Ti-Nb ALLOYS FOR APPLICATION IN MEDICINE

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Introduction: The average life expectancy of people all over the world is increasing since the early 1950s and it is predicted that this trend will continue in future [1]. Geetha et. al payed attention to the fact that 90 % of population over the age of 40 suffer from degenerative diseases [2]. This tendency in combination with the wish to improve life quality of older people increases demands for biomedical implants. The nowadays mostly used biomedical materials are stainless steel, Cr-Co alloys and Ti - 6Al - 4V. One drawback of these alloys is that their Young's modulus are several times higher compared to Young`s modulus of human bones. This causes an effect called stress shielding [3] which leads to subsequent loosening of implants. To avoid the stress shielding effect metallic alloys with low Young's modulus should be used for manufacturing of the implants. Out of three aforementioned alloys Ti - 6Al - 4V possesses the lowest Young's modulus (~100 GPa). However, alloying elements such as aluminium and vanadium exhibit several disadvantages. Aluminium can be reason for Alzheimer`s or Parkinson's diseases whereas vanadium is a known as rather toxic element for human body[4]. In this study we report on some structural and mechanical peculiarities of Ti-Nb alloys which are currently considered to be promising for application in biomedicine due to their low Young's modulus and perfect biocomatibilty.

Materials and Methods: The ingots made of commercially pure (c.p.) Ti and binary Ti-Nb alloys with Nb content between 0 wt% and 37 wt% (hereafter wt% will refer to as %) were melted using a BUEHLER Arc Melter in a Ti-gettered argon atmosphere. Considering the difference in density (Ti:4,5 g/cm³; Nb: 8,57 g/cm³) and in melting point (Ti: 1941 K; Nb: 2750 K) between the initial materials and because of the relatively broad two phase field in the Ti-Nb phase diagram the samples were melted 16 times and flipped after every second melt to ensure chemical homogeneity. Before and after melting the weight was measured to detect the weight loss during melting. After melting the binary samples were annealed at 1000 °C for 24 h followed by quenching from 1000 °C into oil. Both heat treatments were conducted in vacuum. Microhardness measurements were done with a WOLPERT Group 402 MVD Vickers hardness tester. X-Ray diffraction analysis was implemented using a ARL X`TRA diffractometer using Cu-k$\alpha_{1,2}$ radiation in 2θ range from 30° to 80°.

Results and Discussion: The highest weight loss during melting was found to be 0.83 %. The niobium content as well as the different weight loss values are shown in Table 1. It is well known that in Ti alloys two stable phases, namely α and β and four nonequilibrium phases (martensitic α` and α``, ω and metastable β) can exist. The formation of martensitic phases in Ti-Nb alloys depends on the alloying content as well as on the quenching rate [6]. Metastable ω phase can be achieved in two cases: when the cooling rate is sufficiently high, or during aging. XRD patterns of the samples showed that after annealing the samples are composed of hcp α`and bcc β. The border between α` and β phases lies at 25% Nb. After quenching the samples mainly consist of martensitic α`` and β phase. Stable β phase is reached when the alloying content is above 37 %.

Table 1 - Chemical Composition, weightloss and microhardness of researched alloys

Alloy Code	Nb, %	Ti, %	Weight loss, %	Microhardness after annealing, $HV_{0.05}$	Microhardness after quenching, $HV_{0.05}$
c.p. Ti		100		165 ± 5	
Ti-14Nb	14 ± 0,7	Balance	0.83	233 ± 4	246 ± 6
Ti-24Nb	24 ± 0,8	Balance	0.10	271 ± 4	212 ± 5
Ti-29Nb	29 ± 0,2	Balance	0.13	393 ± 10	225 ± 5
Ti-34Nb	34 ± 0,5	Balance	0.01	322 ± 7	195 ± 3
Ti-37Nb	37 ± 0,4	Balance	0.04	245 ± 3	211 ± 4

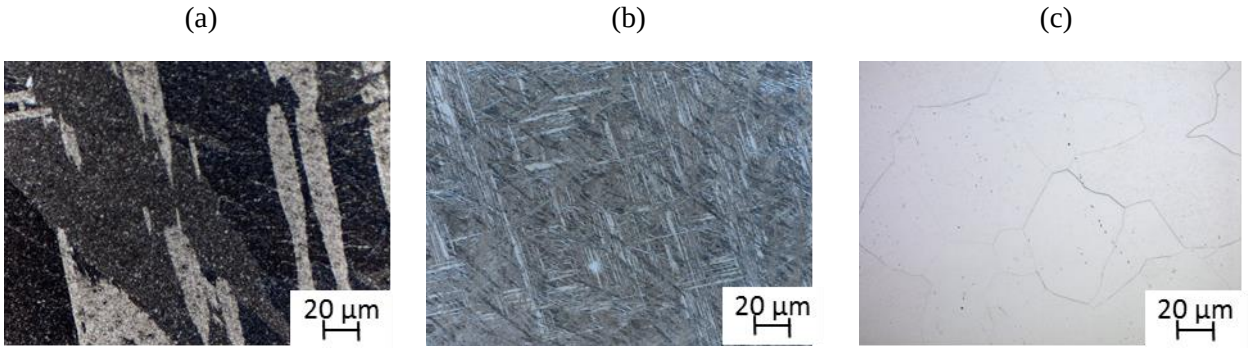

Fig. 1. Optical microstructures of a) c.p. Ti; b) annealed Ti-14Nb; c) quenched Ti-37Nb

Fig. 1 shows, that the cast c.p. Ti sample exhibit a typical lath-type morphology while the microstructure of the binary samples strongly depends on alloying content and heat treatment. The annealed sample with a Nb content of 14 % shows a fine acicular martensitic structure. When the alloying content reaches 25% Nb the needle like structure is replaced by a typical β structure. The quenched sample with 14% Nb exhibits a fine martensitic structure like the annealed sample. With increasing the alloying content the amount of martensitic structure increases. It is suggested that this happens because to the solute decreased martensite transformation starting temperature (Ms). The sample with 37% Nb shows a typical β structure where only the grain boundaries are visible. The results of the microhardness testing are also shown in Table 1. All binary alloys show a higher microhardness than c.p.-Ti. The microhardness value of the sample with 14% Nb is higher due to the solid solution strengthening effect due to Nb addition. For annealed alloys the microhardness increased further with increasing the alloying content up to a maximum of 393 $HV_{0.05}$. It is suggested that this happens because the samples were cooled down in the furnace after annealing. The cooling rate was so low that the samples were subjected to aging treatment. Mantani and Tajima showed with his research that 1h of aging treatment above a temperature of 573 K is enough to receive metastable ω phase in Ti-Nb alloys in an alloying range between 25 and 40 % [6]. It has to be mentioned that XRD and optical microscopy of annealed samples did not show the presence of ω phase, because of the nanometer size and low volume fraction of ω precipitations. For quenched samples the microhardness increased to a maximum of 225 $HV_{0.05}$. This microhardness value corresponds to the sample with 29% Nb which consists of α`` phase. When Nb content is above 34 % the microhardness decreases because the β phase dominates in structure.

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