Chapter 9: Phase Diagrams II

- When we combine two elements...

  what equilibrium state do we get?

- In particular, if we specify...

  --a composition (e.g., wt% Cu - wt% Ni), and

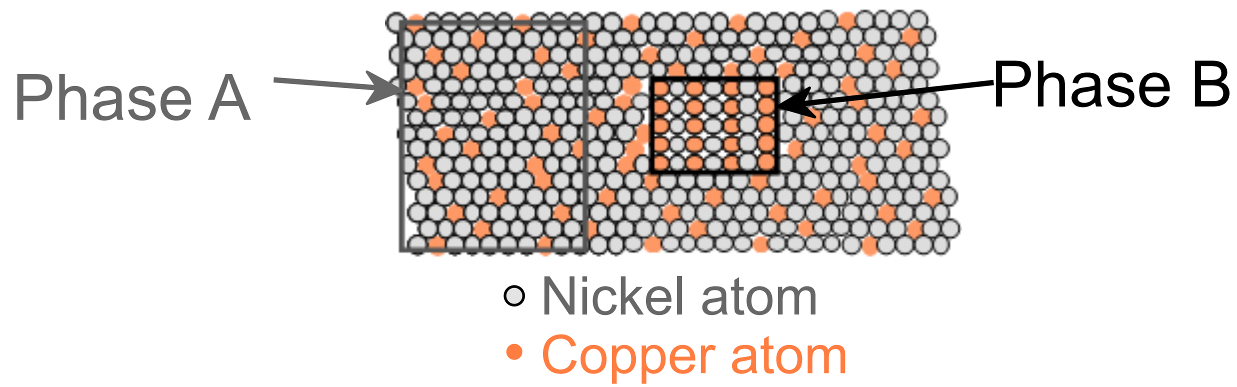
  --a temperature (*T*)

  then...

  How many phases do we get?

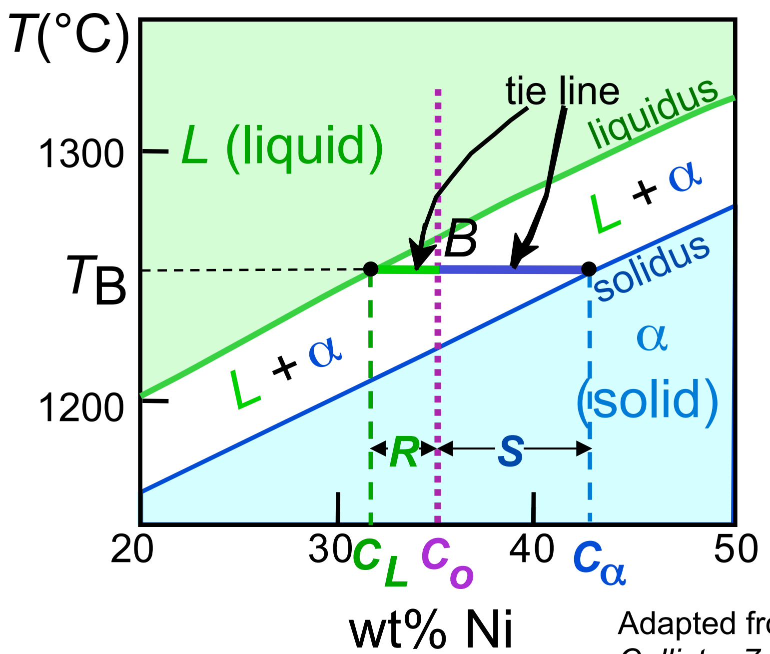
  What is the composition of each phase?

  How much of each phase do we get?



The Lever Rule

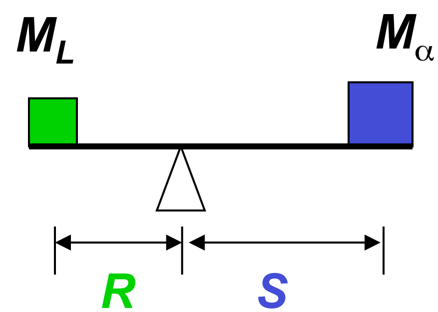
- Tie line – connects the phases in equilibrium with each other - essentially an isotherm



Adapted from Fig. 9.3(b), *Callister 7e.*

How much of each phase?

Think of it as a lever (teeter-totter)



$$M_\alpha \cdot S = M_L \cdot R$$

$$W_L = \frac{M_L}{M_L + M_\alpha} = \frac{S}{R+S} = \frac{C_\alpha - C_0}{C_\alpha - C_L}$$

