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Yttrium segregation at alumina grain boundaries

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Alumina ceramics (α-Al_2O_3) is one of the most utilized structural materials because of their remarkable structural and chemical stability at high temperatures. It is well known that the mechanical properties of fine-grained polycrystalline α-Al_2O_3 can be dramatically improved by the addition of small amounts of rare-earth elements. However, strengthening mechanism by the rare-earth doping is still under controversy. Yoshida et al. reported that the creep resistance of polycrystalline α-Al_2O_3 is highly improved by the doping of R_2O_3 (R: La, Y, Lu) in the level of about 0.045mol % at 1250-1350℃ [1]. By transmission electron microscopy (TEM) - energy dispersive spectrometry (EDS) analyses, the impurities are only detected along grain boundaries (G.B.), but not from grain interiors. It is now recognized that segregating rare-earth atoms preferentially occupy very specific atomic sites along grain boundaries [2]. These breakthroughs have opened up the possibility of clarifying the mechanism of dopant effect in α-Al_2O_3 grain boundaries. In the present study, we characterize the Y atomic positions along the several model grain boundaries with different orientation relationships.

In this study, $\Sigma13(10\bar{1}4)$ twin G.B. [3,4], $\Sigma37(\bar{1}018)$ twin G.B. [5,6,7], and $\Sigma11(10\bar{1}1)$ twin G.B. [4,8] with rotation axis of $[1\bar{2}10]$ were selected as the model grain boundaries. Pristine and Y-doped bicrystals were fabricated by diffusion bonding at 1500℃ for 10 hour in air. In the case of Y-doped bicrystals, 0.02mol/l $Y(CH_3COO)_3$ aq. was coated on one side of the polished surfaces, and then sandwiched by the other crystal during diffusion bonding. HRTEM and STEM observations were performed by using JEM-4010 (400kV) and Cs-corrected JEM-2100F(200kV).

Fig. 1 shows the experimental HRTEM images of pristine (a) Σ13 G.B., (b) Σ37 G.B., (c) Σ11 G.B., and Y-doped (d) Σ13 G.B., (e) Σ37 G.B., (f) Σ11 G.B., respectively. It is clearly seen that there are no secondary/amorphous phases along the boundaries, and the two crystals were well-bonded at an atomic level. If comparing two HRTEM images of Σ13 G.B. ((a) and (d)), slight difference in contrast can be seen in the vicinity of the boundary core region. In the image of Σ37 G.B.((b) and (e)), contrast in grain boundary clearly changed, from faceted structure to straight one. On the other hand, we can't find large differences between pristine and Y-doped Σ11 G.B.((c) and (f)), which suggests that Y may not segregate to this grain boundary. These results suggest that segregation behavior of Y atoms strongly depend on the grain boundary characters. In the poster session, we will show the HAADF STEM images of above-mentioned grain boundaries and discuss their segregation behaviors.

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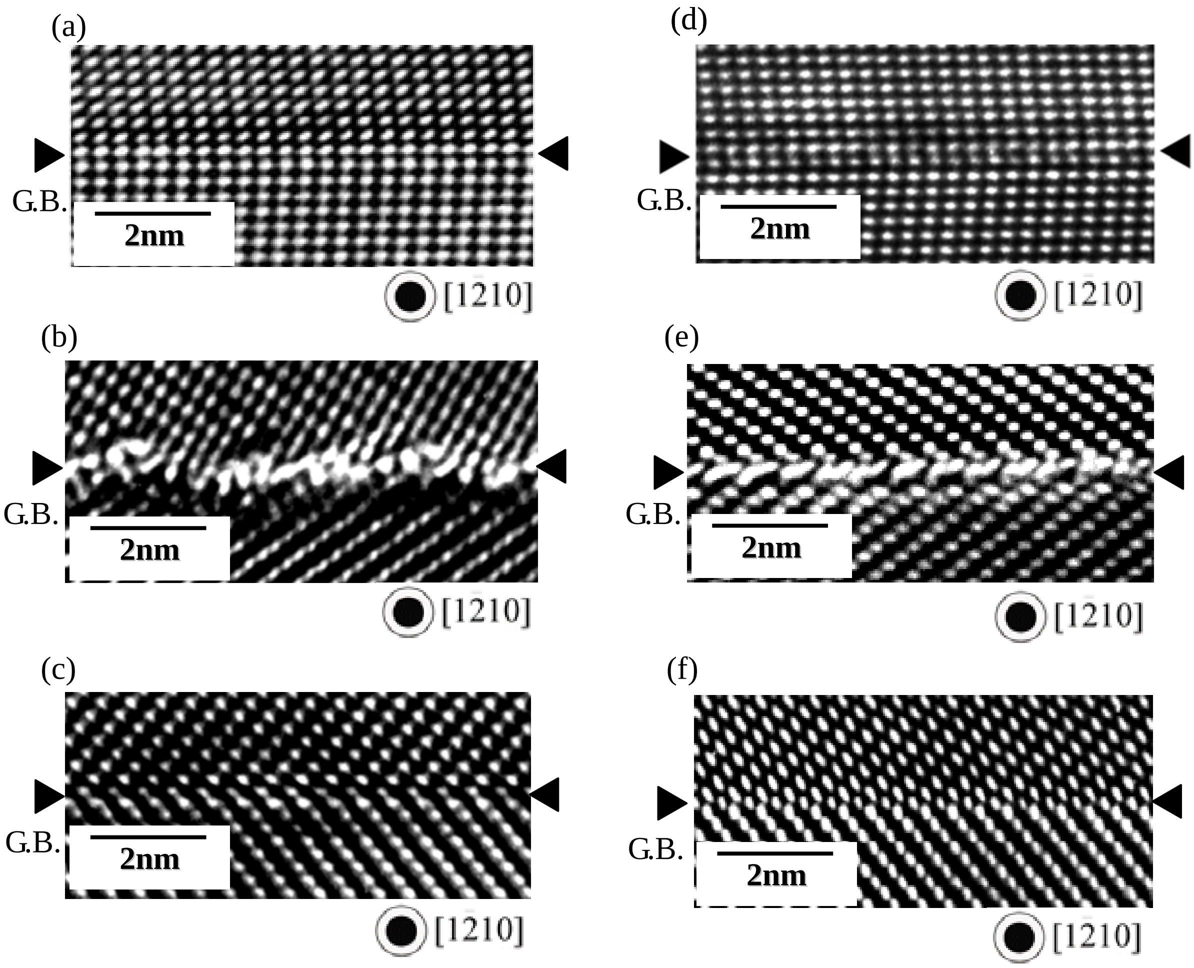

Fig. 1. HRTEM images of pristine (a) Σ13, (b) Σ37 and (c) Σ11 twin G.B. and Y-doped (d) Σ13, (e) Σ37 and (f) Σ11 twin G.B.. Arrows indicate the position of grain boundaries.