Inhibition of the degradation mechanisms responsible for the premature destruction of bioresorbable Mg alloys

Dr Piotr Sakiewicz, Silesian University of Technology, Gliwice, Poland (presenter)
Prof. Rafał Babilas, Silesian University of Technology, Gliwice, Poland
Prof. Ryszard Nowosielski, Silesian University of Technology, Gliwice, Poland
Prof. Krzysztof Piotrowski, Silesian University of Technology, Gliwice, Poland

Abstract

Statement of the Problem: The aim of this paper was identification of degradation mechanisms responsible for premature destruction of bioresorbable magnesium alloys - polymer composites. The $MgCa_{4,5}Gd_{0,5}$ alloys with and without polymer coatings are designed for biodegradable medical implants. The amount of evolved hydrogen and a corrosion rate of alloy and composite were compared and correlated. In general, two mechanisms were identified as responsible for premature destruction of these composites: pressure increase under the coating due to the release of significant amounts of hydrogen and systematically increasing volume of gaseous corrosion products from magnesium alloys, resulting in increased coating stress and change in original sample geometry.

In a number of studies [1-5] on the dissolution of resorbable metal orthopedic implants made of magnesium-based alloys, the problem of determining the appropriate length of maintaining the mechanical load-bearing capacity of the tested samples is encountered. The problem is to find the optimal correlation between the fulfillment of stabilizing functions and the time of dissolution in the human body fluids. Due to the relatively high rate of degradation of magnesium alloys in the body and the need to maintain permissible concentrations of elements, it is necessary to use alloy additives and/or protective coatings. The aim of the work was to identify the main degradation mechanisms responsible for the premature destruction of bioresorbable magnesium alloys and to propose some new coating responsible for inhibiting of these adverse processes. An additional aim of the study was to compare the corrosion rate and the mass/volume of hydrogen released from magnesium alloys with and without a bioresorbable polymer coating in a simulated environment of body fluids. Corrosion tests were performed in multi-electrolyte Ringer's physiological fluid. The amount of hydrogen released and the corrosion rate of the alloy and composite were compared. During the tests, it was possible to obtain a composite whose coating prolonged the degradation time, and the polymer coating itself showed resistance to such defined corrosion environment through 21 days. After this time, a significant release of large amounts of hydrogen was observed. This may be related to the loss of polymer molecular weight and reduced its strength. It should be noted that during the tests, hydrogen bubbles began to appear on the surface of the polymer coating with varying intensity. The second mechanism responsible for the destruction of the coating was the systematic formation and increase in the volume of accumulated of magnesium alloys corrosion products under the polymer coating, which resulted in an increase in stress and a change in the original geometry of the sample, causing cracking of the polymer coating. The relationship between the degradation time of the polymer and its permeability to body fluids is of key importance for the resistance to the increase in pressure under the coating as a result of the release of significant

Image

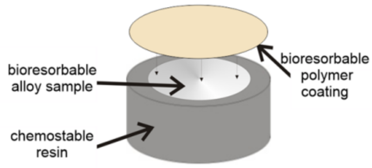

Fig. 1. Scheme of the sample for coating durability testing made of resorbable Mg alloy and protective PLA coating

Fig. 2. Samples made of $MgCa_{4.5}Gd_{0.5}$ alloy A) without coating after 2 days and with PLA coating, during immersion tests in Ringer's fluid, B) after 5 days, C) after 9 days

amounts of hydrogen and the systematically increasing corrosion of the volume of magnesium alloy products, which increases the coating stress and changes the original geometry of the sample.

Conclusion & Significance: The work identified degradation mechanisms responsible for premature degradation and destruction of biocompatible composites based on magnesium alloys and PLA polymers. By adjusting the thickness of appropriate PLA-based polymer coatings, it is possible to restrict the dissolution rate of the Mg alloy and also inhibit two mechanisms responsible for the premature failure of composites. Due to the high corrosion rate, a composite made of $MgCa_{4.5}Gd_{0.5}$ alloy and covered with PLA was selected as a reference point for testing. As a result of many tests, authors managed to extend the load-bearing time of the sample.

Recent Publications

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4. Hornberger H., Virtanen S., Boccaccini A.R., Biomedical coatings on magnesium alloys - A review. ,,Acta Biomaterialia", 2012 Vol. 8(7), 2442-2455.
5. Sakiewicz P., Piotrowski K., K., Babilas R., Simka W., et.al., Surface Modification of Biomedical MgCa4.5 and MgCa4.5Gd0.5 Alloys by Micro-Arc Oxidation. „Materials", 2021, Vol. 14(6), 1360

Photograph

Biography

Dr. Eng. Piotr Sakiewicz is a long-time practitioner and theoretician in the field of materials engineering and mechanical engineering. His interests include research in particular relationships between processes affecting the change of material properties over time and the subsequent transfer of the observed phenomena to practical commercial applications.

Email: piotr.sakiewicz@polsl.pl