity κ(T) of solids, based on the multilateral verification of the concepts and predictions of the new theory of thermal conductivity [Simoncelli-Marzari-Mauri, Nature Physics (2019) https://doi.org/10.1038/s41567-019-0520-x]. With original methods it is expected to find manifestations of quantum tunneling in thermal conductivity according to experimental data. The methodology includes a) the study of isochoric thermal conductivity of disordered molecular crystals, amorphous materials and composites; b) measuring the isobaric thermal conductivity coefficient of highly anisotropic molecular crystals; c) analysis and systematization of literature data with subsequent computer processing on the temperature dependences of the thermal conductivity of complex crystals and amorphous materials.
Direct measurements of κ(T) of amorphous material in an isochoric process, under conditions closest to theoretical predictions, should provide information on the diffusive channel of thermal conduction and test its universality using a comparative analysis with other crystalline and amorphous materials. The factors such as crystal anisotropy, polycrystallinity, the complexity of the crystal structure of both single-component and multi-component substances, the presence of internal degrees of freedom and others will be taken into account.

Supervisor: Dariusz Kaczorowski, prof. (d.kaczorowski@intibs.pl)

Subject: ***Synthesis and characterization of multifunctional half-Heusler compounds with tunable topological quantum effects.***

Discipline: Physics

Description: We invite ambitious graduates to join the team dynamically developing research in the field of topological materials - one of the hottest research areas in modern solid state physics. Doctoral work will be done in the frame of the research project "Synthesis and characterization of multifunctional half-Heusler compounds with tunable topological quantum effects – TOPOHH" (Grant no. 2021/40/Q/ST5/00066 funded by the National Science Center), carried out in the Division of Magnetic Research, and led by Professor Dariusz Kaczorowski, in collaboration with the Institute of Physics, Chinese Academy of Sciences, Beijing.
The tasks of the scholarship holder will include obtaining single crystals of selected compounds, their crystallo-chemical characterization, measuring their transport and thermodynamic properties, interpretation of experimental results, participation in the editing of scientific publications, presentation of results at scientific conferences. The results of the work will be the basis for the doctoral dissertation prepared under the supervision of a member of the research project team.

Additional information: The doctoral scholarship will be paid on the basis of an agreement concluded between the PhD student and the Director of INTiBS PAS, in the amount of PLN 3260 net1 (PLN 3675 gross2), until the month in which the mid-term evaluation will be carried out (24 months after the start of studies). After obtaining a positive evaluation of the scholarship holder's achievements, the contract will be extended for another 24 months, however, by the 36th month of studies, the amount of the scholarship will be PLN 3720 net (PLN 4190 gross), and for the last 12 months of doctoral studies it will be financed by the INTiBS PAN, in accordance with Art. 209 par. 4 pt. 2 of the Act of July 20, 2018 (Law on Higher Education and Science) and the applicable ordinances of the Director of ILTSR PAS. The maximum period of receiving a doctoral scholarship is 48 months.

Supervisor: Dariusz Kaczorowski, prof. (d.kaczorowski@intibs.pl)

Subject: ***Anomalous electron transport in magnetic insulators and topological semimetals***

Discipline: Physics

Description: We invite ambitious graduates to join the team dynamically developing research in the field of topological materials - one of the hottest research areas in modern solid state physics. Doctoral work will be carried out in the frame of the research project "Anomalous electron transport in magnetic insulators and topological semimetals", funded by the National Science Center (grant no. 2021/41/B/ST3/01141) at the Department of Magnetic Research, headed by prof. Dariusz Kaczorowski, in cooperation with the Institute of Molecular Physics of the Polish Academy of Sciences in Poznań.
The tasks of the scholarship holder will include obtaining single crystals of selected compounds based on europium, conducting research on their transport and thermodynamic properties, interpretation of the obtained physical characteristics, participation in the editing of scientific publications, presentation of results at scientific conferences. The results of the work will be the basis for the doctoral dissertation prepared under the supervision of a member of the research project team.

