

## MAE 212: Spring 2001

### TEST II

Monday, April 2: 7:30 - 9:30 p.m.

Closed books and notes. Answer all questions. Make sure your answers are legible. Circle your final answer and show all work. Solutions not supported by appropriate development will not be accepted.

1. (10 points)

A tensile specimen is machined to a gage diameter of 0.505-in. When subjected to a tensile test, the following results were found: (i) yield load = 4,000 lbf and (ii) area reduction at the maximum load = 20 %

- (a) (2 points) What is the yield stress for this specimen?
- (b) (4 points) After completing this test, you are informed that the tensile specimen had been cold-worked (plastically deformed) some amount before it was machined and tested, and that in the 'annealed' state  $\sigma = K \epsilon^n$  with  $n=0.45$ . How much strain was induced by the unknown amount of cold work?
- (c) (4 points) Find  $K$ .

2. (10 points)

Consider a plane strain state ( $\epsilon_2 = 0$ ). Assuming the von-Mises yield criterion:

- (3 points) Calculate an expression for the equivalent plastic strain  $d\bar{\epsilon}$  in terms of  $d\epsilon_1$  alone (recall  $d\bar{\epsilon} = \sqrt{\frac{2}{3}(d\epsilon_1^2 + d\epsilon_2^2 + d\epsilon_3^2)}$  ).
- (4 points) Calculate an expression for the equivalent stress  $\bar{\sigma}$  in terms of  $\sigma_1$  and  $\sigma_3$  alone (recall  $\bar{\sigma} = \frac{1}{\sqrt{2}}\sqrt{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2}$  ).
- (3 points) Consider a rigid plastic material (constant yield stress  $Y$ , i.e. no hardening). For this material, calculate the plastic work increment per unit volume  $dw$  in terms of  $Y$  and  $d\epsilon_1$ .

3. (10 points)

At 400° C, the fraction of aluminum lattice sites vacant  $\frac{n_v}{n_{sites}}$  is  $2.29 \times 10^{-5}$ . Calculate the fraction at 660° C (just below its melting point). The energy required to create a single vacancy in the aluminum crystal structure is  $E_v = 0.76$  eV. (Hint: the number of vacancies  $n_v$  at a given temperature  $T$  is given from the Arrhenius law  $\frac{n_v}{n_{sites}} = Ce^{-E_v/kT}$ , where  $k = 86.2 \times 10^{-6}$  eV/K and  $C$  is an unknown material constant.)

4. (10 points)

Consider many dislocations moving on the same slip plane with the same Burgers vector and average velocity  $\bar{v}$ . Prove that the shear strain rate  $\dot{\gamma}$  (= change in  $\gamma$  per unit time) produced by the motion of dislocations is equal to  $\dot{\gamma} = \rho b \bar{v}$ , where  $\rho$  is the dislocation density and  $b$  is the magnitude of the Burgers vector.

5. (15 points)

The energy necessary to generate a dislocation is proportional to the square of the energy of the Burgers vector  $|\mathbf{b}|^2$ . This means that the most stable (lower energy) dislocations have the minimum length  $|\mathbf{b}|$ . For the BCC metal structure, calculate relative to  $E_{\mathbf{b}=[111]}$  the dislocation energy for  $E_{\mathbf{b}=[110]}$ .

6. (10 points)

Calculate the resolved shear stress on the  $(111)[0\bar{1}1]$  slip system of a unit cell in an fcc nickel crystal if a stress of 13.7 MPa is applied in the  $[001]$  direction of a unit cell.

