HABILITATION THESIS

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\- Obtaining, study of the microstructure and properties usage of magnesium based biodegradable materials -

Abstract

The habilitation thesis represents a concise presentation of the teaching and scientific research activities carried out during the period 2013–2025 in the field of materials engineering (the development and complex characterization of various types of biocompatible and biodegradable alloys based on magnesium and alloyed with calcium, zinc, manganese, gadolinium, yttrium, and zirconium). The habilitation thesis highlights the results of experimental research developed within the Department of Mechanical Engineering, Mechatronics, and Robotics – Materials Engineering group, at the Faculty of Mechanical Engineering, "Gheorghe Asachi" Technical University of Iași.

The first chapter of the habilitation thesis presents a synthesis of the specialized literature, describing introductory concepts regarding metallic biodegradable materials based on magnesium, with characteristics required for use in the medical field. The current state-of-the-art analysis highlights the evolution of biodegradable materials from their discovery to the present. The classification of magnesium-based biodegradable materials is also presented, as well as the influence of alloying elements from the perspective of microstructure, mechanical properties, corrosion resistance, and biocompatibility, through in vitro and in vivo analyses.

The second chapter of the habilitation thesis highlights the experimental results regarding the production and microstructural analysis of various types of magnesium-based biodegradable alloys. The targeted studies focused on the following alloy systems: Mg-0.5Ca-xZr/Y/Mn/Gd/Zn (x = 0.5/1/1.5/2/3 wt.%), funded by national grants. The design of biodegradable alloys was carried out in accordance with the requirements imposed by medical applications, namely microstructural analysis, mechanical properties, electrochemical analyses, and biocompatibility evaluation through in vitro and in vivo testing. The influence of various alloying elements was highlighted, and it was found that the optimal percentage of Ca is below 1 wt.%, while for the other alloying elements, the optimal percentages are below 3 wt.%, thus identifying the optimal chemical compositions for medical applications.

The third chapter of the habilitation thesis synthesizes the mechanical properties obtained by indentation testing performed on the metallic biodegradable alloys from the Mg-0.5Ca-xZr/Y/Mn/Gd/Zn (x = 0.5/1/1.5/2/3 wt.%) system. Comparative results were obtained, highlighting the apparent friction coefficient, hardness, stiffness, and elastic modulus of the experimental alloys.

The fourth chapter of the habilitation thesis presents the results of corrosion resistance evaluation through electrochemical analyses of the new magnesium-based biodegradable alloy systems in specific biological media. Corrosion zones and products resulting from the electrochemical process were highlighted, aiming to determine the degradation rate over time of the biodegradable metallic alloys.

The fifth chapter of the habilitation thesis presents the results of biocompatibility evaluation through in vitro and in vivo analyses of these magnesium-based biodegradable alloy systems, using MTT tests from culture extracts and implantations in laboratory rats.

The sixth chapter of the habilitation thesis summarizes the conclusions and proposes a plan regarding future research and development directions in the thematic area of the habilitation thesis. This plan is based on the experience accumulated in previous years during the doctoral thesis, research contracts, and the specialized events in which I participated. The

research directions are as follows: 1) identification of new coatings that will allow more rigorous control of the biodegradation process; 2) implementation of specific heat treatments to improve mechanical properties and corrosion resistance; 3) in vitro testing in a dynamic system for the study of corrosion/degradation in various simulated biological fluids, in order to determine the osmolarity and concentration of magnesium and other ions released from the base alloy or coating layer, with special interest in correlating and extrapolating in vitro results to in vivo corrosion conditions in animal or human organisms.