Ph.D. Qualifying Examination

Materials

Spring 2012

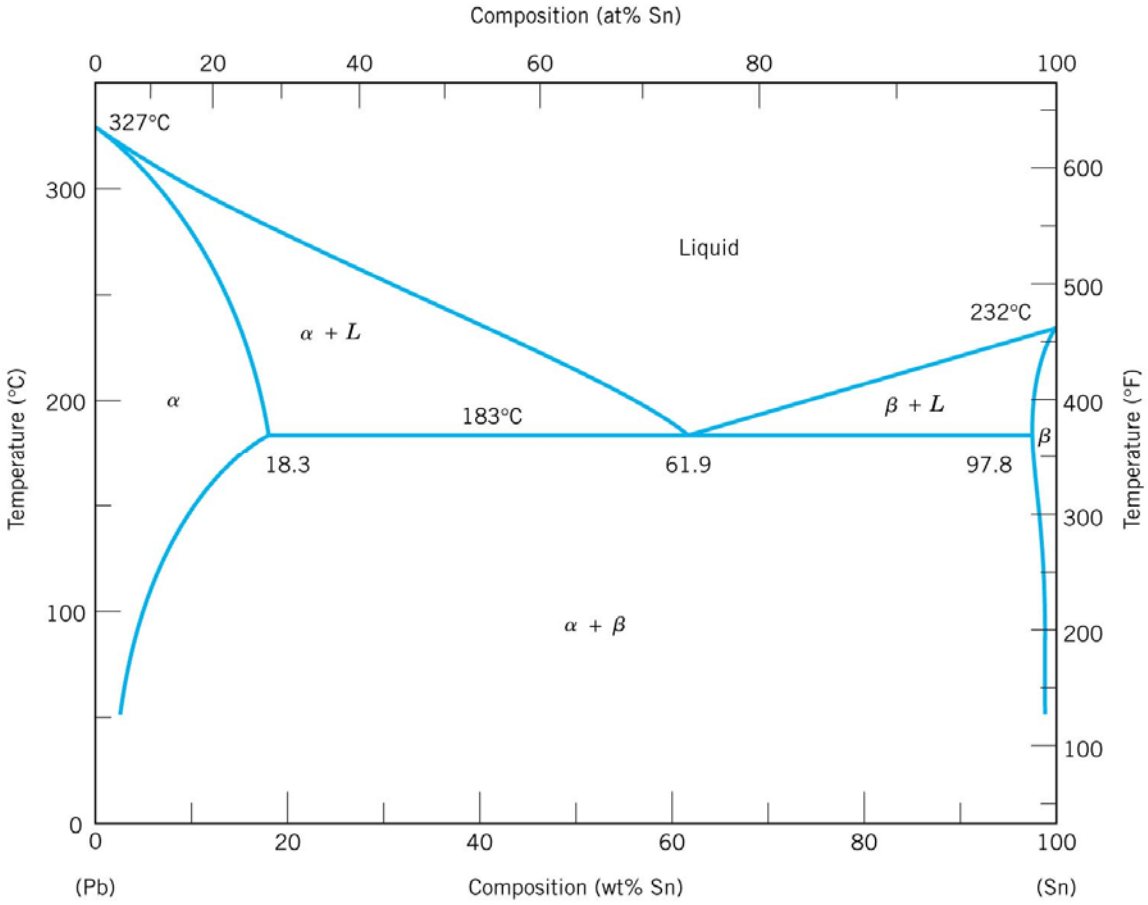
Notes:

- There are a total of 4 problems.
- Time allowed: 2 hours.
- Exam is closed book and closed notes
- Problems count 25 points each (total=100 points).
- Show your work on these exam sheets. (Add additional sheets, if needed.)
- You may use a calculator.
- Laptops and cell phones are not allowed.

Problem 1

In reference to the Lead-Tin Phase Diagram shown, start at a temperature of 300°C and cool down to room temperature.

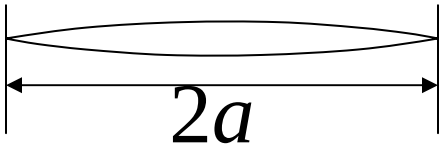
a- What is the point in the phase diagram with a nominal composition of 61.9 wt% Sn and temperature of 183 °C?
b- What are the micro-constituents composing the final microstructure upon cooling a 40 wt% Sn from 300 °C to room temperature?
c- What is the rate of cooling (or heating) used to construct this phase diagram?
d- Assuming a nominal composition of 40 wt% Sn, what is the weight fraction of the liquid just above 183 °C?
e- Assuming a nominal composition of 40 wt% Sn, what is the weight fraction of the α phase just below 183 °C?