$$W_\alpha = \frac{R}{R+S} = \frac{C_0 - C_L}{C_\alpha - C_L}$$

Binary-Eutectic Systems

2 components

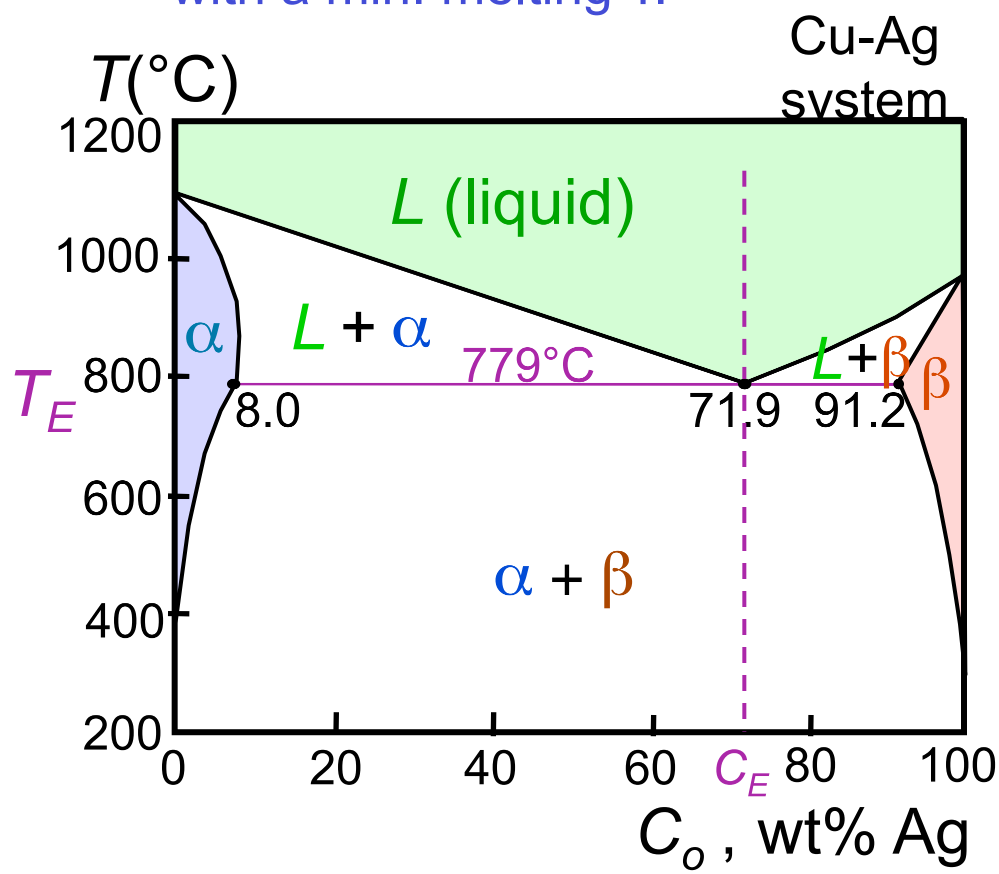
has a special composition with a min. melting T.

Ex.: Cu-Ag system

- 3 single phase regions (L, α, β)
- Limited solubility:
  - α: mostly Cu
  - β: mostly Ag
- T_E : No liquid below T_E
- C_E : Min. melting T_E composition

- **Eutectic transition**

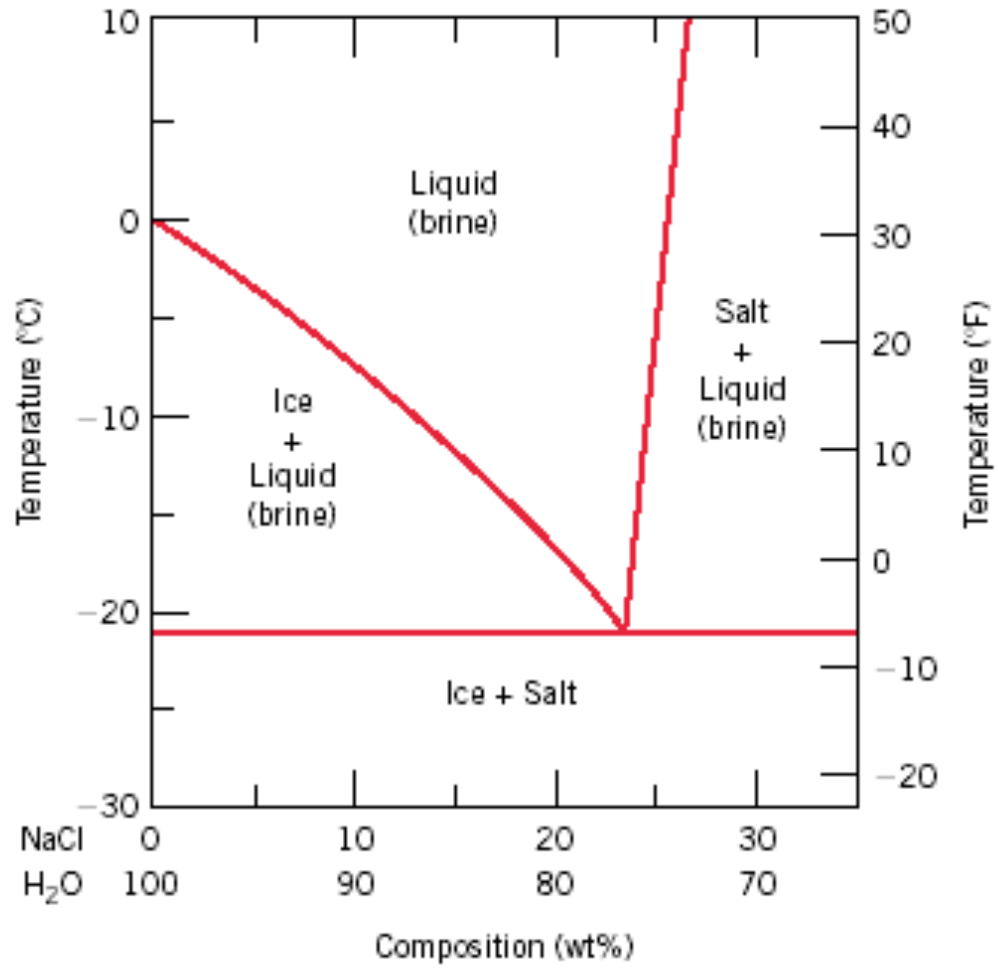
$$L(C_E) \rightleftharpoons \alpha(C_{\alpha E}) + \beta(C_{\beta E})$$



