Application form for research topics in the field of engineering and technology for candidates to the Doctoral School in the academic year 2025/2026

Proposed subject matter of a doctorate
New coatings improving tribological properties and corrosion resistance of metal alloys for medical applications
Scientific discipline
MECHANICAL ENGINEERING
Proposed doctoral thesis supervisor
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Brief description of the research topics with an indication of the scientific issues (max. 350 words)
The aim of the proposed work is to determine the impact of vacuum-plasma surface treatment selected alloys for medical applications, on their mechanical and tribological properties corrosion resistance in the environment of body fluids. The objects of interest are materials currently used to produce dental implants. The available ones were selected from research market medical steels (e.g. austenitic steel 316L) and cobalt-based alloys (e.g. CoCrMo: F 75; ISO 5832-4). These materials show high biotolerance and good physicochemical properties the ability to passivate, i.e. create a sealing oxide layer [1]. However, in the dynamic conditions elements/implants are exposed to fatigue processes and tribocorrosion wear leading to damage to the passive layer, which limits their durability [2]. Improving the durability of medical alloys is achieved by modifying their surface (surface processing). Among the solutions currently used, we can distinguish low-temperature ones like plasma carburizing [3] and deposition of protective coatings [4]. As part of this work, selected materials (316L steel and CoCrMo alloy) will be coated with FeCrNiC/a-C and CoCrMoC/a-C coatings, respectively. The coatings with different carbon content, including amorphous carbon (a-C), will be tested. Synthesis/deposition processes of the above mentioned coatings will be carried out using high-power pulsed magnetron sputtering method - HiPIMS (High Power Impulse Magnetron Sputtering). This method guarantees obtaining a carbon deposit free from bound hydrogen, the presence of which could affect the physicochemical properties of the surface. The planned research aims to determine: - mechanical and tribological properties of alloy/coating systems (microhardness, adhesion, crack resistance, dry friction coefficient in relation to selected counter-samples), - the impact of surface treatment (deposition of protective coatings) on physicochemical properties (contact angle, surface energy) and corrosion and tribocorrosion resistance of these materials in the environment of selected synthetic body fluids. Assessment of corrosion resistance will be performed

using electrochemical polarization methods and electrochemical impedance spectroscopy.
During tribocorrosion tests, simultaneous recording of electrochemical parameters and friction coefficient is planned.
Additional structural tests and microscopic observations of the modified biomaterials are planned It will facilitate the interpretation of the results of corrosion and tribocorrosion tests.

List of literature: [1] E.R. Axente et al., Tribology International 174 (2022) 107769.

[2] S. Saha et al., Wear 523 (2023) 204755.

[3] C. Liu et al., Electrochemica Acta 241 (2017) 331-340.

[4] E. Dobruchowska et al., Surface and Coatings Technology 460 (2023) 129398.

Justification of the purposefulness of taking up the research topics (max. 150 words)

The proposed topic concerns a broad trend of research on nanocomposites of metals/transition metal carbides in an amorphous carbon matrix, including coatings containing elements with high (e.g. Cr, Mo) and low (e.g. Fe, Co, Ni) affinity for carbon, obtained using the HiPIMS method. It is assumed that developed procedures for the synthesis of FeCrNiC/a-C and CoCrMoC/a-C coatings and results of research conducted will constitute the scientific basis for the design and production of coatings increasing the corrosion resistance of medical alloys. Prospectively, the results obtained should prove helpful in predicting the durability of orthodontic implants.

Proposed topics of doctoral theses within the proposed research subject matter (up to 3 topics)

1. Tribological properties and corrosion resistance of FeCrNiC/a-C nanocomposite coatings deposited by pulsed magnetron sputtering (HiPIMS) on medical steels.

2. Tribological properties and corrosion resistance of CoCrMoC/a-C nanocomposite coatings deposited by pulsed magnetron sputtering (HiPIMS) on cobalt medical alloys.

The sources of financing of the research topics (the subject matter of currently implemented research grants financed from external sources or as part of subsidies)

Internal project. Koszalin University of Technology

Confirmation of the possibility of ensuring access to scientific apparatus and software necessary for the realization of the proposed research topics

PARTIALLY

If the answer is PARTIALLY or NONE please indicate a type of missing scientific apparatus and/or software and the sources of financing an access to them

Access to a high resolution transmission electron microscope (HRTEM), XPS spectrometer and a goniometer enabling dynamic wetting angle measurements will be provided by the units listed below in the framework of scientific cooperation:

1. Aleksander Krupkowski Institute of Metallurgy and Materials Engineering of the Polish Academy Sciences, Cracow (PL)

2. Linköping University, Thin Films Group at the Department of Physics, Chemistry and Biology, Sweden,

3. University of Gdańsk, Faculty of Mathematics, Physics and Computer Science, Institute of Physics Experimental Department of Surface Chemistry and Interfacial Phenomena

List of the supervisor's scientific achievements in the field of indicated scientific problems

A list of up to 5 major supervisor’s publications related to the proposed research topics, published in journals indexed in the Web of Science or Scopus for the period of the last 3 years (taking into account the IF Impact Factor and the MNiSW score)

1. T. Suszko, W. Gulbiński, J. Morgiel, G. Greczynski, E. Dobruchowska, P. Dłużewski, J. Lu, L. Hultman, Amorphous FeCrNi/a-C:H coatings with self-organised nanotubular structure, Scripta Materialia 136 (2017) 24-28/IF 6,0/140p.
2. T. Suszko, W. Gulbiński, E. Dobruchowska, G. Greczynski, L. Hultman, J. Morgiel, Quasi amorphous, nanostructural CoCrMoC/a-C:H coatings deposited by reactive magnetron sputtering, Surface and Coatings Technology 378 (2019) 124919/IF: 5,4/100p.
3. T. Suszko, W. Gulbiński, K. Załęski, G. Greczynski, J. Morgiel, V. Lapitskaya, Nanocolumnar, self-organised NiCrC/a-C:H thin films deposited by magnetron sputtering, Applied Surface Science 591 (2022) 153134/IF: 6,7/140p.
4. E. Dobruchowska, T. Suszko, G. Greczynski, D. Adamczewska, W. Gulbiński, Amorphous/quasi amorphous CoCrMo-C coatings for improved electrochemical properties and tribocorrosion resistance of biomedical alloys, Surface and Coatings Technology, 460 (2023) 129398/IF: 5,4/100p.

A list of research grants financed by the National Science Centre, the National Centre of Research and Development and the European Research Council for the period of the last 5 years

1. New, advanced composite anti-wear coatings on austenitic steel – project financed by the National Science Centre under the OPUS competition, no. UMO 2011/03/B/ST8/06130 (2012 2015) – project coordinator
2. Self-organised coatings on 3D substrates for Hydrogen Evolution Reaction – synthesis, nanostructure and properties, 2024/53/B/ST11/03015, coordinator in partner institution.

A list of research services provided for industry related to the proposed research topics for the period of the last 5 years

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