Spinodal Decomposition in Compositionally Modulated Ti-Mo Alloy

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Over the past few decades, β-stabilized Ti-alloys have attracted considerable attention as an alloy for various medical applications due to its bio-compatibility and corrosion resistant properties. However, gaps in knowledge of phase transformation behaviour may limit its use. The present study reports results of an investigation of a non-conventional transformation pathway associated with atomic scale structural and chemical modulations which were seen in a Ti-Mo alloy.

Selected area diffraction patterns recorded from localized regions in <100>$_{\beta}$, <110>$_{\beta}$, <102>$_{\beta}$ and <203>$_{\beta}$ zone axes of quenched Ti-15wt%Mo alloy are presented in Fig. 1. After indexing reflections from stable and metastable phases, additional satellite spots have been observed near β reflections[1]. A close examination reveals that β spot splitting occurs along [100]$_{\beta}$ direction and the spacing of satellite spots from the neighbouring β reflections is constant (~1.3 nm). These same regions, when observed at relatively lower magnification in phase contrast microscopy mode, exhibit broad undulations in intensity with a modulation periodicity of ~1.3 nm over localized regions of 10-20 nm as shown in Fig. 2a-c. The phase contrast images were recorded at defocus values slightly away from Scherzer defocus, at which the bright and dark striations are prominent relative to atomic column contrast. From these images, it is evident that the striations are in a specific direction, i.e., normal to [001]$_{\beta}$, same as that indicated by spot splitting in Fig. 1. Power spectra from these images show the characteristic satellites on β reflections (Fig. 2d-f). Where the phase contrast images are recorded with orientation exactly along a low-index zone axis, the satellite spot pair is seen to be symmetrically placed about each β reciprocal lattice point. The width of the splitting of all β spots is same as the wavelength of the modulation (~1.3 nm) and is independent of the order of reflection. The splitting of the satellites is in one of <100>$_{\beta}$ directions, which are elastically soft directions for the bcc matrix.

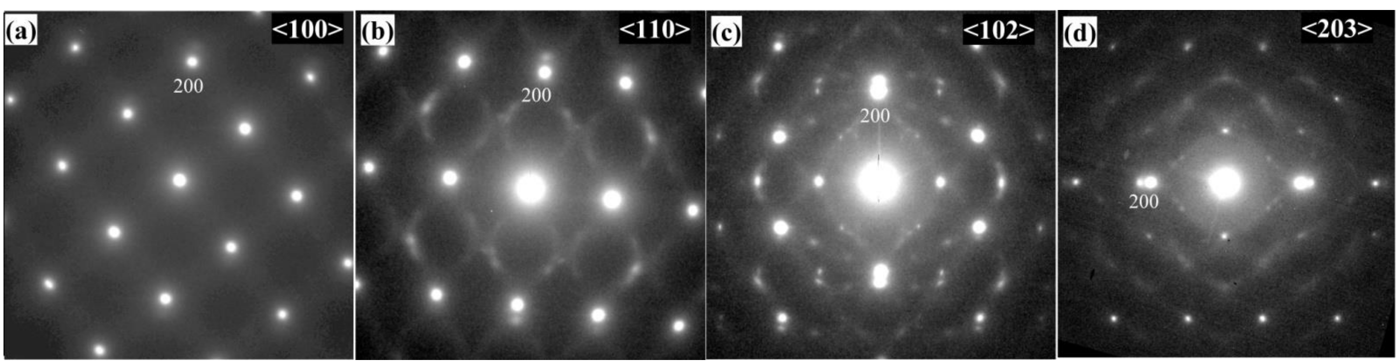

Fig. 1. SADP recorded in (a) <100>$_{\beta}$, (b) <110>$_{\beta}$, (c) <102>$_{\beta}$ and (d) <203>$_{\beta}$ zone axes.

The observed features in diffraction and imaging indicate the occurrence of spinodal decomposition in this alloy having nominally 15% molybdenum by weight. As an added support, chemical analysis results using EDX technique shows the region with striations in intensity to have an average composition that is significantly richer, 18wt% of molybdenum while the region without striations shows a relatively lower Molybdenum content. While it is understood that beam broadening effects over the thickness of the TEM specimen limits ability to determine elemental fluctuations on the scale of 20 nm, a qualitative study over many regions confirm that variations in composition accompany the image and diffraction effects. Hence the experiment concludes the phase separation by spinodal decomposition being limited to the solute-rich regions and thus demonstrates the occurrence of concurrent compositional and structural instability in this Ti-Mo alloy.

