COATING OF NEAR-NET SHAPED ADDITIVELY MANUFACTURED COMPONENTS WITH BIOCOMPATIBLE PROPERTIES

The properties of additively manufactured, biomedical components made of titanium alloys coated by PVD are investigated. The focus of the investigation is on TiAl6Nb7 (α+β) and TiNb24Zr4Sn8 (β) processed by selective laser melting. Both alloys have the required mechanical properties and corrosion resistance for use as an implant. The mechanical properties, corrosion and fatigue behavior are determined by means of material analysis and mechanical characterization. The biocompatibility is increased by multilayered or graded coating systems of Ti(Zr,Hf)CN and verified by biological investigations (e.g. cell adhesion, cell culture growth or bio-film formation).

PROJECT OVERVIEW

DURATION

01/2019 – 12/2021

PARTNER

- Technical University of Dortmund, Institute of Materials Engineering (LWT)
- University of Veterinary Medicine, Hannover, Foundation (TiHo)

FUNDED BY

German Research Foundation (DFG)

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Objective

Materials used for biomedical applications, such as permanent or bioresorbable implants, see Figure 1, require adapted mechanical properties as well as biocompatible features. Titanium alloys build a passivating titanium oxide layer and therefore, have a high corrosion resistance along with an excellent biocompatibility and adequate mechanical properties. TiAl6V4 alloys are already established in biomedical engineering. Due to the addition of niobium and substitution of vanadium, the biocompatible performance of such an alloy can be enhanced. So far, the main focus of the research is on the (α+β)-type TiAl6Nb7 in comparison to TiAl6V4, so that the required properties for biomedical applications can be achieved, see Figure 2.

The aim of this research project is the analysis of the coatability of additively manufactured specimens made of TiAl6Nb7 and TiNb24Zr4Sn8 with PVD coatings. Furthermore, the influence of the coatings on the biocompatibility and fatigue behaviour of the components used as implants will be investigated.

Approach

The Chair of Materials Science (LWK) analyses the processing parameters for the additive manufacturing of TiAl6Nb7 and TiAl6V4. In addition, the LWK investigates the mechanical properties for quasi-static and for cyclic loading as well as the corrosion resistance of the alloys and coating systems. The Institute of Materials Engineering (LWT) in Dortmund examines the coating parameters and various layer architectures concerning the feasibility and the effects of the stress states of the coating. The University of Veterinary Medicine Hannover, Foundation (TiHo) inspects the influences of the coatings regarding biocompatibility, cell adhesion and biofilm formation. The collaboration between the LWK, the LWT and the TiHo is shown in Figure 3.

For manufacturing components with selective laser melting the process parameters have to be adapted for each alloy. Additively and conventionally manufactured components of both alloys, TiAl6Nb7 and TiAl6V4, are investigated and compared to provide information regarding the processability of the materials.

To analyze the microstructure optical light and scanning electron microscopy are employed, including various techniques as electron backscatter diffraction and X-ray diffraction. The microstructures of conventionally and additively processed materials influence the mechanical properties, e.g. strength and ductility. In addition, the mechanical properties are assessed by experiments under different loading conditions, for example tensile tests.

Corrosion tests are conducted in Ringer's lactate solution to identify degradation rates, promising coating systems and to characterize the corrosion properties of the alloys and coatings.

Outlook

In further researches the longterm mechanical behavior of TiAl6Nb7 and TiAl6V4 under cyclic loading will be investigated. The aim of this research project is to investigate the processability, coatability and biocompatibility of TiAl6Nb7 and TiNb24Zr4Sn8 components manufactured by laser beam melting. The correlation of the microstructure and mechanical properties as well as the influence of the adapted process parameters and coatings on the fatigue behaviour will be determined. Finally, the biocompatibility and degradation characteristics under conditions similar to those experienced in the human body are examined.

[1] The Use of Additive Manufacturing in the Custom Design of Orthopedic Implants; Marie Cronskär (2011).
[2] Medizintechnik - Life Science Engineering; Erich Wintermantel, Suk-Woo Ha (2008).

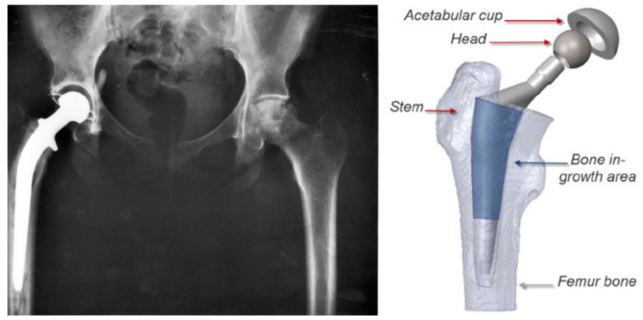

FIGURE 1 X-ray of a total hip replacement (left) and schematic overview of the different parts of an permanent implanted hip endoprosthesis (right); [1].

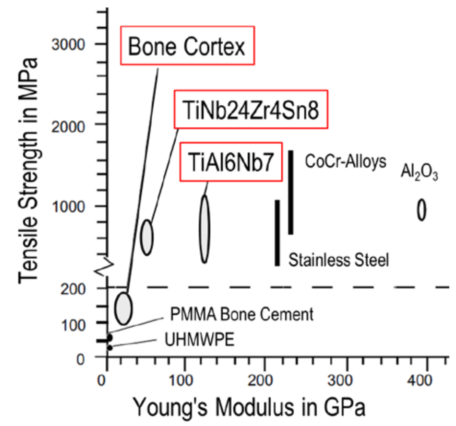

FIGURE 2 Comparison of mechanical properties of different implant materials used in hip arthroplasty and bone cortex; based on [2].

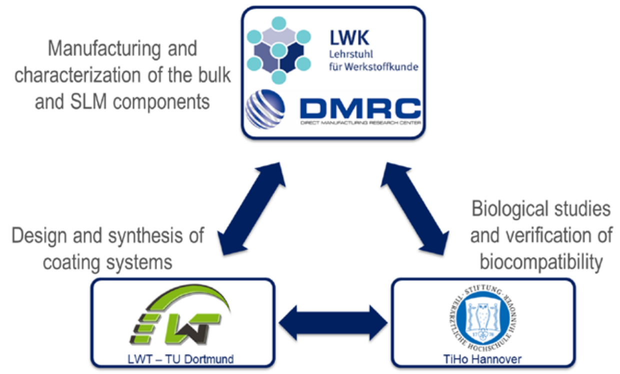

FIGURE 3 Organization and responsibilities within the DFG project