Adapted from Fig. 9.7, *Callister 7e.*

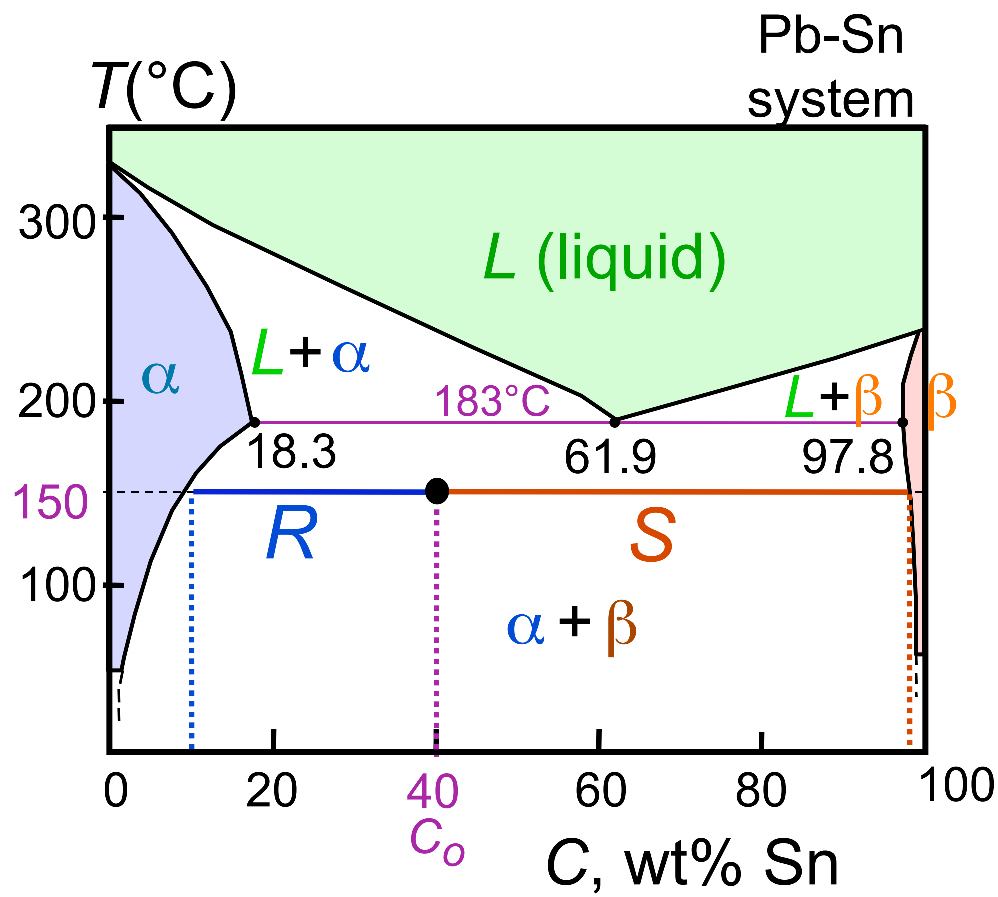
Binary eutectic systems (Example)

- **Explain how spreading salt on ice that is at a temperature below 0^0C can cause the ice to melt.**



EX: Pb-Sn Eutectic System (1)

- For a 40 wt% Sn-60 wt% Pb alloy at 150°C, find...
  --the phases present:
  --compositions of phases:



Adapted from Fig. 9.8, *Callister 7e.*

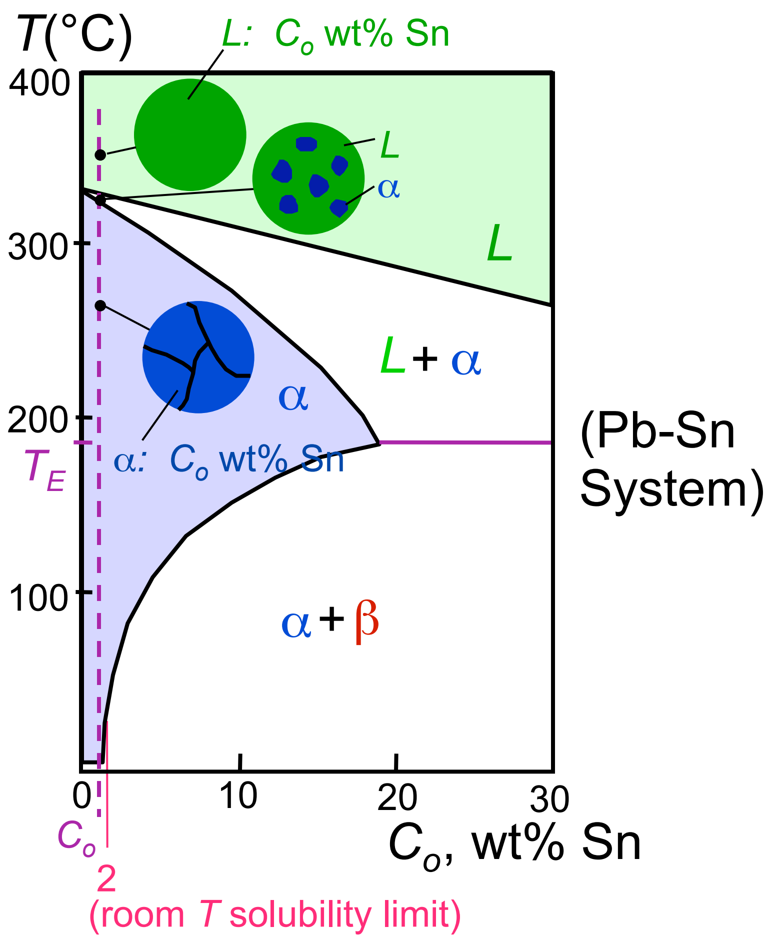
Microstructures in Eutectic Systems: I

- C_o < 2 wt% Sn
- Result:

