Solidification of alloys

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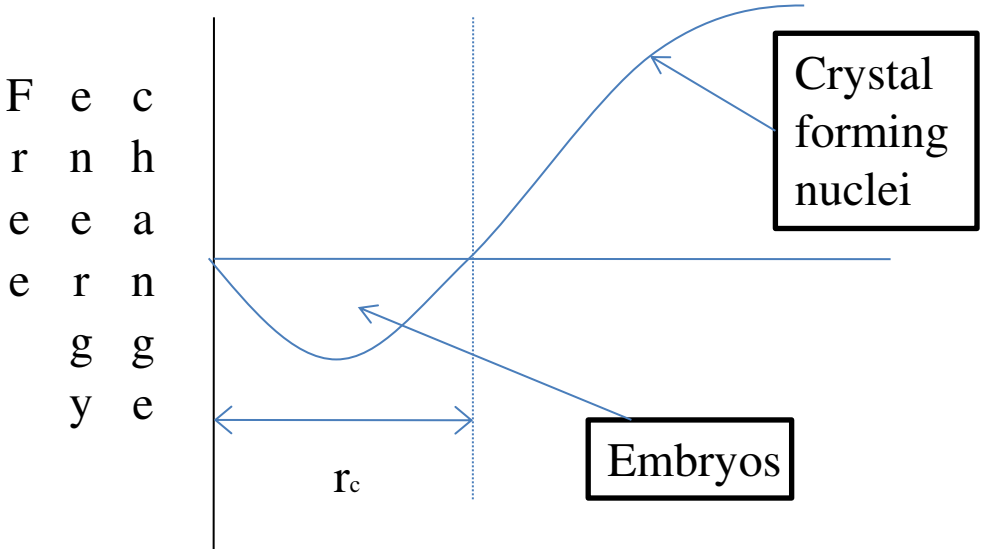
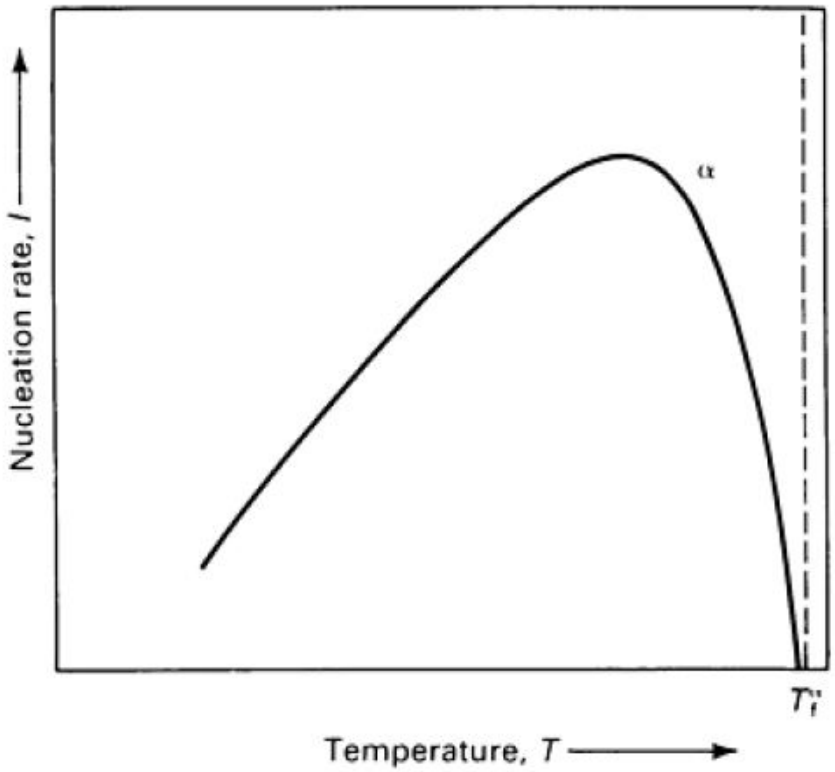
SOLIDIFICATION

- Solidification :
  - Process of a material of transforming from liquid to solid state is called solidification.
- Steps in solidification :
  - Liquid state
  - Nucleation
  - Crystallization and solid liquid interface
  - Grain growth
- Why study solidification :
  - It affects properties of material
  - Most metals are made through casting
  - For process and quality control during casting
  - For controlling phases in material

Nucleation

- Nucleation : Formation of a centre around which further crystallization takes place is called nuclei and process of its formation is called nucleation.
  - It largely depends on critical radius of nucleation ($r_{c)}$
  - Nuclei with smaller than r_c are less likely to form crystal and are called embryos. They may get dissolve in liquid again.
  - Generally nucleation is combination of both types.
- Homogeneous nucleation
  - Nucleation takes place throughout material simultaneously
  - Nucleation sites uniform throughout material
  - Takes place due to under cooling
  - Most of solidification takes place through it.
- Heterogeneous nucleation
  - Nucleation takes place randomly
  - Takes place at mould melt interface surface of melt and impurities
  - Smaller role in solidification





nucleation

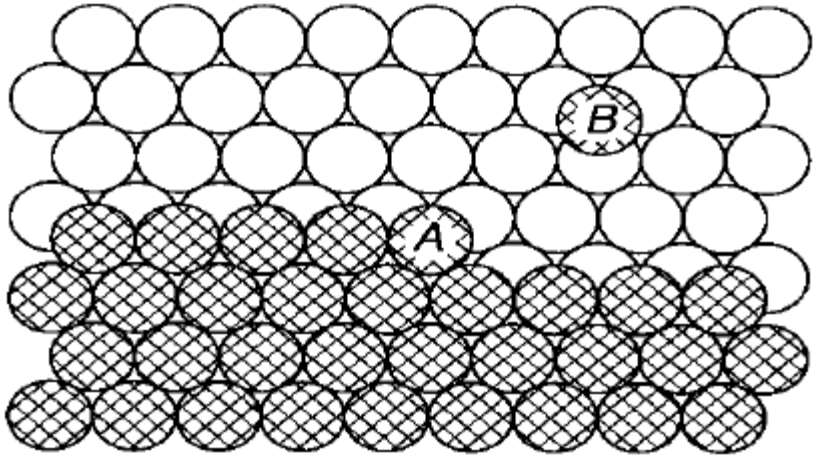
Nuclei with radius > r_c will form crystals

