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HIGH-RESOLUTION IMAGING OF SYMMETRIC TILT AND MIXED CHARACTER BOUNDARIES IN Al

M. Shamzuzzoha, P.A. Deymier and David J. Smith*

Department of Materials Science and Engineering, University of Arizona, Tucson, AZ 85721, USA
*Center for Solid State Science and Department of Physics, Arizona State University, Tempe, AZ 85287, USA

The determination of the core structure of grain boundaries is central to a better understanding of the properties of polycrystalline materials. With the recent advent of intermediate-voltage electron microscopes (300-400kV), it is possible to obtain atomic-resolution images of grain boundaries in many metals[1] - for example, the atomic structure of periodic grain boundaries in selected metals has been studied.[2,3] Our knowledge of materials properties can be further enhanced by investigating more complex, arbitrarily misoriented grain boundaries. In this paper, we will report HREM imaging of a symmetric tilt low-angle grain boundary and a twist-and-tilt (mixed character) grain boundary in Al.

The Al bicrystals used in this study were produced by cross-rolling and annealing methods described in detail elsewhere.[4] Thin foil specimens of 3mm diameter containing specific boundaries were obtained by spark-cutting and subsequent electropolishing in 73% methanol, 25% nitric acid and 2% hydrochloric acid. HREM was performed with a JEM-4000EX operated at 400kV, using axial illumination and without an objective aperture. High-resolution electron micrographs were recorded near the optimum defocus, typically at a magnification of 500,000 times.

A HREM image of a symmetric tilt 6° [100] grain boundary is shown in Fig. 1. The dislocation cores along the length of this boundary are arranged in a linear manner and the boundary plane is roughly (001). Each dislocation is of perfect character and exhibits 1/2[110] Burgers' vector. The approximate spacing of 32 Å between dislocations is in close agreement with the theoretically predicted value[5] given by the forumula $D=a/\theta$ (where a = atomic spacing, θ = misorientation angle, D=dislocation spacing). A mixed character high-angle grain boundary is shown in Fig. 2. Its mixed nature can be described as a 45° [100] rotation (twist) of crystal 1 with respect to crystal 2 followed by a ~29° rotation (tilt) about the common $[011]_1$ and $[010]_2$. The grain boundary is generally parallel to (100) of crystal 2 and $(3\bar{2}2)$ of crystal 1, and exhibits microfacets parallel to $(1\bar{2}0)$ of crystal 1. The $(1\bar{1}1)$ plane of crystal 1 and the (010) planes of crystal 2 almost coincide for every 3 interplanar spacings along the GB plane.

In summary, the results of this investigation show that low angle [100] tilt grain boundary structure agrees well with that predicted by simple dislocation models.[6] Mixed boundaries exhibit well-defined crystalline structure but with a complex core configuration.[7]

References

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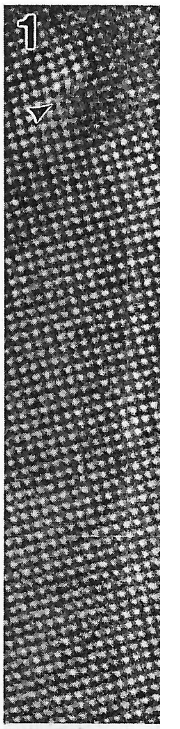
7. This work has been supported by DOE Grant DE-FG02-87ER45285.



