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September 1964

ON THE ORIENTATION OF PERFECT PRISMATIC
DISLOCATION LOOPS IN PURE ALUMINUM

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In quenched and aged aluminum and other face centered cubic metals of high or medium stacking fault energy perfect $\frac{a}{2} \langle 110 \rangle$ dislocation loops that form from excess vacancies often have the shape of a rhombus; all four sides lying on the two $\{111\}$ planes that contain the Burgers vector.^(1,2) A logical explanation for this shape results if it is assumed that the dislocation splits into partials on the two $\{111\}$ planes that are tangent to the glide cylinder. During growth, climb of the dislocation apparently takes place more rapidly at undissociated segments that do not lie in these planes resulting in their gradual elimination. The rhombus is not an equilibrium shape for a prismatic loop in aluminum. It is assumed by a growing loop probably because of the greater difficulty of forming new jogs on the dissociated segments. During shrinkage in size, which does not require the formation of new jogs, perfect loops in aluminum become round.⁽³⁾

For a rhombus loop all four sides lie on $\{111\}$ glide planes. Therefore, those loops that have achieved this shape should be best able to assume the orientation of minimum energy by rotational glide. The orientation dependence of loop energy has recently been considered by Bullough and Foreman.⁽⁴⁾ They have shown that the orientation of minimum energy is not that of

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shortest total dislocation length which is the pure edge orientation but lies between the $\{110\}$ edge orientation and $\{100\}$. The energy minimum shifts farther away from $\{110\}$ as the diameter of the loop decreases. There has already been some experimental evidence that perfect loops sometimes have a habit plane between $\{110\}$ and $\{100\}$. For example, Makin and Hudson⁽⁵⁾ have reported a preference for the $\{210\}$ plane in Al-1% Mg alloys.

In the present experiments it has been possible to determine the orientation of large rhombus loops in 99.999 aluminum.

Specimens quenched as 0.4 mm⁽⁶⁾ thick polycrystalline sheet from 540°C into water at 40°C contain many well developed rhombus shaped loops with $\frac{a}{2} \langle 110 \rangle$ Burgers vector. The remainder are large stacking fault loops of the type $\frac{a}{3} \langle 111 \rangle$ (see Fig. 1). These imperfect loops which must lie exactly on $\{111\}$ and have sides that lie along $\langle 110 \rangle$ provide means for determining the orientation of the foil. If it is assumed that the rhombus loops have four sides of equal length all of which lie on a plane of the type $\{111\}$ then it is possible from the shape of their projections to estimate their orientations on their glide cylinders. In this way the habit planes for many of the loops in Fig. 1 were determined. The poles of these habit planes are plotted on the stereographic projection (Fig. 2). Figure 1 is close to being an exact (001) projection. Two loops, (a and d), can be seen edge-on. They can be assumed to be perfect because they do not lie on $\{111\}$. Figure 2 shows that the orientations of the rhombus shaped loops cluster about $\{320\}$ rather than $\{110\}$. By assuming that the hexagonal

perfect loops, i, were also symmetrical in shape, when viewed in the direction of the Burgers vector, it was also possible to estimate their orientation. All of these loops had an orientation between $\{111\}$ and $\{110\}$.

The results are in agreement with the calculations of Bullough and Foreman.⁽⁴⁾ The fact that the loops of well developed rhombus shape were rotated to orientations near $\{320\}$ suggests that their glide mobility was great enough to allow them to assume an orientation near that of lowest energy. The considerable scatter about the average $\{320\}$ orientation is also consistent with the calculations. The energy minimum for large ($4000\text{\AA}$) loops is not sharply defined. Within the range between $\{110\}$ and $\{210\}$ the change in loop energy is very small. Therefore, the exact orientation of a given loop probably depends on the sign of the last stress to act on it. Any stress that has a shear component on the glide planes in the direction of the Burgers vector exerts a torque on the loop. Therefore, orientations anywhere within the region of small energy change should be expected. Image forces due to the nearness of external surfaces in a thin foil can also affect the orientation of various loops in different ways depending on loop position relative to the two foil surfaces. Hexagonal perfect loops had probably been converted from stacking fault loops at a late stage of growth or even during handling of the electron microscope specimen. For these loops, their orientation between $\{111\}$ and $\{110\}$ suggests that their glide mobility was less than that of rhombus loops, probably because two sides of the glide cylinder are $\{100\}$ rather than $\{111\}$.

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Figure Captions

Fig. 1., Perfect rhombohedral $\frac{a}{2}$ $\langle 110 \rangle$ loops and hexagonal stacking fault $\frac{a}{3}$ $\langle 111 \rangle$ loops in 99.999 aluminum.

Fig. 2. Stereogram showing poles of habit planes for loops identified on Fig. 1.

ZN-4496

Fig. 1

MUB-4238

Fig. 2

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