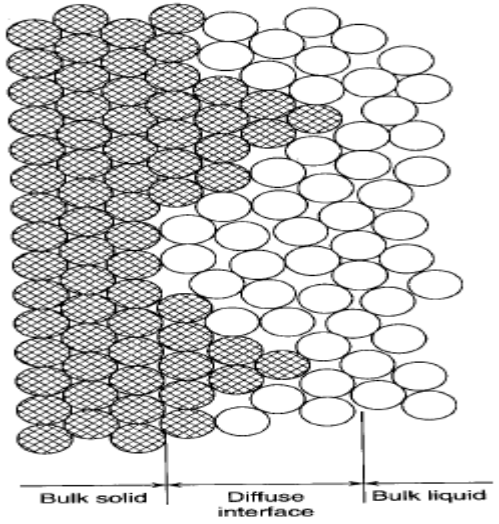
Nuclei with radius < r_c will dissolve as liquid

Max under cooling (˚K) for metals :
Hg 88, Cd 110, Pb 153, Al 160, Sn 187
Ag 227, Au 230, Cu 236, Fe 286, Mn 308
Ni 365, Pt 370, Nb 525

Crystallization and solid liquid interface

- Crystal Growth from the Liquid Phase:
- The movement of a boundary separating liquid from solid, under the influence of a temperature gradient normal to the boundary, is the result of two different atomic movements.

