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Dislocation-less plasticity in small grained Al alloys.

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The Hall-Petch relationship, that describes the increase of a metal's yield strength with the inverse of its grain size holds down to the nanometer scale. In nano-sized grains, generally void of dislocations the strength saturates or decreases, which is generally attributed to plastic processes carried by the grain boundaries (GBs) themselves, such as rotation, intergranular slip and/or shear-migration coupling. Although many observations account for these mechanisms, they have rarely been quantified experimentally in small-grained metals.

Fig.1. Superimposed EBSD map and topological SEM image to show deformation at GBs in an Al3%mg UFG alloy

The dominant model to explain shear-migration coupling is based on the lattice dislocation content of a tilt boundary and predicts that the coupling factor (β = shear/migration distance) increases with the GB misorientation. It has been partly validated on large bicrystals [1], but rare polycrystal experiments indicate an opposite trend.

Using *in situ* transmission electron microscopy (TEM) and atomic force microscopy (AFM), coupled with automated crystalline orientation mapping techniques (ACOM, EBSD) we both followed the movement of GBs in real time and measured the coupling factor with image correlation. In dislocation-free ultra-fine-grained aluminum (UFG, resulting from severe plastic deformation and subsequently annealed), we quantified the shear-migration coupling statistically in all directions of space. It appears that:

- The shear-migration coupling factor β is not a function of the GB misorientation
- A given GB may have several β during a single migration
- All the measured β in this study were much lower than those predicted by , explaining at least in part why GB-based plastic mechanisms are not as efficient as dislocations and why small-grained metals exhibit limited ductility [2].
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Keywords: Grain boundaries, shear-migration coupling, disconnections, UFG Al

References:

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