  --at extreme ends

  --polycrystal of α grains

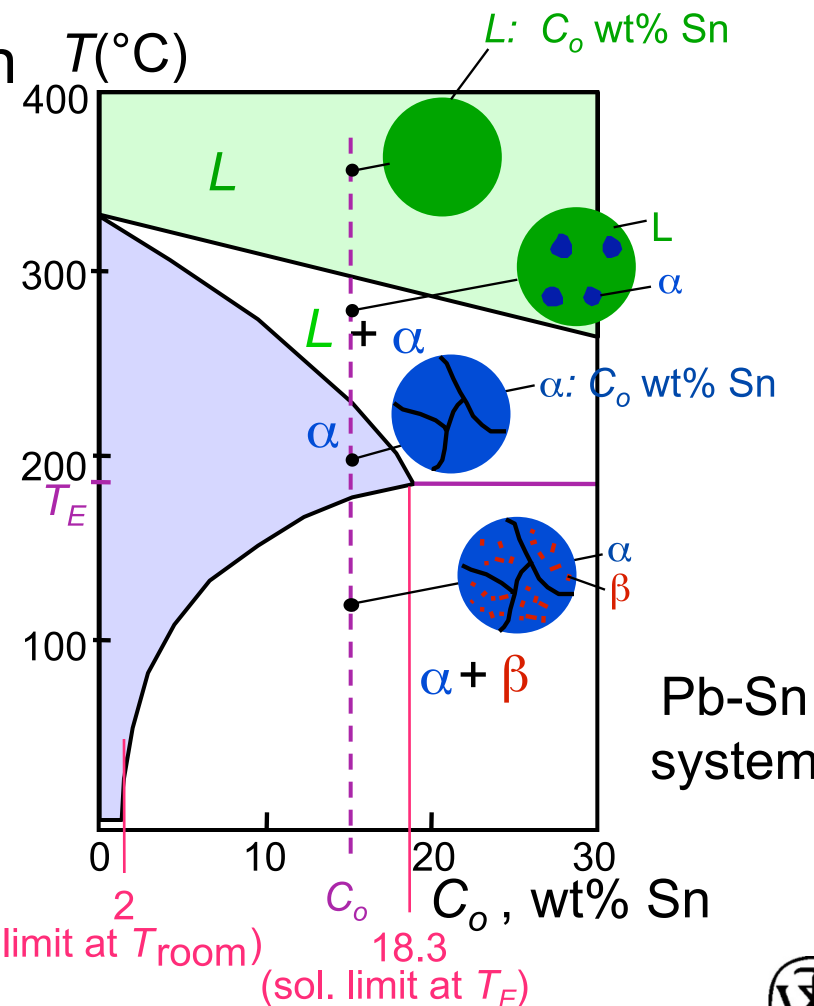
  i.e., only one solid phase.



Adapted from Fig. 9.11, *Callister 7e.*

Microstructures in Eutectic Systems: II

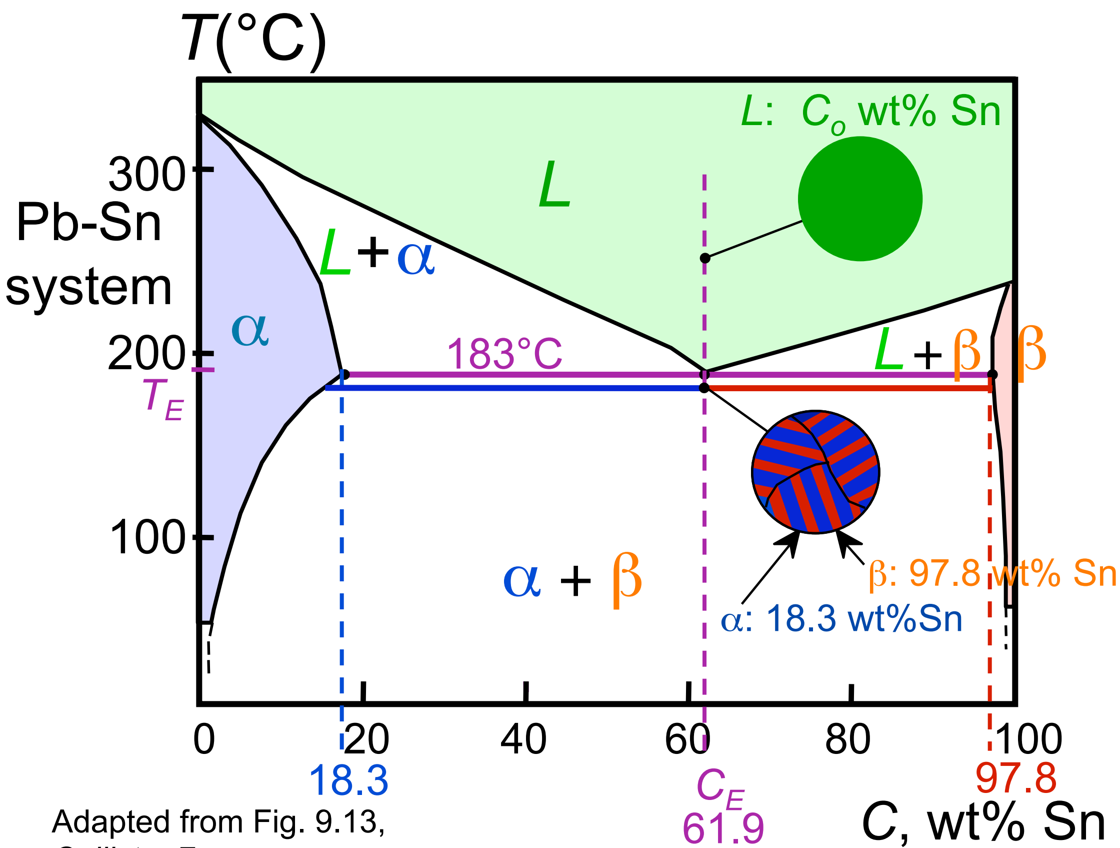
- 2 wt% Sn < C_o < 18.3 wt% Sn
- Result:
  - Initially liquid + α
  - then α alone
  - finally two phases
    - α polycrystal
    - fine β-phase inclusions