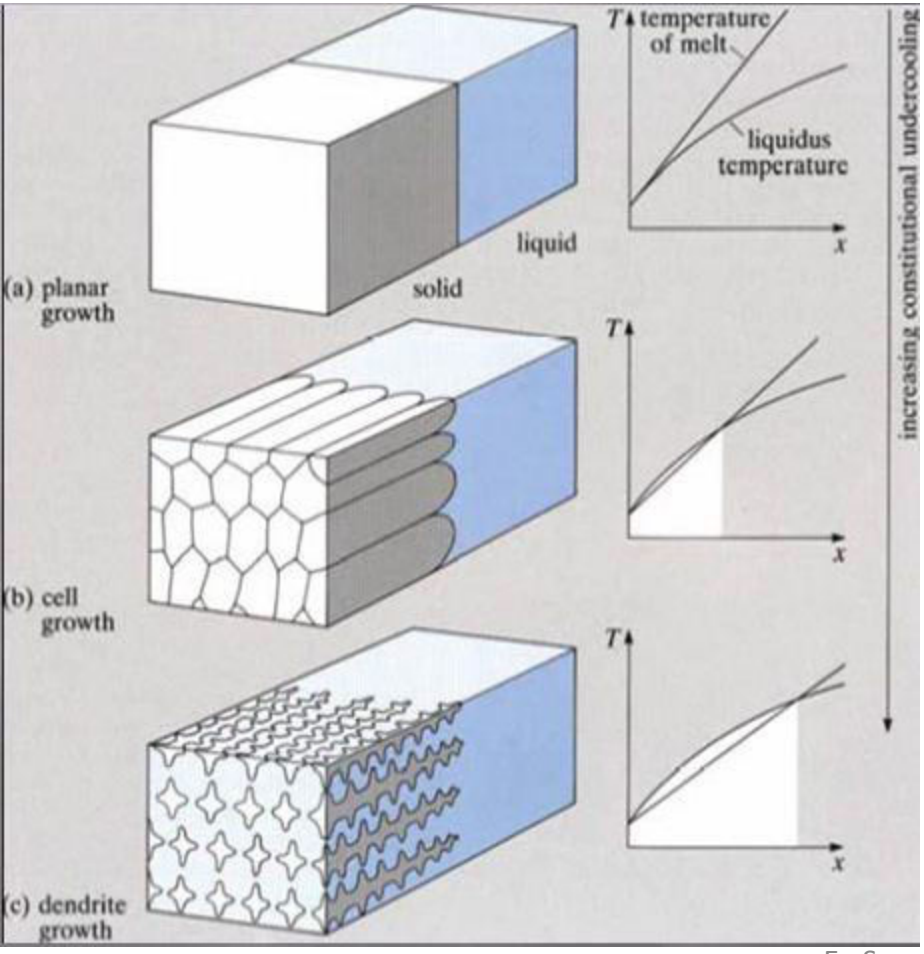


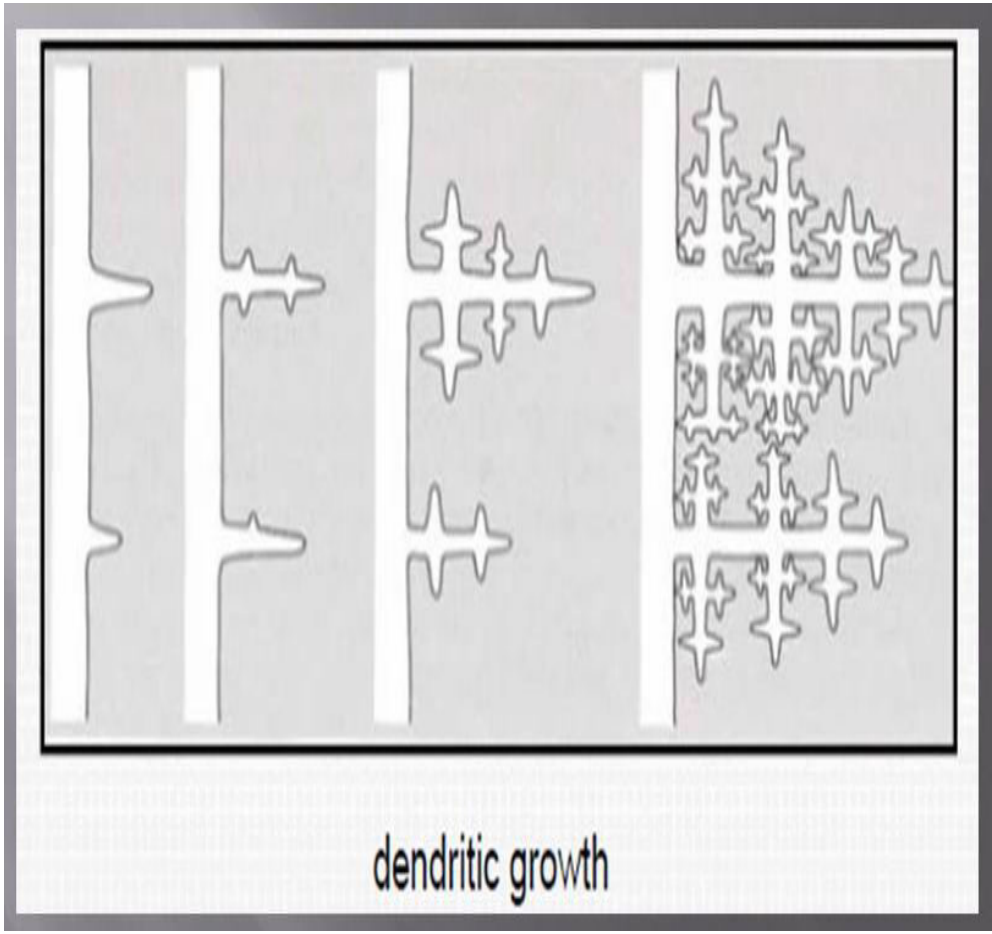


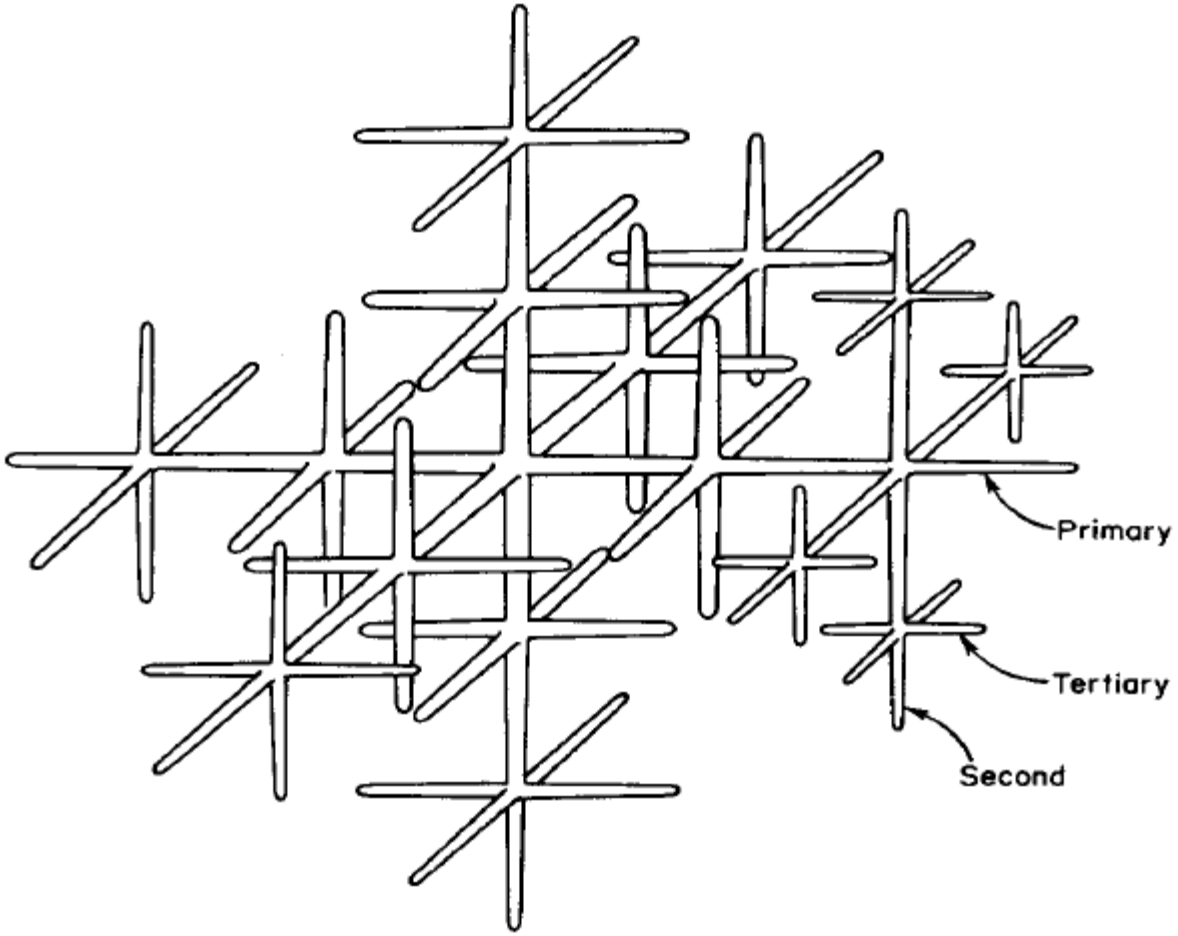
Atoms leave the liquid and join the solid = rate of attachment (SOLIDIFICATION)
Atoms leave the solid and join the liquid = rate of detachment (MELTING)

