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On the Estimation of Dislocation Densities in Deformed Metals from Small Angle Scattering Data

The dislocations produced in a specimen by deformation can be studied by means of double Bragg X-ray and neutron scatterings [1, 5]. The dislocation density can be estimated, if the distribution in tilt angles of the subgrains is known. Two kinds of substructure models have been used in the interpretation of the small angle measurements. In the first model it has been assumed that the subgrain normals are uniformly distributed over a cone of small half-angle δ [4, 5]. The other model is based on the assumption that the distribution of the normals obeys a Gaussian curve [1, 3, 4].

The dislocation density, D, can be estimated by equation [2]

$$D = \frac{\alpha^2}{b^2}, \tag{1}$$

where b is the Burgers vector and α is the mean angle between two neighbouring subgrains.

If the subgrains are distributed about the mean position in the form of a Gaussian distribution, then [2]

$$\alpha = \frac{\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} |\,\theta - \phi\,|\, e^{-k^2(\theta^2+\phi^2)}\, d\theta d\phi}{\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} e^{-k^2(\theta^2+\phi^2)}\, d\theta d\phi} = \frac{J}{J_0} \tag{2}$$

The value of α has been solved graphically by Gay, Hirsch and Kelly [2].

It may readily be shown that

$$J = \frac{\sqrt{2\pi}}{k^3} \tag{3a}$$

$$J_0 = \frac{\pi}{k^2} \tag{3b}$$

whence

$$\alpha = \frac{\sqrt{2}}{\sqrt{\pi}}\frac{1}{k} = 0.45\,\epsilon_m, \tag{4}$$

where

$$\epsilon_m = \int_{-\infty}^{+\infty} e^{-k^2\epsilon^2}\, d\epsilon = \frac{\sqrt{\pi}}{k}\,.$$

Finally, we can write

$$D = \frac{\alpha^2}{b^2} = \frac{2}{\pi k^2 b^2} = \frac{2\epsilon_m{}^2}{\pi^2 b^2}\,. \tag{5}$$

When the subgrain normals are uniformly distributed over a cone of half-angle δ, we get, immediately, on the basis of equations 1 and 2

$$D = \frac{4}{9}\frac{\delta^2}{b^2} \tag{6}$$

which is given also by Taglauer [5].

The values of the parameters k and δ in equations 5 and 6 can be determined by the small angle measurements. Thus, it is possible to estimate the dislocation density in deformed specimens [1, 3, 5].

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17 *November* 1969

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