TEM investigation of dislocation structures and twinning behavior in oxide crystals

Eita Tochigi

Institute of Engineering Innovation, The University of Tokyo

Dislocations and twins are known to be lattice defects in crystals that generated by plastic deformation. To understand the plasticity of crystals, it is important to investigate dislocation and twins. Transmission electron microscopy (TEM) is a powerful technique to characterize lattice defects in nanometer to atomic-scale. Furthermore, by using in situ techniques, their dynamic behavior can also be examined. In this study, we investigate dislocations and twins in oxides by TEM including atomic-resolution imaging and in situ mechanical testing.

Alumina (α-Al_2O_3) is a representative high-temperature structural material. At elevated temperature, its plastic deformation behavior is controlled by dislocation slip. It is known that a low-angle grain boundary consists of dislocations, and the character of dislocations depends on the boundary orientation. Based on this relationship, several types of low-angle grain boundary of alumina were designed and fabricated using the bicrystal method, where two single crystals are joined at elevated temperature. Dislocations formed in the resultant grain boundaries were characterized by conventional TEM and atomic-resolution TEM. We will discuss their core atomic structures, dissociation reactions, and associated stacking faults.

Quartz (α-SiO_2) is one of the key engineering materials used for such as oscillators and microbalances. It has a twinning system activated at low temperatures, which is called Dauphiné twinning. Little is known about nucleation and propagation processes of Dauphiné twinning. Here, quartz nanopillars were fabricated by focused ion beam (FIB), and their deformation behavior and mechanical responses were examined by in situ TEM compression testing. Our in situ observation showed that a Dauphiné twin grown within a nanopillar with loading and it shrunk with unloading, indicating that Dauphiné twinning is reversible phenomenon. We will show the dynamic behavior of the Dauphiné twinning and discuss its mechanisms in detail.