Adapted from Fig. 9.12, *Callister 7e.*

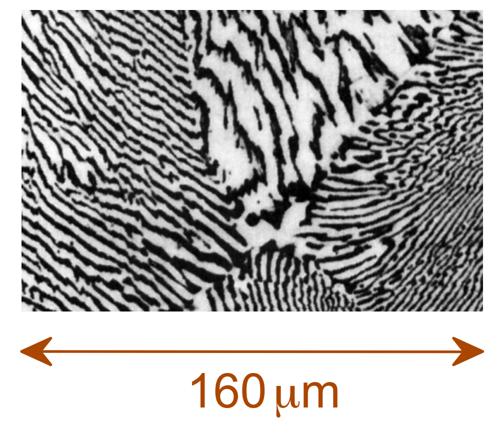
Microstructures in Eutectic Systems: III

- $C_o = C_E$
- Result: Eutectic microstructure (lamellar structure)
  --alternating layers (lamellae) of α and β crystals.



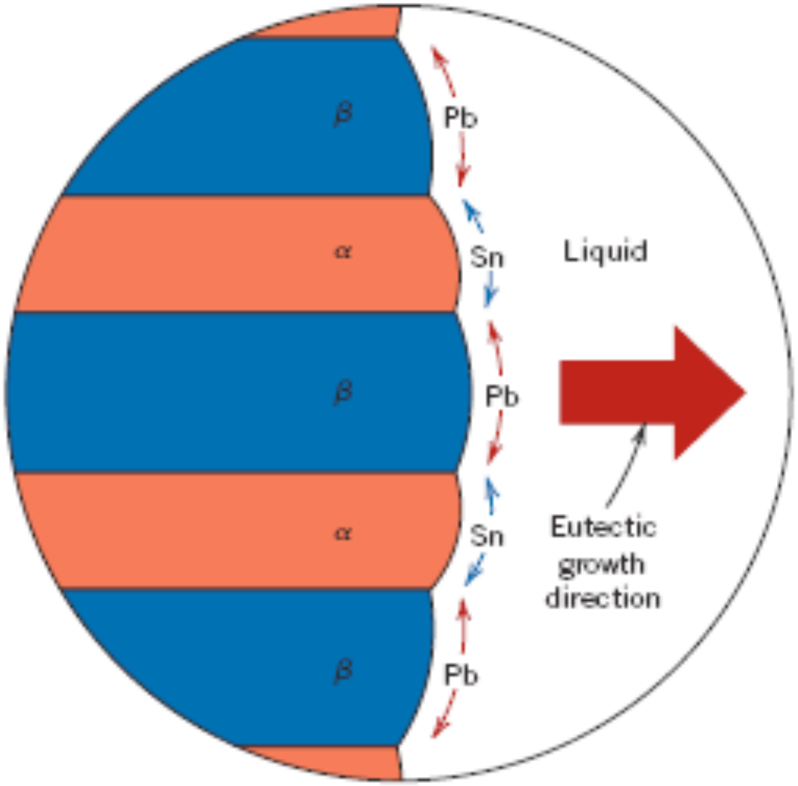
Adapted from Fig. 9.13, *Callister 7e.*

Micrograph of Pb-Sn eutectic microstructure

