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ON THE TERMINATION OF DISLOCATION DIPOLES

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ABSTRACT

The direct electron microscope evidence of the mechanism of dipole termination by cross-slip at the ends of the dipole is presented. Another mechanism, where two opposite dislocations constituting the dipole come close enough to annihilate each other and terminate, is described and supported by transmission electron micrographs.

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A dislocation dipole can be terminated by climb, cross-slip, condensation of jogs or intersection with dislocations. The termination by climb can occur only at high temperatures where vacancies can migrate by pipe diffusion, i.e., along the core of the dislocations constituting the dipole.^{1,2} Tetelman considered two mechanisms for termination by cross-slip. Firstly, termination is by kinking within the dipole to produce screw segments which subsequently cross slip and annihilate and secondly, termination is by cross-slip at the end of the dipole whose two dislocations are of unequal length. He concluded that the first process would be rare because kinking followed by cross-slip is energetically favorable only if the angle between the dipole and its Burgers vector is less than 50° . The second process was found to take place only with the help of an applied stress acting in the cross slip plane. Li and Swann⁴ showed on a theoretical basis that the first process is never energetically favorable. The second mechanism of termination requires a high resolved shear stress on the cross slip plane to enable the screw segments at the end of the dipole to cross slip.⁴ The termination model proposed by Stokes and Olsen⁵ is a very special case and produces dipoles whose length is less than their height. Louat and Johnson⁶ have proposed that dipoles are terminated upon intersection with a single dislocation of the same Burgers vector, traveling on the cross slip plane. However, as shown by Li and Swann,⁴ the intersection by a single dislocation may often have no permanent effect on the dipole. The intersection by a single dislocation with Burgers vector different from that of the dipole can create glissile or sessile jogs but cannot terminate the dipole. However, a group of

dislocations traveling on one plane or on closely spaced planes can terminate a dipole if the sum of their Burgers vectors has a component equal to or greater than the height of the dipole. The necessary conditions for termination by the latter mechanism have been considered by Li and Swann and shown experimentally for dipoles in 18 Cr 18 Ni 0.12N stainless steel.⁴

The termination of a dipole by cross-slip at its ends was proposed by Washburn.⁶ Here the screw and mixed dislocation segments at the end of the dipole attract one another with a force which may cause the screw segments to cross slip and terminate the dipole (Fig. 1). Li and Swann⁴ have shown that energetically this is the most favorable mechanism of dipole termination. For this method of dipole termination, the stresses acting on the cross slipping screw dislocation may or may not help the formation of a constriction, and therefore cross-slip may have to nucleate from obstacles in the glide plane^{7,8,9} or from a jog¹⁰ or in a manner proposed by Fleischer. Fleischer's mechanism does not require the formation of a constriction since it is supposed that cross slip occurs by the dissociation of the leading partial dislocation into a stair rod and a partial on the cross slip plane. This is followed by the combination of the trailing partial with the stair rod to complete the cross slip of the dissociated dislocations.

In general, the unpinned parts of dislocations extending from the ends of a dipole will be of different length and they will thus expand unequally under the action of an applied stress causing the dipole to become curved. The configuration shown in Fig. 1 is thus obtained.

Under this situation, due to mutual attractions between two arms of the dipole at the end, screw segments cross slip and the dipole is terminated. Figure 2A shows an edge dipole a, b, c in MgO with $b = \frac{1}{2} [\bar{1}01]$. There is cross slip plane (101). Opposite screw segments at the end of the dipole on (101) plane attract and annihilate each other and the dipole formation starts over again by formation of jogs and cross slip. The end point of dipole the "a" and beginning point of the dipole "b" are along $[\bar{1}01]$, which proves that cross slip has occurred on (101) slip plane. On the micrograph the direction $[\bar{1}01]$ is along [200] because the direction of electron beam is [001]. The same is true for dipoles "b" and "c". Dipoles a, b, c and d in Fig. 2B have been terminated from the dipole e by the same mechanism. Another interesting example is in Fig. 2C, where dipoles a and b are terminated from the dipole c. In all above cases the end and the beginning points of the successive dipoles are along [200], which shows the cross slip of screw segments on (101) plane and their annihilation by mutual attraction. Figure 3 shows the mechanism of termination, where during the process of collection of jogs at the time of deformation, two dislocations of the dipole may come within a spacing one b-vector and terminate. In Fig. 3A at A, dipoles a, b, c and d have been terminated from a trailing screw dislocation by this mechanism. The dark contrast of the dipole may be due to change in the nature of dipole (vacancy into interstitial or vice versa) which causes the change in contrast from outside to inside or vice versa.¹² During the process of collection of jogs, two dislocations in the dipole might have crossed each other and resulted in change in nature of the dipole. Figure 3B at B shows the example

where the dipole is just being terminated by this mechanism. Note the mother screw dislocation, which collects jogs during the deformation. There are several other examples of these mechanisms of termination in Figs. 2 and 3.

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FIGURE CAPTIONS

- Fig. 1. The termination of a dipole by cross slip due to attractive interaction between a and b (after Washburn⁶).
- Fig. 2. The termination of dipoles a, b and c (Fig. 2A) dipoles a, b, c and d from e (Fig. 2B), and dipoles a and b from c (Fig. 2C) by Washburn's mechanism. Note the line joining the end of the first and start of the next is parallel $[\bar{1}01]$, i.e., along $[200]$ when projected on (001) plane.
- Fig. 3. The termination of dipoles a, b, c and d (3A) and dipole at B (3B) during collection of jogs. The end of the first and the start of next dipole perpendicular to Burgers vector. Note the change in contrast of dipole 'd' (BA), probably due to change in the nature of the dipole (vacancy to interstitial or vice versa).

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Fig. 1

XBB 724-2035

Fig. 2a

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Fig. 2b

XBB 724-2034

Fig. 2c

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Fig. 3a

XBB 709-3898

Fig. 3b

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