材科 4

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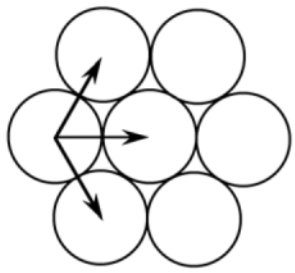
1. One slip system for the HCP crystal structure is {0001} <$11\bar{2}0$>. In a manner similar to Figure 9.6b, sketch a {0001}-type plane for the HCP structure and, using arrows, indicate three different <$11\bar{2}0$> slip directions within this plane.

7.8 *One slip system for the HCP crystal structure is* $\{0001\}\langle 11\bar{2}0\rangle$. *In a manner similar to Figure 7.6b, sketch a* $\{0001\}$*-type plane for the HCP structure and, using arrows, indicate three different* $\langle 11\bar{2}0\rangle$ *slip directions within this plane. You might find Figure 3.8 helpful.*

Solution

Below is shown the atomic packing for an HCP $\{0001\}$-type plane. The arrows indicate three different $\langle 11\bar{2}0\rangle$-type directions.



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7.15 *A single crystal of a metal that has the FCC crystal structure is oriented such that a tensile stress is applied parallel to the [110] direction. If the critical resolved shear stress for this material is 1.75 MPa, calculate the magnitude(s) of applied stress(es) necessary to cause slip to occur on the (111) plane in each of the* $[1\bar{1}0]$, $[10\bar{1}]$ *and* $[01\bar{1}]$ *directions.*

Solution

In order to solve this problem it is necessary to employ Equation 7.4, but first we need to solve for the for λ and ϕ angles for the three slip systems.

For each of these three slip systems, the ϕ will be the same—i.e., the angle between the direction of the applied stress, [110] and the normal to the (111) plane, that is, the [111] direction. The angle ϕ may be determined using Equation 7.6 as

$$\phi = \cos^{-1}\left[\frac{u_1u_2 + v_1v_2 + w_1w_2}{\sqrt{\left(u_1^2 + v_1^2 + w_1^2\right)\left(u_2^2 + v_2^2 + w_2^2\right)}}\right]$$

where (for [110]) $u_1 = 1$, $v_1 = 1$, $w_1 = 0$, and (for [111]) $u_2 = 1$, $v_2 = 1$, $w_2 = 1$. Therefore, ϕ is equal to

$$\phi = \cos^{-1}\left[\frac{(1)(1) + (1)(1) + (0)(1)}{\sqrt{\left[(1)^2 + (1)^2 + (0)^2\right]\left[(1)^2 + (1)^2 + (1)^2\right]}}\right]$$

$$= \cos^{-1}\left(\frac{2}{\sqrt{6}}\right) = 35.3°$$

Let us now determine λ for the $[1\bar{1}0]$ slip direction. Again, using Equation 7.6 where $u_1 = 1$, $v_1 = 1$, $w_1 = 0$ (for [110]), and $u_2 = 1$, $v_2 = -1$, $w_2 = 0$ (for $[1\bar{1}0]$. Therefore, λ is determined as

$$\lambda_{[110]-[1\bar{1}0]} = \cos^{-1}\left[\frac{(1)(1) + (1)(-1) + (0)(0)}{\sqrt{\left[(1)^2 + (1)^2 + (0)^2\right]\left[(1)^2 + (-1)^2 + (0)^2\right]}}\right]$$

$$= \cos^{-1} 0 = 90°$$

Now, we solve for the yield strength for this (111)–$[1\bar{1}0]$ slip system using Equation 7.4 as

$$\sigma_y = \frac{\tau_{crss}}{(\cos\phi\ \cos\lambda)}$$

$$= \frac{1.75\text{ MPa}}{\cos(35.3°)\ \cos(90°)} = \frac{1.75\text{ MPa}}{(0.816)(0)} = \infty$$

which means that slip will not occur on this (111)–$[1\bar{1}0]$ slip system.