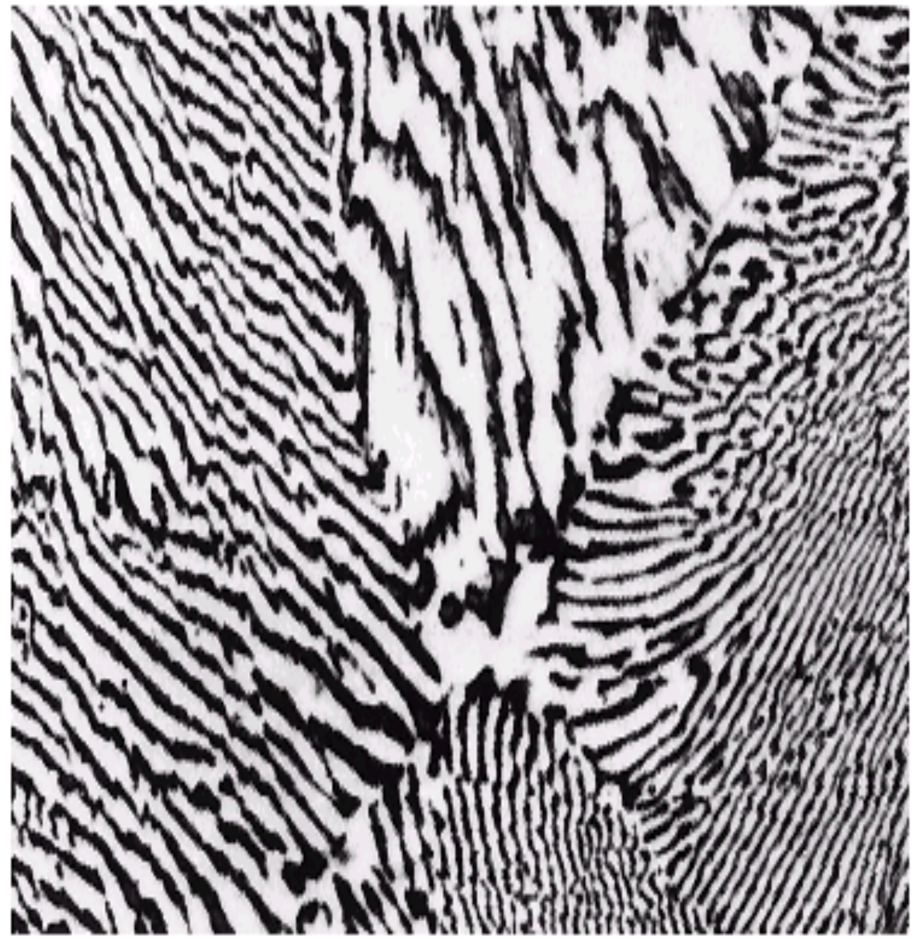


Adapted from Fig. 9.14, *Callister 7e.*

Lamellar Eutectic Structure

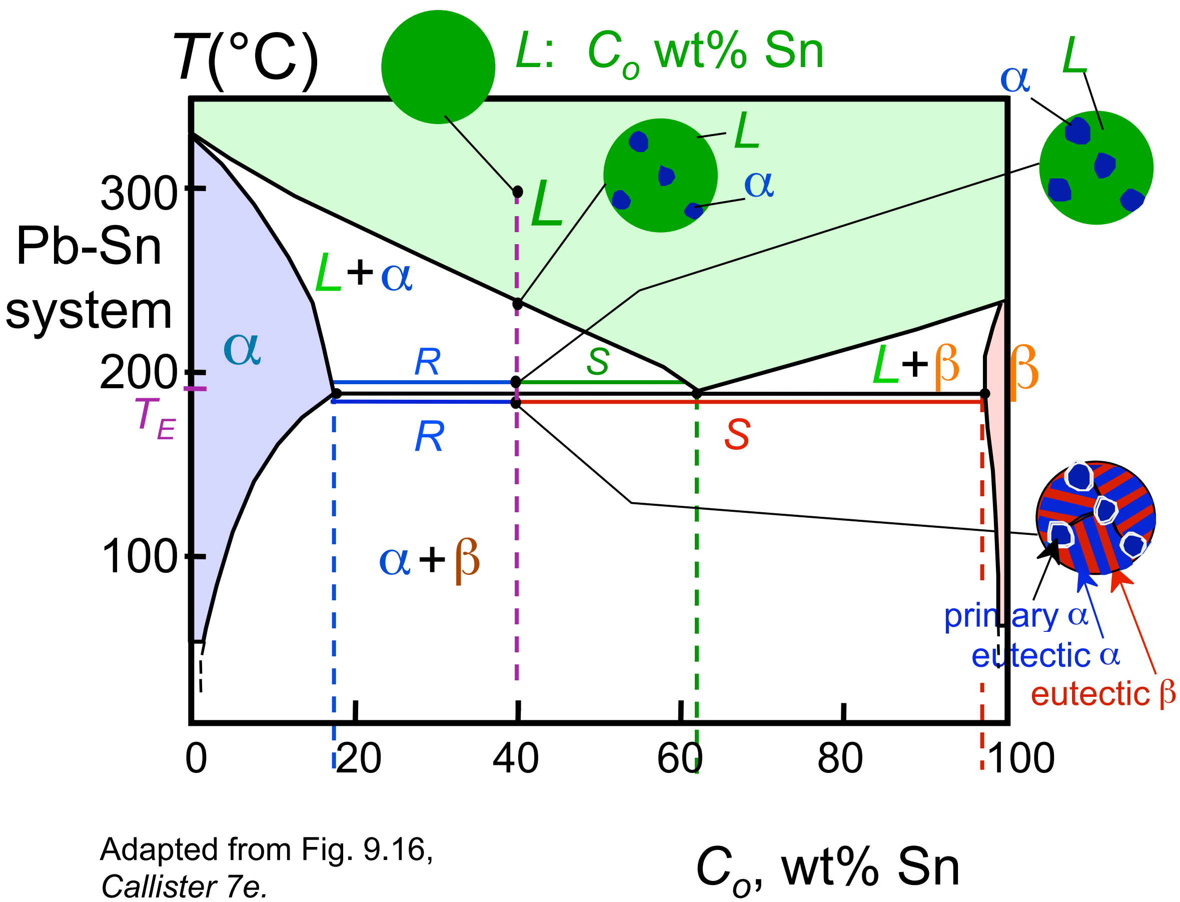


Adapted from Figs. 9.14 & 9.15, *Callister 7e.*



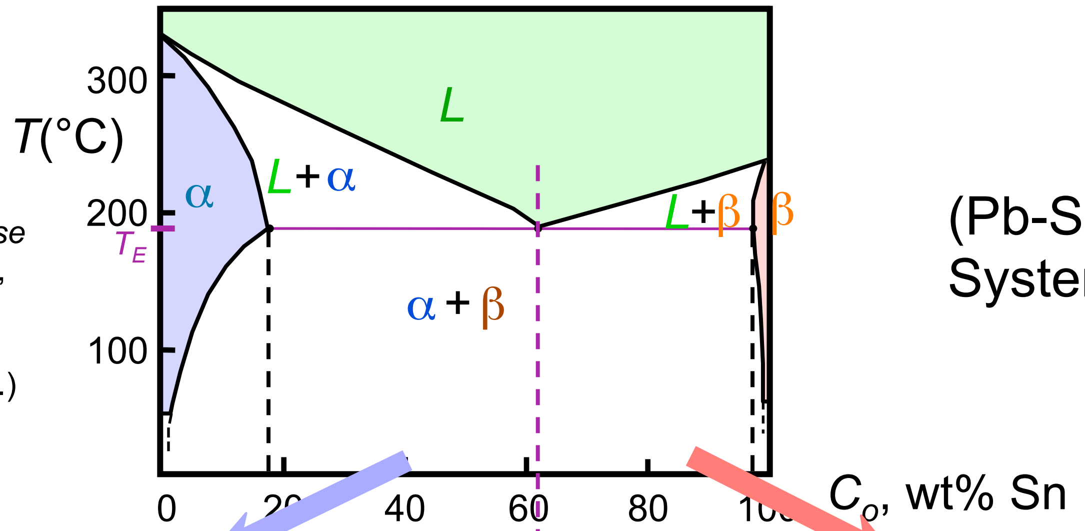
Microstructures in Eutectic Systems: IV

- 18.3 wt% Sn < C_o < 61.9 wt% Sn
- Result: α crystals and a eutectic microstructure