Grain growth

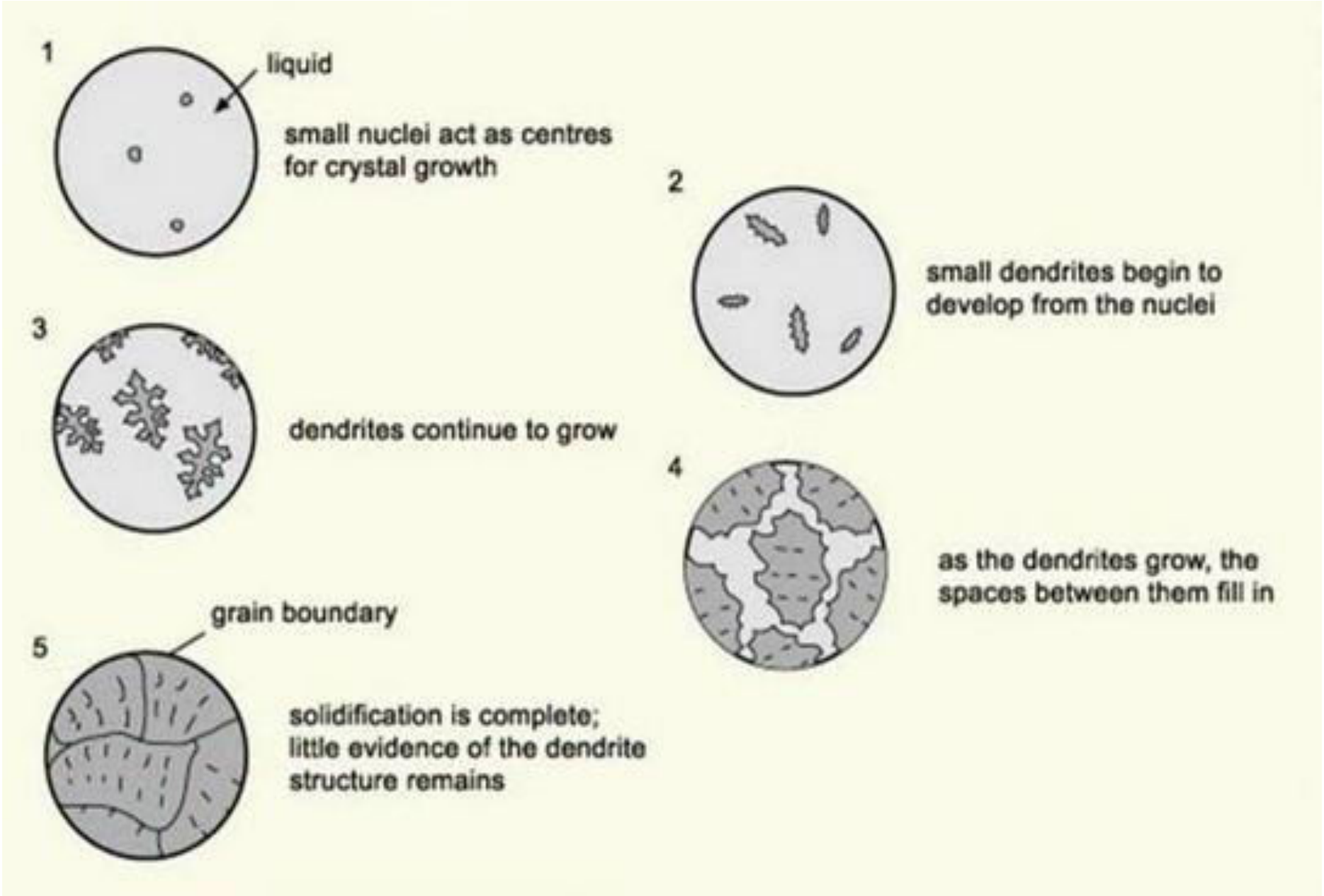
- Types of grain growth







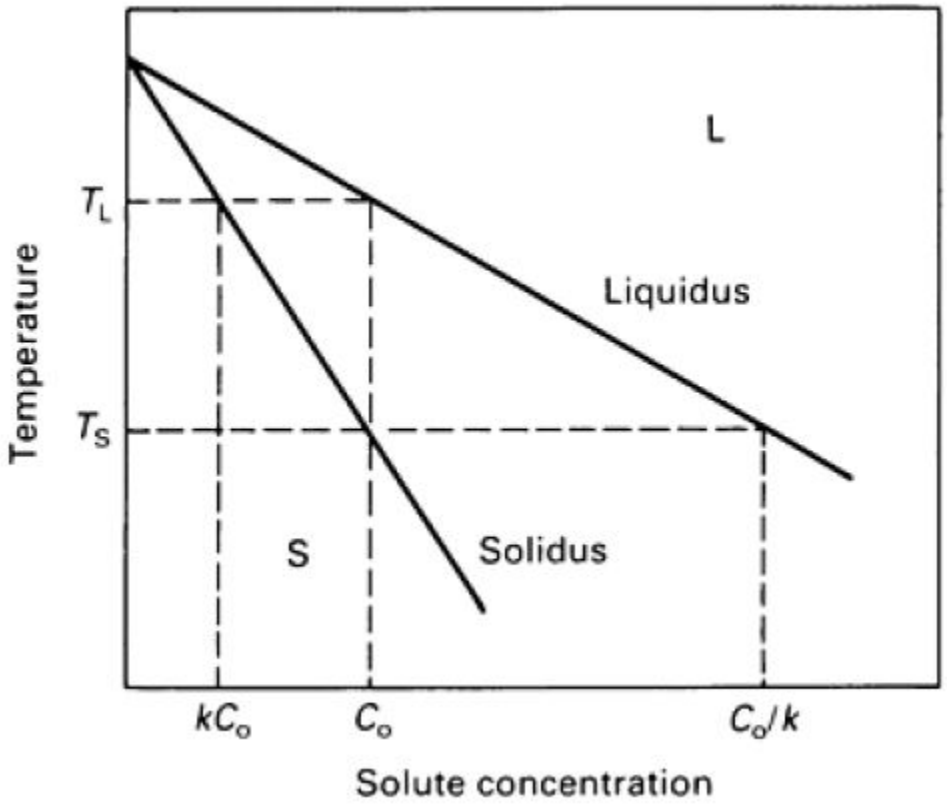
Dendritic grain growth 3 D



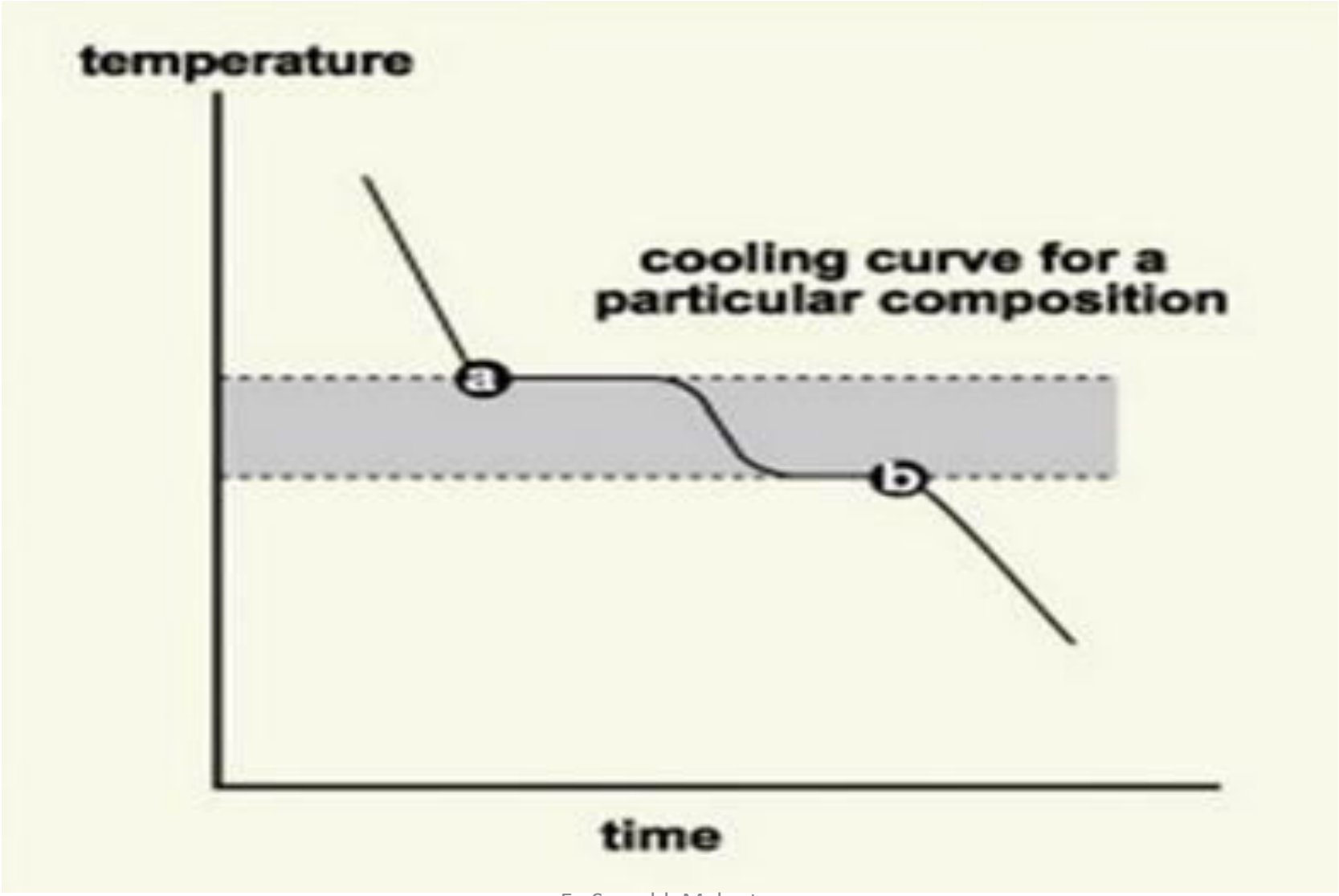
Steps in solidification of alloys

