Series 9 Solution **29 November 2024**

Exercise 1 Creep

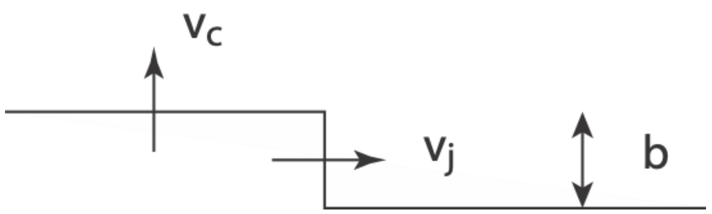
a) When a Frank-Read source is activated:

$$\sigma = \frac{\mu b}{\ell}$$

with ℓ the distance between strong pinning points. If we have a Frank network of dislocations: $\Lambda = \ell^{-2}$ and, therefore:

$$\sigma = \mu b \sqrt{\Lambda} \quad \text{and} \quad . \quad \Lambda = \left(\frac{\sigma}{\mu b}\right)^2$$

b) Climb occurs by lateral movement of jogs :



$\mathbf{v}_c = \frac{n_j}{n}\mathbf{v}_j$. n_j is the number of jogs, and $n = \frac{\ell}{b}$ is the number of atoms on the dislocation length, i.e., the number of atoms the jog has to go across to reach the dislocation anchoring point.

In the course, we have defined $C_j = \frac{n_j}{n}$ and therefore.

$$\mathbf{v}_c = C_j \mathbf{v}_j \, .$$

But $\mathbf{v}_j$ is controlled by the diffusion velocity of vacancies, and the Einstein equation tells us that:

$$\mathbf{v}_j = \frac{DF}{kT}$$

Since a jog is a dislocation with a length of *b*, we can say that $F = \sigma b \cdot b = \sigma b^2$. So:

$$\mathbf{v}_c = C_j \frac{\sigma b^2}{kT} D$$

c) The Orowan equation determines the creep occurring due to dislocations:

$$\dot{\varepsilon} = \Lambda b \cdot \mathbf{v}$$

In this case, the dislocation velocity is the climb velocity. Therefore :

$$\dot{\varepsilon} = \Lambda(\sigma) b \cdot \mathrm{v}_c(\sigma) = \left(\frac{\sigma}{\mu b}\right)^2 \cdot b \cdot C_j \frac{\sigma b^2}{kT} D = \frac{C_j D b}{\mu^2 kT} \sigma^3$$

This illustrates the formula (9.56) of the text. Remember that diffusion of interstitials or vacancies to the dislocation core at critical temperatures facilitates dislocation climb, and diffusion rates are key parameters in creep mechanisms and rate of creep.