Size dependence of grain boundary migration in metals under mechanical loading

With the support by the National Natural Science Foundation of China, the research team directed by Prof. Lu Ke (卢柯) and Prof. Li XiuYan (李秀艳) at Shenyang National Laboratory for Materials Science, Institute of Metal Research, Chinese Academy of Sciences, recently reported an abnormal grain size dependence of mechanically induced grain boundary (GB) migration in metals, which was published in *Physical Review Letters* (2019, 122: 126101).

Mechanically induced GB migration with concomitant coarsening of grains occurs easily in nanograined metals, which not only deteriorates the properties of nanograined materials but also hinders their processing by plastic deformation. Various theoretical models and computational simulations suggest that this process is dependent on GB structure and composition. It is generally believed that the mechanically induced GB migration is related to the GB energy, GB curvature and disconnections in GBs. The smaller the grain size, the faster the migration rate.

They discovered that mechanical stability of nanograins prepared by plastic deformation shows a turning point (critical size) under the condition of quasi-static tension. Above the critical size, the grain coarsening amplitude increases with a decrease of grain size. While below this size, the grain coarsening amplitude drops with the decrease of grain size. The critical sizes in pure Cu, Ag, and Ni are about 75, 80, and 38 nm. The abnormal mechanical stability of nanograins below the critical size is ascribed to the strain-induced relaxation of GBs during preparation, which leads to the formation of low-energy and faceted GBs. And its deformation mechanism under tension is dominated by movement of partial dislocations to form twins or stacking faults in the nanograins. It is also found that GBs of nanograins with size slightly larger than the critical size in Cu could be relaxed by a suitable annealing process, which obviously enhanced its mechanical stability.

This discovery is important for understanding the nature of GBs at the nanoscale and their response to mechanical stimuli. It also shows a potential to fabricate finer structures of metals with better stability by plastic deformation.

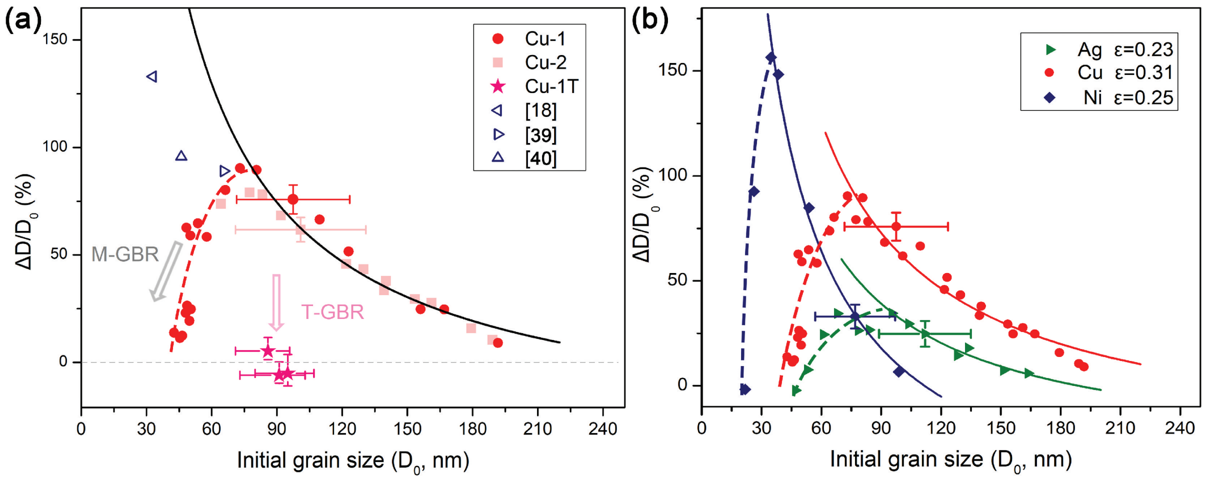

Figure (a) Variations of measured relative grain size change ($\Delta D/D_0$) as a function of initial grain size (D_0) for Cu after tension with a strain of 0.31 for Cu-1 and Cu-2. Cu-1T represents Cu-1 after thermal annealing for relaxing GBs, and its true strain is 0.3. (b) Variations of $\Delta D/D_0$ as a function of D_0 for Ag (strain: 0.23), Cu (strain: 0.31), and Ni (strain: 0.25), respectively. Error bars represent the typical variation ranges of $\Delta D/D_0$ and the standard deviations of D_0.