INNOVATIVE ALLOYING CONCEPTS FOR ADDITIVE MANUFACTURING

Laser Beam Melting (LBM) allows not only the cost-effective production of metal components with highly complex geometries, but also the processing of materials that cannot be produced by conventional methods such as casting. The design of new application-adapted alloys therefore enables the manufacture of intelligent products with superior properties as well as the expansion of additive production to new areas of application. The aim of the project is to establish a process chain from alloy design and powder production to material analysis and quality control.

PROJECT OVERVIEW

DURATION

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FUNDED BY

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- Ministry of Economic Affairs, Innovation, Digitalisation and Energy of the State of North Rhine-Westphalia

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Objective

One of the biggest challenges in additive manufacturing (AM) is to guarantee a high powder quality, since only a few external companies produce metallic powder for AM. Although the material and the desired powder fraction may be specified, the quantity of powder ordered is not always sufficient due to the high production costs. Furthermore, the process of the powder production itself is not necessarily prescribed and can take a long time, which limits the research activities within ongoing projects. Finally, powder producers do not guarantee the desired particle morphology, particle size distribution and precise chemical compositions – especially for light elements such as carbon. Since both, an exact chemical composition and the powder quality, i.e. particle size and morphology, have a decisive influence on the microstructural and mechanical characteristics of the additively manufactured components, research should not only focus on LBM itself, but also on powder production and characterization.

The design of new alloy concepts addresses three main scientific issues:

- Soft magnetic iron-based alloys for the additive manufacture of electric motors.
- Functionally graded materials with defined local differences in microstructure and/or chemical composition, which for example enable a reduction of the moving mass in additively manufactured electric motors.
- Innovative silver-based alloys as an additive to iron-based biodegradable components for medical purposes, which are expected to degrade at a predefined rate parallel to the dissolution of the Fe-matrix.

Soft magnetic iron-based alloys

The gas-atomization of powder with a predefined particle size of the alloy FeSi9 has been performed.
Adjusting the process parameters of LBM enabled a significant reduction in the porosity of the specimens (Figure 1). In addition, appropriate post-processing, especially heat treatment, allows the simultaneous reduction of residual stresses and adjustment of the desired grain size. The greatest challenge in processing this alloy is its high susceptibility to cracking during production. This can be explained by an excessive temperature gradient in the samples during manufacture. Therefore, investigations are ongoing to minimize the crack formation, e.g. via the reduction of the laser power and the use of a space heater.

Functionally graded materials

The processability of the functionally graded specimens made of the alloy FeSi3 (soft magnetic middle part of the rotor) and the quenched and tempered steel (Q & T steel) 34CrNiMo6 (shaft end with reduced mass compared to FeSi3) has already been confirmed. Not only cube samples, but also tensile and fatigue specimens with a density > 99.9 % have been successfully manufactured. The analysis of the microstructure shows a non-porous bond between the two materials (Figure 2a). By a subsequent heat treatment, the desired profile of mechanical properties can be adjusted, which means reducing the residual stresses in the soft magnetic alloy FeSi3 while ensuring a high ductility and strength in the Q & T steel (Figure 2b). The next step is to analyse the fatigue properties of the metal compound.

Innovative silver-based alloys

Based on the results of degradation tests (immersion tests), performed on various silver alloys containing Ca, Mg, Si, Ge and La, two alloys were selected, namely Ag-14Mg and Ag-7Ca. These alloys show a faster degradation rate than pure silver (Figure 3) and are electrochemically nobler than iron, which should allow the desired catalysis of iron-based matrix degradation in the human body. Here, the Ca content can be further increased up to 14.0 wt.-% and the Mg content up to 18.5 wt.-% in order to control the degradation process of the silver-based particles. As a next step, the selected alloys will be atomized and added to the iron-based powder. Subsequently, the specimens will be manufactured via LBM followed by an analysis of their degradation behaviour.

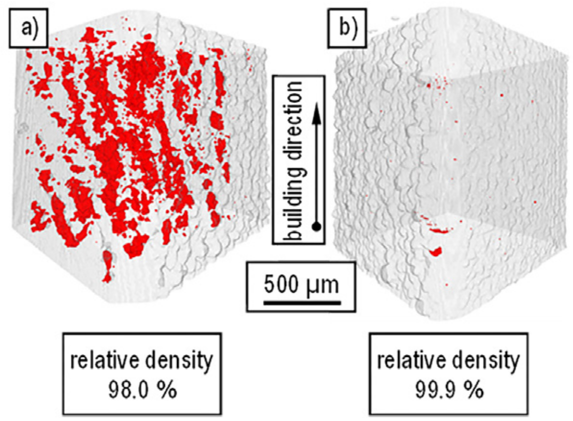

FIGURE 1 µCT-scans of specimen build with standard LBM-parameters (a) and with optimized LBM-parameters (b)

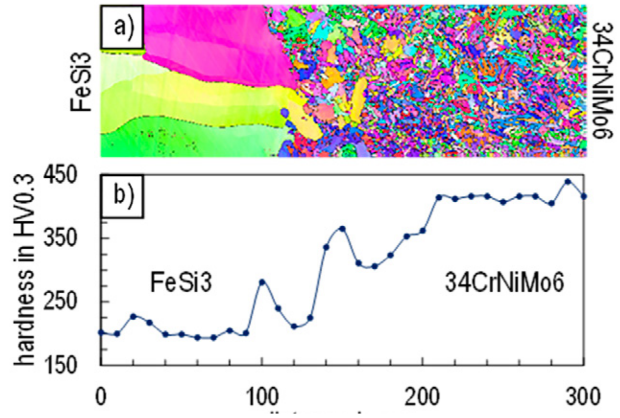

FIGURE 2 Microstructure of the interface between FeSi3 and 34CrNiMo6 in a functionally graded specimen (a) with corresponding hardness profile after heat-treatment (b)

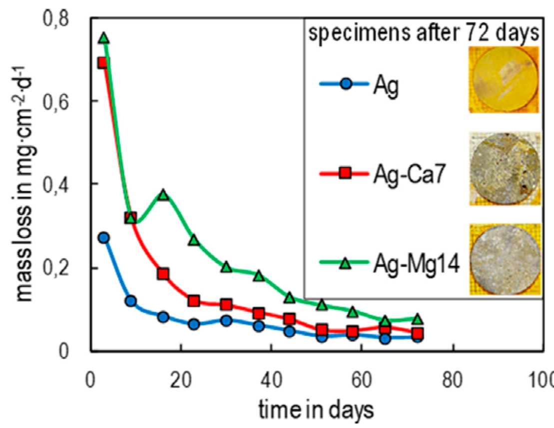

FIGURE 3 Degradation of different silver-based alloys after immersion tests