PRODUCTION AND CHARACTERIZATION SUPERELASTICITY BIOCOMPATIBLE Ti-Nb-BASED ALLOYS

Konopatsky A.S., Zhukova Yu.S., Filonov M. R., Prokoshkin S. D.

NUST «MISiS», Moscow, Russia

ankonopatsky@gmail.com

There are high requirements to materials which are used in maxillofacial surgery and arthroplasty. At the moment there is no solution for the problem of biocompatible material which could replace bone tissue or work in pair with bone tissue. Such materials should exhibit wide range of various functional properties. These properties determine if material is biochemically and biomechanically compatible with bone tissue. Biomechanical compatibility is based on similarity in mechanical properties of implant's material and bone tissue. Low elastic modulus and superelasticity are one of the most important of such properties. These properties allow implant to imitate behavior of bone tissue during exploitation. In terms of biochemical compatibility it is very important to use only safe alloy constituents. Due to these requirements Ti-based alloys have become widely used. Nowadays there are perspective metallic systems among Ti-based alloys which are not fully investigated. One of such metallic system is Ti-Nb-Ta(Zr) which exhibits superelasticity and compounds only safe components.

Special attention should be given to the search of rational method of producing biocompatible alloys because the quality of obtained ingot has great influence on material's functional properties, their stability and reproducibility. It is also very important to search for the chemical composition of the alloy which can exhibit perfect superelasticity at human body temperature. Hence the search of the rational method of obtaining these alloys is very important objective. In this work Ti-Nb-Ta (Zr) alloys were produced by vacuum induction melting and vacuum arc remelting.

Three test ingots of Ti-22Nb-3Ta-3Zr (at. %) alloys were obtained by vacuum induction melting in «Leybold-Heraeus» furnace using high purity raw materials. Melting and crystallization was carried out in BeO crucible.

Melt #1 mass was 105 g, the process took 9 min. Some pieces of niobium were not remelted completely which led to significant deviation from the nominal chemical composition. Melt #2 mass was 75 g, the process took 33 min. Melt #3 mass was 77 g, the process took 34 min. There were a lot of pores on the surfaces of ingots #2 and #3.

Samples #2 and #3 were prepared from ingots #2 and #3 and investigated by scanning electron microscopy with micro X-ray spectral analysis (MXRA).

The results showed that sufficient degree of homogeneity was not reached; there were areas which were depleted with some of the main components. The areas depleted with niobium contained increased amount of titanium and the areas depleted with titanium contained increased amount of niobium. Inhomogeneity of Zr and Ta was not as noticeable due to low content of these elements in alloy.

Large amount of pores on the ingot's surface and uneven distribution of components in the alloy led to inevitability of finding another way to produce these alloys.

When searching for the rational method of producing biocompatible alloys it is important to consider components' features such as high melting temperature and high affinity to oxygen. Vacuum arc remelting (VAR) is widely used and reliable method of producing high-reactive and refractory alloys.

Ingot of Ti-22Nb-3Ta-3Zr (at. %) was obtained in vacuum arc furnace with a non-consumable electrode under argon protective atmosphere. Crystallization was carried out in the water-cooled copper mold. Melt mass was 196 g, the process took 1 min.

Observation of cross-section of the obtained ingot showed that there was interface between lower and upper ingots parts. Such areas indicated that there was uneven distribution of components in the alloy. Also there was small amount of pores in the lower area.

The surface of the sample was etched. The upper part of the sample became black after etching while the lower part remained almost unchanged. This indicates that the lower part contains more refractory elements such as Nb and Ta while the upper part contains more Ti and Zr.

Results obtained by X-ray fluorescence spectrometry confirmed that there was increased amount of Nb and Ta in the lower part of the sample and increased amount of Ti and Zr in the upper part of the sample. Ta showed the most significant difference in concentrations between two areas. Considering these results it was suggested to remelt ingots several times.

Taking into account obtained results VAR was used for further remelting. Ingot of Ti-22Nb-6Zr (at. %) alloy was remelted 3 times and ingot of Ti-22Nb-6Ta (at. %) alloy was remelted 4 times. Ingot was turned upside down after each remelting.

Samples of these alloys were investigated by scanning electron microscopy with MXRA and element distribution maps were obtained (fig. 1). Results showed that chemical composition of the alloys was very close to nominal chemical composition and both alloys have high degree of homogeneity.

