DESIGN OF MICROSTRUCTURE AND DEGRADATION BEHAVIOR OF OXIDE-PARTICLE MODIFIED FE-BASED ALLOYS PROCESSED BY SELECTIVE ELECTRON BEAM MELTING

Bioresorbable iron alloys are of high in biomedical applications. However, in most cases the dissolution rate of iron-based alloys in physiological environments is to low. In this project EBM is used as for additive manufacturing of surface modified iron particles. The aim is to control mechanical properties and corrosion rates of iron allys based on the control of the dimensions and the presence or absence of oxides in the created part. The competences in the field of EBM (Thomas Niendorf, Universität Kassel), fatigue (Hans Jürgen Maier, Leibniz Universität Hannover) and interface chemistry and corrosion (Guido Grundmeier, Universität Paderborn) are joined in this project.

PROJECT OVERVIEW

DURATION

09/2018 – 08/2020

PARTNER

- Institute for material science (IfW) of Kassel University
- Institute for engineering (IW), Hannover Leibniz University
- Technical and Macromolecular Chemistry, Paderborn University

FUNDED BY

German Research Foundation (DFG)

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German Research Foundation

Objectives

Implant materials have to meet various demands. A high structural strength of both solid and filigree structures as well as tailored degradation behavior are desired. In this regard, Mg-alloys employed suffer too rapid degradation, while Fe-based systems are characterized by sluggish dissolution. The aim of this project is to significantly increase dissolution rates of Fe-alloys by design of new oxide-modified Fe-based alloys. Additive manufacturing (AM) using metal powders, e.g. the selective electron beam melting (EBM) process, allows for realization of new alloys due to unique melting- and solidification conditions prevailing in the process.

Scientific Approach

In comparison to the laser-based SLM technique, EBM is characterized by processing in vacuum atmosphere at elevated temperatures. In light of the general aims of the project, only the conditions prevailing in EBM will allow for analysis of elementary degradation mechanisms as a function of the composition of the new alloys. As is well-known, SLM processing leads to a non-defined, slight enrichment of light elements such as oxygen in the material processed as well as to the evolution of relatively high residual stresses. These factors will strongly affect initial corrosion behaviour and, thus, will impede in-depth evaluation of corrosion induced by the alloy design being in focus of the project. The material in focus of evaluation will be iron modified by different kinds of oxide particles. Initial corrosion will be analyzed in load-free and mechanically loaded structures in selected electrolytes. Based on current literature, the role of the process induced microstructure, the surface condition as well as the alloy design on mechanical and corrosive performance cannot be evaluated. Pure iron as matrix and reference, respectively, and different modifications of iron- and oxide-particles will be processed by EBM. The EBM process technology is developed by the group of Prof. Niendorf in Kassel. Oxides will be introduced differently. Firstly, micron-scale oxide particles will be incorporated by mixing of relatively large fractions of these particles with pure Fe-powder. Secondly, nano-scale oxide phases will be grown on the Fe-particle surfaces by a wet-chemical approach. Consequently, the differently processed oxide-modified powders will be variable in terms of overall oxide fraction, surface morphology and oxide-iron particle bonding. The impact of these differences on processability, microstructure evolution as well as mechanical and corrosion performance will be evaluated thoroughly. The relationships revealed will serve as basis for development of new biodegradable implants in future studies.

Outlook

The project started end of 2018. In 2019 first alloys based on surface modified iron particles will be produced and characterised.

References

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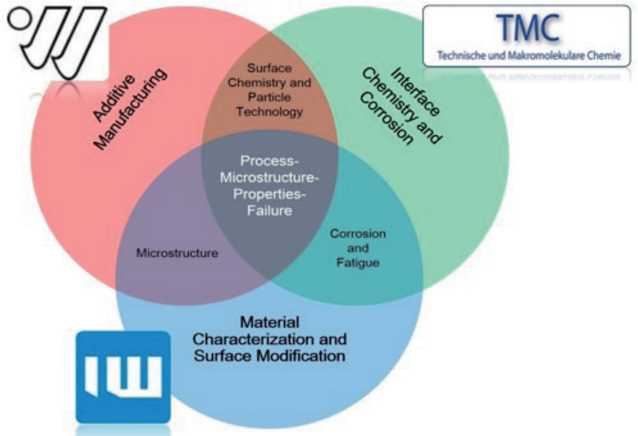

FIGURE 1 Cooperative approach

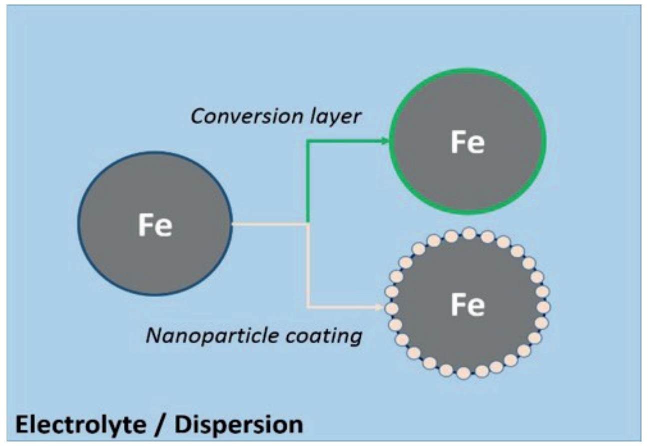

FIGURE 2 Particle surface modification stratgeies at the TMC

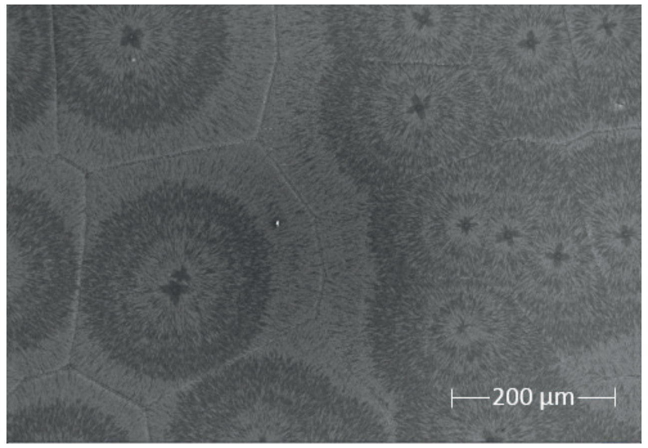

FIGURE 3 FE-SEM image of a PEG based film simulating the barrier properties of an extra cellular matrix