Alloys and Intermetallics

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An EBSD approach for estimating the a´´ martensite fraction in ß titanium

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The newly developed β metastable titanium alloys (Ti-Nb-Ta-Zr alloys, TNTZ) exhibit superior biocompatibility due to properties such as reasonable bio-corrosion resistance, Young's modulus close to the bone stiffness, high strength, and good formability [1]. The stability of the β phase, which is controlled by chemical composition and deformation conditions, provides certain influences on the active deformation mechanism including dislocation slip, twining, crystallographic lattice rotation and martensitic transformation. The heat- and stress-induced α´´ martensitic transformation and reversion affect superelastic and shape memory behavior [2]. A recent study was focused on the correlation between strain rate sensitivity and deformation-induced α´´ phase volume fraction [3].

TNTZ (actually Ti-27.96 Nb-11.97 Ta-5.02 Zr-0.05 O-0.01 C-0.014 N) alloy samples in as-forged and annealed (850°C, 45 min) condition were subjected to an isothermal (25 - 500°C) compression test under strain rates between 0.3 and 0.003 s^{-1}. Cross-sections parallel to the loading axis were prepared with a vibration polishing surface finish for SEM/EBSD studies. The microstructure evolution changes from nearly unaffected ß grains at the sample edges and increasing twinning in a transition region to severe plastic deformation with α´´ phase formation in the sample centre (Figure 1). Deformation-induced martensite has been confirmed by XRD [3].

Of further interest is the volume fraction of martensite formation which was estimated by EBSD with a conventional indexing routine after Hough transformation. The approach is based on the specific lattice correspondence between α´´ and β phases. Assuming the crystal structure of the α´´ phase as simple tetragonal with the [100] and [001] directions parallel to the [011] and [100] directions in the cubic β phase [4], the martensitic phase may be obtained from a minute distortion in the primary β titanium. A comparison of the thus calculated lattice parameters (0.3295 nm and 0.4659 nm) with our XRD results of the orthorhombic α´´ phase (0.3289 nm, 0.4798 nm, and 0.4814 nm) [3] reveals that the α´´ phase can be considered as fcc structure with diminutive deviations. Accordingly, only the ß phase using the lattice parameters derived from XRD, was considered for indexing the electron backscatter diffraction patterns during EBSD analysis and the mean angular deviation (MAD value) was determined (Figure 2). The MAD distribution between 0 and 5° shows two peaks around 2.2° and around 3.2° (Figure 2 g-h). The first peak representing the β phase is broadened due to the occurrence of TNTZ solid solutions formation. The second peak is attributed to the α´´ phase which proves to be justified by correlating the different regions of the inhomogeneous microstructure (Figure 2).

The microstructure observed by electron channeling contrast [5], shows a large number of dislocation arrangements, slip lines, twins and martensite laths in the deformed material which are not present in the almost undeformed edge regions (Figure 1 and 3). Mainly in the transition region, some of the features (Figure 3a) have been attributed to fine twin lamellae showing a disorientation corresponding to the type Ti twinning system {112} <111> by EBSD. Deformation-induced martensite laths can be observed across the grains (Figure 3b). The increase of the martensite volume fraction has been relatively quantified by EBSD analysis.

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Figure1. Structural changes between the edge (left) and the centre (right) of a compression test sample.

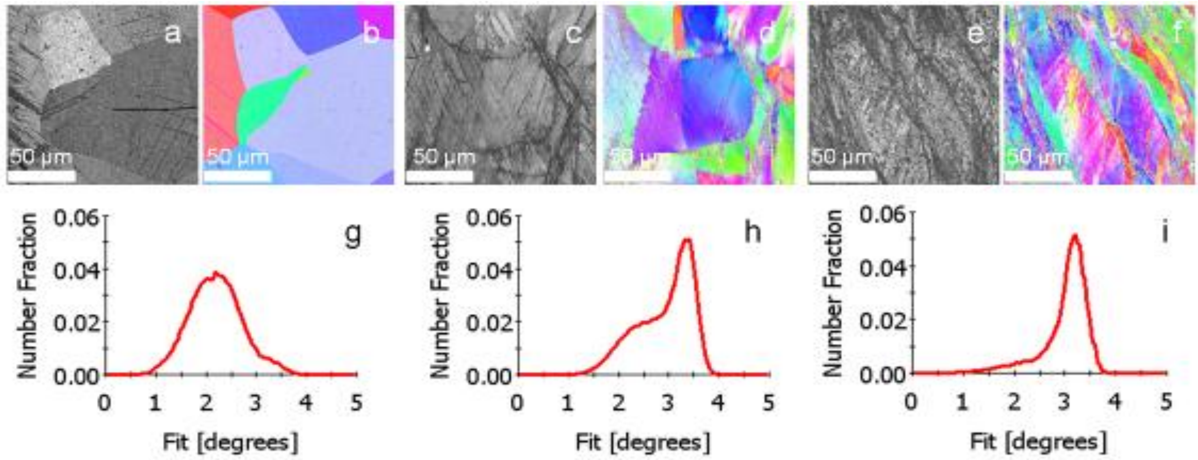

Figure 2a-i. EBSD pattern quality maps, crystal orientation maps and MAD distributions of 3 sample regions: almost undeformed (a, b, g), deformation-twinned (c, d, h) and severely deformed (e, f, i).

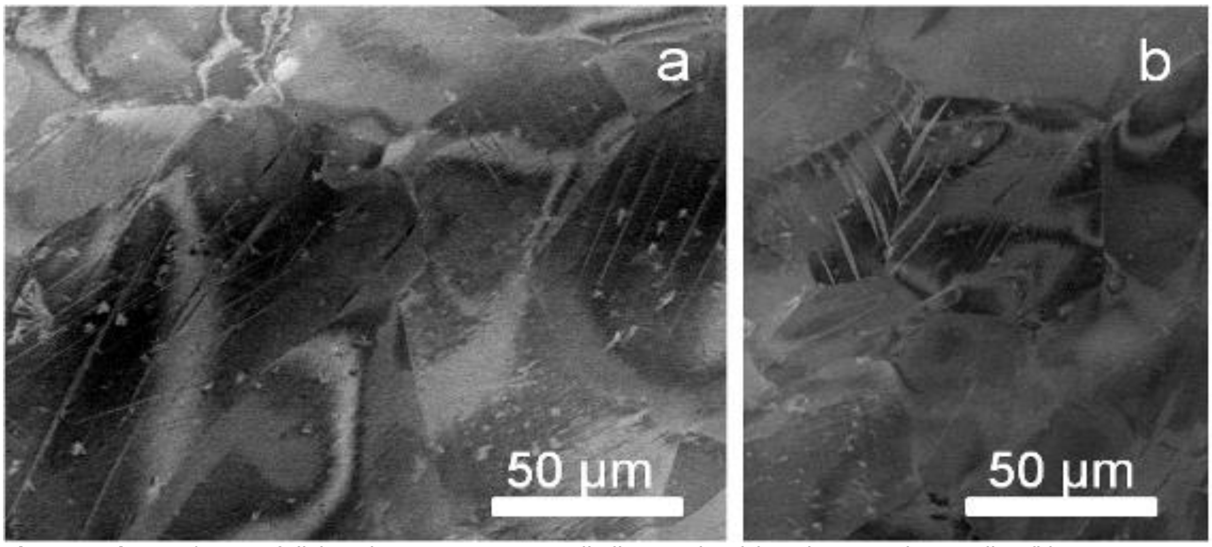

Figure 3a-b.SEM/ECCI of dislocation arrangements, slip lines, twins (a) and martensite needles (b).