Międzynarodowa Środowiskowa Szkoła Doktorska
przy Centrum Studiów Polarnych
w Uniwersytecie Śląskim w Katowicach

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Title of PhD project:

Development of new multi-component Zr-Nb-Mo alloys for medical applications with improved corrosion resistance produced by powder metallurgy and arc melting methods

The leading unit:

Institute of Materials Engineering, Faculty of Science and Technology, University of Silesia

Requirements:

1. Master of Engineering degree in materials science, biomedical engineering or related field.
2. Fluency in English (oral and written).
3. Very good proficiency in:
   a. materials based on biocompatible elements, in particular zirconium and zirconium alloys for medical applications,
   b. knowledge and ability to use the arc melting and powder metallurgy methods,
   c. knowledge and ability to plan and carry out experiments on zirconium-based materials,
   d. knowledge of techniques to study the microstructure and phase composition of materials, such as X-ray diffraction, scanning electron microscopy, optical microscopy,
   e. knowledge of techniques for the examination of material's mechanical properties, microhardness, reduced elasticity modulus, etc.,
4. Achievements: awards, prizes, participation in thematic conferences, publications in scientific journals, etc.

Tasks description:

1. Determination of technological conditions and production of Zr-Nb-Mo alloys by arc melting.
2. Investigation of the effect of chemical composition and parameters of the preparation process on the possibility of obtaining solid metallic alloys

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3. Analysis of the phase composition and structure of the materials using X-ray diffraction.
4. Characterisation by microscopic methods (OM, SEM) of the microstructure of samples at different stages of production.
5. Analysis of phase composition and atomic structure carried out using transmission electron microscopy for selected samples.
6. Study of the mechanical properties (i.e. static compression tests) of the materials obtained, as well as in micro and nano areas (i.e. nanoindentation). Comparison of the mechanical properties of the obtained materials.
7. Electrochemical characterisation of the materials conducted using electrochemical impedance spectroscopy in simulated physiological solutions (i.e. Tyrode's solution, Ringer's solution, artificial saliva).
8. Osteoconductivity and cytotoxicity characterisation of samples. Biological analysis determining the ability of the produced coatings to osteoblast's proliferation and morphology.
9. Data analysis.
10. Preparation of scientific publications and conference presentations.
11. Systematic reports on the work progress.

Summary of a doctoral project:

The steadily increasing demand for new medical solutions, poses a challenge to engineering science in terms of investigating innovative materials. The global market for dental and orthopaedic implants is characterised by a growing trend, both for human and veterinary medicine. However, the metallic biomaterials currently in use are marked by two main disadvantages: potentially harmful wear products and an inadequate biomechanics compared to bone. The associated risk of diseases, such as metallosis or osteopenia, promotes further research into metals with potentially better properties, also characterised by bioactivity to support implant's integration with surrounding tissues. Therefore the cooperation between materials engineering and medicine shares a common goal – improving patients' quality of life.

The main of objective of the doctoral thesis is to produce new alloys from the Zr-Nb-Mo system with high application potential in medicine, by combining powder metallurgy and

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arc melting methods of production. The designed new alloys should be characterised by improved corrosion resistance and optimised mechanical performance, as close as possible to the requirements for innovative biomaterials for orthopaedic and dental applications. The conducted studies will allow to determine the influence of the content of individual elements and the technological processes used on the structure, physicochemical, mechanical, tribological and corrosion properties of the obtained alloys. Moreover, this approach directly translates into the potential for their further modification, both material and surface, as well as heat-treatment or thermomechanical processing for potential use in the medical industry. Importantly, the materials planned in the project belong to a new titanium-free group of metallic alloys for potential use in personalized medicine as well.

Based on the literature review, it can be concluded that the proposed alloys are a novelty, and that Zr-based materials exhibit a number of interesting properties, demonstrating their high application potential. The ongoing research shows that Zr, Nb and Mo are non-toxic and do not pose a risk of causing adverse effects on human body. The emphasis should be put on the interesting biological properties, bioactivity, and high corrosion resistance of oxides based on used elements, Zr and Nb in particular. The implementation of the proposed doctoral thesis may provide a basis for further research on the production of biologically inert coatings on a metallic substrate composed of Zr, Nb and Mo.

The planned scope of fundamental research within the doctoral thesis will cover the preliminary characterisation of the obtained alloys, including their chemical composition, methods of preparation and further processing. The research will include microstructure analysis using scanning electron microscopy (SEM). Qualitative and quantitative phase analysis by X-ray diffraction (XRD) techniques will be carried out to determine the phase composition of the alloys. Using transmission electron microscopy (TEM), the real atomic structure will be assessed. Analysis of the chemical composition, including the distribution of elements in the areas of the material, will be carried out using energy dispersive spectroscopy - SEM-EDS and TEM-EDS. The mechanical parameters of the alloys will also be characterised. The scope of the planned research includes evaluation of the theoretical wear of the materials, which will be supported by corrosion resistance studies, as well as tribological tests. Biological tests are also planned.

The expected outcome of the doctoral thesis is to obtain new materials with improved corrosion resistance and superior mechanical properties using powder metallurgy and arc

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melting methods, as well as heat treatment processes. It is expected that, based on the achieved results, materials with the highest application potential for the medical industry will be identified, promoting further modifications to obtain the biomaterial of the best quality. Conclusions resulting from the doctoral thesis will compile the structures and properties mentioned above for the various chemical compositions of alloys prepared by using powder metallurgy and arc melting, leading to the preparation of a catalogue of alloys based on Zr, Nb and Mo.

Other information:

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

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