Application of EBSD and Precession-Enhanced Diffraction (PED) to Study Crystallography of β-Titanium Alloy During β→α Transformation under Severe Hot Plastic Deformation

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Over the past two decades EBSD has become one of the most powerful and widely used techniques for statistically proven microstructural characterization, including for grain size and crystallographic orientation. Since EBSD is a bulk-sample, SEM-based technique, it can analyze sample areas at the centimeter scale, yet is capable of mapping grains as small as a few 10s of nanometers. Still finer grained materials are analyzable with diffraction-based mapping techniques on thinned samples, including by SEM/EBSD-based Transmission Kikuchi Diffraction (TKD) and by TEM-based Precession-Enhanced Diffraction (PED). PED uses spot patterns under pseudo-kinematical diffraction conditions, and has successfully demonstrated phase and orientation mapping in a variety of materials at resolutions down to 3-5nm, allowing analysis of previously inaccessible grains in nanostructured materials [1]. The improved resolution of the transmission techniques also makes them more amenable to higher strain materials, since in general fewer dislocations are present in the interaction volume at any given point; however, they are limited in coverage to the electron transparent region of a thinned sample. Thus, for some materials a combination of methods such as PED and EBSD is especially useful for analysis of characteristics at different length scales.

Here we present our recent results on the microstructure and texture of a typical titanium-based metastable β-alloy, VT22 (Ti-5.0Al-4.79Mo-4.70V-0.97Fe-0.71Cr, wt. %), processed by severe hot (below 750°C) plastic deformation. This type of deformation results in a microstructure comprised of elongated, un-recrystallized β-phase grains having a sharp axial texture, and fine intragranular α-precipitates. Experimental details are reported elsewhere [2]. EBSD and PED were used in this study for analysis of the phases involved in the β→α transformation. Both techniques are in good agreement, even over very different sample areas. The Burgers orientation relationship (OR) is fulfilled; however, the realization probability of some OR variants within individual β-grains is not evenly distributed between all possible variants. This can be attributed to the stress accommodation taking place during β→α transformation under conditions of severe plastic deformation.

