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Microstructural Evolution of Cold-Rolled β Metastable Ti-29Nb-2Mo-6Zr Alloy

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Ti alloys developed for orthopedic implants must combine a low Young's modulus with high strength and excellent corrosion resistance, in order to avoid stress-shielding phenomenon [1,2]. In β titanium alloys, low Young's modulus can be obtained by stress-induced martensite formation during cold forming processes [3]. The possible deformation mechanisms during cold forming are dislocation slipping, stress-induced martensitic transformation and deformation twinning [4]. This study investigates the microstructural evolution of a new metastable β Ti-29Nb-2Mo-6Zr alloy during cold rolling. After homogenization for 24h at 1000°C and water quenching, the ingot was cold rolled up to 70% thickness reduction. Samples were characterized by optical microscopy (OM), transmission electron microscopy (TEM), X-ray diffraction (XRD) and electron backscattered diffraction (EBSD).

The β metastable Ti-29Nb-2Mo-6Zr alloy presents 100% equiaxed β grains after homogenization heat treatment and water quenching as shown in Figure 1.

In figure 2, the XRD pattern indicates the presence of a small amount of stress-induced α" martensite after 30% deformation whereas the EBSD orientation map indicates the occurrence of numerous β primary and secondary twins. Primary twins have a coincidence lattice site (CSL) boundary Σ11 (in blue) which corresponds to a {332} <113> twinning system. Secondary twins have a CSL boundary Σ3 (in black) which corresponds to a {112} <111> twinning system. These 2 systems are the twinning systems already mentioned in the literature for β-Ti alloys [4].

The XRD pattern in figure 3a shows a significant increase of the volume fraction of α" martensite after 70% thickness reduction. Beside primary and secondary twins, TEM bright-field (BF) imaging reveals a strip-shaped structure (figures 3b and 3c). The corresponding electron diffraction pattern determines that this is a bi-phased (α" + β) strip-shaped structure (figure 3d). The dark-field image from diffraction spot $001_{\alpha''}$ (figure 3e) distinguishes an alternation of α" martensite laths (in white) and β laths (in black).

In conclusion, the deformation modes in the Ti-29Nb-2Mo-6Zr alloy are twinning and martensitic transformation. Young's modulus measurements by nanoindentation indicates that the Young's modulus decreases when the degree of deformation increases, from 93GPa in the homogenized state to 83 GPa after 70% deformation. According to Xu et al [3], this decrease in Young's modulus can be attributed to the β to α" stress-induced martensite transformation. In any case, the Young's modulus is much lower than the Young's modulus of the widely used Ti-6Al-4V alloy (140 GPa). Therefore, the cold-rolled β metastable Ti-29Nb-2Mo-6Zr Alloy has a great potential for orthopedic applications [5].

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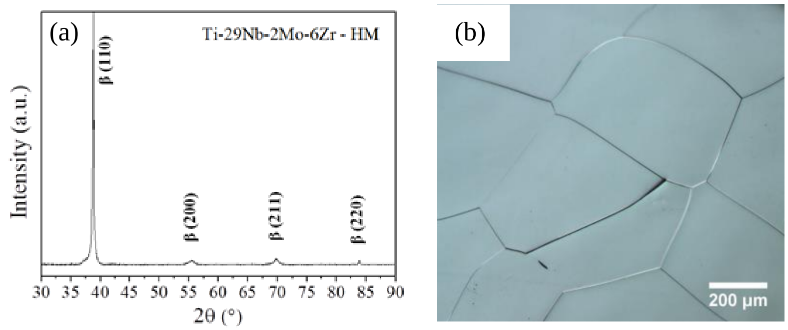

Figure 1. Microstructural characterization of Ti-29Nb-2Mo-6Zr alloy homogenized and water quenched; (a) XRD pattern (b) OM image.

