DEVELOPMENT AND CHARACTERIZATION OF BIODEGRADABLE FeMnAg-MATERIALS USED FOR THE SLM-PROCESS

Since bioresorbable implants are highly interesting for biomedical applications to reduce patient burden, significant efforts are ongoing to develop adjusted metal alloys. Apart from magnesium (Mg) alloys, the iron-manganese (FeMn) system is promising concerning its biocompatibility. Although Mn increases the degradation of Fe, further efforts are necessary to enhance the degradation rate. For example, silver (Ag) phases promote the cathodic dissolution of the matrix material due to their high electrochemical potential. Therefore, the development of new Ag alloys with an adapted degradation profile, are a focal point of this work. Due to the immiscibility of Fe and Ag, it is not possible to cast FeMnAgX alloys, but it is feasible to manufacture these alloys using powder-bed-based additive technologies.

PROJECT OVERVIEW

DURATION

04/2019 – 03/2021

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- University of Veterinary Medicine Hanover, Foundation (TiHo)

FUNDED BY

German Research Foundation (DFG)

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Objective

The aim of the research project is to develop and char-acterize bioresorbable FeMnAgX alloys and their qualifi-cation for additive manufacturing, specifically Laser Beam Melting (LBM). The cooperative approach includes the development, production and characterization of additively manufactured structures made of convention-ally immiscible alloys with strongly different melting points such as FeAg. Due to the potential application of resorbable implants in biomedical engineering, the bio-compatibility as well as higher degradation rates of these structures compared to pure iron alloys are of particular interest aside from consistent production.

These new and innovative alloys present novel challeng-es to process management in LBM and in the post-processing of the manufactured to some extend com-plex components. Due to the high stiffness and strength of FeMn alloys compared to the human bone, the re-quired mechanical properties are moderately. Therefore, the biocompatibility and degradation behaviour are in focus of the process adjustment. The microstructural properties, especially the distribution, including size, structure and shape of the Ag particles in the FeMn matrix, have to be adjusted to control the degradation rates. Since particles released into the tissue during the implant's degradation will be phagocytized, they must consist of a modified, biocompatible, non-corrosion-resistant Ag alloy to prevent complications, e.g. blocked blood vessels. Upon its antibacterial effect, silver is a promising candidate for the devel-opment of a degradable alloy with high electrochemical potential. Unfortunately, the extremely slow corrosion of silver needs to be increased via alloying based on the formation of interme-tallic phases or eutectica. Apart from degradable Ag alloys, further approaches are the processing of Ag coated FeMn particles to achieve fine distributed Ag phases as well as the mixture of FeMn with other de-gradable elements, like pure Fe.

Approach

Primary to the fabrication of specimens from the final FeMnAgX and FeMn-Fe alloy, the base materials (FeMn, Fe) are manufac-tured via LBM. These samples are characterized regarding their chemical composition (spark spectroscopy) and microstructure e.g. porosity (light microscopy, scanning electron microscopy, mi-cro-computertomography, X-ray-diffraction). In addition, different potentially degradable AgX alloys are conven-tionally casted and examined regarding their microstruc-ture (light microscopy, scan-ning electron microscopy, X-ray-diffraction). Furthermore, the surface chemistry of the silver-based alloys and base materials is character-ized at the Department of Technical and Macromo-lecular Chemistry (TMC) and the biocompatibility is investigated at the University of Veterinary Medicine Hanover, Foun-dation (TiHo). Corrosion tests are conducted in Ringer's lactate and modified simulated body fluid (m-SBF) solutions to identify prom-ising alloy systems and to charac-terize the corrosion properties (TMC, TiHo). As the gas-atomization of each potential AgX-alloy is to expensive, conventionally casted bulk material is taken as reference for fundamental examination. Only the AgX alloy with best chance to fulfil the requirements (biocompatibility, degrada-tion rate, processability) is casted and gas-atomized.

The gas-atomized and sieved powder of base material and AgX alloy is analyzed concerning particle size distribution (mastersizer), morphology and chemical composi-tion (scanning electron microscopy, micro-computertomography). Parallel to the alloy-design, a modification of the FeMn powder particles within the synthesis of nanoparticular Ag on the surface is addressed at the TMC. All promising alloy systems are investigated in terms of degradation behavior (ex-vivo and in-vitro), immunotoxicity and microbiological behavior at the TiHo.

Outlook

The influence of the interaction between mixed FeMn and AgX powders during LBM will be investigated. Final-ly, the biocom-patibility and degradation characteristics under conditions similar to those experienced in the human body will be examined for additively manufac-tured specimens.

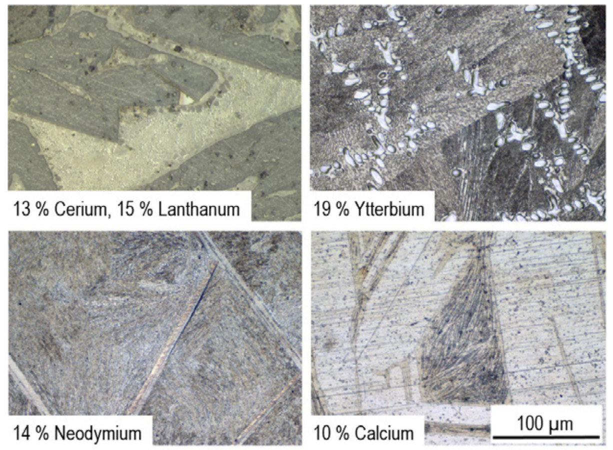

FIGURE 1 Microstructure of conventionally casted degradable silver alloys (alloy content in weight percent)

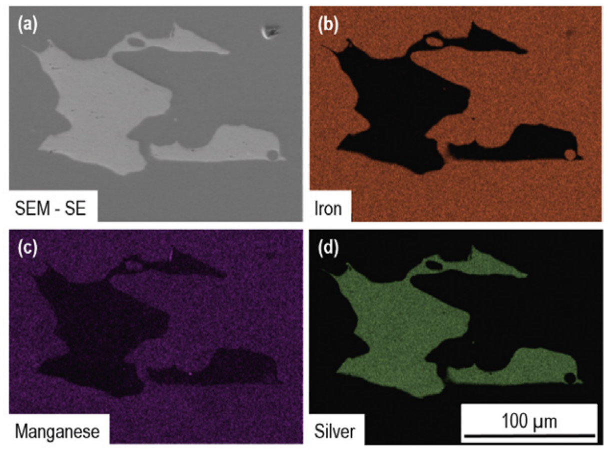

FIGURE 2 SEM-images of pure Ag particles embedded in an iron-manganese matrix (processed via LBM); SE-image (a) and EDS mapping (b)-(d)

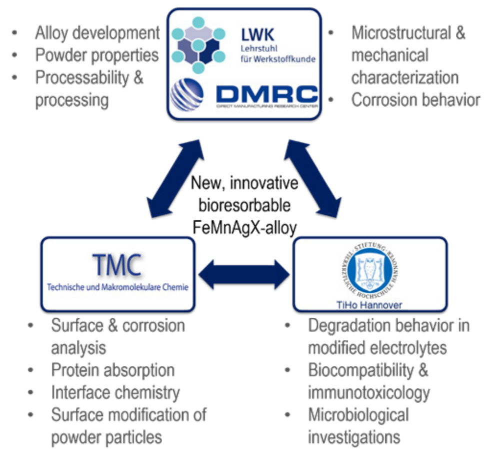

FIGURE 3 Organization and responsibilities within the DFG project