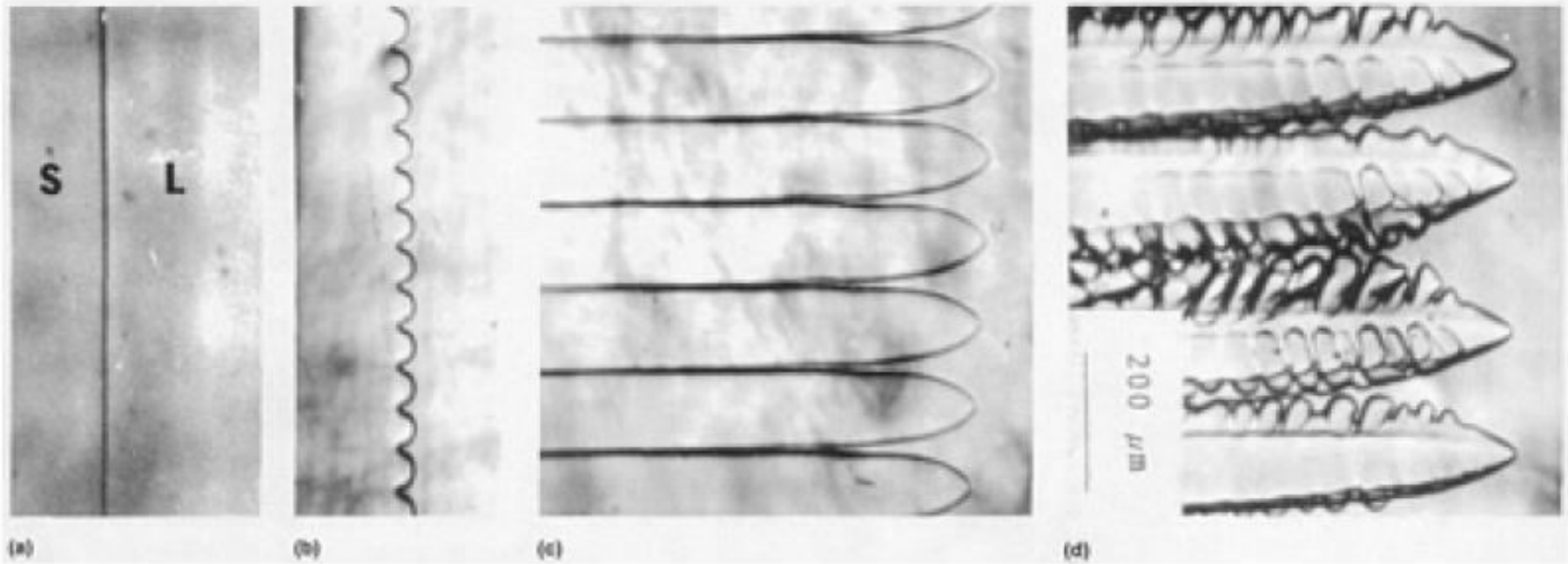
Solidification of alloys

- Solidification of iso morphous alloys
  - Takes place over a range of temperature
  - Solute solvent distribution is given as chart below