Additional information: The doctoral scholarship will be paid on the basis of an agreement concluded between the PhD student and the Director of INTiBS PAS, in the amount of PLN 3260 net1 (PLN 3675 gross2), until the month in which the mid-term evaluation will be carried out (24 months after the start of studies). After obtaining a positive evaluation of the scholarship holder's achievements, the contract will be extended for another 24 months, however, by the 36th month of studies, the amount of the scholarship will be PLN 3720 net (PLN 4190 gross), and for the last 12 months of doctoral studies it will be financed by the INTiBS PAN, in accordance with Art. 209 par. 4 pt. 2 of the Act of July 20, 2018 (Law on Higher Education and Science) and the applicable ordinances of the Director of ILTSR PAS. The maximum period of receiving a doctoral scholarship is 48 months.

Supervisor: Tadeusz Kopeć, prof. (t.kopec@intibs.pl)

Subject: ***Condensation phenomena and related physical properties of strongly interacting anisotropic boson systems on a lattice.***

Discipline: Physics

Description: The aim of the dissertation topic is the issue of multi-body quantum phenomena, phase transitions and the determination of possibilities of non-trivial phases in boson systems on a lattice. Among many effects in the bosonic system is a Bose-Einstein condensation that plays a special role. This phenomenon takes place at low temperatures and in the presence of interactions between particles. The essence of the condensation is that all atoms are in the same quantum state, their wave functions are delocalized in the whole volume. The theoretical description of this phenomenon is possible only with the consideration of many-body effects that lead to a strong correlations, as a result of interactions among particles. For this purpose, the proposed theoretical methods involve both analytical and numerical approaches based on the so-called Bose-Hubbard model in the context of strong boson interactions. Both the parameters of the model, the determination of the observed quantities, and the theoretical approaches used will be so as to best suit the experimental configurations. The generalization of the Bose-Hubbard model to anisotropic structures will be the key study of condensation in heterostructures. The subject of the doctoral dissertation is sumptuous with the growing interest in superfluid phases as a macroscopic manifestation of quantum mechanics and the role of quantum phase transitions visible in the professional literature.

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 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: The aim of the project is to theoretically study the properties of strongly interacting ultra-cold bosons in optical lattices. Such systems, intensively studied in recent years experimentally, mimic the behavior of strongly correlated electrons in the solid body, while allowing a very wide range of control properties of particles in a model environment. As a result, they are very helpful in giving insight into the quantum phenomena of multibody solid state physics, which in their case are not disturbed by lattice defects, disorder or strong thermal fluctuations. The theoretical description will be based on the quantum rotors approach. This method is based on the use of phase variables - degrees of freedom naturally appearing in these systems - and allows for a universal description of the phenomena appearing in the ultracold atoms in optical lattices. It goes beyond the mean-field approximation, properly describing phase transitions between low temperature ordered and unordered phases depending on the dimensionality, lattice geometry and taking into account additional modifying factors such as the gauge potentials of "artificial" magnetic fields. The areas of interest will include investigation of quasiparticle excitations in bands with trivial and non-trivial topology, transport properties in lattices with restricted geometry, in presence of gauge potentials, analysis of role of dissipation in creation and nature of ordered states.

Additional information: The PhD scholarship will be financed by the PRELUDIUM BIS 2 project (DEC-2020/39/O/ST3/01148) for 48 months (planned cost in the project is 5000 PLN/month before mid-term evaluation and 6000 PLN/month after it). In order to select a doctoral student in the project, a competition will be held in parallel with the recruitment to WSD IPAN. Candidates expressing interest in the project should attach to their application to the WSD IPAN an application for participation in the competition as well as any information indicating their suitability for the competition (the competition will assess competencies to implement the topic of the doctoral dissertation and the candidate's academic achievements, including publications in reputable scientific journals).

