Title
RESPONSE TO DISCUSSION BY EVANS AND FLANIGAN ON THE DORN-RAJNAK ANALYSIS

Author
Lau, S.S.

Publication Date
1966-11-01

UCRL-17270

University of California

Ernest O. Lawrence Radiation Laboratory

RESPONSE TO DISCUSSION BY EVANS AND FLANIGAN ON THE DORN-RAJNAK ANALYSIS

Berkeley, California

Submitted to Trans. AIME

UCRL-17270
Preprint

UNIVERSITY OF CALIFORNIA

Lawrence Radiation Laboratory
Berkeley, California

AEC Contract No. W-7405-eng-48

RESPONSE TO DISCUSSION BY EVANS AND FLANIGAN ON THE DORN-RAJNAK ANALYSIS

S. S. Lau

November, 1966

RESPONSE TO DISCUSSION BY EVANS AND FLANIGAN ON THE DORN-RAJNAK ANALYSIS

The authors of the previous comment stated that Dorn and Rajnak[2] and others[3-9] concluded that "agreement with this function $\{(\tau^*/\tau_p) = f\left(\frac{U_n}{2U_k}\right) \simeq T/T_c\}$ may be used as a criterion for that (the Peierls) mechanism of deformation." In contrast, however, Dorn and Rajnak[2] and others[3-9] never made such a statement. In order to clarify the issues involved it is appropriate to recapitulate the conditions that must be satisfied in order to suggest that some deformation process might obey the Peierls mechanism:

(1) Within permissible variations due to changes in the slope of the Peierls hill the τ^*/τ_p-T/T_c relationship must be obeyed. Although some mechanisms, e.g. solute atom stress field, recombination of dissociated partials in b.c.c. metals, intersection of dissociated dislocations etc. give about the same τ^* - T relationship, other mechanisms such as cross slip, disruption of attractive junctions, climb, motion of jogged screw dislocations etc. mechanism give distinctly different τ^* - T relationships. On this basis some distinction can be made of the various mechanisms.

(2) An important feature of the Peierls mechanism concerns its physical origin based on the nucleation of pairs of kinks. The value of τ^* at 0^{o}K increases with the density of dislocation (i.e. cold work) for the intersection mechanism and it increases with the square root of the atomic fraction of solute atoms in the solute atom interaction mechanism. In contrast the value of τ^* at 0^{o}K, for the Peierls mechanism which depends only on the line energy and the shape of the Peierls hills, is

independent of cold working and the square root of the solute atom concentration. These differences have been employed by various investigators for elimination of a few other possible mechanisms. On the other hand it is not possible to eliminate all mechanisms, e.g. the recombination of dissociated dislocations in b.c.c. metals etc. on this basis alone.

(3) Further discrimination between possible mechanisms is based on the activation volume. For the intersection mechanism this volume increases with the reciprocal of the square root of the dislocation density and for the solute atom interaction, the activation volume increases with the reciprocal of the square root of the atomic fraction of solute atoms. In contrast the activation volume for the Peierls mechanism is independent of density of dislocations and does not increase with the reciprocal of the square root of the concentration of solute atoms. The activation volume for the Peierls mechanism depends only on τ^*, the line energy, and the shape of Peierls hills. It usually ranges from about 5 to about 60 Burgers vectors cubed, increasing with decreasing values of τ^*. In contrast the activation volume for interaction mechanism is usually much larger than this value; that for solute-atom interactions with dislocations might fall in the same range as the activation volume for the Peierls mechanism only at one concentration of impurities. On the other hand the mechanism based on the recombinations of dissociated partial dislocations in very high stacking fault b.c.c. metals give about the same activation volumes as those obtained by the Peierls mechanism.

(4) Perhaps the most important feature of the Dorn-Rajnak analysis is the provision for the experimental determination of the line energy

of a dislocation when the Peierls mechanism is operative. This is accomplished through the functional dependence of the kink energy on the Peierls stress and the line energy of a dislocation. The line energy, Γ, deduced from the experimentally determined τ^* at 0^oK and the experimentally determined value of the kink energy, should approximate the Nabarro estimate of $\Gamma \approx \frac{Gb^2}{2}$ (G = shear modulus, b = Burgers vector). Exact agreement, however, cannot be expected because of the very crude theoretical deduction of the Nabarro estimate, the approximations made in the Dorn-Rajnak line energy model for the Peierls mechanism, and the experimental errors in determining the kink energy.

(5) A further check concerns the correct range of the pre-exponential term in the expression for the shear strain rate. This issue, however, is not too critical since the pre-exponential term contains factors that may differ by several orders of magnitude for different cases.

Whenever all first four conditions listed above are satisfied the case for assuming that the Peierls mechanism is operative is indeed very strong. If, however, any one of these four conditions is not satisfied some other mechanism is operative.

ACKNOWLEDGMENT

This report was prepared as part of the activities of the Inorganic Materials Research Division of the Lawrence Radiation Laboratory of the University of California, Berkeley, and was done under the auspices of the U. S. Atomic Energy Commission.

REFERENCES

1. K. R. Evans and W. F. Flanagan, Trans. AIME, 236, 1381 (1966).
2. J. E. Dorn and S. Rajnak, Trans. AIME, 230, 1052 (1964).
3. P. Guyot and J. E. Dorn, Presented at the Deformation of Crystalline Solids Conference, Ottawa, Canada, August, 1966; UCRL-16992.
4. S. S. Lau, S. Ranji, A. K. Mukherjee, G. Thomas and J. E. Dorn, Accepted by Acta Met.,
5. A. K. Mukherjee and J. E. Dorn, Trans. AIME, 230, 1065 (1964).
6. A. Rosen, J. D. Mote and J. E. Dorn, Trans. AIME, 230, 1070 (1964).
7. P. P. Wynblatt, A. Rosen and J. E. Dorn, Trans. AIME, 233, 651 (1965).
8. P. Wynblatt and J. E. Dorn, Submitted to Trans. AIME.
9. A. Ahmadieh, J. Mitchell and J. E. Dorn, Trans. AIME, 233, 1130 (1965).