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Statistics of Deformation Twinning in Cu/Nb Nanolamellar Composites Measured Using Electron Backscatter Diffraction (EBSD)

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Properties of nano-layer composites are dominated by the high density of interfaces and the interfacial structure of the interfaces. We use repeated accumulative roll bonding (ARB) to fabricate Cu/Nb multilayers with average layer thicknesses ranging from tens of microns down to tens of nanometers. Below average layer thicknesses of 100nm, twinning becomes an important deformation mode in the Cu layers, and has a considerable effect on the evolving Cu texture. We use Electron Backscatter Diffraction to perform a statistical analysis of deformation twinning in 30 and 58nm thick Cu layers.

Because of its combination of spatially correlated orientation data and large sampling areas, electron backscatter diffraction (EBSD) is an excellent tool for examining twinning statistics in micron grain sized, low symmetry metals. It has been previously used for statistical studies of deformation twinning in micron grain size Mg, Zr, and U. However, EBSD has been of limited use for statistical studies of deformation twinning in copper and other cubic metals. There are two primary factors that have limited the usefulness of EBSD for measuring twinning statistics in copper. First, the high symmetry of fcc metals makes twin variant determination ambiguous with regard to boundary misorientation. There are three twin variants for each {111} plane, and all of the <112>{111} variants result in an equivalent boundary misorientation. Second, the scale of twins in copper is usually below the practical EBSD spatial resolution. Even for large grain copper deformed at cryogenic temperatures or at high rates the twin thicknesses are generally below the spatial resolution of EBSD.

We have overcome these limitations to use EBSD to perform statistical studies of twinning on sub-100nm thick Cu layers in ARB material. First, we use a wedge mounting technique [1] demonstrated in Figure 1 to take advantage of the fact that our layered nano-materials are only nano in one direction. The wedge technique makes it so that within the metallographic plane of observation, the apparent layer thickness is increased by 575% for a 10° wedge. We also use a computer program to post-process EBSD data similar to the program used for statistical twin studies in other materials, but have altered the algorithm for twin variant selection to deal with the symmetry effects.

Figure 2 shows an example of the 58nm ARB microstructure obtained using the wedge technique. Twin statistics for the 58nm ARB material were based on scans totaling an area of 3500 μm^2. Figure 3 is an ODF slice that compares twin parent orientations at 58nm (contours) with the distribution of orientations for 135nm ARB material (just prior to the onset of twining). This difference in peak positions is an indication of the orientation dependence of twinning in nano-layered copper. Figure 4 shows the grain twin fraction as a function of grain thickness indicating a clear size effect for deformation twinning in Cu layers.

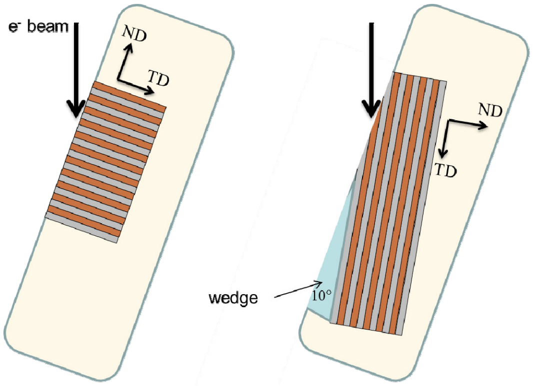

Figure 1. Schematic of typical cross-section mounted nano-layered sample in EBSD configuration compared with a 10° wedge mounted sample. The apparent layer thickness for the 10° wedge sample is 575% the actual layer thickness.

[1] Carpenter, McCabe, et. al., JAP Comm. (2013) in press.