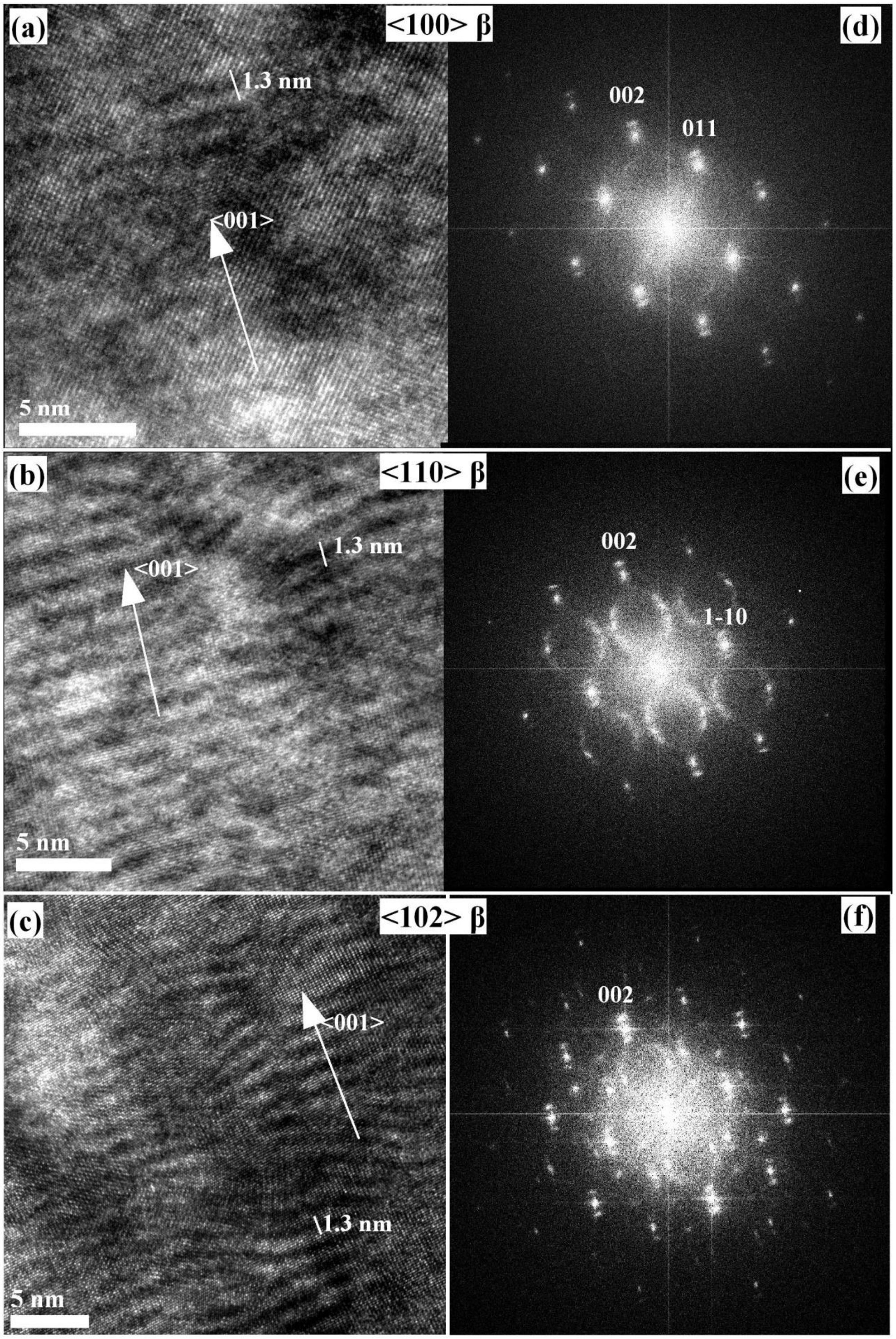

Fig. 2. HRTEM images and corresponding FFTs

References

[1] G. Alphy, V. Sharma, R. Divakar, M. Sabeena, E. Mohandas, Micron 102 (2017) 73-87.

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