Problem 2

The following 2D crack is in a brittle material. For this material, Young's modulus is 100GPa, the specific surface energy is 0.5 J/m^2, and Poisson's ratio is 0.3. If the full-length of the crack is 20μm, what is the maximum tensile stress that can be applied in the direction normal to the crack plane?

Hint: the following equation might be useful $\sigma_c = \sqrt{\frac{2E\gamma_s}{\pi a}}$



Problem 3

A creep test under constant stress was conducted on an alloy. The steady-state creep rate is found to be 1% per hour at 800°C and 5.5×10^{-2} % per hour at 700°C.

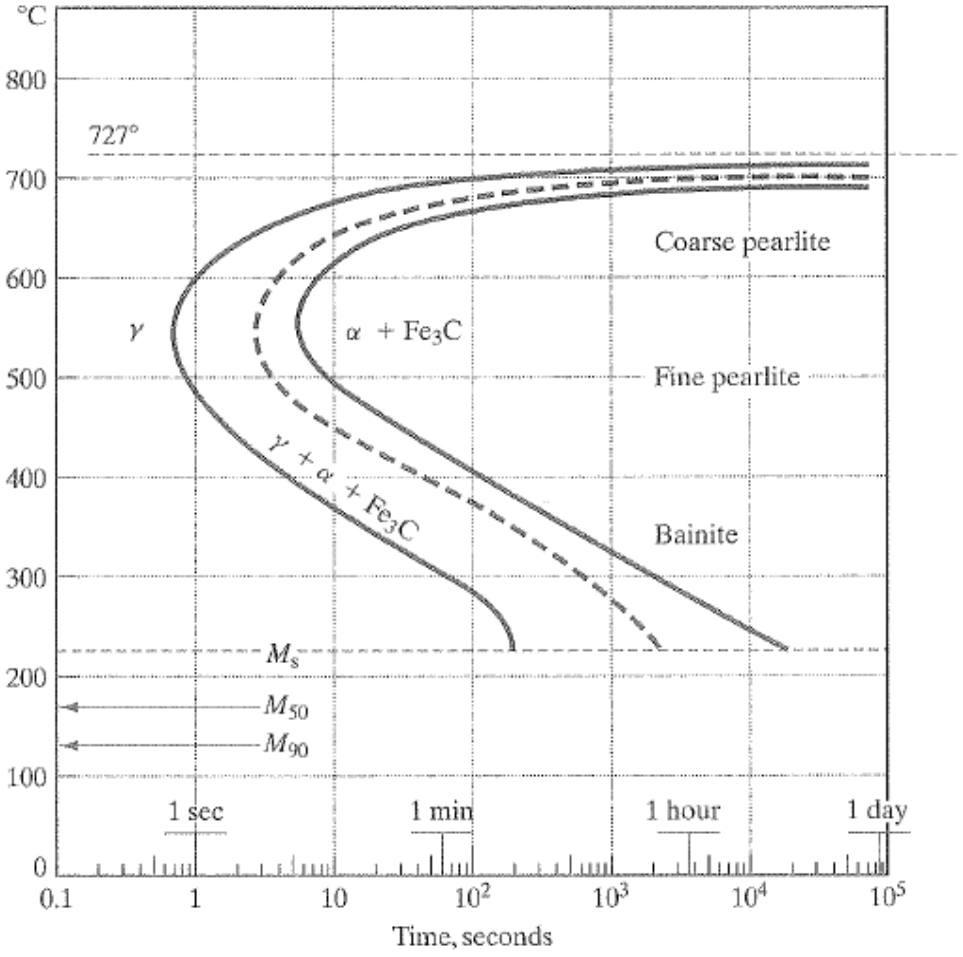
(a) Calculate the activation energy for creep in this temperature range. (Hint: Creep deformation is a thermally activated process which follows the normal Arrhenius type of relation. A useful constant: universal gas constant R = 8.314 J/mol·K.)

(b) Estimate the creep rate to be expected at a service temperature of 500°C.

(c) What important assumption underlies the validity of your answer in part (b)?

Problem 4

Consider the following TTT diagram for the eutectoid steel.



Three different eutectoid steel samples are given the following heat treatments:
(a) instantaneously quenched to 600°C, held for 2 minutes, then cooled to room temperature;
(b) instantaneously quenched to 400°C, held for 2 minutes, then cooled to room temperature;
(c) instantaneously quenched to 100°C, held for 2 minutes, then cooled to room temperature.
List these heat treatments in order of decreasing hardness of the final product. Briefly explain your answer.