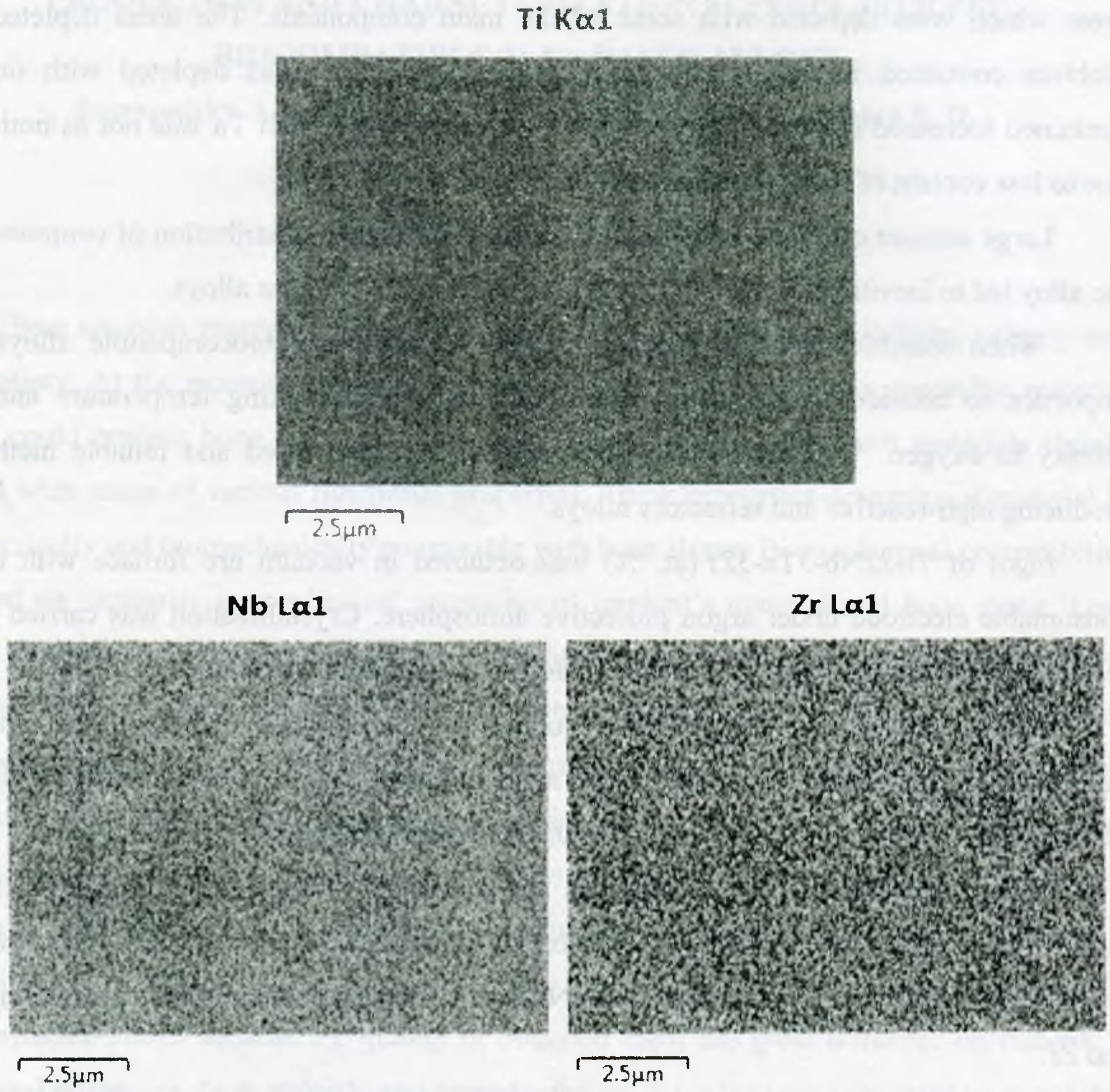

Figure 1. Element distribution maps for Ti-22Nb-6Zr

It is important to notice that VAR may produce ingots with rough surface. Sometimes it is needed to remove up to 3 mm of such surface. Few pores were observed on ingot of Ti-22Nb-6Ta alloy.

Analysis of ingots of Ti-22Nb-6Ta and Ti-22Nb-6Zr alloys produced by VAR showed prospects of this method in producing superelastic Ti-Nb-based alloys for medical application. At the moment the development of VAR-based technique is in progress.