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Characterization of Various Interfaces Structure in a Titanium Alloy Using Aberration-Corrected Scanning Transmission Electron Microscope

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The chemical and structural interface between phases plays an important role in metallic materials, not only by influencing microstructural evolution due to extra energy arising from lattice distortion near the interface, as well as diffusion of multiple solute elements across the interface, but also by affecting the performance of materials due to interaction with defects. Therefore, it is critical to obtain detailed structural and chemical information about interfaces in order to better manipulate the microstructural evolution and therefore improve the overall performance. In beta titanium alloys, the hexagonal closed pack (*hcp*) structure, alpha phase, is the most common stable phase. The omega phase is a metastable phase with hexagonal structure found in the body centered cubic (*bcc*) structure beta phase matrix. The anisotropy present in the alpha/beta interfacial structure influences the morphology of alpha phase precipitate and structural defects, such as dislocations and ledges present at alpha/beta interface, may also alter the precipitate-dislocation interaction and change the deformation mechanism [1]. The structural defects present at the omega/beta interface have been reported to influence the subsequent alpha phase precipitation by means of providing extra driving force [2] and the misfit at the omega/beta interface can also influence the morphology of omega precipitates to adopt an ellipsoidal or cuboidal morphology. Many efforts have been made to characterize these events using conventional transmission electron microscopy (TEM), such as systematic dislocation analysis using diffraction contrast to study alpha/beta interface structure and dark field imaging to study the correlation between pre-formed omega phase and subsequent formed alpha phase. With the development of aberration-corrected scanning transmission electron microscope, atom columns near various interfaces have been characterized directly and the structure of various interfaces in beta titanium alloys has been analyzed.

In the first part of this current work, the crystallography and the structure of the habit plane of coarse and refined alpha precipitates in the beta matrix of Ti5553 were studied using probe corrected scanning transmission electron microscope (FEI Titan 80-300). For the first time, in z-contrast HAADF-HRSTEM atomic terrace and ledge structures on the habit plane of coarse and refined alpha precipitates were observed directly along [011] beta direction (shown in Fig 1(a)). The lengths of terrace, or the spacing of ledges, are not uniform while conversely the height of ledge is always twice of {112} atom plane spacing. The crystallography analysis indicates that the Burgers vector of disconnection on the habit plane is ½[3 -3-5]. It has been determined on coarse alpha precipitate interfaces that misfit dislocations lie on the habit plane, but no misfit dislocation has ever been observed on the habit plane of refined alpha precipitates (shown in Fig 1(b) and 1(c)). The correlation between {0001} atom planes in *hcp* structure and {011} atom planes in *bcc* structure and the misfit of two sets of lattice along [0001]alpha/[011]beta direction are different for coarse alpha precipitates and refined alpha precipitates, which could be the reason why two different morphologies and size scale alpha precipitates are formed in Ti5553 [3].

The second part of the work to be presented focused on the structure of the omega/beta interface and its influence on subsequent alpha precipitation in Ti5553. This phenomenon was investigated using probe corrected scanning transmission electron microscope (FEI Titan™ 80-300). As shown in Fig 2(a), from the center of omega particle to the omega/beta interface, the degree of {222} beta atom planes collapse alters from complete collapse to partial collapse. Atomic terrace and ledge structure are characterized at the omega/beta interface (highlighted by blue dashed line in Fig 2(a)). The presence of ledges along the omega/beta interface is to increase the coherency between hexagonal and *bcc* phases. These ledges could act as a favorable nucleation site for subsequent alpha precipitates. Such a case is shown in Fig 2(b), one super-refined alpha lath nucleates at the omega/beta interface and grows into beta matrix. This is the first time the nucleation site of alpha precipitation is clearly characterized indicating the influence of pre-formed omega particles [4].

References:

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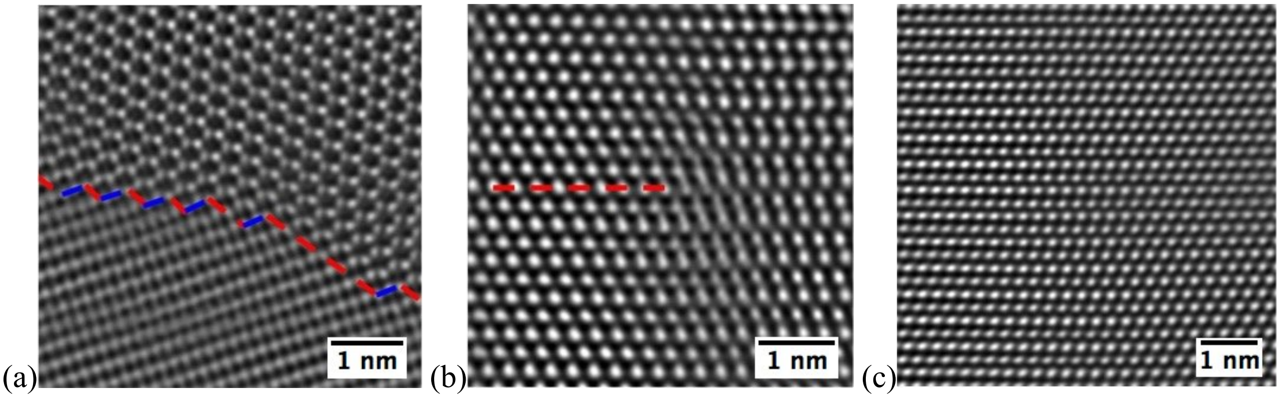

Figure 1. Filtered HAADF-HRSTEM images showing the alpha/beta interface structure from (a) [011]beta/[0001]alpha direction and (b), (c) [111]beta/ [11-20]alpha direction

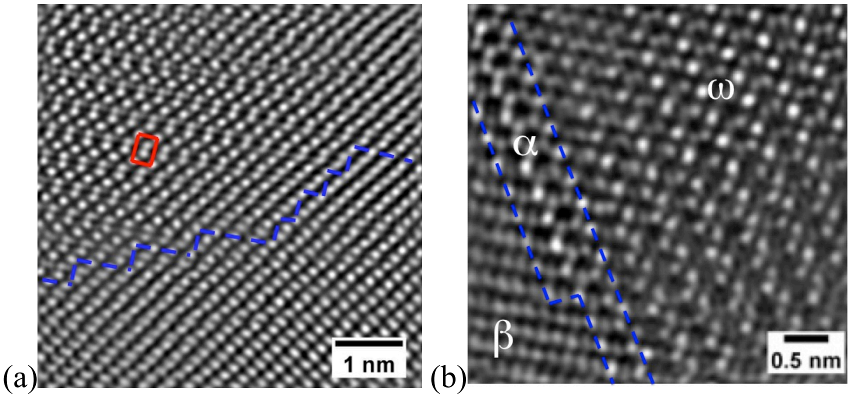

Figure 2. Filtered HAADF-HRSTEM image showing the structure of (a) omega/beta interface (b) omega/alpha interface