Cumulative Quiz #2 MSE Fall 2006

10-18-2006

1. (7 points)
Answer each of the following questions with a true (T) or false (F).

(a) The tensile modulus of semi-crystalline polymers usually decreases significantly with increasing degree of crystallinity. increases __F__

(b) The tensile strength of plastic polymers corresponds to the stress at which fracture occurs. __T__

(c) Vulcanization decreases crosslinks in polymers. increases __F__

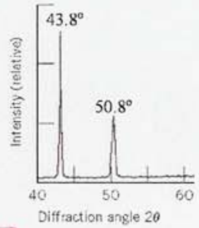
(d) With increasing strain rate, polymers tend to become more ductile. decreasing __F__

(e) The Burgers vector of an edge dislocation is parallel to the dislocation line. perpendicular __F__

(f) During elastic deformation, dislocation motion occurs in a specific slip system. plastic __F__

(g) Necking begins to occur in ductile specimens when they fail to fracture. reach the tensile strength __F__

2. (9 points) The right graph shows an X-ray diffraction spectrum for copper measured using an X-ray beam with the wavelength of 0.1542 nm. The data shows only the first and second peaks. The structure of copper is FCC. Using this data, answer the following questions.



(a) (4 pts) Calculate the interplanar spacing for each set of planes corresponding to the first and second diffraction peaks.

$$d_{111} = \frac{0.1542}{2\sin(43.8°/2)} = 0.207 \text{ nm}$$

$$d_{200} = \frac{0.1542}{2\sin(50.8°/2)} = 0.180 \text{ nm}$$

(b) (3 pts) Compute the lattice constant (parameter) of copper.

$$a = d_{111} \cdot \sqrt{1^2+1^2+1^2} = 0.359 \text{ nm}$$

$$\left(\text{or } a = d_{200} \cdot \sqrt{2^2+0^2+0^2} = 0.359 \text{ nm}\right)$$

(c) (2 pts) What angle in 2θ would the third peak be observed?

$$a = 0.359 \text{ nm}$$

$$2d\sin\theta = \lambda$$

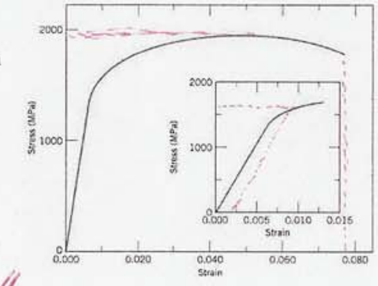
$$d = \frac{a}{\sqrt{h^2+k^2+\ell^2}}$$

The third peak for FCC is (220)

$$d_{220} = \frac{0.359}{\sqrt{2^2+2^2+0^2}} = 0.127$$

$$\theta = \sin^{-1}\left(\frac{0.1542}{2\times 0.127}\right) = 37.4° \quad \therefore 2\theta = 74.8°$$

3. (16 points) Consider a cylindrical specimen made of gold that has diameter 8.5 mm and length 80 mm. It was tested in tension, and the engineering stress-strain curve was obtained.



(a) (2 pts) Find the Young's modulus of this specimen.

$$\frac{1000 \text{ MPa}}{0.005} = 200 \text{ GPa}$$

(b) (2 pts) Determine the 0.2% offset yield strength.

1600 MPa

(c) (2 pts) Suppose that the tensile stress is applied along the [100] direction of gold. Compute the critical resolved shear stress along the (111) plane and in the $[1\bar{1}0]$ direction.

$$\tau_{crss} = \sigma_y \cos\theta \cos\phi$$

$$= 1600 \cdot \frac{1}{1\cdot\sqrt{3}} \cdot \frac{1}{1\cdot\sqrt{2}}$$

$$= 654 \text{ MPa}$$

(d) (2 pts) What is the (ultimate) tensile strength?

1900 MPa

(e) (2 pts) What is the length of the specimen when it fails by fracture?

$$\varepsilon_f = 0.077 = \frac{l_f - l_0}{l_0} = \frac{l_f - 80}{80}$$

$$l_f = 80 \times (1 + 0.077) = 86.2\ mm$$

(f) (6 pts) In the class, you learned 3 mechanisms of strengthening in metals. Briefly explain each of the 3 mechanisms.

Grain size reduction

By reducing grain size, the grain boundary area increases. Since grains are oriented crystallographically in different directions, dislocations frequently need to change direction when moving along a slip system. Hence, dislocation motion is hindered.

Solid-solution Strengthening

Impurity atoms with different size imposes lattice strain on the host atoms. The stain readily interacts with the strain around dislocations, and the dislocations are stabilized. Hence, Dislocation motion is hindered.

Strain Hardening

By plastically deforming ductile metals, the dislocation density increases. The dislocations counteract each other to hinder their motion.

4. (8 points)

(a) (4 pts) Suppose that a wing component on an aircraft is fabricated from an aluminum alloy that has a plane strain fracture toughness of 26 MPa√m. It has been determined that fracture results at a critical stress of 112 MPa when the maximum internal crack length is 8.6 mm. For this same component and alloy, compute the stress level at which fracture will occur for a critical *internal* crack length of 6.0 mm.

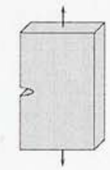
$$K_{IC} = Y \sigma_c \sqrt{\pi a}$$

$$26 = Y \cdot 112 \cdot \sqrt{\pi \left(\frac{8.6 \times 10^{-3}}{2}\right)}$$

$$Y = 2.00$$

$$\sigma_c = \frac{K_{IC}}{Y\sqrt{\pi a}} = \frac{26}{2.00 \times \sqrt{\pi \cdot \left(\frac{6.0 \times 10^{-3}}{2}\right)}} = 134\ MPa$$

(b) (4 pts) A ceramic component must not fail when a tensile stress of 13.5 MPa is applied. Determine the maximum allowable *surface* crack length if the surface energy of the ceramic is 1.0 N/m. The Young's modulus of this ceramic is 225 GPa.



$$\sigma_c = \left(\frac{2E\gamma_s}{\pi a}\right)^{1/2}$$

$$a = \frac{2E\gamma_s}{\pi \sigma_c^2} = \frac{2 \times 225\ GPa \times 1.0\ N \cdot m}{\pi \times (13.5\ MPa)^2}$$

$$= \frac{2 \times 2.25 \times 10^{11}\ Pa \times 1.0\ N/m}{\pi \times 1.8225 \times 10^{14}\ Pa^2}$$

$$= 7.86 \times 10^{-4}\ m$$

$$= 0.79\ mm$$