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Characterization of Alpha/Beta Interface Structure in a Titanium Alloy Using Aberration-Corrected Scanning Transmission Electron Microscope

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In body centered cubic (bcc) β titanium alloys, the precipitate most commonly found in the β matrix is the hexagonal closed packed (hcp) α phase, with the two often in the Burgers orientation [1]. The anisotropy present in the α/β interfacial structure influences the morphology of the α precipitate, and structural defects, such as dislocations and ledges present in the α/β interface, may also affect precipitate-dislocation interactions, and so change the deformation mechanisms. Recently, three different fine scale alpha microstructures in a metastable beta titanium alloy, Ti-5Al-5Mo-5V-3Cr (Ti-5553), have been investigated by Zheng et al, classified as *refined*, *more-refined*, and *super-refined* α microstructures [2-5]. The refined α microstructures (number density ≤10/mm^2), shown in Fig. 1, were produced by step-quenching from above the β transus to 600°C, and rapidly heating (rate ~100°C/min) the as-quenched material to 600°C [2, 3]. It is observed a) that the nucleation and growth of the α plates is extremely rapid, and b) that they align along three specific crystallographic orientations. In order to understand the mechanism of formation of the refined α microstructure in these alloys, a detailed study of the α/β interface structure in the early stages of α phase precipitation, is required.

The precipitation reactions in Ti alloys have traditionally been considered to occur by the mechanism of conventional diffusional phase transformations. In recent years, however, evidence has suggested that the nucleation and growth of hcp α precipitates from the bcc β matrix has more in common with martensitic transformations than with long-range diffusional ones. In particular, the transformation has been shown to be consistent with a topological model, in which the α/β interface consists of areas of coherent terrace planes, separated by disconnections, (**b**, *h*); defects that have both a Burgers vector **b**, plus a step *h* associated with their core [6], and whose motion along the interface causes the growth of one phase at the expense of the other. Previous efforts to characterize these α/β interfaces used conventional diffraction contrast transmission electron microscope (TEM) - more recently the development of aberration-corrected scanning transmission electron microscopes (STEM) allows atom columns near various interfaces to be characterized directly [5, 7, 8]. Combined with focused ion beam techniques for sample preparation it is now possible to examine the atomic structure of a given interface from more than one direction, and so provide a clearer insight into the complete interfacial structure.

The crystallography and structure of the habit plane of refined α precipitates in the β matrix of Ti-5553 were studied using probe corrected FEI Titan 80-300 STEM. In z-contrast HAADF-HRSTEM, the atomic terrace and ledge structures on the habit plane of refined α precipitates were observed directly along the common $[0001]_\alpha:[011]_\beta$ direction (shown in Fig. 2(a)). Lengths of coherent terrace are separated by disconnections with Burgers vector **b** = a_β [-0.0191 0.0191 0.0344]$_\beta$ nm, and height h = 2.d$(\bar{1}1\bar{2})_\beta$ = 0.255 nm. Imaging the terrace plane from the orthogonal direction $[\bar{1}\bar{1}20]_\alpha:[\bar{1}11]_\beta$ shows the interface to be fully coherent within the field of view, with no misfit or lattice invariant dislocations (LIDs) observed (Fig. 2(b)). This arises because the misfit between the hcp and bcc lattices along $[0001]_\alpha:[011]_\beta$ is only ≈ 0.8%, in contrast with the interface structure reported in other titanium alloys where the misfit is larger. These observations are fully consistent with a topological model for the α/β interface structure, and provide evidence for the martensitic nature of the β/α transformation.

