

Characterization of grain boundary deformation processes in commercial purity titanium using nanoindentation and crystal plasticity modeling

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ABSTRACT

The nature of plastic deformation across grain boundaries in α -titanium has been studied using instrumented sphero-conical nanoindentation in complement with crystal plasticity modeling. Following crystal orientation mapping using electron backscattered diffraction, indentation was performed (i) in the center of grains to mimic single crystal indentation and (ii) near grain boundaries to carry out bicrystal experiments. The pile-up topography that forms as a function of nanoindentation axis was characterized using atomic force microscopy (AFM). Crystal plasticity finite element simulations were carried out iteratively by varying the slip parameters until a best fit was found between the experimentally measured single crystal pile-up topographies and the simulated single crystal pile-up topographies of several orientations. AFM characterization of bicrystal nanoindents revealed changes in the pile-up topographies compared to those for single crystal nanoindents carried out in the same grain. In general, the pile-up topographies were not strongly influenced by low angle grain boundaries, indicating significant strain transfer across the boundaries. In contrast, many high angle boundaries strongly influenced the pile-up morphology, with changes in the pile-ups noted in both the grain containing the pile-up and in the neighboring grain. The ability to accurately simulate the influence of grain boundaries pile-up development was examined by carrying out CPFEM simulations of bicrystal nanoindentation. Direct comparison of the AFM-measured topographies with simulated topographies reveals that the general nature of bicrystal pile-up topography is well simulated, but that in general, the measured pile-up transfer is somewhat smaller than the simulated pile-up transfer. The results of the study will be discussed in terms of a number of generalized slip transfer criteria. This research was supported the National Science Foundation through a Materials World Network Grant DMR-1108211 and the complementary Deutsche Forschungsgemeinschaft grant ZA523/3-1.