In situ atomistic observation of disconnection-mediated grain boundary migration

Under the support of the National Natural Science Foundation of China, the research team led by Prof. Zhang Ze (张泽) and Prof. Wang JiangWei (王江伟) at the Center of Electron Microscopy and State Key Laboratory of Silicon Materials, School of Materials Science and Engineering, Zhejiang University, revealed the atomistic mechanism of disconnection-mediated grain boundary migrations in metallic nanostructures, which was published in *Nature Communications* (2019, 10: 156).

Grain boundary (GB) migration is a prevalent plastic deformation mode in nanocrystalline materials, and a comprehensive understanding of GB migration is vital to the development of novel materials through GB engineering. Numerous theoretical and experimental investigations have presented a disconnection model (GB defect exhibiting both dislocation and step-like character) for the shear-coupled GB migration. However, the atomistic mechanism of disconnection dynamics (including nucleation, propagation and interaction) and their contribution to the GB deformation remain largely unclear, especially in experiments due to the technical limitations.

In this research, Wang's group successfully conducted a series of state-of-art *in situ* shear tests on nanoscale bicrystals with different GB structures that were fabricated inside a transmission electron microscope (TEM); they unambiguously revealed a universal atomistic mechanism of the shear-coupled GB migration, which consists of the nucleation, lateral propagation and dynamic interactions of different GB disconnections. They also demonstrated that the lattice defects had little influence on the disconnection-dominated GB migration and the triple junctions could serve as effective nucleation sites of GB disconnections, providing in-depth insights into the GB migration and enriching our understanding of GB-mediated plasticity in a broad class of nanocrystalline materials. Further, they discovered that the shear-coupled migration of some special GBs (e. g. Σ11(113) GB) is fully reversible under cyclic loading, which effectively enhances the deformability of metallic nanostructures, holding significant implication to the improvement of mechanical properties via the proper control of GB structures.

By adopting the similar *in situ* nanofabrication and mechanical testing techniques, Wang's group has also made significant progress in the investigation of the superplastic behavior of metallic nanowires, which was published in *Science Advances* (2018, 4: eaas8850) and *Advanced Functional Materials* (2018, 28: 1805258).

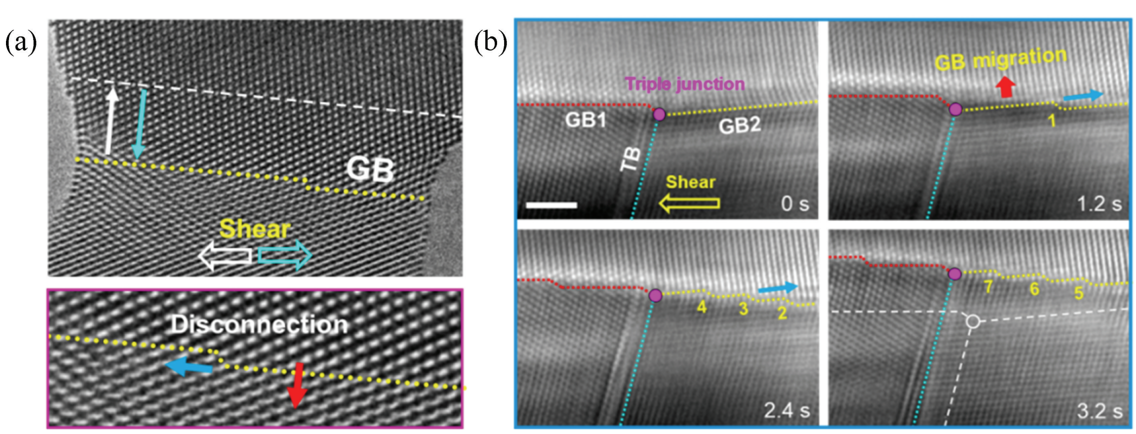

Figure (a) Disconnection-mediated GB migration under shear stress; (b) GB disconnection nucleation from the triple junction.