Binary Phase Diagrams

Lesley Cornish

Definition of a "phase"

- Has a distinctive temperature and composition range
- Has a definite structure
- Usually has an easily seen interface.

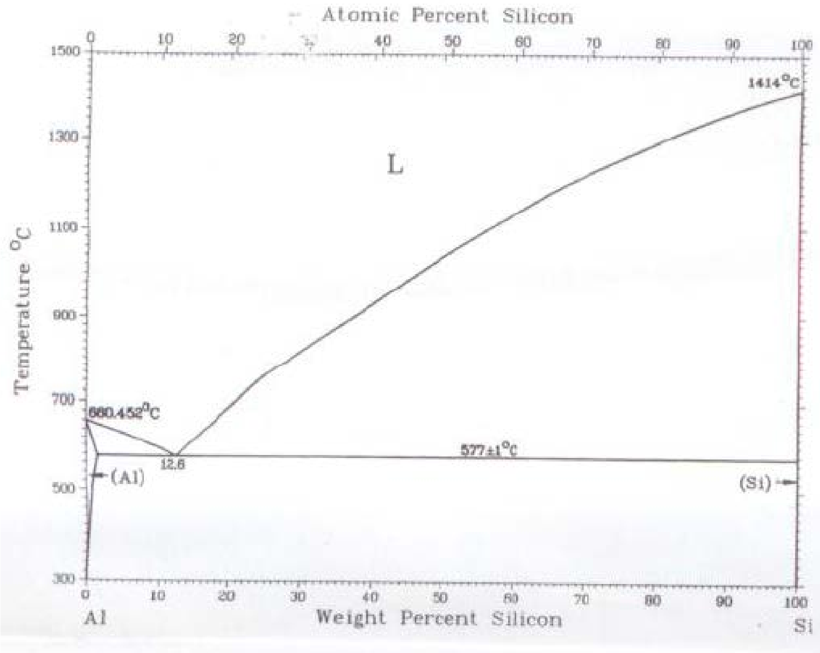
- NB Grain *boundaries* between the same phases, and *interfaces* between different phases.

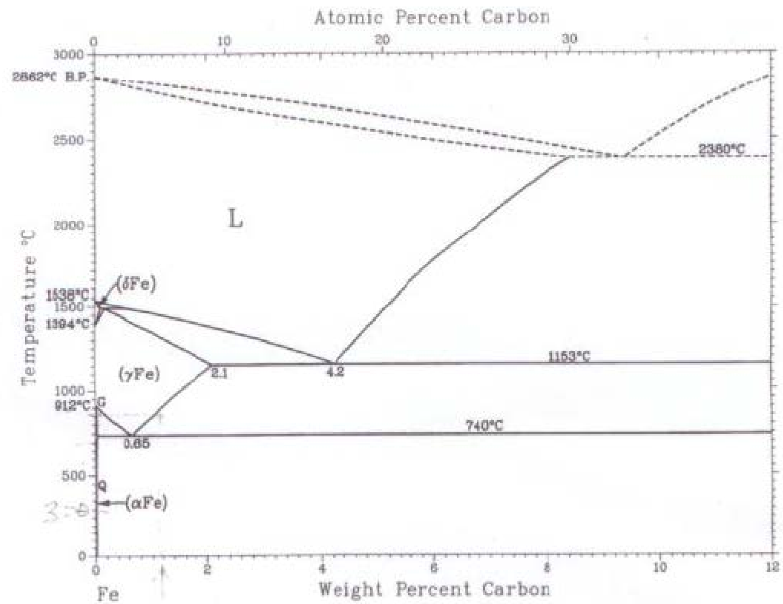
Maps?

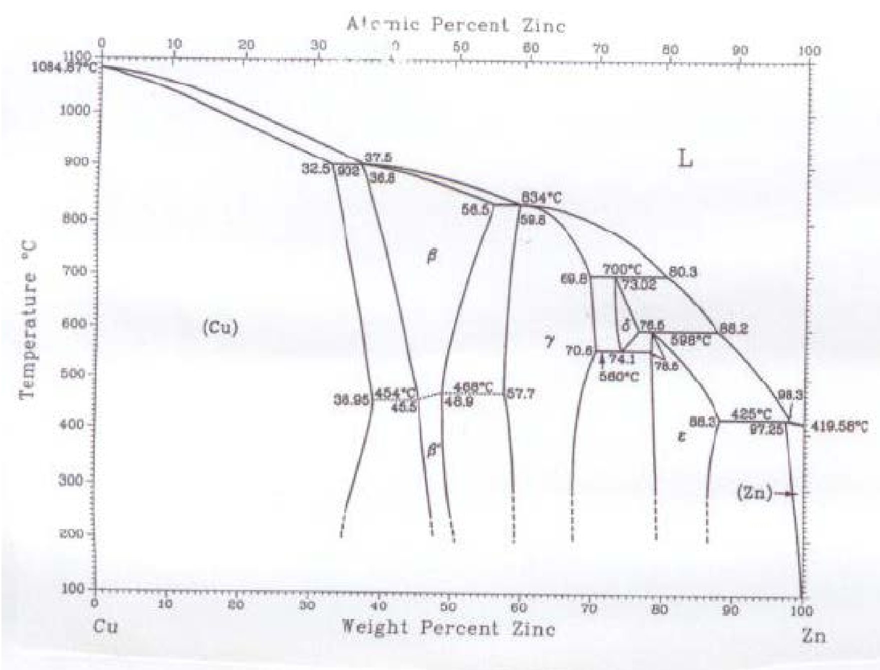
磁気グリーン券をお買い求めのお客さまは、みどりの窓口・停車駅でお買い求めください。
6
5
???
チャージ(ご入金)
履歴表示・印字
残額表示

Public Footpath N135
Newport
Shorwell Road

Examples!