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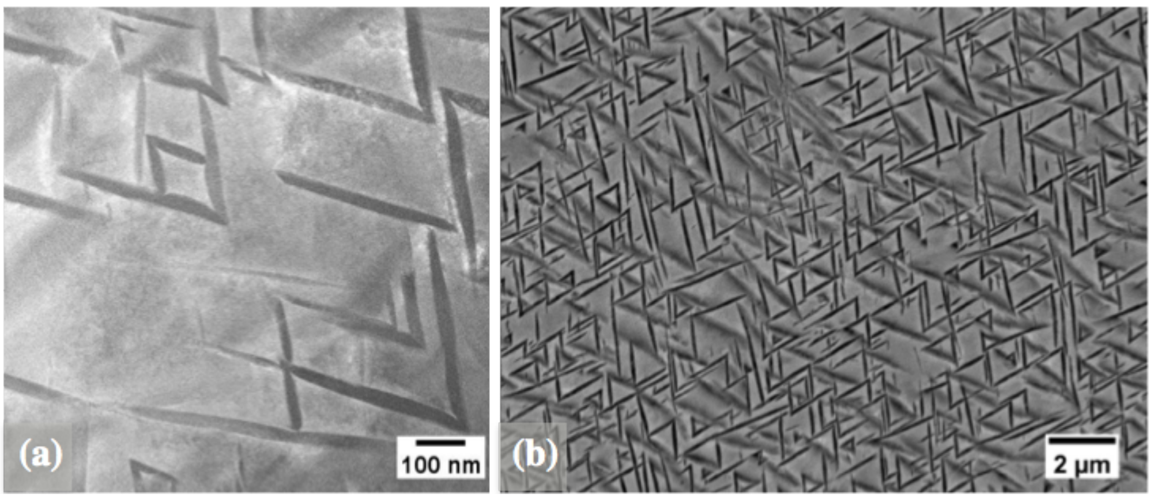

Figure 1. Microstructures of Ti-5553 after aging at 600˚C for a) 0 minutes and b) 5 minutes. Note that while the α laths lengthen and increase in number with aging, there is little change in their thickness over time.

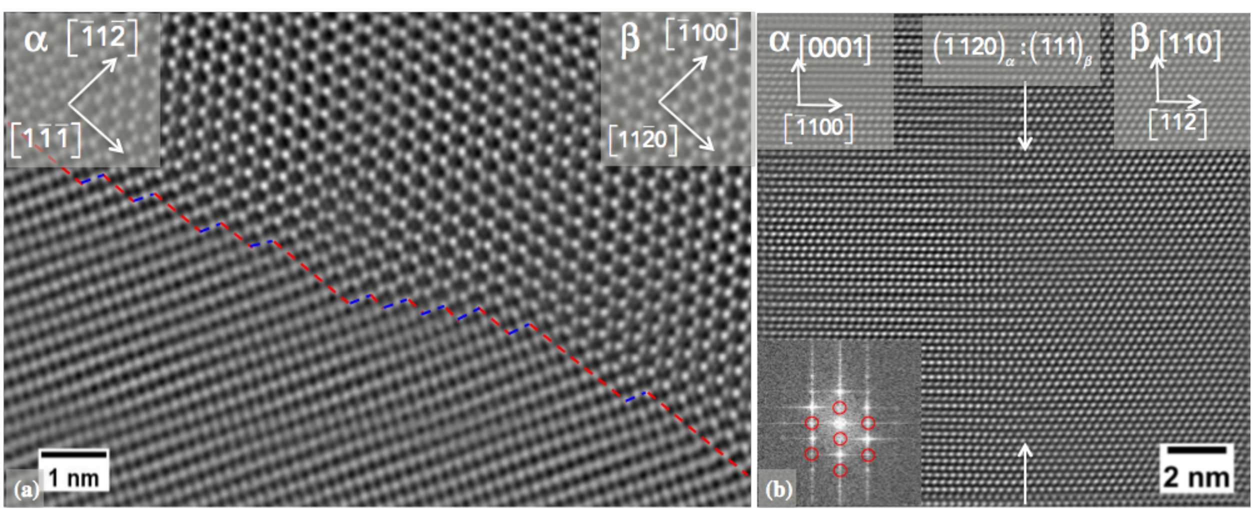

Figure 2. Aberration-corrected HAADF/(S)TEM images of α/β interface in the alloy Ti-5553, a) viewed along $[0001]_\alpha : [011]_\beta$ and b) along $[\bar{1}\bar{1}20]_\alpha : [\bar{1}11]_\beta$.

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