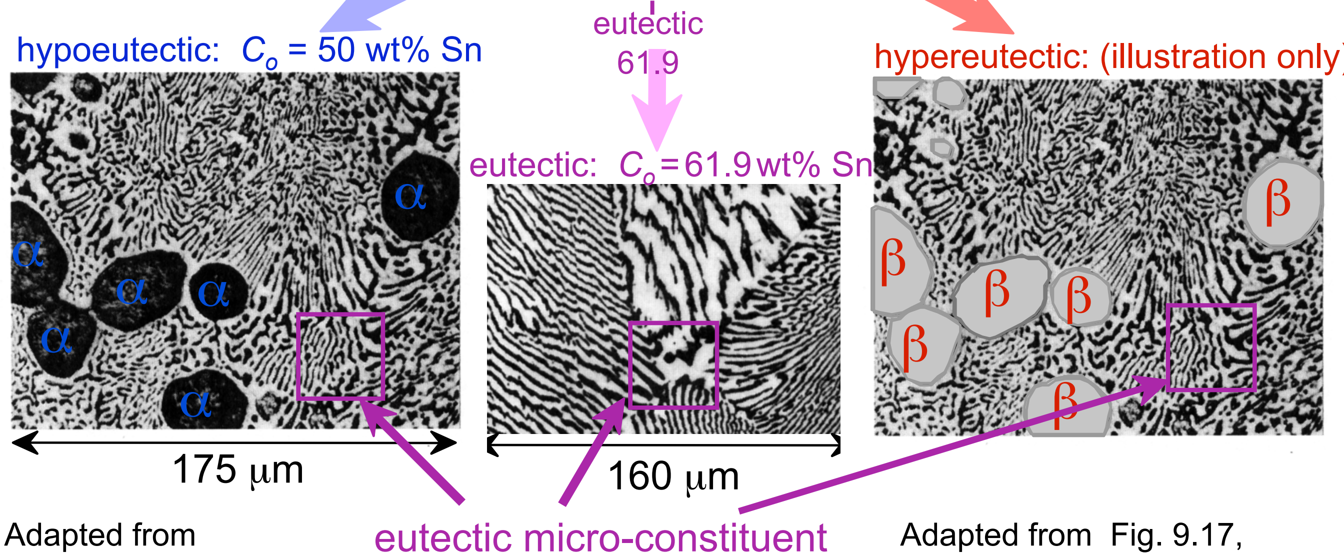
Adapted from Fig. 9.16, *Callister 7e.*

Hypoeutectic & Hypereutectic



Adapted from Fig. 9.8, *Callister 7e.* (Fig. 9.8 adapted from *Binary Phase Diagrams*, 2nd ed., Vol. 3, T.B. Massalski (Editor-in-Chief), ASM International, Materials Park, OH, 1990.)

(Pb-Sn System)



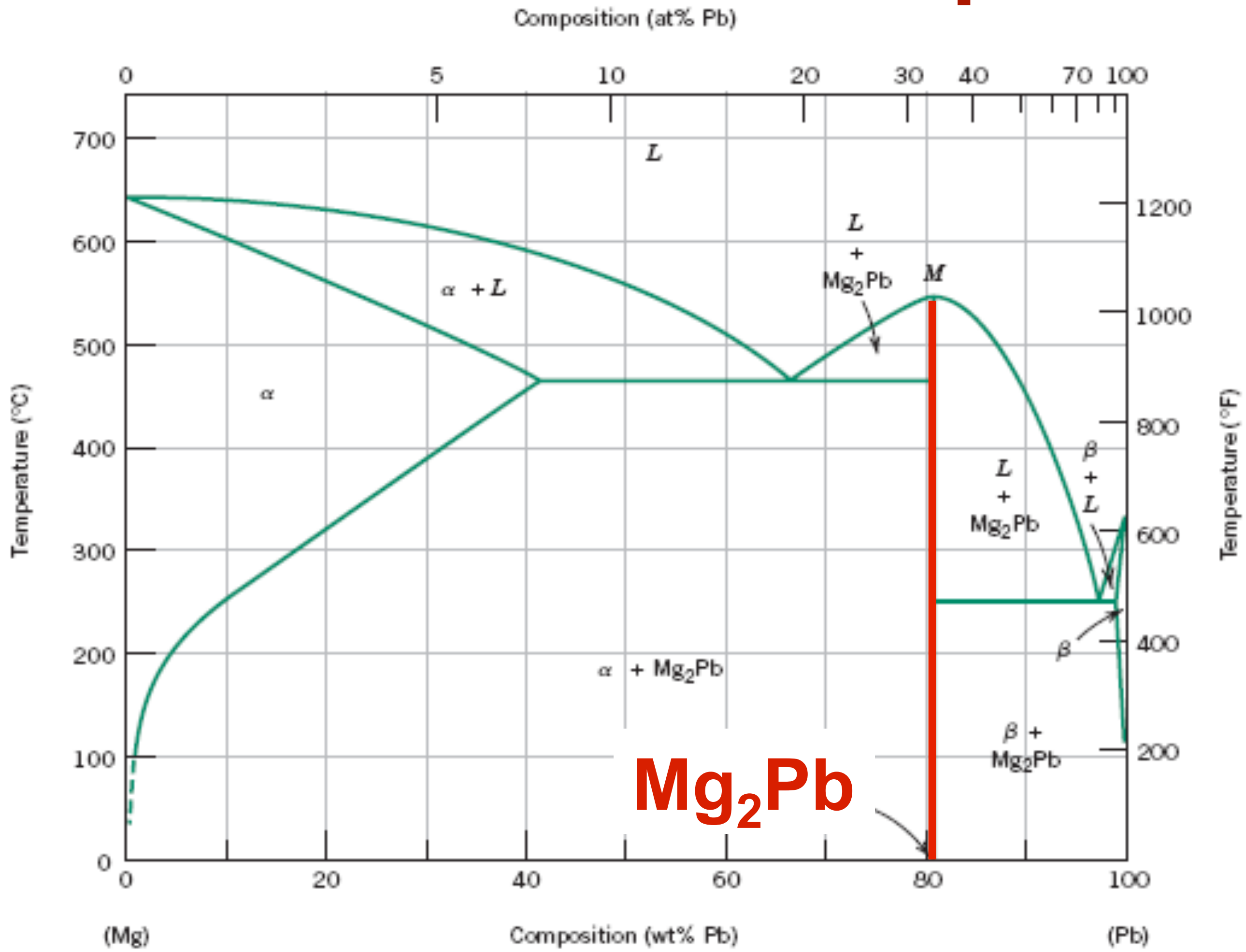
(Figs. 9.14 and 9.17 from *Metals Handbook*, 9th ed., Vol. 9, *Metallography and Microstructures*, American Society for Metals, Materials Park, OH, 1985.)

