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Orthorhombic Martensite Decomposition and its Effect on Microstructure and Mechanical Behavior of β Titanium Alloys

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Abstract – The aim of this work was to investigate the effects of Sn addition to Ti-Nb alloys on orthorhombic martensite decomposition and hence, on mechanical behavior. Ti alloy ingots were prepared, homogenized and hot-rolled. Samples were submitted to solubilization and water quenched. A subsequent two-step aging heat treatment was carried out. Results obtained showed that Sn may act as a suppressor of ω phase precipitation. While rapid quenched Ti-Nb-Sn sample showed yield strength below 350 MPa, whose aged sample value increased up to 900 MPa and elastic modulus was kept below 70 GPa. These final values are very suitable in terms of orthopedic biomaterial applications.

Titanium-based alloys have unique properties and therefore are broadly employed in a number of industrial segments. Among Ti alloys, β type alloys form one of the most versatile classes of materials in relation to processing, microstructure and mechanical properties. It is well recognized that the mechanical behavior of titanium alloys is directly dependent on their microstructure characteristics. Such behavior can be optimized by tailoring the microstructure through the control of the composition and especially phase transformations. This work attempts to examine phase transformations during aging heat treatment of β Ti-Nb alloys with Sn additions and to correlate microstructure and mechanical behavior.

Ti-Nb-Sn samples were homogenized at 1000°C/8 h. Next, they were hot-rolled and submitted to solution heat treatment at 1000°C/1 h, followed by rapid cooling in water (WQ). Aging heat treatments were applied during different periods of time at 260°C and 400°C.

Microstructures of rapid cooled Ti-Nb-Sn alloys exhibit a combination of β and α” orthorhombic martensite and the amount of martensite decreases with increase of Sn, which are depicted in Fig. 1. It is well known that α” structure in titanium alloys can be decomposed by applying aging procedures, which results mainly in the precipitation of β, ω and finally, α phases [1]. Nucleation of the α-phase is possible due to the presence of ω-phase precipitates, since such a phase may act as a substrate for α nucleation. It is worth noting that precipitation of well dispersed α-phase may lead to enhancement in strength with no significant decrease in ductility [2]. The amount of martensite in the Ti-30Nb, Ti-30Nb-2Sn and Ti-30Nb-4Sn samples was confirmed by analyzing DSC results. Martensite decomposition in Ti-30Nb sample was observed in the first stages of aging heat treatment at 260°C. As Sn was added to Ti-30Nb, there was a delay in that decomposition. Such decomposition took more than 2 h at 260^{o}C in the Ti-30Nb-2Sn sample and at least 4 h in the case of the Ti-30Nb-4Sn sample. As aging temperature was increased to 400°C, the effect of Sn became obvious. While Ti-30Nb sample showed a rapid increase in hardness and in elastic modulus as a result of heavy ω-phase precipitation, the sample with Sn addition showed a less intensive precipitation. These results suggest that Sn may act as a suppressor of ω phase precipitation, which allows the control of microstructure features and hence, mechanical properties. The final microstructure was formed by β matrix with disperse precipitates of α phase. While rapid quenched Ti-Nb-Sn samples showed yield strength below 350 MPa, which makes easier cold forging process, whose aged sample value increased up to 900 MPa and elastic modulus was kept below 70 GPa. These final values are very suitable in terms of orthopedic biomaterial applications.

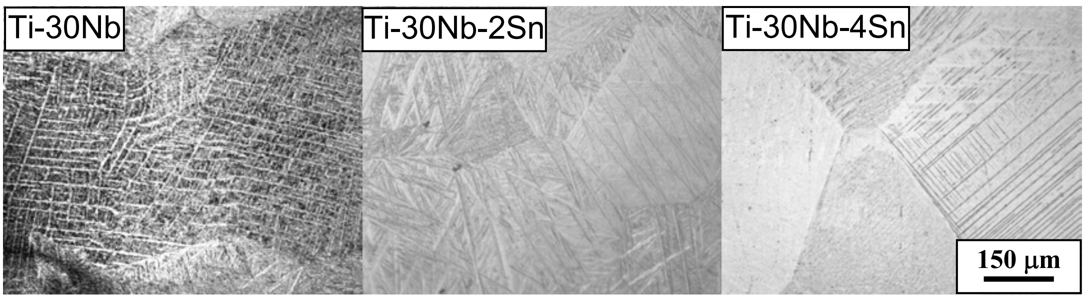

Figure 1: Microstructures of rapid cooled Ti-Nb-Sn alloys exhibit a combination of β phase and α” orthorhombic martensite.

References

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[2] E. Prima, P. Vermaut, G. Texier, D. Ansel and T. Gloriant, Scr. Mater. 54 (2006) 645-648.