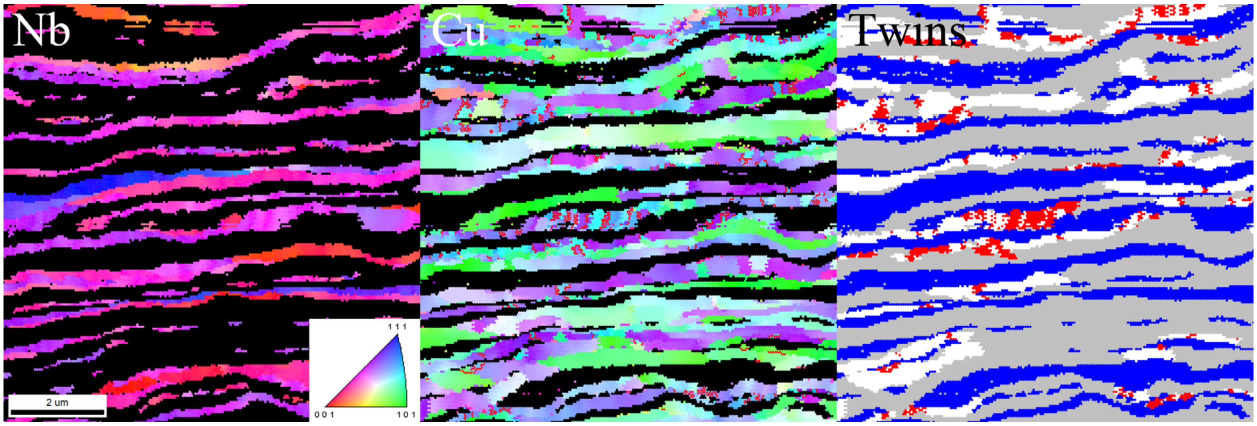

Figure 2. Wedge section microstructure of 58nm ARB Cu/Nb material. Twin statistics were based on 3500 μm^2 of wedge section area.

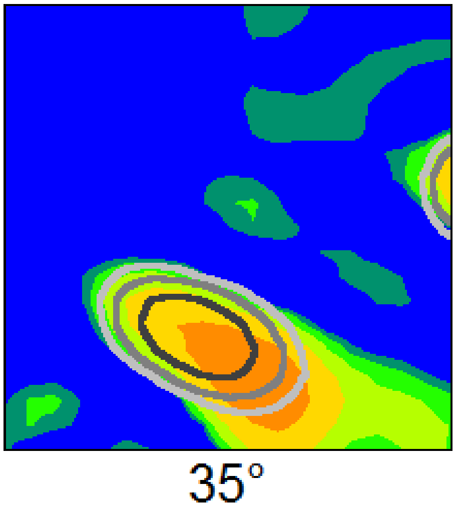

Figure 3. ODF slice showing the 58nm twin parent intensity contours overlaying 135nm (untwinned) ODF intensities. The difference in peak positions illustrates an orientation preference for twinning in the ARB Cu.

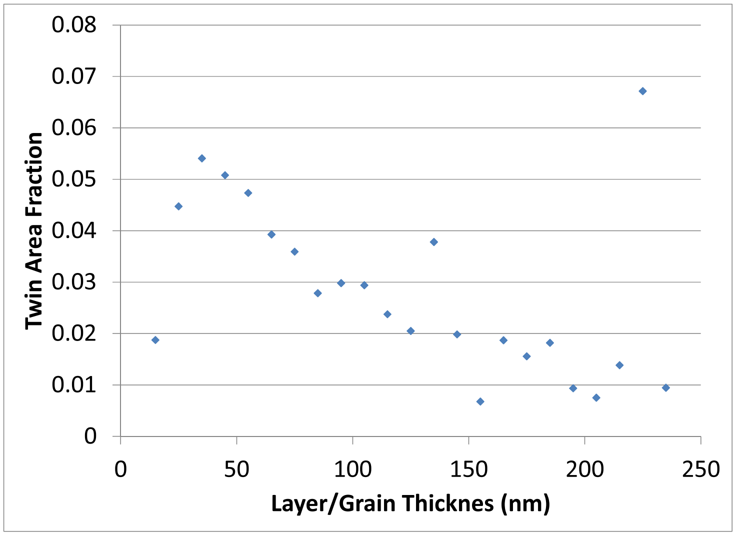

Figure 4. Dependence of grain twin area fraction on grain thickness illustrating a size effect where twinning is more prevalent in thinner copper layers.