The Structure of Screw Dislocations in an α-Al_2O_3 Bicrystal with a Low-angle Twist Grain Boundary

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α-Al_2O_3 is the one of the most utilized structural ceramics. At elevated temperatures, the plastic deformation of α-Al_2O_3 is dominated by basal dislocation motion [1]. Therefore, the structure and glide behaviors of the basal dislocation ($\boldsymbol{b}$ = $1/3\langle 1\bar{2}10\rangle$) have been studied for many years [1-4]. The basal edge dislocation is known to be dissociated into $1/3\langle 1\bar{1}00\rangle$ and $1/3\langle 0\bar{1}10\rangle$ partial dislocations with a 4 - 5nm wide stacking fault on the $\{1\bar{2}10\}$ plane by climb mechanism [2, 3], whereas the basal screw dislocation has not been well characterized yet. The purpose of this study is to characterize the structure of the basal screw dislocation by transmission electron microscopy.

An α-Al_2O_3 bicrystal with a (0001)/[0001] low-angle twist grain boundary was fabricated by diffusion bonding (FIG. 1.). The bicrystal was mechanically cut and ground, and then milled by argon ion to obtain electron transparency. The samples were observed by conventional TEM (JEM-2010HC, 200kV, JEOL) and high-resolution TEM (JEM-4010, 400kV, JEOL).

FIG. 2 shows a plan-view TEM image of the grain boundary. A hexagonal dislocation network is formed on the boundary. The dislocation line direction is parallel to the $\langle 1\bar{2}10\rangle$ directions. Thus, it is found that the dislocation network is consisted of the $1/3\langle 1\bar{2}10\rangle$ screw dislocations. The intervals of screw dislocations having the same line direction, d, are about 60nm. From the Frank's equation ($\theta = |\boldsymbol{b}|/d$) [5], the twist angle of the boundary, θ, is estimated to be 0.45°, where $|\boldsymbol{b}|$ = 0.476nm.

FIG. 3 shows a high-resolution TEM image of a screw dislocation observed end-on. The Burgers circuit is drawn around the dislocation. Since the start and the end points of the circuit correspond to each other, it is verified that this dislocation has no edge component. The image contrast is disturbed little over about 1nm, which should correspond to the dislocation core. This indicates that the basal screw dislocation is not dissociated.

The partial-dislocation pair dissociated from a basal edge dislocation is considered to hardly glide because of the $\{1\bar{2}10\}$ stacking fault formed perpendicular to the slip plane. In contrast, since the basal screw dislocation has the perfect-type core structure, it should be able to move more freely. This would be important to understand the deformation behavior of α-Al_2O_3.

References
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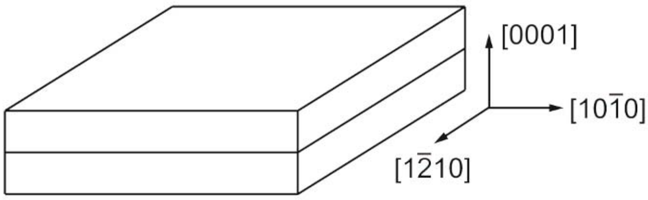

FIG. 1. A schematic illustration showing the bicrystal fabricated in this study. The bicrystal contains a (0001)/[0001] low-angle twist boundary.

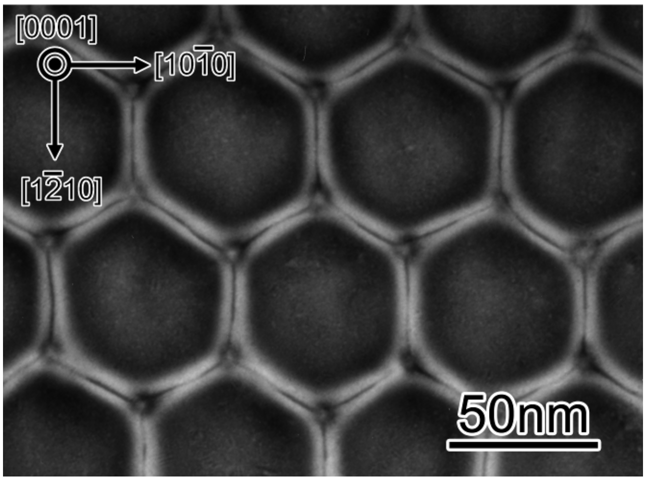

FIG. 2. A bright-field TEM image of the grain boundary observed in plan-view. A hexagonal screw dislocation network is formed.

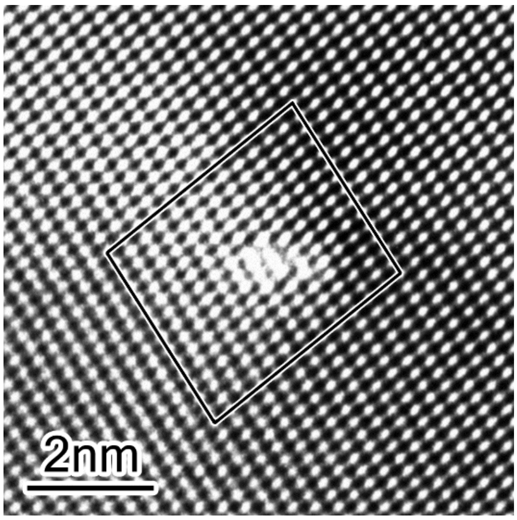

FIG. 3. A high-resolution TEM image of a screw dislocation core observed end-on. The screw dislocation is not dissociated.