

Metastable beta-Ti-Nb alloys for load-bearing bone-implant applications

Annett Gebert¹, Stefan Pilz¹, Romy Schmidt¹, Jens Freudenberger¹, Martina Zimmermann², Mariana Calin¹

- 1- Leibniz-Institut für Festkörper- und Werkstoffforschung Dresden
- 2- Technische Universität Dresden, Institut für Werkstoffwissenschaft

Beta-Ti alloys are the promising new generation of materials for load-bearing bone implant applications substituting currently used CP-Ti and Ti6Al4V. Alloys of the metastable Ti-Nb system are particularly promising as they exhibit in the cast, solution-annealed and quenched state very low Young's modulus values of ~60 GPa (40-45wt.-% Nb), which yield a comparatively low implant stiffness contributing to the reduction of stress shielding effects. However, for optimum mechanical biofunctionality the materials strength must be increased. Appropriate thermomechanical processing strategies including warm and cold rolling as well as annealing steps were developed. Grain refinement of the beta-phase, work hardening and precipitation of secondary phases, i.e. of alpha-phase or nanosized omega-phase, are demonstrated to be effective for significantly increasing yield and tensile strength and to control a low Young's modulus [1,2]. Alternatively, powder metallurgical processing of Ti-Nb alloys was successfully applied. Hot compaction or spark plasma sintering of gas-atomized and intensively milled Ti-45Nb powder yielded fully dense samples with nanograin microstructure exhibiting very high compressive yield strength of >900 MPa and low Young's modulus ~70 GPa [3].

Ti-Nb alloys are composed of non-toxic elements and thus, are biocompatible. However, their naturally passivated surfaces are bioinert and do not enable optimum bone tissue growth. Chemical modification techniques were developed to change the morphology and the chemical nature of those alloy surfaces. Enhanced surface oxidation is possible by electrochemical anodization. In F-containing solutions self-organized layers of oxide nanotubes grow with higher aspect ratios than those on cp-Ti. Plasma electrolytic oxidation yields a two-layer structure with a thick microporous outer oxide. For both techniques the oxide growth on the beta-alloy follows the principal mechanisms that are known for Ti. Nb species cause enhanced layer thickness growth, morphology changes and mixed oxides [4].

This work is funded by the DFG as part of SFB/Transregio 79.

[1] A. Helth, S. Pilz, T. Kirsten, L. Giebeler, J. Freudenberger, M. Calin, J. Eckert, A. Gebert Effect of thermomechanical processing on the mechanical biofunctionality of a low modulus Ti-40 Nb alloy, *J. Mechan. Behav. Biomed. Mater.* 65 (2017) 137-150.

[2] S. Pilz, D. Geissler, M. Calin, J. Eckert, M. Zimmermann, J. Freudenberger, A. Gebert, Thermomechanical processing of In-containing β -type Ti-Nb alloys, *J. Mechan. Behav. Biomed. Mater.* 79 (2018) 283-291.

[3] R. Schmidt, S. Pilz, I. Lindemann, C. Damm, J. Hufenbach, A. Helth, D. Geissler, A. Hens, M. Rohnke, M. Calin, M. Zimmermann, J. Eckert, M.H. Lee, A. Gebert, Powder metallurgical processing of low modulus β -type Ti-45Nb to bulk and macro-porous compacts *Powder Technology* 322 (2017) 393-401.

[4] A. Gebert, D. Eigel, P.F. Gostin, V. Hoffmann, M. Uhlemann, A. Helth, S. Pilz, R. Schmidt, M. Calin, M. Göttlicher, M. Rohnke, J. Janek, Oxidation treatments of beta-type Ti-40Nb for biomedical use, *Surface and Coatings Technology* 302 (2016) 88-99.