Atomic Percent Silicon
Temperature °C
L
1414°C
660.452°C
577±1°C
12.6
(Al)
(Si)
Al
Weight Percent Silicon
Si


Atomic Percent Carbon
2862°C B.P.
2380°C
L
Temperature °C
1538°C
(δFe)
1394°C
1153°C
(γFe)
2.1
4.2
912°C
740°C
0.65
(αFe)
Fe
Weight Percent Carbon


Atomic Percent Zinc
1084.87°C
L
Temperature °C
32.5
902
37.5
36.8
56.5
834°C
59.8
β
69.8
700°C
73.02
80.3
(Cu)
δ
76.5
598°C
88.2
γ
70.6
74.1
560°C
78.6
38.95
454°C
45.5
468°C
46.9
57.7
98.3
β'
88.3
425°C
97.25
419.58°C
ε
(Zn)
Cu
Weight Percent Zinc
Zn

Must be able to understand phase diagrams

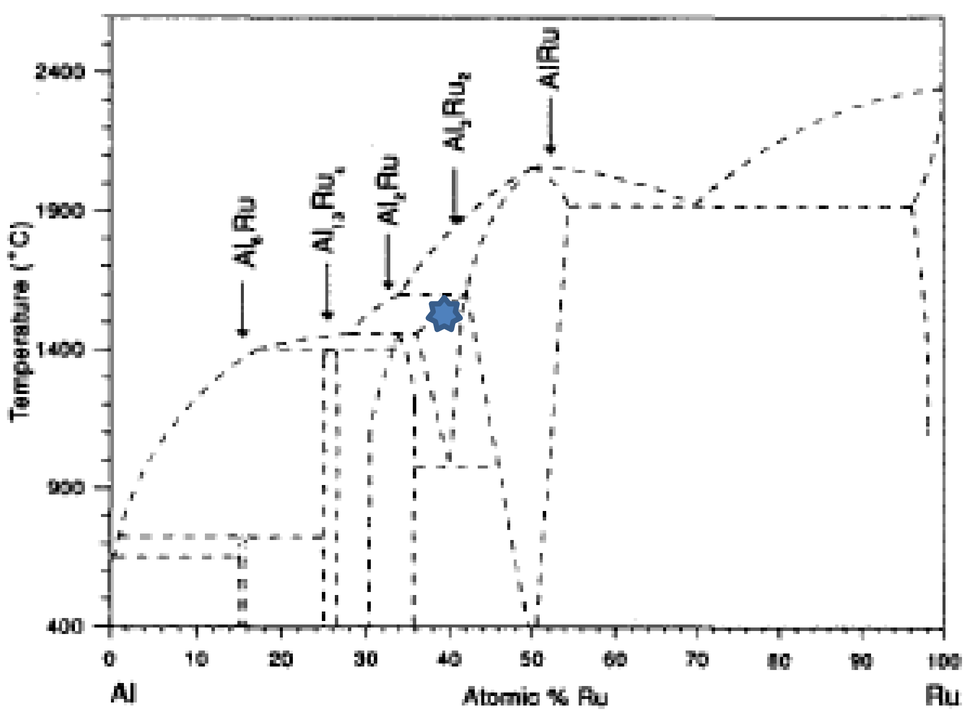
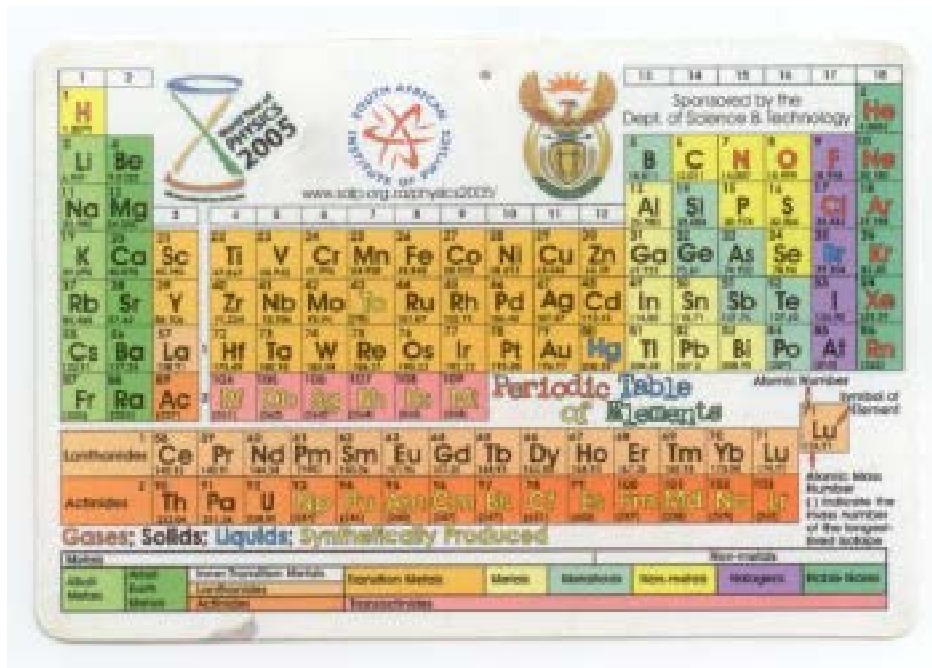


