Phase transformation pathway in Ti-15Mo studied by in situ synchrotron x-ray diffraction

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Phase transformations in a single crystal of a metastable β titanium alloy (Ti-15Mo in wt %) were investigated in situ during heating by synchrotron x-ray diffraction. Metastable β titanium alloys contain such type and amount of alloying elements that the high-temperature β phase (body-centred cubic) can be retained in a metastable state during fast cooling to room temperature; i.e. the formation of low-temperature α phase (hexagonal close-packed) is prevented. Ti alloys from this class generally undergo a wide range of phase transformations due to their metastable nature. First, nano-sized particles of metastable ω phase form in this class of Ti alloys during fast cooling by a difusionless displacement mechanism, which can be characterized as a collapse of neighbouring $(111)_\beta$ planes into their intermediate position. During ageing or heating, ω particles grow by a combined displacement and diffusion process which is accompanied by rejection of alloying elements from the ω phase into the surrounding β matrix. At higher temperatures, lamellae of the thermodynamically stable α phase precipitate in the material; this process can be assisted either directly or indirectly by the previous β+ω microstructure.

In situ x-ray diffraction was measured using 60 keV photons at the high-energy beamline ID11, ESRF, Grenoble, France. This experiment was performed using an oriented single crystal of Ti-15Mo prepared in an optical floating zone furnace. A slice of the single-crystalline material with the $[100]_\beta$ crystallographic axis parallel to the primary beam was placed in a special quartz chamber furnace which allowed measuring in a high vacuum. X-ray diffraction patterns were acquired in situ during heating with a constant heating rate of 5 °C/min. An example of a measured diffraction pattern is shown in Fig. 1(a).

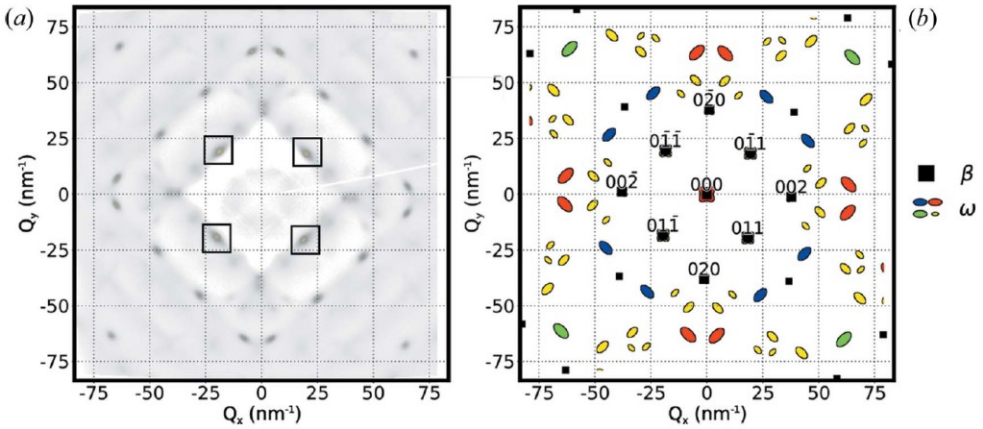

Figure 1. (a) Measured diffraction pattern at room temperature and (b) corresponding calculated pattern with β and ω diffraction maxima denoted by black squares and coloured ellipses, respectively. The four colours represent the four possible orientations of the ω phase with respect to the matrix. The shapes represent the actual shape of ω diffraction spots arising from the shape of ω particles.

Fitting of the temperature dependence of intensity of selected representative single-crystalline diffraction spots showed that at the beginning of linear heating, up to approximately 350°C, the volume of ω phase decreased, which is likely connected with displacement-accompanied ω to β reversion. Between 350°C and 420°C, the volume fraction of ω particles increased which is the consequence of diffusion-driven coarsening of ω phase particles. Subsequently, as the temperature approached the stability limit of the ω phase, the volume of ω decreased. A complete dissolution was observed at 560°C. Finally, a rapid growth of the α phase commenced at about 580°C. It was also verified that during linear heating, none of the crystallographic variants of ω and α phase is preferred.

Keywords: Ti alloys; phase transformations; synchrotron x-ray diffraction

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