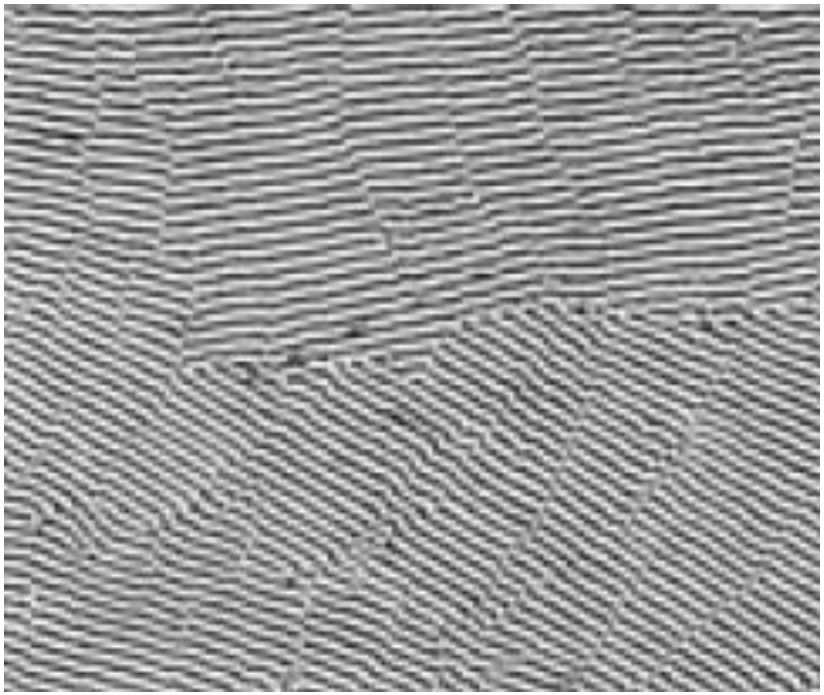
Cooling curve for an alloy



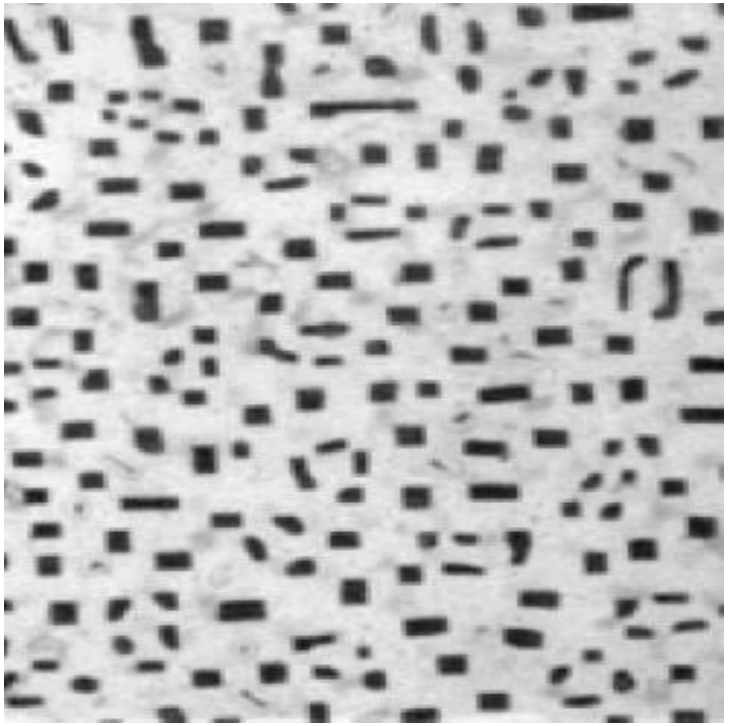


Effect of increasing growth rate on the shape of the solid/liquid interface in a transparent organic system, pivalic acid-0.076 wt% ethanol, solidified directionally at*G = 2.98 K/mm (75.7 K/in.). (a) v = 0.2 μm/s* (8 μin./s). (b) *v = 1.0 μm/s (40 μin./s). (c) v = 3.0 μm/s (120 μin./s). (d) v = 7.0 μm/s (280 μin./s)*

Solidification of eutectic alloy

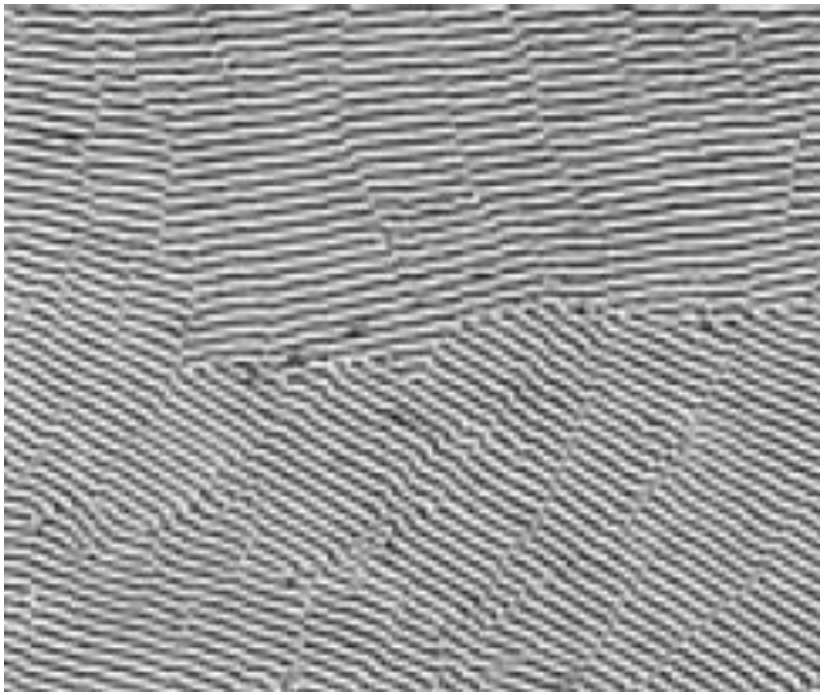


Example of a **lamellar** eutectic microstructure (Al-Al_2Cu) with approximately equal volume fractions of the phases. Transverse section of a directionally solidified sample. As-polished.

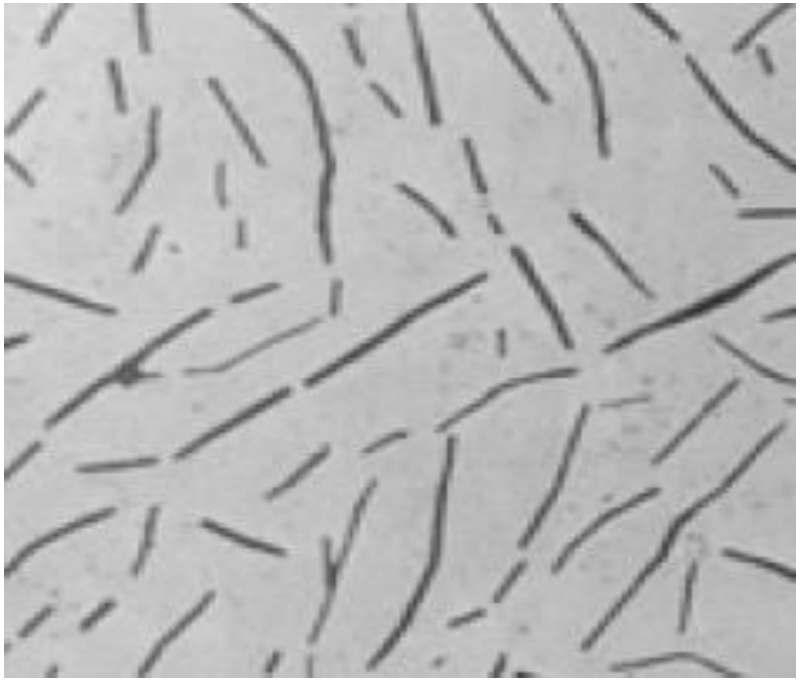


Example of a **fibrous** eutectic microstructure with a small volume fraction of one phase (molybdenum fibers in NiAl matrix). As-polished.

