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Competing bcc β→ hcp α phase transformations in Ti-1Mo alloy

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Ti alloys gain attention in the recent past due to its unique properties like high strength to weight ratio, corrosion resistance, and biocompatibility. The properties of Ti alloys are largely depends on the crystal structure/microstructure, which are in turn influenced by the nature of phase transformations. In the present study, we try to understand the various transformation modes of β phase in Ti-1Mo alloy cooled at various rates from β phase field, using TEM analysis, automated Orientation Imaging Microscopy (OIM) using Precession Electron Diffraction (PED) and Rietveld refinement of XRD pattern.
Ti-1Mo alloy was prepared by vacuum arc melting, followed by homogenization and cooling at ~900°C/s, 3.3°C/s, 0.13°C/s. Formation of acicular martensite with twin morphology and absence of grain boundary α [1] is confirmed in Ti-1Mo alloy cooled at 900°C/s. Selected Area Diffraction (SAD) analysis in TEM revealed the formation of twinned martensite (α') with hcp structure. XRD Rietveld profile analysis showed the formation of 100% hcp structure(space group:p63/mmc) with lattice parameter a=2.9475Å and c=4.6728 Å[2], which is in agreement with SAD analysis.
A reduction in cooling rate, 3.3°C/s and 0.13°C/s change the mode of phase transformation. TEM analysis confirmed presence of alternate lamellae of α and β phases, typical of Widmanstätten transformation. The microchemistry of α and β phases varied widely- 0.08-0.47 wt% Mo in α phase and 8.4 to 26.73 wt% Mo in β phase, suggesting the diffusional transformation proceeded in a wide range of temperatures, for varying times. XRD Rietveld refinement further confirms the formation of 95% α (space group:p63/mmc, a=2.9456(7), c=4.6845(1)) and 5% β (space group:im-3m, a=3.2499(4)) phase at a cooling rate 3.3°C/s. A slight reduction in volume fraction of α phase (93%) with similar lattice parameter (a=2.9456(7),c=4.6845(1) is observed (see fig 1(a)) at a cooling rate of 0.13°C/s. There is no significant change in the lattice parameter of hcp α at various mode of transformation due to weak temperature dependence of solubility limit of Mo. However, a third decimal variation in the β phase lattice parameter is observed due to the segregation of Mo in the bcc phase, which is in agreement with Energy Dispersive X-ray analysis.
Most of the titanium alloys displays variant selection mechanism during β→ α martensitic/ Widmanstätten transformations, when mechanical driving force dominates over chemical driving force. In order to confirm the same, OIM studies were carried for all alloys. Orientations of martensite plates in the two adjacent β grains on either side of the grain boundary are completely different, suggesting an absence of variant selection at 900°C/s cooling rate. A similar trend is observed for Widmanstätten transformation also. Bright field micrograph and orientation image at a cooling rate 0.13°C/s are given in fig. 1(b and c) respectively, shows that orientation of alternate lamellae of α and β phase, in Widmanstätten colony have same orientation, suggesting absence of variant selection. It clearly conveys that variant selection mechanism is not active in this alloy, due to the dominance of chemical driving force over mechanical driving force during the phase transformation.
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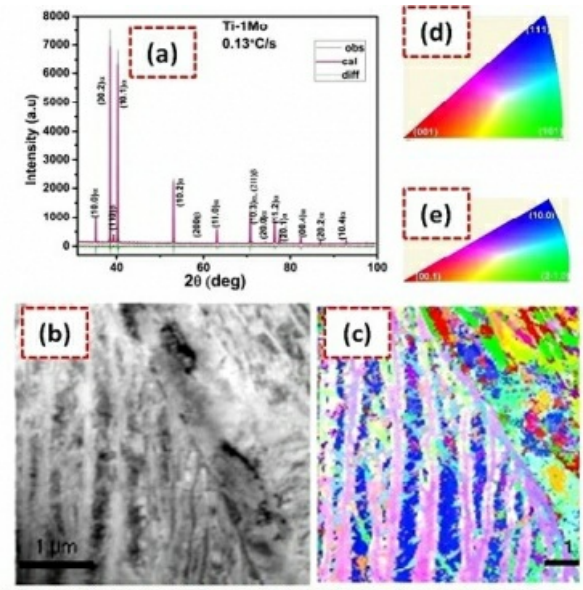

Figure 1 (a) Rietveld refined XRD pattern showing the formation of α and β phase (b) BF image showing Widmanstätten structure (c) Orientation map of same region and (d) and (e)represents IPF colour codes of β and α phases in Ti-1Mo at a cooling rate 0.13°C/s

Keywords: Phase Transformation, Ti-1Mo alloy, XRD and Precession Electron Diffraction