Title of PhD project:

Fabrication of hybrid biopolymer coatings on the surface of porous titanium- and zirconium-based materials obtained by powder metallurgy for medical applications

The leading unit: University of Silesia in Katowice

Requirements:

1. Master of Science in Engineering in the field of Materials Engineering, Biomedical Engineering, or a related discipline.
2. Substantive Requirements:
    a. Comprehensive knowledge of biomaterials, their fabrication, and selection methods based on the functions they will perform in the body. Specifically, knowledge of metallic biomaterials based on titanium and zirconium, surface modification, and functionalization methods.
    b. Experience in the fabrication of metallic biomaterials using powder metallurgy technology, as well as thermal and mechanical processing.
    c. Knowledge of the method of electrophoretic deposition (EPD) coatings:
        i. Understanding of the principles and techniques of the method.
        ii. Experience in preparing suspensions and electrodes for the electrophoretic deposition process.
3. Knowledge of Research Methods:
    a. Scanning Electron Microscopy (SEM):
        i. Proficiency in operating a scanning electron microscope.
        ii. Ability to analyze images and interpret results regarding surface structure and material microstructure.
    b. X-ray Diffraction (XRD):
        i. Understanding of the basics of X-ray diffraction.
        ii. Ability to interpret diffractograms and identify phases in the studied materials.
    c. Fourier Transform Infrared Spectroscopy (FTIR):
        i. Knowledge of the principles of FTIR spectroscopy.

ul. Będzińska 60
41-200 Sosnowiec
tel. +48 32 368 93 80
polarknow@us.edu.pl
www.mssd.us.edu.pl

   ii. Ability to prepare samples and interpret results in the context of identifying chemical groups and compounds in the studied materials.
  d. Optical Microscopy:
   i. Ability to work with optical microscopes and prepare samples.
   ii. Proficiency in image analysis and evaluation of microstructure and material surfaces.
  e. Mechanical Properties Testing Techniques:
   i. Hardness tests, tensile strength, compression, and bending.
   ii. Ability to interpret mechanical test results in the context of biomaterial properties.
  f. Tribological Studies:
   i. Operation of tribometers for friction and wear testing.
   ii. Measurement of surface roughness and topography.
   iii. Hardness testing techniques (microhardness tester).
   iv. Scratch test.
   v. Ability to analyze obtained results.
  g. Biological and Biocompatibility Tests:
   i. Knowledge of basic in vitro and in vivo tests assessing the biocompatibility of biomaterials.
   ii. Understanding of material-tissue interactions.
4. Additional Skills:
  a. Ability to critically analyze research results and interpret them in the context of dissertation objectives.
  b. Ability to conduct scientific research:
   i. Experience in designing experiments, data collection, and analysis.
   ii. Ability to write scientific reports, articles, and present findings at conferences.
  c. Technical and laboratory competencies:
   i. Proficiency in handling research equipment and conducting laboratory experiments.
   ii. Proficiency in using data processing software (e.g., Origin, Microsoft Office suite, ImageJ).

ul. Będzińska 60
41-200 Sosnowiec
tel. +48 32 368 93 80
polarknow@us.edu.pl
www.mssd.us.edu.pl

5. Achievements: Awards, distinctions, participation in thematic conferences, publications in scientific journals, etc.
6. Fluent knowledge of English (both spoken and written).

Tasks description:

1. Determination of technological conditions and fabrication of titanium- and zirconium-based materials with varying degrees of porosity using powder metallurgy.
2. Determination of the conditions for obtaining natural polymer coatings on the surface of porous titanium- and zirconium-based materials using the electrophoretic deposition method.
3. Formation of hybrid coatings enriched with active particles, drugs stimulating tissue growth or reducing inflammation, and other substances supporting implant integration. Determination of their impact on the quality of the obtained coatings.
4. Analysis of the phase composition and structure of the obtained materials using X-ray diffraction.
5. Characterization of the microstructure of samples at various production stages using microscopic methods (OM, SEM).
6. Conducting tribological tests, roughness measurement, and adhesion evaluation of the obtained hybrid biopolymer coatings. Determination of the microhardness of the obtained biomaterials.
7. Assessment of the cytotoxicity of the fabricated biomaterials.
8. Conducting biological studies to determine the capability of the fabricated coatings to support osteoblast proliferation and morphology formation.
9. Evaluation of the bactericidal properties of the fabricated hybrid biopolymer coatings on the surface of porous materials.
10. Determination of the degradation time of the coatings and, consequently, the release time of particles/drugs in the human body environment.
11. Data analysis.
12. Preparation of scientific publications and conference presentations.
13. Regular reporting of work progress.