Adapted from Fig. 9.17, *Callister 7e.*

Adapted from Fig. 9.14, *Callister 7e.*

Adapted from Fig. 9.17, *Callister 7e.* (Illustration only)

Intermetallic Compounds



Adapted from Fig. 9.20, *Callister 7e.*

Note: intermetallic compound forms a line - not an area - because stoichiometry (i.e. composition) is exact.

Eutectoid & Peritectic

- Eutectic - liquid in equilibrium with two solids

$$L \underset{\text{heat}}{\overset{\text{cool}}{\rightleftharpoons}} \alpha + \beta$$

- Eutectoid - solid phase in equation with two solid phases

$$S_2 \rightleftharpoons S_1 + S_3$$

intermetallic compound - cementite

$$\gamma \underset{\text{heat}}{\overset{\text{cool}}{\rightleftharpoons}} \alpha + Fe_3C \qquad (727^{o}C)$$

- Peritectic - liquid + solid 1 → solid 2 (Fig 9.21)

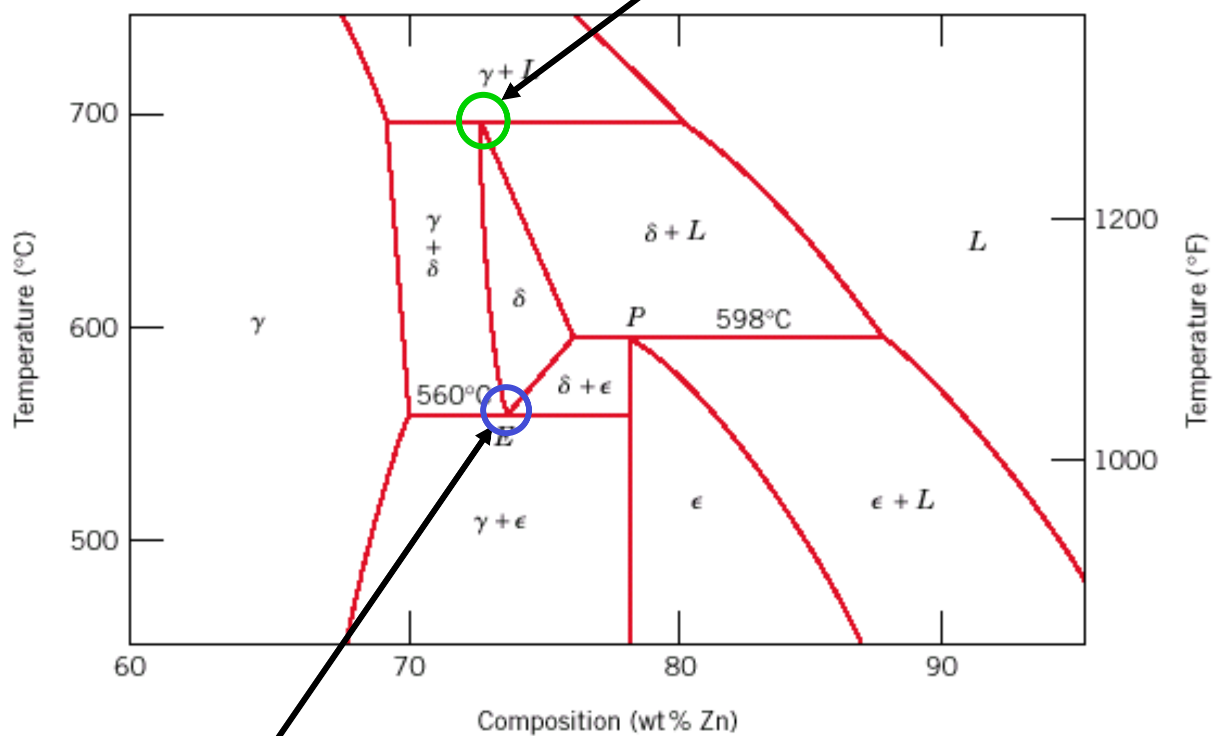
$$S_1 + L \rightleftharpoons S_2$$

$$\delta + L \underset{\text{heat}}{\overset{\text{cool}}{\rightleftharpoons}} \gamma \qquad (1493^{o}C)$$

Eutectoid & Peritectic

Cu-Zn Phase diagram

Peritectic transition $\gamma + L \rightleftharpoons \delta$



Eutectoid transition $\delta \rightleftharpoons \gamma + \varepsilon$

Adapted from
Fig. 9.21, *Callister 7e.*