Plastic deformation in confined volumes: an in-situ TEM study

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Metals with one (whiskers, fibers), two (thin films) or three (small grain materials) reduced dimensions demonstrate a clear trend of strengths that scale as a power-law of their size (the so called « size effect »). In all these metals, interfaces, i.e. free (or oxyde) surfaces or grain boundaries (GB), are supposed to play a crucial role in the deformation mechanisms. Some specific mechanisms may thus be exacerbed, but because exploring these mechanisms in very small crystallites is complex, their nature is still highly debated. To that respect, in-situ transmission electron microscopy (TEM) experiments have proven in the past few years to be efficient to probe these mechanisms at the appropriate length and time scale.

In this talk, I would like to report several in-situ TEM experiments highlighting the importance of GB and interfaces in the plastic deformation either of small grained Al (grain size between 100nm and 1µm) or in sub-micron monocrystalline metallic fibers.

Two important results have been found. In small grained Al, we have shown that several inter- (dislocation emission from internal or GB sources) and intra- granular mechanisms (i.e. GB sliding and GB shear coupled migration, grain rotation) can be activated. The amount of strain produced during shear coupled GB migration can be measured and tentatively modeled. We have proved that this mechanism can be understood by the motion of interfacial dislocations.

In small scale fibers, we have shown that the intial dislocation microstructure plays the most important role in the deformation behavior. Our observations indicate that the activation of dislocation sources randomly distributed in the fibers can explain the size effect observed. Dislocations or twins can also be nucleated directly from the free surfaces.