MAE 3121

SPRING 2007

MATERIALS SCIENCE LAB

MIDTERM

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LAB 1: CRYSTAL STRUCTURE DETERMINATION BY POWDER X-RAY DIFFRACTION

1.1 Why is powder form used in crystal structure determination of an unknown sample? (5 points)

because powders have random orientation which allows the x-ray to diffract off of multiple layers, whereas with a solid it will mainly diffract off of surface.

powder

solid

861100
1.2 Schematically draw the first five (if necessary) diffraction peaks for the following samples:
(a) Bulk Sample with a (110) orientation. (5 points)
(b) Powdered sample with random orientation and FCC crystal structure. (5 points)
(c) An amorphous polymer sample (5 points)
1.3 The metal niobium has a BCC crystal structure. If the angle of diffraction for the (211) set of planes occurs at 75.99° (first-order reflection) when monochromatic X-ray radiation having a wavelength of 0.1659 nm is used, compute (a) the interplanar spacing for this set of planes, and (b) the atomic radius for the niobium atom. (10 points)

\[ 2\theta = 75.99° \]
\[ \theta = 37.995° \]

\[ d = \frac{\lambda}{2\sin\theta} = \frac{0.1659}{2\sin(37.995°)} \]
\[ d = 1.1347 \text{ nm} \]

\[ a = \sqrt[3]{d^2 \left( h^2 + k^2 + l^2 \right)} \]
\[ a = \sqrt[3]{1.1347^2 \left( 2^2 + 1^2 + 1^2 \right)} \]
\[ a = 0.32994 \text{ nm} \]
2.1 Explain and discuss the concept of supercooling in terms of homogeneous and heterogeneous nucleation with a schematic cooling curve and mention the special circumstances in which it occurs. (Do not forget to label the diagrams) (10 points)

Supercooling is the temperature below the transition temp. (melting) which is required for the substance to solidify. Supercooling happens in heterogeneous nucleations because there are no impurities to help solidify the solution. Homogeneous nucleation does not require supercooling because it has impurities and sides for nucleation. Pure elements and eutectic compositions can have supercooling effects.
2.2. The Bi-Sn binary system is given below. The temperature is given in K and the amounts of components are given in mol;
(a) Draw cooling curves for 0, 0.2, and 0.9 mol Sn. Identify and distinctly mark out the inflection points on the cooling curve. (9 points)
(b) What is the eutectic composition and temperature for Bi-Sn binary system. (2 points)
(c) Write the phase names on the binary system and find the number of phases, name of the phases, amount of phases, and composition of phases for 0.3 mol Sn at 550, 450, and 350 K. (9 points)
(You can ignore the horizontal line given above 250K in your cooling curves and phase calculations)

**Bi - Sn**

*Data from BINARY (SGTE) alloy databases*

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(a) [Graph showing phase transitions and compositions]

(b) 0.4 mol Sn 415 K
LAB 3: RECRYSTALLIZATION OF COLD WORKED BRASS

3.1. Show (with rough diagrams) for how cold work percentage and annealing temperatures change the grain shape and size in different stages for a given brass sample. And add the name of the annealing stage. (15 points)
3.2. Calculate the final cross section area of the sample shown below after it has undergone 60% cold work. Will there be a change in any of the other dimensions of the sample after cold rolling? If so, explain why. (10 points)

\[ 60\% = \frac{A_0 - A_f}{A_0} \times 100 \]

\[ A_0 = 20 \times 10 \text{ cm}^2 \]

\[ \frac{200 - A_f}{200} = 0.5 \]

\[ A_f = 20 \text{ mm}^2 \]

The length of the block will get longer because volume has to stay constant.
3.3. Explain the relationship between the cold work percentage and the annealing time and temperature by using the energy diagram (10 points)

Enough energy must be put in to be $= E_g$ or $> E_g$. So with higher LW% less energy is needed to reach the $E_g$ peak.

$E_g$ is the energy required for recrystallization.

There are two ways to achieve energy: either through high temps and short time or low temp for long time. For 10% LW a higher temp or longer time is required to overcome $E_g$. Then would for 60% LW.
3.4. How the mechanical properties of a sample change by cold working and annealing, and explain why? (10 points)

By cold work, the material creates more dislocation density. Making it stronger but less ductile. In the process, plastic deformation occurs. Upon annealing, the dislocations are removed, and strain energy is released. So the material has the desired properties of strength and ductility, and dislocation-free, not actually free, but very little dislocation.