[1] J.G.Brons, G.B.Thompson, JOM (2013) DOI: 10.1007/s11837-013-0799-5.
[2] O.Ivasishin et al., ASME 2013 IMECE 11/2013; 2A:V02AT02A042 IMECE2013-63767, (2013) 1-10.
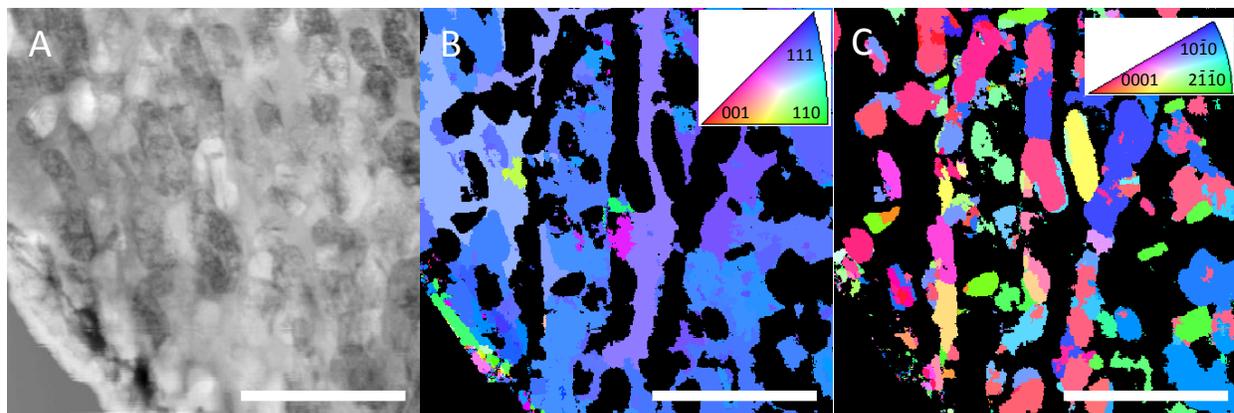
Figure 1. PED results on the crystal structure characterization of the phases involved during β→α transformation of VT22 alloy after severe hot plastic deformation. The e-beam is parallel to the rolling direction. Scale bar is 800 nm. A. Virtual bright-field image. B. Texture map for β-Ti shows essentially a single orientation for the β-phase parent grain, close to {111}. C. Texture map for α- Ti shows a variety of grain orientations.
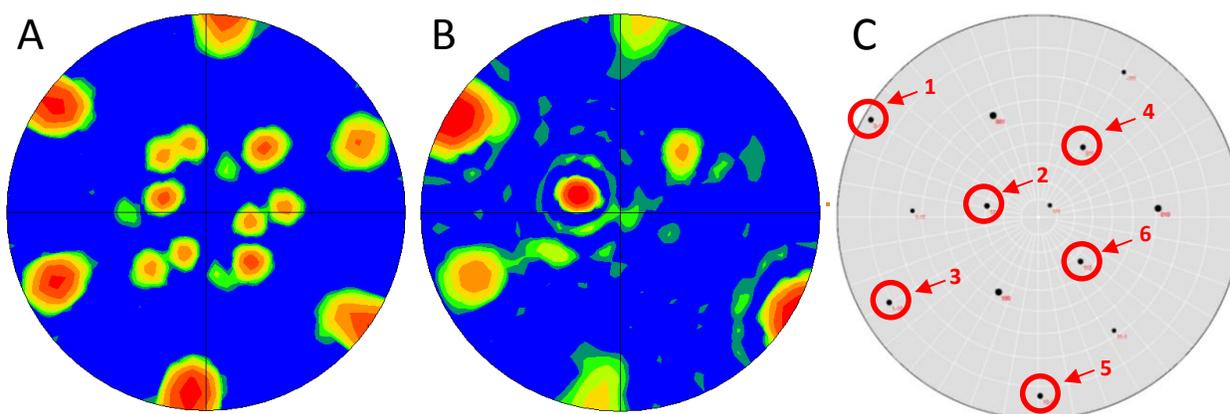
Figure 2. Pole figures obtained using PED of the area on the sample shown in Figure 1. A. {110} of β-Ti shows predominantly one orientation of β-phase parent grain. B. {0002} of α- Ti shows that the vast majority of the α-crystals have {0001}α parallel to {110}β. C. Computer simulated pole figure of {110} of β-Ti shows that the realization probability of some OR variants within individual β-grains is not evenly distributed between all possible variants: variants 1 and 2 are the strongest, 3, 4 and 5 are medium and 6 practically not realized.
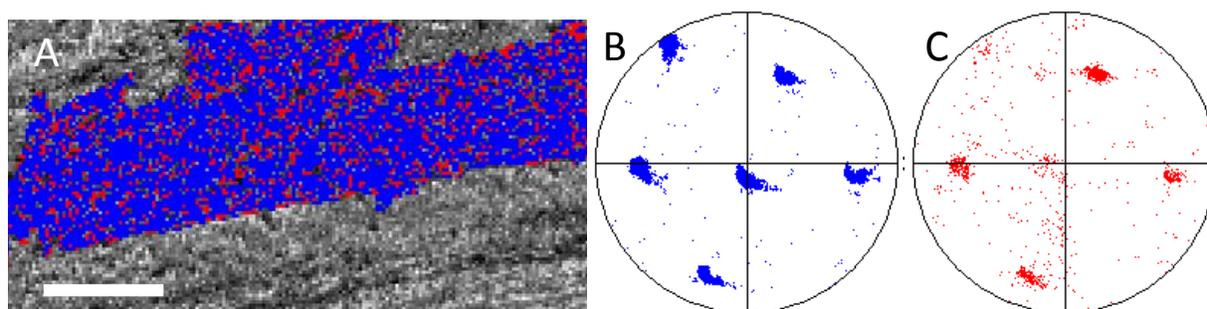
Figure 3. Example of EBSD results. A. Orientation map subset of one β-grain. Blue is for β-Ti and red is for α -Ti. The plane of the image is perpendicular to the rolling direction. Scale bar is 10 μm. B. {110} pole figure of β-Ti. C. {0001} pole figure of α -Ti. {0001}α is parallel to {110}β. Two of 6 possible orientations of α- Ti are not realized strongly.