7. (10 points)

One kilogram of an alloy of 60 weight % Pb and 40 weight % Sn is slowly cooled from 300° C. Refer to the lead-tin phase diagram of the Figure 1 and calculate the following:

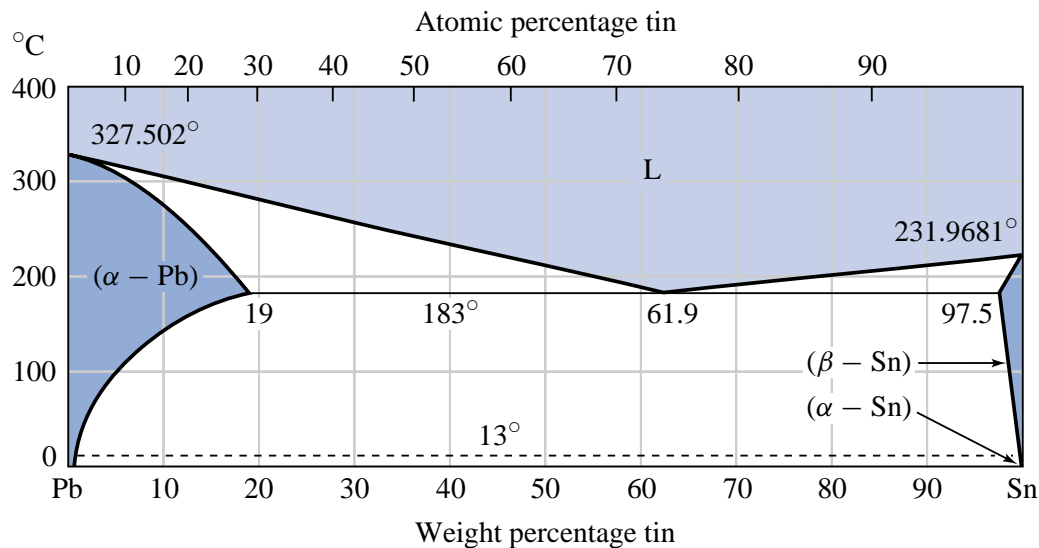


FIGURE 5-38

Figure 1: The lead-tin equilibrium phase diagram.

- (a) (5 points) The weight percent of the liquid and proeutectic alpha just above the eutectic temperature (183° C) and the weight in kilograms of these phases.
- (b) (5 points) The weight in kilograms of alpha and beta formed by the eutectic reaction.

8. (15 points)

A hypoeutectoid plain carbon steel which was slow-cooled from the austenitic region to room temperature contains 9.1% weight eutectoid ferrite. Compute the % carbon content of the steel assuming no change in structure on cooling from just below the eutectoid temperature to room temperature (see Fig. 2 for the Fe-C phase diagram).

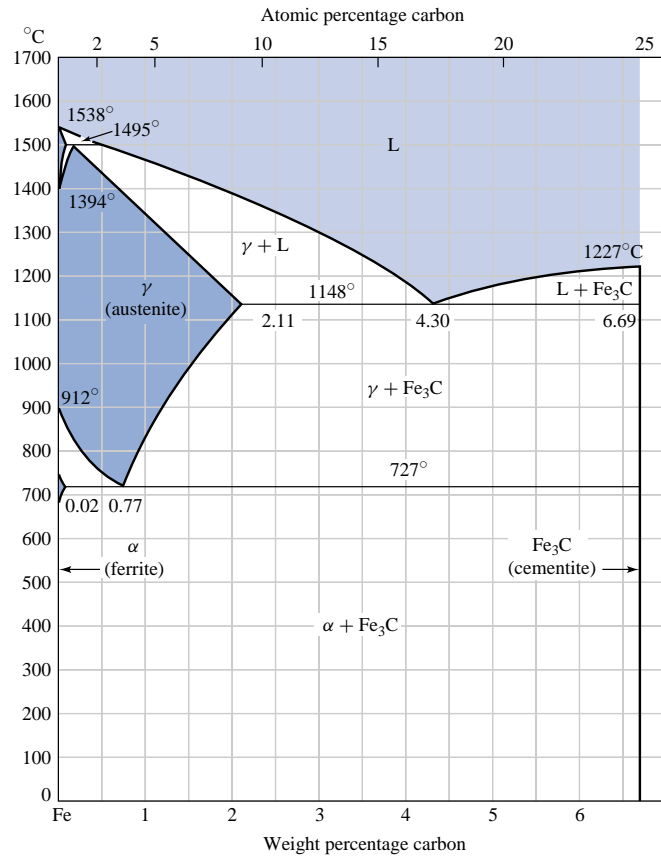


FIGURE 5-26

Figure 2: The Fe-C equilibrium phase diagram.