Summary of a doctoral project:

ul. Będzińska 60
41-200 Sosnowiec
tel. +48 32 368 93 80
polarknow@us.edu.pl
www.mssd.us.edu.pl

The demand for new materials for medical implantology applications increases yearly. The advancement of modern medicine extends the average human lifespan, which is associated with an increase in bone fragility due to age-related demineralization and a higher incidence of dental defects. The significant progress in medicine and implantology now allows for the proper fixation of broken bones and the replacement of their missing fragments. However, it is important to remember that each implantation is accompanied by inflammation, which can lead to implant rejection. Additionally, inappropriate materials used in implants can result in metallosis (metal poisoning) or the resorption of the surrounding tissue. The task of today's scientists is to develop optimal bioactive materials that exhibit high biocompatibility, which means high corrosion resistance and suitable mechanical properties. To date, non-metallic materials meeting the required technological and strength criteria have not been developed, hence, implants are still entirely or partially made of metals or metal alloys. The most promising group of metallic implant materials includes those with osseointegration properties, such as titanium and its alloys or zirconium. Surface modification of metallic biomaterials can significantly enhance their biocompatibility and bioactivity. The proposed method of coating a metallic implant made of porous titanium- or zirconium-based material with special hybrid bioactive coatings based on natural polymers incorporating tissue-forming, antibacterial, and/or antithrombotic substances aligns with the latest research trends aimed at ensuring optimal properties of new biomaterials. Importantly, due to the nature of the base material, the proposed coatings are biodegradable, meaning they disintegrate after fulfilling their function, and bioresorbable, meaning they are absorbed by the body. The main objective of the proposed research is to obtain and develop a method for depositing coatings that enhance the biocompatibility and bioactivity of porous titanium- or zirconium-based implants. This research will produce titanium- and zirconium-based materials with varying porosity degrees using powder metallurgy. The study will attempt to electrophoretically deposit natural biopolymer coatings on the porous substrate (chitosan, alginate, hyaluronic acid coatings), which, due to their properties and low toxicity to the human body, will increase the biocompatibility and bioactivity of the surface of the studied alloy. These polymers are attractive materials widely used in tissue engineering as dressings, drug delivery systems, or as biocompatible coatings. Chitosan is known for its antibacterial and antifungal properties. Additionally, the presence of chitosan promotes bone regeneration. Alginate has immunogenic properties and positively influences cytokine production. Hyaluronan, as a

ul. Będzińska 60
41-200 Sosnowiec
tel. +48 32 368 93 80
polarknow@us.edu.pl
www.mssd.us.edu.pl

component of the extracellular matrix, plays a major role in every phase of the healing process, stimulating cellular migration, differentiation, and proliferation. In the project's first stage, conditions for obtaining coatings with different structures, morphologies, and thicknesses will be optimized. This will enable the formation of hybrid coatings enriched with nanoparticles (ZnO, SnO_2), antithrombotic drugs, anti-inflammatory drugs (heparin, ibuprofen, chlorhexidine), and tissue growth-stimulating substances (bioglass 45S5, calcium orthophosphate - $Ca_3(PO_4)_2$) through co-electrophoretic deposition in the later stages of the project. The properties of the obtained coatings can be modified as needed, depending on the characteristics of the polymer matrix type and the composite components. The phase composition and structure of the obtained coatings will be determined during the research using X-ray structural analysis. Fourier transform infrared spectroscopy will be used to identify the functional groups characteristic of the deposited coatings. Microscopic analysis (SEM, AFM) will allow the determination of the deposited coatings' morphology, thickness, and uniformity. Mechanical and tribological properties of the obtained coatings will also be studied to determine their adhesion and wear resistance. Biological studies will be conducted, including the assessment of the cytotoxicity and bactericidal properties of the obtained coatings. The release kinetics of drugs embedded in the biopolymer coatings will also be analyzed.

Other information:

The work will be carried out under the supervision of Assoc. Prof. Grzegorz Dercz,
e-mail: grzegorz.dercz@us.edu.pl Institute of Materials Engineering, University of Silesia in Katowice

The Secretary of the IEDS Recruitment Committee: +48 32 3689 380, e-mail: polarknow@us.edu.pl
Information on the IEDS admissions: https://www.mssd.us.edu.pl/en/admission-2024-2025/