PROBING GRAIN BOUNDARY MECHANISMS BY IN-SITU TEM

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In small grained metals, specific elementary deformation mechanisms such as GB sliding, dislocation emission from GB, shear coupled GB migration, grain rotation are expected to be active. However, their relative preponderance and activation during the overall plastic deformation is still difficult to assess, mainly because identifying these mechanisms in small crystallite at the appropriate time scale is a challenge.
To that respect, in-situ TEM experiments have proven to be an adequate tool to probe the dynamics of these mechanisms.

In this talk, I would like to report observations obtained during several in-situ straining TEM experiments in small grained Al (grain size between 100nm and 1µm) on MEMS-supported polycrystalline thin films, bicrystals, and bulk polycrystals.

In polycrystalline thin films, several inter- (dislocation emission from internal or GB sources) and intra- granular mechanisms (i.e. GB sliding and grain growth) are activated during plastic deformation in a complex manner that can be first qualitatively retrieved [1].

Grain growth under stress can be interpreted by an unusual mechanism where the GB migration is coupled to a strain. The amount of deformation produced, also called the coupling factor, can be measured during an experiment by image correlation and then tentatively modeled [2]. We have shown, thanks to dedicated experiments in bicrystals, that this mechanism can be understood by the motion of step-dislocations along the GB, a conclusion supported also by recent MD simulations and high resolution observations [3-5]. Because these step dislocations can result from the dissociation of lattice dislocations in the GB [5], we highlight a possible interplay between intra- and inter-granular deformation mechanisms.

Contrary to grain growth that can be easily evidenced, observations of grain rotation remains limited. Experimental evidence are hard to capture in small-grained materials and might lead to artefacts like sample rigid rotation. Recent efforts to unravel elementary GB mechanics mostly focused on individual straight low index coincident GB, and the analysis of the collective behavior of a realistic GB network is still in its infancy. We have developed an original methodology combining sequential in-situ straining experiments followed by automated crystal orientation mapping in a TEM and a custom-made data processing. This configuration allows both dynamical observations of elementary mechanisms, analysis of GB evolution in individual grain and statistical analysis at large scale. We have shown in polycrystalline thin films that grain rotation can be indeed observed and as for grain growth, appears to be a direct consequence of GB dislocation motion with a Burgers vector out of the film plane [6].

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