Now, we must determine the value of λ for the (111)–$[10\bar{1}]$ slip system—that is, the angle between the [110] and $[10\bar{1}]$ directions. Again using Equation 7.6

$$\lambda_{[110]-[10\bar{1}]} = \cos^{-1}\left[\frac{(1)(1) + (1)(0) + (0)(-1)}{\sqrt{\left[(1)^2 + (1)^2 + (0)^2\right]\left[(1)^2 + (0)^2 + (-1)^2\right]}}\right]$$

$$= \cos^{-1}\left(\frac{1}{2}\right) = 60°$$

Now, we solve for the yield strength for this (111)–$[10\bar{1}]$ slip system using Equation 7.4 as

$$\sigma_y = \frac{\tau_{crss}}{(\cos\phi \ \cos\lambda)}$$

$$= \frac{1.75 \text{ MPa}}{\cos(35.3°) \ \cos(60°)} = \frac{1.75 \text{ MPa}}{(0.816)(0.500)} = 4.29 \text{ MPa}$$

And, finally, for the (111)–$[01\bar{1}]$ slip system, λ is computed using Equation 7.6 as follows:

$$\lambda_{[110]-[01\bar{1}]} = \cos^{-1}\left[\frac{(1)(0) + (1)(1) + (0)(-1)}{\sqrt{\left[(1)^2 + (1)^2 + (0)^2\right]\left[(0)^2 + (1)^2 + (-1)^2\right]}}\right]$$

$$= \cos^{-1}\left(\frac{1}{2}\right) = 60°$$

Thus, since the values of ϕ and λ for this (110)–$[01\bar{1}]$ slip system are the same as for (111)–$[10\bar{1}]$, so also will σ_y be the same—viz 4.29 MPa.

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7.23 *(a) From the plot of yield strength versus (grain diameter)$^{-1/2}$ for a 70 Cu–30 Zn cartridge brass, Figure 7.15, determine values for the constants σ_0 and k_y in Equation 7.7.*

(b) Now predict the yield strength of this alloy when the average grain diameter is 1.0×10^{-3} mm.

Solution

(a) Perhaps the easiest way to solve for σ_0 and k_y in Equation 7.7 is to pick two values each of σ_y and $d^{-1/2}$ from Figure 7.15, and then solve two simultaneous equations, which may be created. For example

$d^{-1/2}$ (mm) $^{-1/2}$	σ_y (MPa)
4	75
12	175

The two equations are thus

$$75 = \sigma_0 + 4\,k_y$$

$$175 = \sigma_0 + 12\,k_y$$

Solution of these equations yield the values of

$$k_y = 12.5 \text{ MPa}\,(\text{mm})^{1/2} \quad \left[1810 \text{ psi}\,(\text{mm})^{1/2}\right]$$

$$\sigma_0 = 25 \text{ MPa} \quad (3630 \text{ psi})$$

(b) When $d = 1.0 \times 10^{-3}$ mm, $d^{-1/2} = 31.6$ mm$^{-1/2}$, and, using Equation 7.7,

$$\sigma_y = \sigma_0 + k_y d^{-1/2}$$

$$= (25 \text{ MPa}) + \left[12.5 \text{ MPa}\,(\text{mm})^{1/2}\right]\left(31.6 \text{ mm}^{-1/2}\right) = 420 \text{ MPa} \quad (61{,}000 \text{ psi})$$

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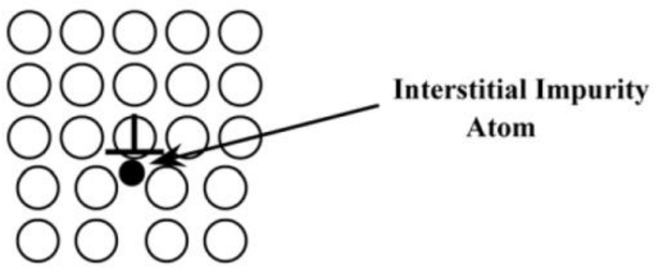
7.26 *In the manner of Figures 7.17b and 7.18b, indicate the location in the vicinity of an edge dislocation at which an interstitial impurity atom would be expected to be situated. Now briefly explain in terms of lattice strains why it would be situated at this position.*

Solution

Below is shown an edge dislocation and where an interstitial impurity atom would be located. Compressive lattice strains are introduced by the impurity atom. There will be a net reduction in lattice strain energy when these lattice strains partially cancel tensile strains associated with the edge dislocation; such tensile strains exist just below the bottom of the extra half-plane of atoms (Figure 7.4).



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7.20 *Briefly explain why small-angle grain boundaries are not as effective in interfering with the slip process as are high-angle grain boundaries.*

<u>Solution</u>

Small-angle grain boundaries are not as effective in interfering with the slip process as are high-angle grain boundaries because there is not as much crystallographic misalignment in the grain boundary region for small-angle, and therefore not as much change in slip direction.

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