MSE170 U. Washington

Fundamentals of Materials Science

LABIV

PHASE TRANSFORMATIONS

Study Questions:

1. A 50wt% Pb-50wt% Sn alloy is cooled from 350^{o}C to room temperature; at what temperature does the first solid appear ?
2. What is the composition of the first solid? How about that of the remaining liquid?
3. What is the composition of the last liquid to freeze when the temperature decreases to 183^{o}C?
4. How much liquid is still left upon first reaching that temperature?
5. What would you see if you looked at the microstructure at room temperature?
6. Now consider a 95wt% Sn-5wt% Sb alloy at 300^{o}C. What is the temperature at which the first solid appears? What is the composition of the first solid and of the remaining liquid?
7. What is the composition of the last liquid to freeze at about 232^{o}C? How much liquid is left to solidify at that temperature, if any?
8. Now compare what you would see as microstructure for Sb-Sn and Pb-Sn at room temperature in terms of the phases present and their percent amount.
9. A steep liquidus line leads to a high constitutional supercooling, therefore to high instability ahead of a growing solid/liquid interface. Comparing the phase diagrams of Pb-Sn and Sb-Sn, which of the two alloys is expected to produce more dendrites?

All pure crystalline solids, including metals, have the property of melting and freezing at a single temperature. A metal's temperature decrease is due to the thermal conduction of the metal, for both the liquid and solid forms. At the melting/freezing point the heat loss continues, but the temperature drop discontinues. The heat of fusion released by the solidifying metal exactly balances the heat lost to the environment. This "thermal arrest" in the metal's cooling curve is exactly analogous to water freezing onto ice. As long as there is metal in both the solid and liquid phases the temperature will remain constant at the metal's melting/freezing point. As soon as the last bit of liquid solidifies the temperature drop will resume, although at a somewhat slower rate due to the lower thermal gradient and conductivity of the metal.

Some combinations of metals have a eutectic composition (Greek for "easy melting"), the eutectic being the alloy composition that has the lowest melting point (minimum in the liquidus curve), and the property of melting/freezing at a single temperature like a pure metal. Thus, the cooling curve of an alloy of eutectic composition will look like that of a pure metal.

It is also characteristic of a eutectic that it transforms from a single uniform liquid phase to as many solid phases as there are metallic components in the alloy. In the case of binary alloys, such as copper-silver, there will be two solid phases upon complete solidification of the eutectic composition. This typically results in a finely laminated "eutectic structure". A small amount of *supercooling* may occur just before solidification has a chance to begin. A eutectic should not be confused with an eutectoid; the eutectoid transforms from a single solid phase to as many different solid phases (distinct from the initial phase) as there are metallic components in the alloy and typically forms a finely laminated structure, but does so entirely in the solid state, starting and finishing as a solid.

In alloy compositions other than the eutectic and the pure metal, different phases of the alloy melt/freeze at different temperatures, resulting in a melting zone that spans a range of temperatures. Although the slope of the cooling curve decreases as the heat is released from the solidifying metal, there is no thermal arrest in this zone since there is no pure metal or eutectic to cause one. As one phase of the alloy solidifies preferentially, the composition of the solid and liquid change continuously with temperature. When the last bit of liquid has solidified the cooling curve becomes steeper since there is no longer any release from the heat of fusion. The slope of the curve after solidification will be somewhat less than before solidification since the solid metal has a lower thermal conductivity and difference in temperature from the environment. For some alloys of a eutectic forming alloy system, the compositional shifts that occur during solidification will cause the final liquid to solidify and reach a eutectic composition. This liquid will behave like a eutectic and will cause a thermal arrest at the eutectic temperature until it has entirely solidified

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Laboratory Construction of a Eutectic Phase Diagram

For this lab you will construct a binary metallic phase diagram of tin and bismuth.

Samples

Eleven different molten bismuth and tin alloy mixtures are located in the furnaces, the compositions of each crucible are:

1. 100%Bi
2. 40 Bi - 60 Sn
3. 90 Bi - 10 Sn

4. 30 Bi - 70 Sn
5. 80 Bi - 20 Sn
6. 20 Bi - 80 Sn
7. 70 Bi - 30 Sn
8. 10 Bi - 90 Sn
9. 60 Bi - 40 Sn
10. 57 Bi - 43 Sn
11. 100% Sn

Procedure

1. The alloys have heated in the furnace above the melting point to 400°C.
2. Carefully remove the crucibles of the molten alloy from the furnace and place securely into the cooling unit.
3. Insert a thermocouple into each crucible.
4. Allow the alloy to cool undisturbed while recording the measured temperature every 30 seconds.
5. Stop taking measurements once the temperature drops below 110^{o}C.
6. For each alloy composition construct a graph of time vs. temperature. Note the changes in slope of the cooling curve as the temperature of the alloy slowly decreases.
7. For each alloy composition note at what temperatures phase changes occur. After each of these critical points are identified for each alloy composition, a phase diagram can be constructed.

Questions

These are just a few of the questions that should be incorporated into the write-up of your lab:

1. What are the crystal structures of Bi and Sn?
2. Describe the microstructure that exists within each of the six distinct regions of the phase diagram and how they develop during solidification.
3. In the Bi-Sn binary phase diagram, at what compositions does thermal arrest occur?
4. What is Newton's law of cooling? What is *supercooling*?
5. Discuss each trend of the three cooling curves at; the eutectic point, and 80Bi-20Sn composition.
6. Discuss in detail the microstructural development of the: and 20Bi- 80Sn alloy compositions during cooling.
7. Discuss two reasons why you would you choose to specify a 58%Bi - 42%Sn composition for a soldering application?