EFFECT OF POWDER TYPE ON MICROSTRUCTURE AND MECHANICAL PROPERTIES OF BIOCOMPATIBLE Ti-Zr-Nb-Ta ALLOY

OLEKSANDR STASIUK[1], DENYS ORYSHYCH[1], SERHII TARAN[2]

1. G. V. Kurdyumov Institute for Metal Physics of NAS of Ukraine
2. Interregional academy of personal management, Ukraine

A biocompatible Ti-Zr-Nb-Ta alloy was produced via powder metallurgy. Using blended powders led to high porosity and undissolved Ta due to low diffusion. The pre-alloyed powder approach reduced porosity (~3%) and improved homogenization. As a result, strength reached 1053 MPa, yield strength 1005 MPa, and ductility ~16%. Pre-alloying enhances mechanical performance of titanium-based biomaterials.

Keywords: Zr-Nb-Ta alloy, powder metallurgy, pre-alloyed powder, porosity, mechanical properties

Introduction. Nowadays biocompatible Ti-Zr-Nb alloys are widely used for biomedical applications. Tantalum is the most suitable element for further alloying this system for its high biocompatibility [1]. Also, as shown in [1], the tantalum addition of a certain concentration allows to significantly reduce Young's modulus. However, at high concentrations it begins to increase. In [2], the alloy of the composition Ti-35Nb-7Zr-5Ta was presented as one of the most promising.

Method. This alloy was obtained by powder metallurgy method. It was cold pressed with further sintering at 1250 °C with isothermal holding for 4 hours.

Results. This alloy was obtained by powder metallurgy method. It was cold pressed with further sintering at 1250 °C with isothermal holding for 4 hours. During microstructure analysis (fig. 1), it was observed that the alloy is quite porous with undissolved tantalum particles, which is consistent with the results of the article [3]. Thus, in the bright spots (fig. 1) there was approximately 96.82 wt.% of this element.

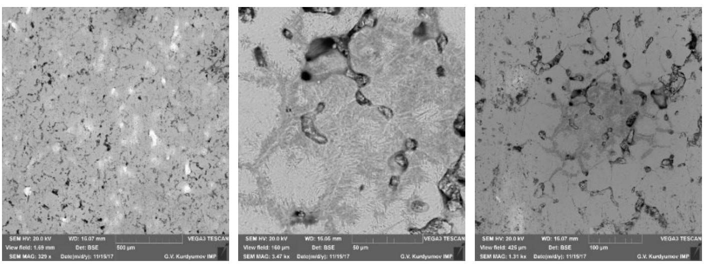

Fig.1. Ti-35Nb-7Zr-5Ta alloy after isothermal hold at 1250 °C during 4 h.

The reason may be the Frenkel effect, since tantalum is characterized by a low diffusion rate into titanium [4] which is demonstrated in Table 1. It is obvious that the rate of diffusion fluxes is so low that tantalum does not have time to dissolve in the titanium matrix.

Table 1 Diffusion velocity at 1250 °C

№	Element	Self-diffusion at 1250°C, m^2/s
1	Ti	2×10^{-12}
2	Nb	10^{-13}
3	Zr	8×10^{-13}
4	Ta	5×10^{-20}

As can be seen from the figure 2, this material has a rather low strength and very low plasticity. This is due to the significant porosity of the material.

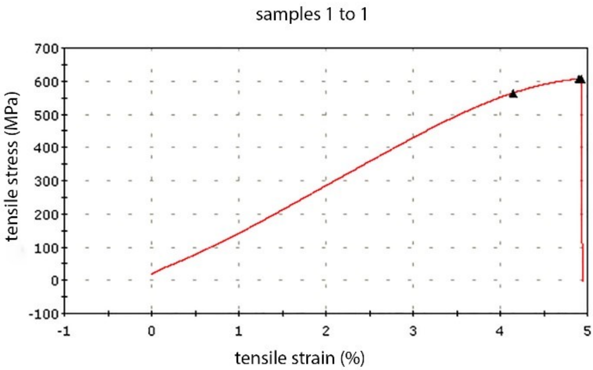

Fig. 2. Stress-strain diagram Ti-35Nb-7Zr-5Ta.

