Phase transformations in Ti-Nb-Zr-Ta-O beta titanium alloys with high oxygen and reduced Nb and Ta content

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Beta titanium alloys possess several attractive properties for use in load-bearing biomedical implants of large body joints, in particular the high strength combined with low Young's modulus, biocompatibility and corrosion resistance. Recently developed alloy Ti-35Nb-6Ta-7Zr-0.7O (wt. %) with high content of strengthening oxygen exhibits the high strength of 1000 MPa and the Young's modulus of 80 GPa. By reducing the content of beta stabilizing elements (Nb, Ta), the high strength of 1000 MPa is preserved due to oxygen strengthening and the Young's modulus is reduced, reaching value of approx. 60 GPa in Ti-29Nb-7Zr-0.7O (wt. %). The pure beta phase after solution treatment is retained even at these low Nb/Ta concentrations. On the other hand, the phase transformations during heating differ significantly. The ongoing phase transformations in this alloy were investigated by *in-situ* dilatometry and electrical resistance measurements as well as by ex-situ methods after linear and isothermal heating. The *ex-situ* methods include: scanning electron microscopy, microhardness measurements and X-ray diffraction. It was found, that the beta phase stability is reduced significantly by reducing the content of Nb/Ta.

The main findings of this complex experimental investigation of several Ti-Nb-(Ta)-Zr-0.7 wt%O may be summarized as follows:

- The yield strength exceeding 1000 MPa and the ductility of approx. 20% was achieved in these alloys.

- The decrease of the content of Nb and Ta resulted in the decrease of the Young's modulus from 80 GPa at Ti-35Nb-6Ta-7Zr-0.7O to 60 GPa at Ti-29Nb-7Zr-0.7O alloy.

- In-situ dilatometry and electrical resistance measurements suggest ω phase formation in less stable alloys.

- The lower phase stability leads to more homogeneous alpha precipitation at higher temperatures (700 °C).

- At lower temperatures (400 °C), no phase transformation occurs in highly stabilized alloys while in the least stable alloy, very fine α lamellae and relatively large ω particles (tens of nm) are formed. This is also accompanied by a significant microhardness increase.

- The Ti-29Nb-7Zr-0.7O alloy seems to be a suitable material for orthopaedics and implantation surgery.

Keywords: Titanium alloys, phase transitions, elastic modulus

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