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Investigation of Novel Phase Transformation Mechanisms in Titanium Alloys Using Atom Probe and Aberration-Corrected Scanning Transmission Electron Microscope

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Metastable beta titanium alloys have attracted significant amount of attentions in recent years, because their microstructures can be manipulated by different phase transformation mechanisms and therefore the corresponding mechanical properties vary significantly by adopting various thermal/mechanical processes. In our recent studies, coupling atom probe and aberration-corrected scanning transmission electron microscope, several novel phase transformation mechanisms have been systematically explored in a beta titanium alloy, Ti-5Al-5Mo-5V-3Cr (Ti-5553, wt.%) [1-4]. It has been clearly shown that the size, morphology and number density of *hcp* structure alpha precipitates in Ti-5553 can be significantly influenced by the nano-scale structural and compositional instability, more specifically the metastable *hexagonal* structure isothermal omega phase, present in parent *bcc* structure beta phase. Computational simulation has shown that the compositional and/or stress field associated with such nano-scale instabilities may contribute to an increased driving force for alpha nucleation [3, 5, 6]. In order to provide accurate input into computational simulation, the compositional and structural insights of nano-scale instabilities in parent phase matrix are highly demanded in experiment. Such detailed characterization is relied on the recent technological improvement in atom probe and TEM that has the potential to provide atomic resolution information in titanium alloys.

In the first part of this current work, nano-scale omega phase particles in Ti-5553 were investigated using atom probe (LEAP 3000X HR) and probe corrected scanning transmission electron microscope (FEI Titan™ 80-300) [3]. For the first time, using atom probe, the elliptical morphology isothermal omega phase particles of nano-scale are clearly observed and the concentration of omega phase is characterized that both alpha phase stabilizer, Al, and beta phase stabilizers, V, Mo, and Cr, are rejected from omega phase into beta phase matrix, shown in Fig. 1(a). The structure of omega phase is characterized using Z-contrast HAADF-STEM imaging, that every two of three adjacent {111} atom planes are observed to collapsed leaving the third atom plane unaltered, as shown in Fig 1(b).

The second part of the work to be presented focused on the characterization of omega phase assisted alpha precipitation in another beta titanium alloy, Ti-20V [7]. For the first time, conclusive experimental evidence of nucleation of alpha precipitates at the omega/beta interface was obtained using atom probe (LEAP 3000X HR) and probe corrected scanning transmission electron microscope (FEI Titan™ 80-300), as shown in Fig. 2. HAADF-STEM image in Fig. 2(a) shows the clear contact of *hcp* structure alpha precipitate with pre-formed *hexagonal* structure isothermal omega particle, which is further validated using atom probe shown in Fig. 2(b) that alpha precipitate is formed at the pre-formed interface between coarse cuboidal morphology omega particle and beta matrix in three dimensions with a similar composition to omega particle.

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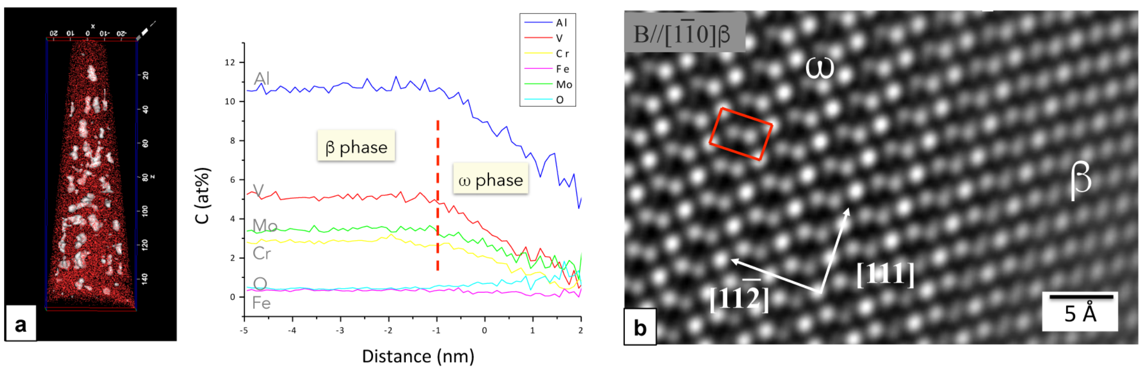

Figure 1. (a) Atom probe reconstruction showing isothermal omega particle and composition profile of Al, V, Mo, Cr, O, Fe across the omega/beta interface; (b) HAADF-STEM image showing the structure of isothermal omega particle [3].

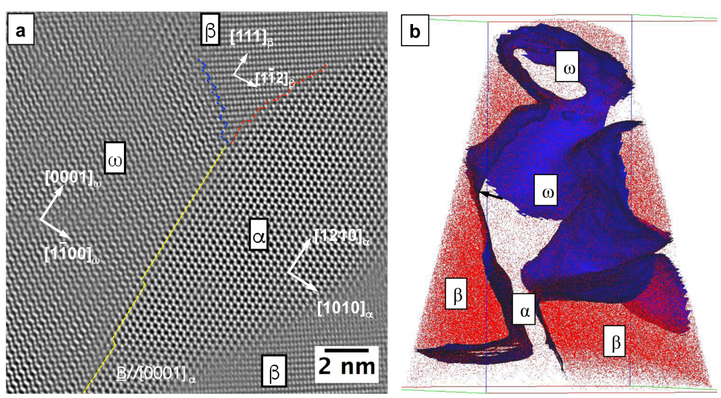

Figure 2. (a) HAAD-STEM image showing the nucleation of alpha precipitate from pre-formed isothermal omega particle; (b) reconstructed atom probe tip via red-V ions and 84% Ti iso-surface showing nucleation of alpha precipitate from pre-formed omega/beta interface ［7］

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