Biology

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

Subject: ***Bactericidal phage proteins – designing chimeric enzymes with dual activity***

Description: Creation of a platform of phage-based chimeric proteins (CHP), which are a combination of two enzymes active against pathogenic bacteria. In general, in the case of the ESKAPE group of pathogens, the CHP will possess exopolysaccharide degrading activity and paving the way for the second protein to destroy the bacterial cell. The concept includes characterization of the phage protein with proven bactericidal activity and noted as a protein with unknown function in the genome database and development of antibacterial proteins with synergistic activity and improved efficacy. 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.

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

Subject: ***Relationship between gregariousness and human immunity***

Description: The classic immune system is one of the adaptations evolved to protect individuals from pathogens. Another defence system against pathogens is behavioural immunity which includes behavioural and psychological responses that minimize the risk of infection. Both systems are tightly intertwined although the nature of their relationship is poorly understood. Recent evidence shows that behavioural protection from pathogens and classic immunity may influence in-person interactions which could be important in the context of infectious disease epidemiology. The planned project aims to determine the extent to which behavioural and classic immune attributes are related to gregariousness and the position of an individual in proximity networks among school children.
The study methods will include questionnaires, data acquisition from proximity sensors, collection of blood samples for laboratory analyses (standard blood profiles) and statistical modelling. The results of the study will broaden our knowledge regarding the link between immune protection and social integration as well as allow to design more effective monitoring techniques of disease transmission in closed environments.

Supervisor: Krystyna Dąbrowska, prof. (krystyna.dabrowska@hirszfeld.pl)

Subject: ***Identification of interactions between phage-derived proteins and mammalian host immunity.***

Description: Bacteriophages (phages) are viruses that can kill bacteria, including those bacteria that infect and endanger humans. We know phage biology, however exact functions of phage genes have not been discovered yet in many cases. These genes are so-called "phage dark matter" and they probably mediate many important functions of phage. These functions are often difficult to identify since they are not self-evident: they may relate to how phage interacts with animal and human organisms, even though phage is a bacterial virus, not able to infect animal or humans. However, not able to infect does not necessary mean not able to interact with. The goal of this project is to find out how and why our immune system responds to proteins produced by bacteriophages, with special regard to the proteins that belong to the phage-derived dark matter. Significance of this problem results directly from the problem of drug-resistant infections. In the EU alone, more than 25 000 patients die from infections by multidrug-resistant bacteria every year. This problem has even been called the threat of a return to the pre-antibiotic era. Antibiotic-resistant bacteria can be sensitive to phage-derived products since cross-resistance is not observed. Phage-derived products are proposed as an alternative to the insufficient antibacterial drugs arsenal. Moreover, phages belong to microorganisms that are omnipresent in our environment and inside our bodies together with beneficial bacteria. It means that we all are constantly exposed to various phages and our bodies are exposed to interactions with these viruses.

This project starts with a high-throughput assay that allows for complete screening of all proteins, including the "dark matter" of representative bacteriophages of various types. Responses of mammalian cell lines to these proteins will be investigated. This will allow for selection for the active proteins. Also, typical complexes of phage proteins with bacterial products (as produced when a phage lyses a bacterium) will be investigated. Further, identified active phage products, either those stimulating mammalian immune system or those attenuating ones, will be studied in complex assays allowing for understanding how and why they are able to exert their effects on the cells.

As a result, new functions of bacterial viruses (phages) in mammals will be discovered and described. This will explain yet unknown effects of phages on our health (as natural the part of natural microflora) and will enhance safety and efficacy of phages when used as antibacterials in treatment of difficult bacterial infections.

Approach&Methodology: phage protein arrays (protein expression systems), screening active phage proteins in reporter cell lines (high throughput reporter systems), cellular response of mammalian cells to active phage proteins, testing of active phage proteins on model infection in vitro and in vivo, pattern-recognition receptors (PRRs) hunting, intracellular pathways responsive to phage proteins identification (RNAseq and knock-out cells and in vivo models).