Regular & irregular growth



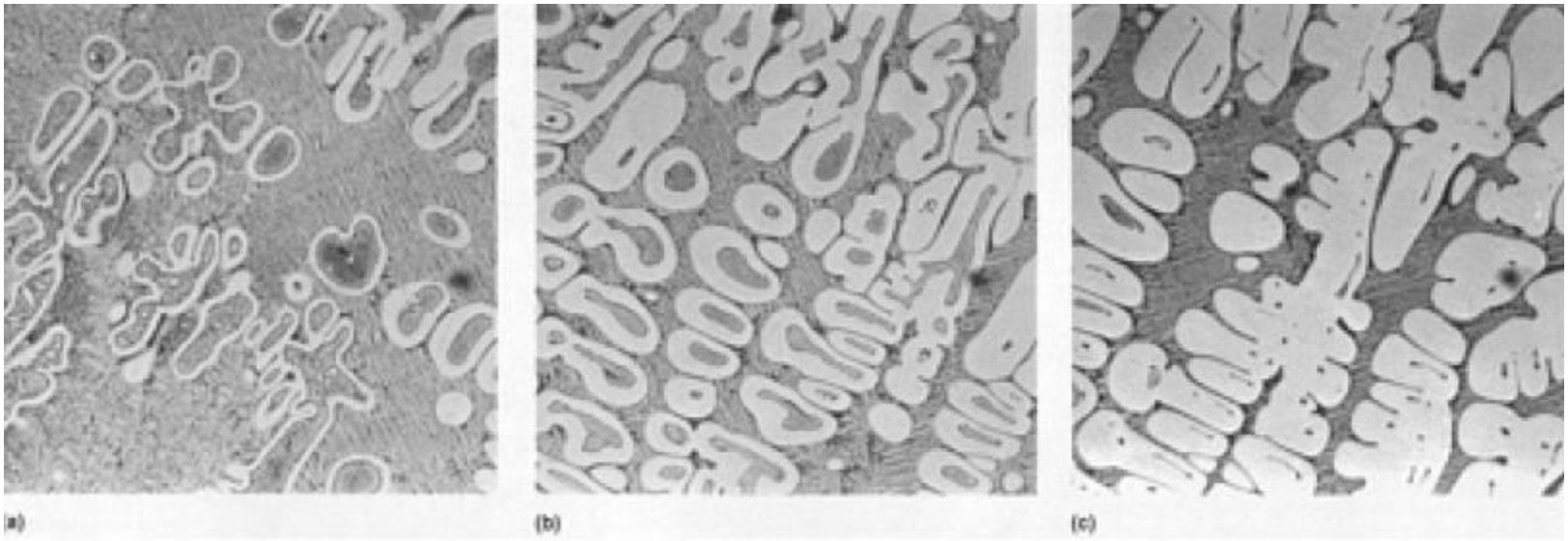
Regular growth
Repetetive pattern



Irregular growth
Non repetetive pattern

Solidification of peritectic alloy (less solid solubility)

- Diffusion through the β (solid) layer
- Precipitation of β (solid) directly from the liquid
- Precipitation of β directly from the α (liquid) phase



Three stages of a peritectic reaction in a unidirectionally solidified high-speed steel. (a) First stage structure. Dark gray is austenite, white is ferrite. The mottled structure is quenched liquid. (b) Subsequent peritectic transformation of (a). (c) Further peritectic transformation of (a) and (b). Dark gray in the middle of the white ferrite is newly formed solid

PERITECTIC ALLOYS

- **Peritectic is a phase where there is limited solid solubility.**
- **They are not of much use in dentistry except for silver tin system.**

Eg: Silver-tin

Silver –platinum

Palladium-ruthenium

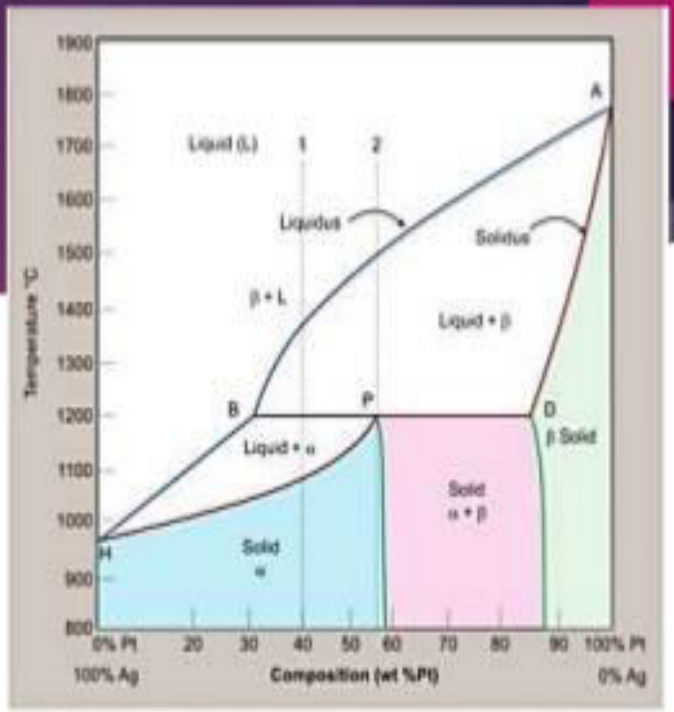


FIGURE 3.13 Equilibrium phase diagram for the platinum-silver system demonstrating peritectic reaction

α - Silver rich phase
β - Platinum rich phase
P - Peritectic transformation point
A - Platinum melting point (1768 °C)
H - Silver melting point (961.8 °C)
A peritectic reaction is a reaction where a solid phase (β) and liquid phase will together form a second solid phase (α) at a particular temperature and composition.
In this case, it occurs at a composition of 58% Pt

Liquid + β solid solution ⟶ α solid solution

References

- ASM Handbook vol. 15 casting
- Solidification – Loren A. Jacobson METE 327, Fall 2008
- Explanation of Solidification of Metals & Alloys - Dragonfly Education
- Solidification of alloys – aseem khatri, navneet kumar, aditya gupta
- Cooling and solidification of metal alloys (video)


Thank you