Multi-scale 3D characterization of two-phase microstructure in Ti-alloys

Three dimensional (3D) characterizations were conducted in dual-phase Ti-Mo model alloys in order to gain insight into the microstructural aspects on meso and nano scales. Here, focused ion beam scanning electron microscopy (FIB-SEM) was used to characterize solid state phase transformation products. In the atomic scale investigations, the role that Molybdenum plays at the α/β phase boundaries was studied by using 3D atom probe tomography (3DAPT).

Most titanium alloys used in aerospace and industrial applications consist of two-phase mixtures of α and β phases combined in different arrangements [1]. Their relative volume fractions, distribution, size and morphology play a significant role in controlling the mechanical properties, which in turn, determine the in-service performance of the alloy [2]. Thus, it is industrially important and of considerable scientific interest to gain improved understanding of the microstructure development through the β → α phase transformation. Conventional microstructural characterization using two-dimensional analysis may provide insufficient information. Therefore, three dimensional microstructural investigations are often desirable for a more accurate bulk analysis.

In this study, a FEI Helios Nanolab 600i, focused ion beam scanning electron microscope, was used to investigate solid state phase transformation products, formed during continuous cooling at 0.1°C/s in binary Ti-alloys with 2 and 6wt.% Mo additions. The 3D reconstructions of microstructures exhibit allotriomorphic α and colonies of plate-like α precipitates, called Widmanstätten structures, resulting from diffusion-controlled phase transformations at high temperatures, as shown in Fig. 1 for Ti-6wt.%Mo.

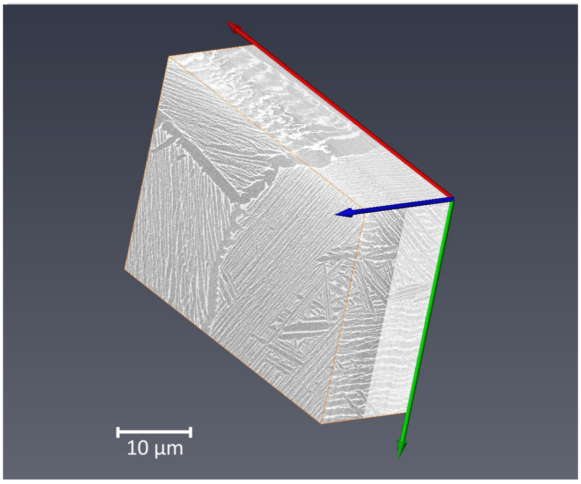

Fig. 1: 3-dimensional microstructural reconstruction of the Ti-6 wt.% Mo alloy.

A preliminary qualitative analysis shows a higher number of α variants for Ti-6wt.%Mo as compared to Ti-2wt.%Mo. In addition, a significant reduction of α plate thickness was observed with increasing Mo content, which can be related to the rejection rates of Mo from the α phase.

3D atom probe tomography (3DAPT) was used to elucidate in more detail the effect of Mo on the β → α phase transformation kinetics. Here, a Ti-6wt.%Mo sample, β-solutionized and isothermally held at 800°C for 15 min prior to quenching, was investigated. 3DAPT needles were prepared in a FEI Quanta 200 3D microscope from an α/β interface with a non-Burgers orientation relationship. 3DAPT analysis was performed on a Cameca LEAP 4000 HR system operating at a base temperature of 80K.

The Mo composition profile across the α/β interface reveals a Mo partitioning into the β phase with concentrations ranging from ~6 to 7 at.%, whereas the α phase is Ti-rich and only contains ~2 at.% Mo. While other elements appear to distribute homogeneously within the α and β phases, a significant pile-up of Mo at the interface is observed. Such a preferential pile-up ahead of a growing α phase can substantially decrease its growth rate. Moreover, it can also affect the local misfit between the α and β phases and consequently influence the morphology of the α precipitates [3].

Further analyses are yet to be conducted for a more comprehensive quantification of the effect of Mo on the α formation kinetics and morphology.

References

[1] G. Lutjering and J.C. Williams, Titanium, 2nd Edition, Engineering Materials and Processes, Springer, 2007.

[2] J.D. Cotton, R.D. Briggs, R.R. Boyer, S. Tamirisakandala, P. Russo, N. Shchetnikov and J.C. Fanning, JOM (2015) 1281-1303.

[3] S. Nag, R. Banerjee, J.Y. Hwang, M. Harper and H.L. Fraser, Philos. Mag. 89 (6) (2009) 535-552.

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