Supervisor: Andrzej Gamian, prof. **(andrzej.gamian@hirszfeld.pl)**

Subject: ***Structural studies of a new advanced glycation end product (AGE) present in human tissues.***

Description: Advanced glycation end products (AGEs) are combinations of proteins with sugars and aldehyde metabolites. They occur in a large number for example in diabetes mellitus and are also supplied with food. In a high level the AGE are pro-inflammatory factor. Monoclonal antibodies to these products recognize a hitherto unidentified antigen present in human tissues, including cancer [Sci Rep. 2021 Feb 3;11(1):2940]. The task is to identify the structures present in the cells recognized by monoclonal antibodies by SEM and TEM electron microscopy. The work will also concern the separation and purification of AGE, and then structural investigation using mass spectrometry and NMR spectroscopic methods. The research methodology mainly includes glycobiology, immunochemical, cell biology, electron microscopy techniques. The research is important for understanding the basic cellular processes and will be used in the immunohistochemical diagnosis of diseases, including cancer.

Supervisor: Tomasz Goszczyński, D.Sc. (dr hab.) (tomasz.goszczynski@hirszfeld.pl)

Subject: ***Novel antimicrobials derived from metallacarborane structures.***

Description: Boron can create extraordinary, three-dimensional, σ-aromatic structures called boron clusters. These unusual entities differ from compounds formed by other elements of the periodic table and are absent in biological systems. Therefore, living organisms have not developed mechanisms capable of metabolizing boron clusters. These properties create wide possibilities for the application of boron clusters in biological chemistry for the synthesis of new biologically active compounds. Studies on the properties of these compounds may create a source of new substances with anticancer and antibacterial properties.
In the Laboratory of Biomedical Chemistry, we have studied a special subgroup of boron clusters – metallacarboranes. Many of the metallacarborane derivatives obtained in our laboratory show high antimicrobial activity.
The main research topic will be the synthesis of novel derivatives of metallacarboranes and the study of their interactions with bacteria and fungi to gain insight into structural motives favorable for antibacterial activities.
The presented topic is interdisciplinary - candidates will gain knowledge and skills in the field of chemistry, biochemistry, and microbiology.

Supervisor: Mariola Paściak, D.Sc. (dr hab.) (mariola.pasciak @hirszfeld.pl)

Subject: ***Immunomodulatory potential of Mycobacterium bovis BCG lipid antigens.***

Description: The project concerns studies of cell fractions and isolated lipid compounds of Mycobacterium bovis BCG strain. BCG vaccine contain live attenuated mycobacteria and is used both for the prevention of tuberculosis and in immunotherapy of bladder cancer. Intravesical administration of the BCG is associated with many side effects such as possible systemic infections or sepsis, and a large number of patients do not complete the entire course of therapy. The aim of the project is to obtain various cell fractions of the BCG, to create a preparation that does not contain live bacteria, but only their components/extracts; thorough examination of their chemical composition and biological activities, obtaining the most effective cell fraction or antigens with potential to replace the whole-cell BCG vaccine. The methodology will be based on microbiological, chromatographic, and cell culture methods. The biological activity tests will be performed in in vitro experiments using bladder cancer cells.

Additional information: Project for highly motivated PhD students.

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

Subject: ***Characterization of the orphan histidine kinase CpkM from the Streptomyces coelicolor A3(2) coelimycin synthase gene cluster.***

Description: The proposed study of the orphan histidine kinase CpkM will continue an ongoing topic in our laboratory on the regulation of coelimycin polyketide synthesis in *S. coelicolor* A3(2). We have shown that the *cpkM* gene encoding a histidine kinase is an element of an intricate system regulating the synthesis of coelimycin and other secondary metabolites (doi: 10.3389/fmicb.2021.616050). Preliminary studies conducted in our laboratory confirm the association of CpkM kinase with coelimycin synthesis.
The research hypothesis is that CpkM kinase is part of a signalling pathway that links coelimycin synthesis to environmental signals. This aspect of secondary metabolite synthesis regulation in *Streptomyces* is poorly understood. Gaining knowledge of the effects of environmental factors on the regulatory cascades of secondary metabolite synthesis will significantly facilitate the search for new potentially valuable compounds such as antibiotics or immunomodulators.

