SHEAR-COUPLING MIGRATION OF GRAIN BOUNDARIES IN UFG AL

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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 "grain boundaries (GBs) plastic processes". Among the several ones often envisaged to account for permanent deformation (rotation, intergranular slip, dislocation accumulation), shear-migration coupling has recently emerged as the most efficient one. And although many observations account for these mechanisms, they have rarely been quantified experimentally in small-grained metals.

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 (b = shear/migration distance) increases with GB misorientation. Partly validated on large bicrystals [1], 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 b is not a function of the GB misorientation
- A GB may have several b during a single migration (b is not an intrinsic characteristic of a given GB)
- All the measured b in this study were much lower than those predicted, 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]

Figure 1 – Superimposed EBSD map and topological SEM image showing surface deformation at GBs in a crept Al3%mg UFG alloy

References:

[1] T Gorkaya, DA Molodov, G Gottstein. Acta Materialia 2009;57:5396–405.
[2] R Gautier, A Rajabzadeh, M Larranaga, N Combe, F Mompiou, M Legros. C.R. Phys. 2021;22:1–16.