To solve the high porosity and chemical homogenization in this alloy, it was decided to use the pre-alloyed powder method. The positive effect was considered for the Ti-Zr-Nb system. As can be seen from the typical microstructures of this alloy (Fig. 3), it was possible to reduce the simplicity to ~ 3%, as well as achieve complete chemical homogenization of the alloy.

As can be seen (Fig. 4), the use of pre-alloyed materials allowed to significantly increase the mechanical properties of this material. Thus, the tensile strength reached 1020-1053 MPa with a yield strength of 990-1005 MPa, and plastic deformation was ~ 16%.

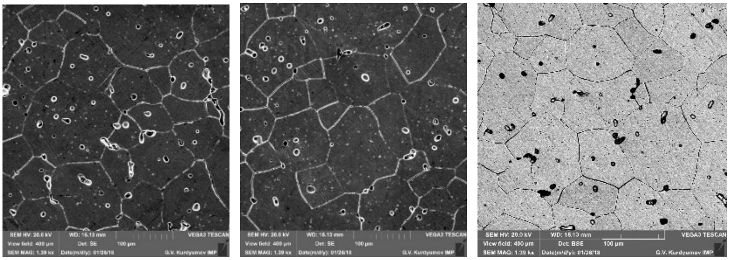

Fig. 3. Alloy microstructure and element distribution in Ti-35Nb-7Zr-5Ta alloy made from pre-alloyed particles

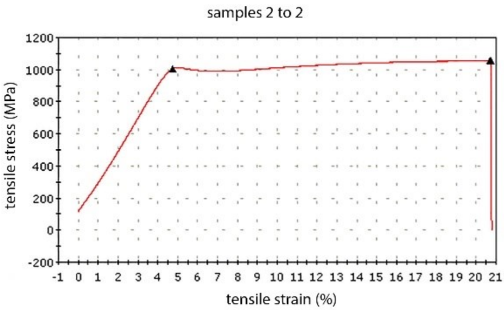

Fig. 4. Stress-strain diagram of Ti-35Nb-7Zr-5Ta fabricated using pre-alloyed powders.

Conclusions. A low-modulus Ti-Zr-Nb-Ta alloy was produced with press-and-sinter approach using hydrogenated powders. It was shown that Sintering kinetic and residual porosity markedly depend on type of starting powders used to achieve prescribed alloy composition. Blended elemental approach did not provide total homogenisation for this alloy. On the other hand, there was achieved low porous state of material with total humanisation by usage of pre-alloyed powder. This approach helps to increase mechanical properties of material.

1. *Geetha M., Singh A. K., Asokamani R., and Gogia A. K. Ti based biomaterials, the ultimate choice for orthopaedic implants – A review // Prog. Mater. Sci. – 2009. – 54 (3). – P. 397–425. https://doi.org/10.1016/j.pmatsci.2008.06.004.*
2. *Niinomi Mitsuo. Mechanical properties of biomedical titanium alloys // Mater. Sci. Eng. A. – 1998. – 243 (1-2). – P. 231–36. https://doi.org/10.1016/s0921-5093(97)00806-x.*
3. *Taddei Elisa B., Vinicius André Rodrigues Henriques, Cosme Roberto Moreira Silva, Carlos Alberto Alves Cairo. Characterization of Ti-35Nb-7Zr-5Ta alloy produced by powder metallurgy // Mater. Sci. Forum. – 2005. – 498–499. – P. 34–39. https://doi.org/10.4028/www.scientific.net/msf.498-499.34.*
4. *Dictra database. – https://thermocalc.com/products/add-on-modules/diffusion-module-dictra/*