Supervisor: Andrzej Rapak, D.Sc. (dr hab.) (andrzej.rapak @hirszfeld.pl)

Subject: ***Immunotherapy of canine haematological disease with the use of NK cells modified with specific antibodies.***

Description: NK cells are important effector cells in antibody dependent cellular cytotoxicity ADCC, a mechanism that in humans accounts for most of the anti-tumor effect of mAbs. This process is mediated by CD16 receptor on NK cells that must be first induced by certain interleukins or another pharmacological inductors.
Recently our laboratory established a new canine NK-type cell line (CNK-89) and checked its phenotypic and cytotoxic properties. We also developed two monoclonal antibodies B5 and E11 recognized DLA-DR antigen on canine malignant lymphoid cells.
The project involves studying the induction of CD16 receptor expression, testing the cytotoxicity of modified NK cells in vitro on canine lymphoma and leukemia cells, and in vivo on a mouse model. The methodological part will include cell culture and treatment, PCR, Western blot, ELISA and FACS analysis as well as in vivo experiments.
The obtained results may contribute to the development of effective immunotherapy and the elucidation of the mechanism of CD16 receptor activation and the induction of apoptosis in target cells.

Supervisor: Jacek Rybka, D.Sc. (dr hab.) (jacek.rybka@hirszfeld.pl)
Auxiliary Supervisor: Paweł Migdał, dr

Subject: ***Immune and antimicrobial responses in honeybee larvae after stimulation with plant-derived compounds with immunomodulatory effects.***

Description This study addresses the problem of immunological and antibacterial resistance of honeybee (*Apis mellifera*), which is becoming the civilization problem for the entire human population. Immune and antimicrobial responses of honeybee larvae will be tested after the stimulation with various plant-derived compounds, which possess the immunomodulatory activity. Also, the model of bacterial infection of the larvae will be used during the study. The immunological and antibacterial response will be studied using the analysis of produced antimicrobial peptides (AMP), the expression of AMP production genes and other genes involved in antibacterial response, biochemical analysis of antioxidant and detoxification pathways and also analysis of other potential effects of stimulation. The project involves the techniques of molecular biology, immunology, microbiology, biochemistry and mass spectrometry.

Supervisor: Joanna Wietrzyk, prof. (joanna.wietrzyk @hirszfeld.pl)
Auxiliary Supervisor: Magdalena Milczarek, dr

Subject The significance of heat shock protein 90 in calcitriol and tacalcitol anticancer activity against colorectal cancer cells.

Description: Little is known about the role of heat shock protein 90 (Hsp90) in vitamin D receptor (VDR) function in the context of anticancer properties. But there is evidence that low Hsp90β expression or activation reduces the calcitriol-mediated *CYP24* gene expression because the VDR present in the nucleus is ineffectual as a ligand-activated transcription factor. Possibly the Hsp90 plays a role in VDR-VDRE binding. On the other hand, after chronic exposure of colorectal cancer (CRC) cells to 5-FU, the expression and activation of Hsp90 protein increases and consequently leads to the induction of thymidylate synthase (TS) expression and thus acquisition of resistance to 5-fluorouracil (5-FU) by CRC cells. The purpose of this research is to determine the influence of Hsp90 on VDR action at various steps in vitamin D_3 derivative-mediated signalling, including VDR ligand-binding, translocation to the nucleus, and recruitment of members of the transcriptional machinery as well as to explain whether the increased expression and activity of Hsp90 following 5-FU treatment could enhance the sensitivity of CRC cells to vitamin D_3 derivatives (VDDs).
The research will include the evaluation of the sensitivity of CRC cell lines to VDDs with regard to the expression level and activity of Hsp90 protein (*in vitro*). The determination of the significance of VDR interaction with Hsp90 in the context of anticancer activity: VDR/Hsp90 complex formation, VDR translocation to the nucleus, and VDR activity as a ligand-activated transcription factor. The evaluation of the responsiveness of 5-FU-resistant CRC cells to VDDs (*in vitro* and *in vivo*).