Characterization of Grain Boundary Related Mechanical Phenomena via TEM Nanoindentation

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The presence of grain boundaries has strong influence on materials' properties. Especially in mechanical phenomena, grain boundaries crucially affect the deformation and the fracture processes of polycrystalline materials. In deformation, grain boundaries act as effective barriers against the dislocation slip, while in fracture process, grain boundaries behave as preferential paths for the crack propagation. So far, these phenomena, dislocation-grain boundary interaction and grain boundary fracture, have been extensively investigated in large scale. However, the fundamental processes are still not well understood because the elementary process of these phenomena occur in nano/atomic scales. In the present study, we carried out the nanoindentation experiments to $SrTiO_3$ and Al_2O_3 inside a transmission electron microscope. We prepared several kind of bicrystals to obtain the well-defined single grain boundaries, which enable to perform the systematic experiments.

For the study of dislocation-grain boundary interaction, we successfully controlled the introduction and propagation of dislocations in $SrTiO_3$ and observed the interaction processes of the individual dislocations with single grain boundaries. The dynamic interaction processes strongly depend on the grain boundary characters, which will be discussed in detail in the presentation.

For investigating the grain boundary fracture, a sub-micro scale crack was introduced along a dopant-segregated Al_2O_3 grain boundary. From the direct observations of atomic structures of the as-fractured surface and the crack tip in a scanning TEM, the atomistic fracture path, i.e. which atomic bonds were broken in the crack propagation within the grain boundary core, was determined. The relationship between the atomistic crack propagation path and the grain boundary structure will be discussed in the presentation.

[1] S. Kondo *et al.*, Sci. Adv. **2**, e1501926 (2016).
[2] S. Kondo *et al.*, Nat. Comun. **10**, 2112 (2019).