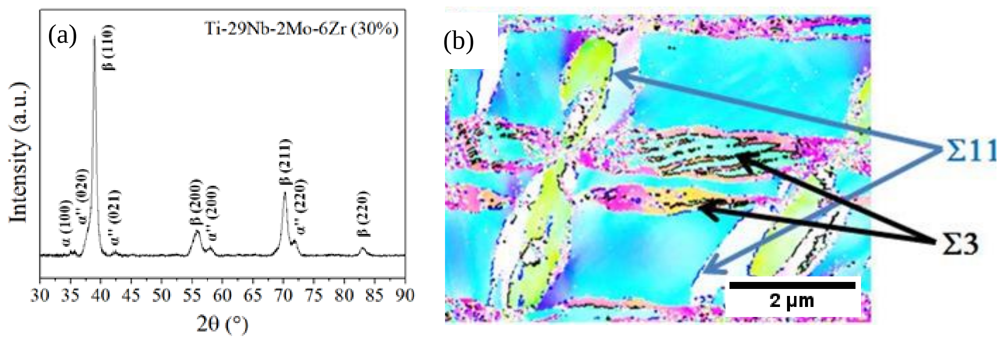

Figure 2. Microstructural characterization of Ti-29Nb-2Mo-6Zr alloy after 30% deformation; (a) XRD pattern (b) EBSD β orientation map with CSL boundaries (Σ3 in black, Σ11 in blue).

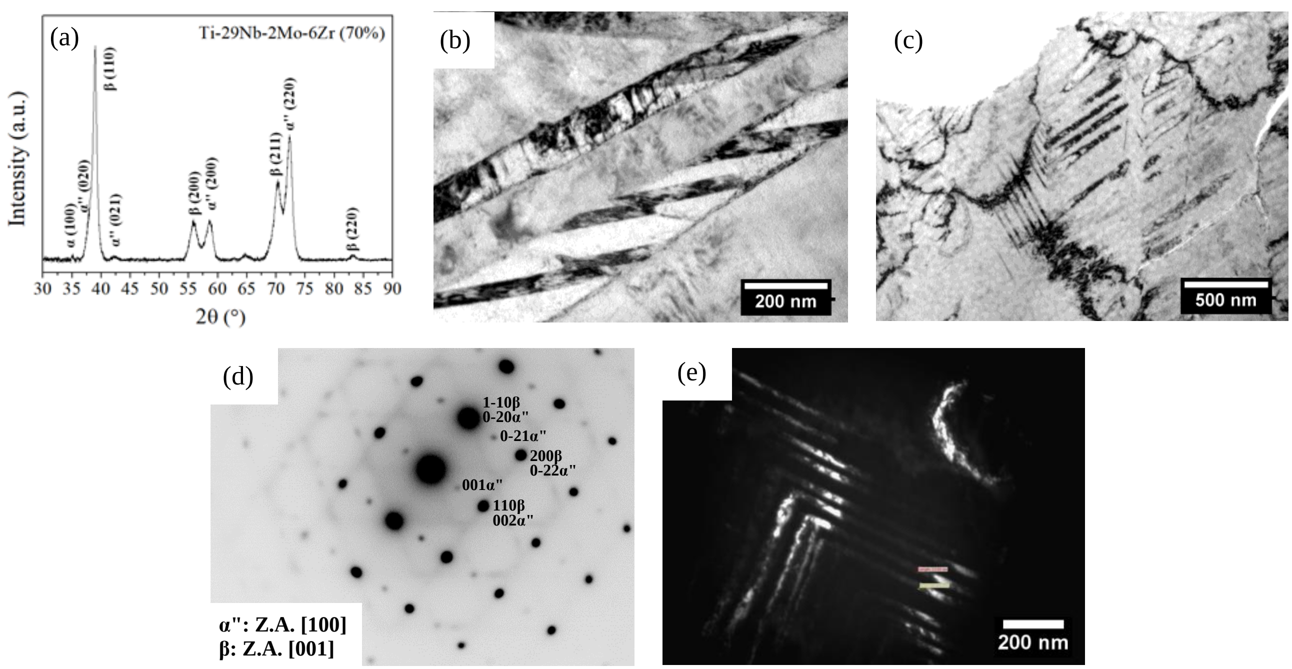

Figure 3. Microstructural characterization of Ti-29Nb-2Mo-6Zr alloy after 70% deformation; (a) XRD pattern (b) TEM BF image of twins (c) TEM BF image of strip-shaped structure (d) EDP from figure 3c region (e) DF image from spot $001_{\alpha''}$.

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