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Lecture for M. Sc. Physics IV Semester students

Paper-I: Condensed Matter Physics

Unit-2: Defects in Solid

M.Sc. IV Sem
Paper-1: [Condensed Matter Physics]
Unit 2: Defects in Solid.

Density and Mobility of Dislocations

The density of dislocation is the no. of dislocation line that intersect a unit area in the crystal.

On the other hand, we can say that the dislocation density is the measure of how many dislocations are present in a quantity of materials. Therefore a dislocation is a line defect. In general, dislocation density is defined as the total length of dislocations per unit volume. Dislocation density is usually of the order of 10^{10} per m^2 in metals.

If 'S' is total length of the dislocation line & 'V' is the volume of the crystal then the dislocation density 'ρ' is given by the relation:-

$$\rho = \frac{S}{V}$$

Interaction between dislocations:-

As any dislocation is surrounded by a stress field, the energy required to form a dislocation in a piece of material which already contain another dislocation will be different from that required to form the dislocation in absence of the other. ie. there will be energy of interaction between two dislocations, the ~~gradie~~ gradient (slope) of the interaction energy determines the force between them.

Suppose a piece of material contain a screw dislocation along the z-direction [Fig-1] and let us produce a second screw dislocation parallel to first one, at a distance 'r'.

As before, we produce a cut extending from A to B and displace the material one one side of cut relative to that on the other side over a distance 'b' along the z-direction. Since, we are to concentrate only on the interaction energy of the two dislocations, so we shall calculate only the work required to produce the second dislocation. This work is determined by the presence of the first dislocation. Thus, if E_i represents the interaction energy per unit length of dislocation. We may write

$$E_i = \int (Gb/2\pi r)\, b\, dr$$

Here, $(Gb/2r)$ is the shear stress produced along the ~~fast~~ cut by the dislocation at the origin. The force between the two dislocations is then

$$F(r) = -\frac{dE_i}{dr} = \frac{Gb^2}{2\pi r}$$

Thus, Force is proportional to $1/r$. For dislocations of opposite sign the force is attractive; for same signs, the force is repulsive.

Similarly, considering the interaction between edge dislocation. In this case, the force has a radial ~~part~~ as well as tangential component. Thus, for two-edge dislocation of same signs along the z-direction & with the Burger's vector along the x-direction. We get,

$$F_r = \frac{Gb^2}{2\pi(1-\nu)r} , \quad F_\theta = \frac{Gb^2 \sin 2\theta}{2\pi(1-\nu)r}$$

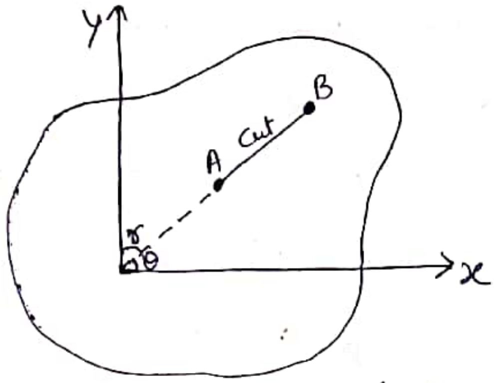

Fig:- 1

Where, θ is the angle between r and x-axis. Here, again the radial force is repulsive or attractive depends on whether the dislocations have same or opposite signs.

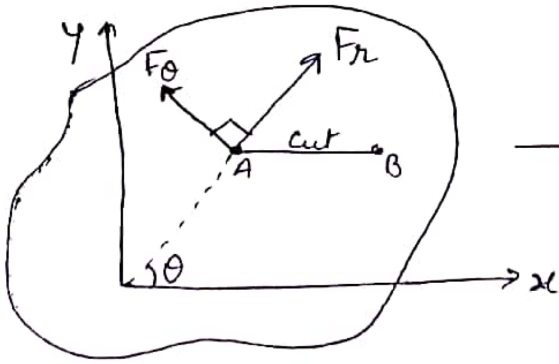

Fig: 2

The force component along x-direction is the most important; for two edge dislocation of same sign this component may be obtained from the relation given as

$$F_x = F_r \cos\theta - F_\theta \sin\theta$$

Substituting F_r and F_θ, we get,

$$F_x = \frac{Gb^2 x (x^2 - y^2)}{2\pi (1-\nu) r^4}$$

It is observed that this component vanishes for $x=0$ and for $x=y$. Further, when the same signs repel each other in the direction of slip plane. For $x<y$ or $\theta > 45°$, they attract each other along the x-axis. The stable configuration for the two dislocations occur when they lie vertically above each other. This conclusion is also true when a large number of edge dislocations of same signs are involved.

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