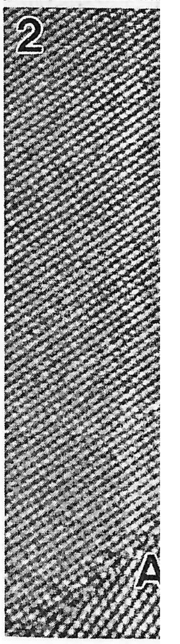
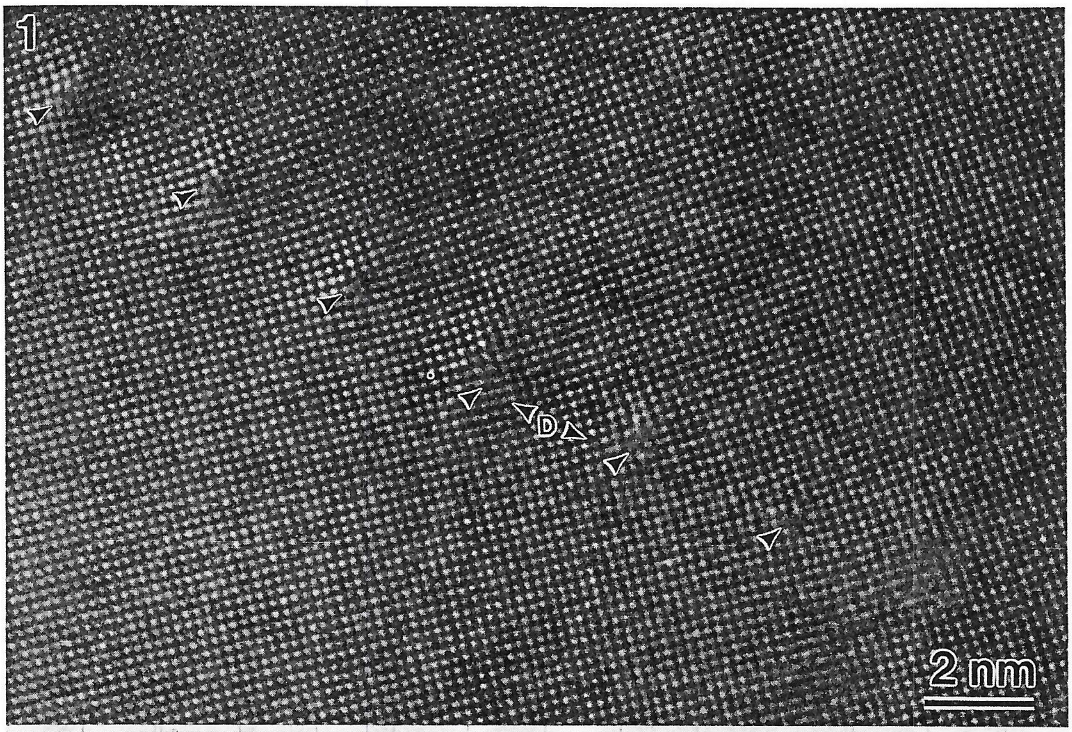


Fig. 1: HREM
dislocatio
Fig. 2: HRE
microfacet



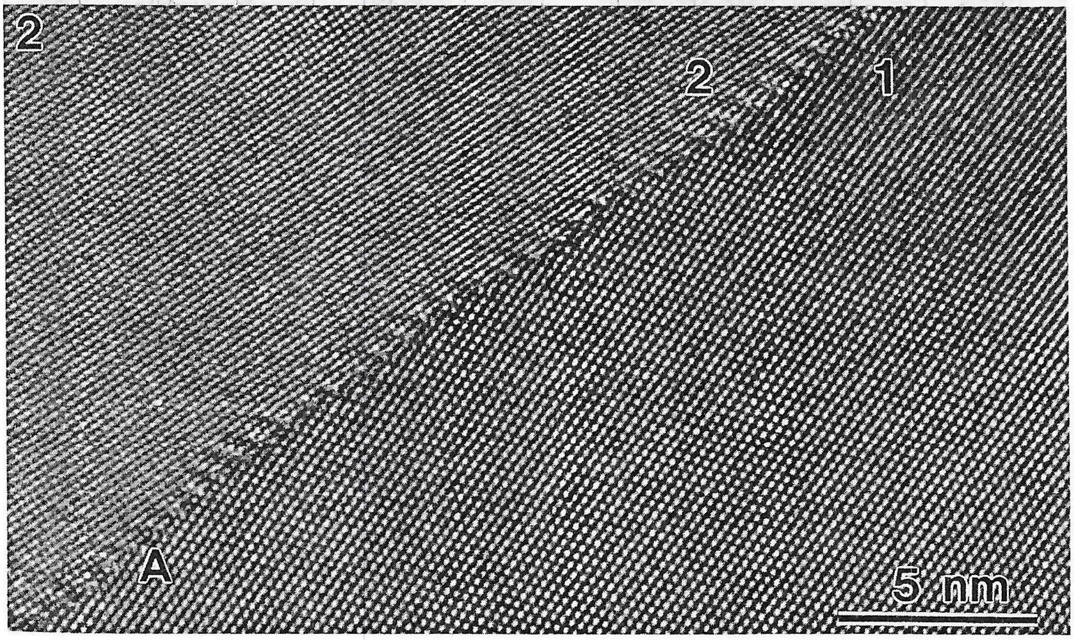


Fig. 1: HREM micrograph showing 6° [100] symmetric tilt grain boundary in Al with dislocation spacing shown as D. Dislocation Burgers vector is b=1/2 [110].

Fig. 2: HREM micrograph of a mixed tilt and twist boundary. "A" labels a microfacet along the (120) plane of bottom crystal.