9. (10 points)

Consider 0.77 wt % C steel.

- (a) (3 points) Estimate the quench rate from 727° C to avoid pearlite transformation.
- (b) (3 points) How long a time is required for austenite to transform to 50% bainite at 300° C?
- (c) (4 points) Calculate the microstructure that results from the following heat treatment from the  $\gamma$  region: (a) instantly quenched to 500° C, (b) held for 5 secs and (c) quenched to room temperature.

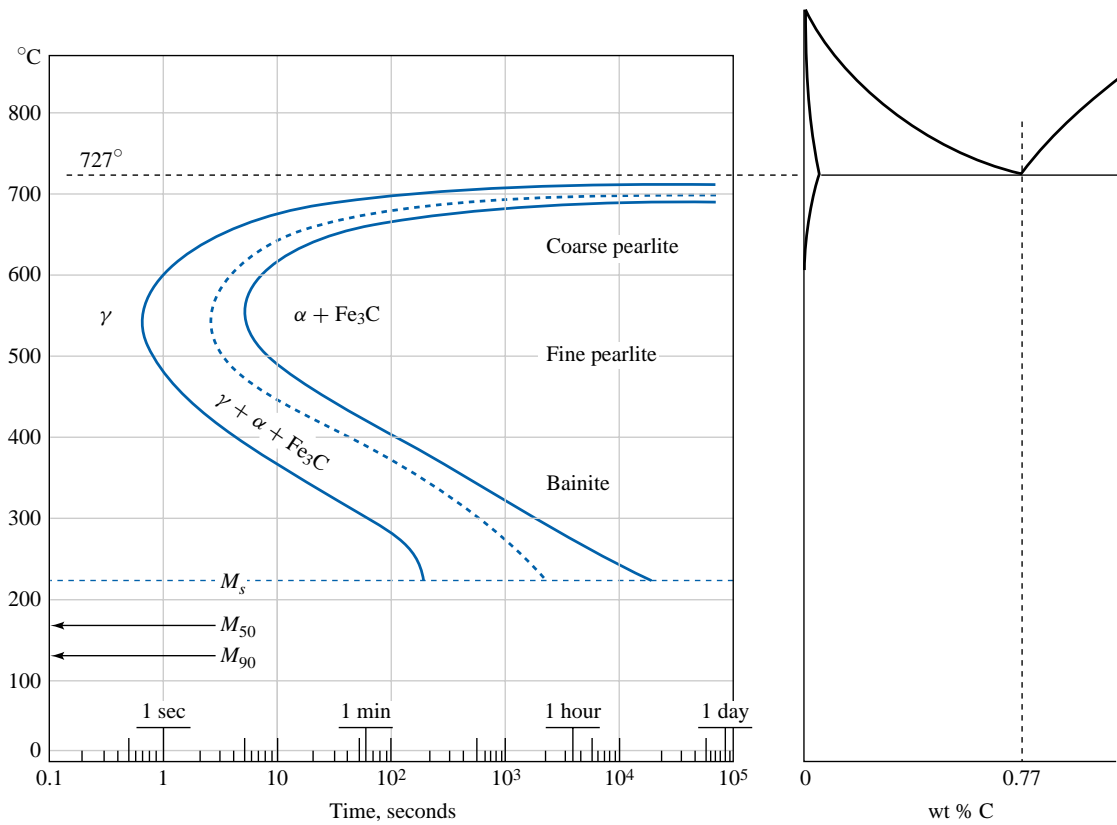


FIGURE 6-10

Figure 3: The TTT diagram for eutectoid steel.