

ENGR-1600-01 Quiz 5 - 100 pts Prof. Lewis Name: _____

Some useful equations are given below:

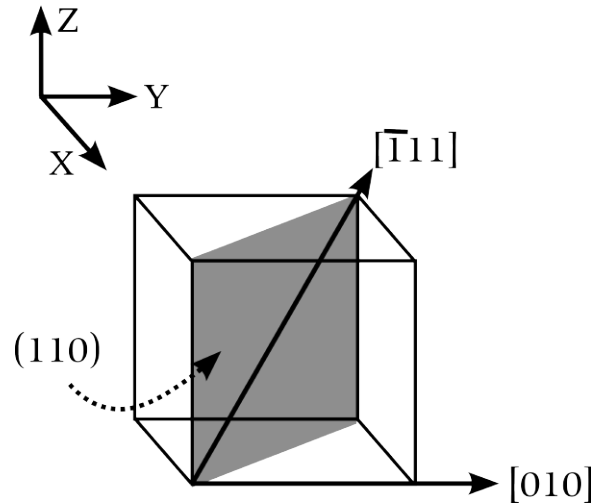
$$n\lambda = 2d \sin(\theta) \quad d_{hkl} = \frac{a}{\sqrt{(h^2 + k^2 + l^2)}} \quad N_A = 6.023 \cdot 10^{23} \quad \rho = \frac{nA}{V_C N_A}$$

$$\sigma = \frac{F}{A_0} \quad \sigma = E\epsilon \quad \tau_{crss} = \sigma_y \cos \theta \cos \phi \quad \nu = -\frac{\epsilon_x}{\epsilon_z} = -\frac{\epsilon_y}{\epsilon_z}$$

$$SC : a = 2R \quad FCC : a = \frac{4R}{\sqrt{2}} \quad BCC : a = \frac{4R}{\sqrt{3}} \quad \mathbf{a} \cdot \mathbf{b} = |a||b| \cos \theta$$

$$\%CW = \frac{A_0 - A_f}{A_0} \cdot 100 \quad K_{IC} = Y\sigma_c \sqrt{\pi a} \quad \epsilon = \frac{l_i - l_0}{l_0} = \frac{\Delta l}{l_0}$$

1. A small volume of a BCC material is shown below. All edges are $1 \cdot 10^{-6}$ meters. It is known that slip occurs on $\{110\}$ planes in $\langle 111 \rangle$ directions. The critical shear stress required to initiate slip in this system is 30 MPa. Determine the load, P, in the $[010]$ direction necessary to initiate slip. Show all work.



The critical shear stress is 30 MPa. Once a load is applied to the face of the crystal (now a stress) and that stress resolves to be 30MPa or greater, slip will occur. That is, dislocations will start to move in $\langle 111 \rangle$ directions along $\{110\}$ planes. Therefore 30MPa is the critical resolved shear stress. So we need to determine the stress applied to the $[010]$ face that resolves to 30 MPa in the $\langle 111 \rangle$ direction. This is:

$$\tau_{CRSS} = \sigma_0 \cos(\theta) \cos(\phi) \quad (1)$$

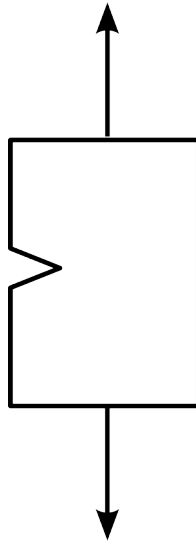
$$\frac{30 \text{ MPa}}{\cos(45) \cos(54.7)} = \sigma_0 \quad (2)$$

$$30 \text{ MPa} \cdot \sqrt{2} \cdot \sqrt{3} = 73.48 \text{ MPa} \quad (3)$$

Since "mega" is ten to the sixth and "micro" is ten to the minus sixth, the load to apply is $73.48 \text{E}6 / 1\text{E}-12$ or 73.48 micro Newtons.

2. A material with a 1 mm flaw is loaded as shown below to a stress of 100 MPa. If the material is 1040 steel, will the component fracture at the applied load? If the material is silicon, what is the maximum flaw size allowed to prevent fracture for this applied load? The data for 1040 steel and Si are given in the table below.

Property	1040 Steel	Si
K_{IC} (MPa \sqrt{m})	54	1
σ_y (MPa)	260	N/A
E (GPa)	207	129
γ_S (N/m)	1.7	0.7



Taking $Y=1$. The 1040 steel stress intensity is:

$$K = (1) \cdot (100 \text{ MPa}) \cdot \sqrt{\pi 1 \cdot 10^{-3}} \quad (4)$$

$$K = 5.6 \text{ MPa}\sqrt{m} \quad (5)$$

$$K < K_{IC} \quad (6)$$

therefore the material will not fracture. We must use the Griffith criterion for the Si material. The critical flaw size can be expressed as:

$$a = \frac{2E\gamma}{\pi\sigma^2} \quad (7)$$

$$a = \frac{2 \cdot 129 \cdot 10^9 \cdot 0.7}{3.14 \cdot (100 \cdot 10^6)^2} \quad (8)$$

$$a = 5.8 \mu m \quad (9)$$

3. Examine the two figures below where dislocation "A" is gliding along slip plane "P". There are solute atoms located near the slip plane. These solute atoms are of larger atomic radius than the matrix.

A) Identify the dislocation and label the compressive and tensile stress fields. Label the stress field around the solute atoms as either compressive or tensile.

At "A" and above "P" the stress is tensile. Below "P" it is compressive. The solute atoms create a compressive stress field.

B) Explain how the stress fields interact and how, specifically, these interactions affect the macroscopic mechanical properties.

In the left hand figure, the compressive stress fields repel one another making it harder for the dislocation to approach the solute atoms. In the right hand figure the stresses are attractive making it harder for the dislocation to move away from the solute atoms. Each of these interactions make it harder for dislocations to move, therefore, they are strengthening mechanisms.

C) Do both situations produce a strengthening mechanism?

Yes.

