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Characterization of Nanoscale Twin Boundary Structure in Metastable β Titanium Alloys Using Aberration-corrected Scanning Transmission Electron Microscopy

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Microstructural evolutions in metastable β titanium alloys can be influenced by a series of microscale and nanoscale compositional and structural non-uniformities, e.g., β grain boundary, dual-phase interface and twin boundary. In our recent studies, we have found that the high-index deformation twins in the cold-rolled metastable β Ti-5Al-5Mo-5V-3Cr alloy (wt.%, Ti-5553) can assist the formation of hierarchical α microstructure during the subsequent heat treatment [1]. In the hierarchical α microstructure, thick layers of the coarse α plates were formed, that is speculated to be related to the pre-formed deformation twin boundaries in the cold-rolled Ti-5553. Thus, it is of critical importance to investigate the nanoscale twin boundary structure in the metastable β titanium alloys. With the development of the aberration-corrected scanning transmission electron microscopy (STEM), the crystal structure near the twin boundary region can be investigated at the atomic resolution [2-4]. For example, recent study of β {332}<113> type deformation twinning using the aberration-corrected STEM in a Ti-30Nb-3Pd alloy has shown a nanoscale layer of orthorhombic α" martensite phase formed at the twin boundary [2]. In this work, our latest study of nanoscale structure at the boundary of different deformation twins in the metastable β Ti-24Nb-4Zr-8Sn (wt. %, Ti-2448) alloy using the probe-corrected Thermo Scientific Themis Z scanning transmission electron microscope will be introduced.

In the first part of this work, the atom arrangement near the boundary of the primary high-index {332}<113> deformation twin in the cold-rolled Ti-2448 was studied using the aberration-corrected STEM. The atomic resolution high angle annular dark field – scanning transmission electron microscopy (HAADF-STEM) imaging in the Fig. 1 reveals the atom arrangement at the primary twin boundary. Two sets of crystal lattices with the body centered cubic structure (the matrix and twin) are clearly observed showing a misorientation of approximately 50.5°. In addition, between the two sets of lattices, a layer of orthorhombic structured α" phase is characterized, marked using the green color dotted lines in the Fig 1.

The second part of this work focuses on the crystal structure near the boundary of the other type of deformation twin, the secondary {112}<111> twin, in the cold-rolled Ti-2448 using the aberration-corrected STEM. In contrary to the {332}<113> deformation twin, the misorientation between the matrix and the {112}<111> twin lattice observed is approximately 60° in the HAADF-STEM imaging. In addition, there exists a nanoscale layer between the matrix and the {112}<111> twin, but this nanoscale layer exhibits hexagonal structure, belonging to ω phase, rather than the orthorhombic α" phase [5].

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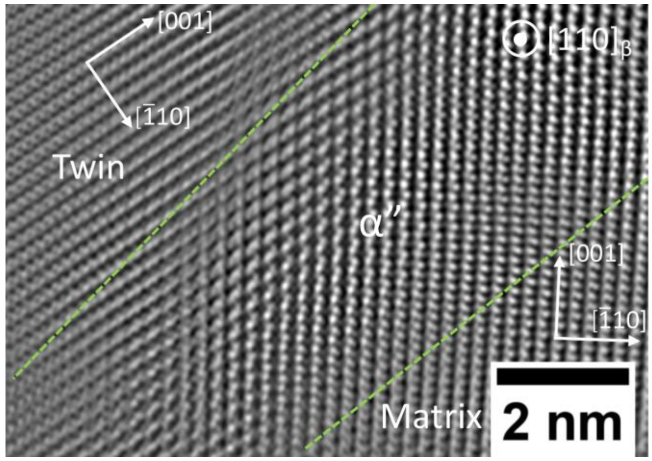

Figure 1. HAADF-STEM imaging showing the nanoscale twin boundary structure of the primary {332}<113> twin in the Ti-2448 alloy, with green color dotted lines marking the nanoscale orthorhombic structure α" phase.

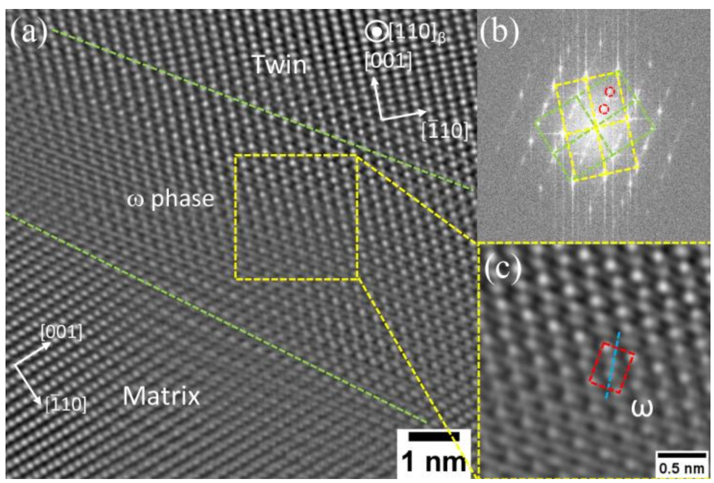

Figure 2. HAADF-STEM imaging and its FFT showing the nanoscale twin boundary structure of the secondary {112}<111> twin in the Ti-2448 alloy: (a-b) the FFT processed HAADF-STEM image and its FFT displaying the crystal lattice of the matrix and the {112}<111> twin; (c) high-magnification HAADF-STEM image showing the hexagonal ω phase layer at the twin boundary.

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