Fig. 9. Modified Al–Ru phase diagram.

Might expect single phase….
but if as-cast, or not
annealed for long enough,
might be surprised!

Good tools for analysis

SEM in backscattered electron mode → see average Z

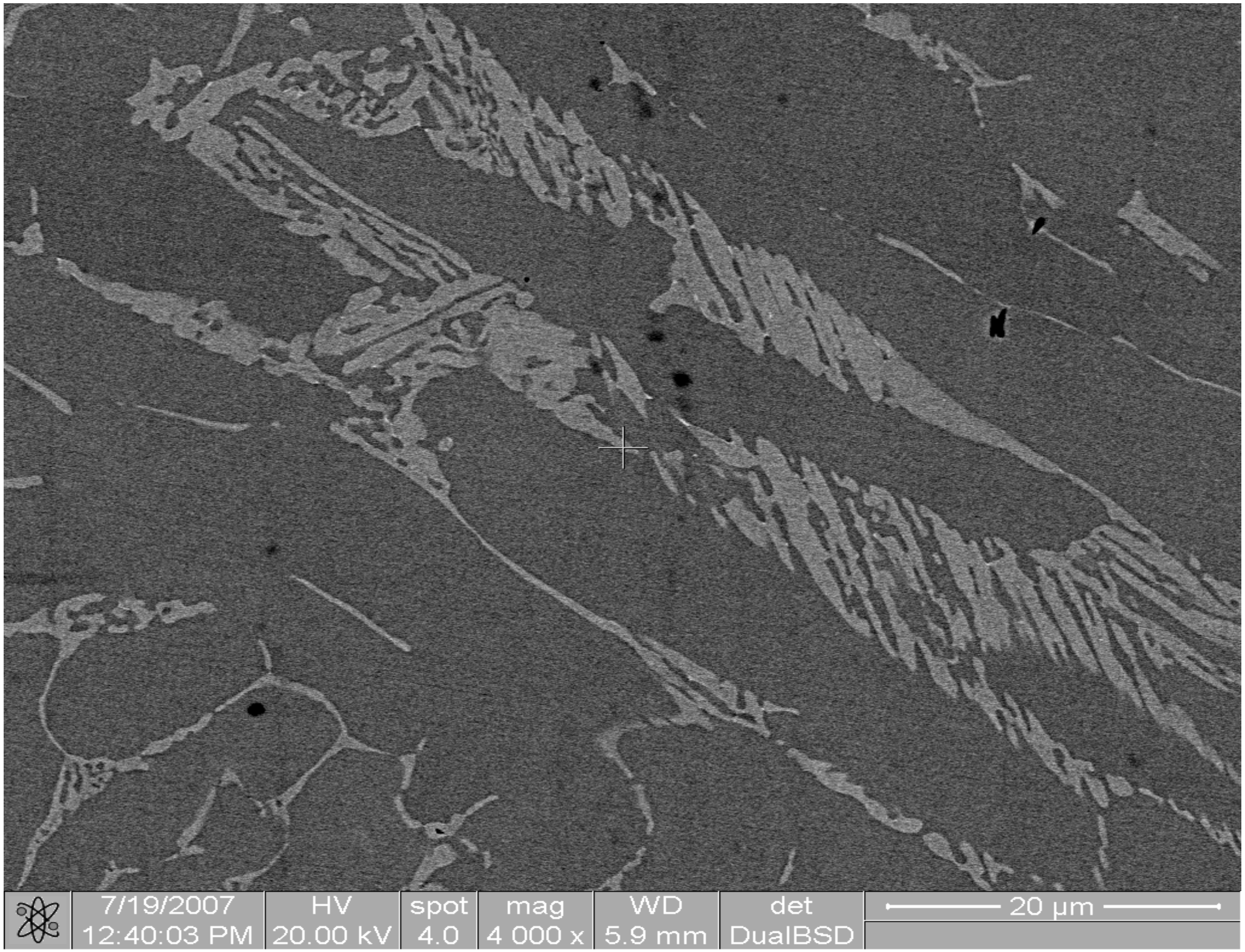


SEM in 2ndry electron mode → check for holes, by tilting

X-ray diffraction → identify phases and structures

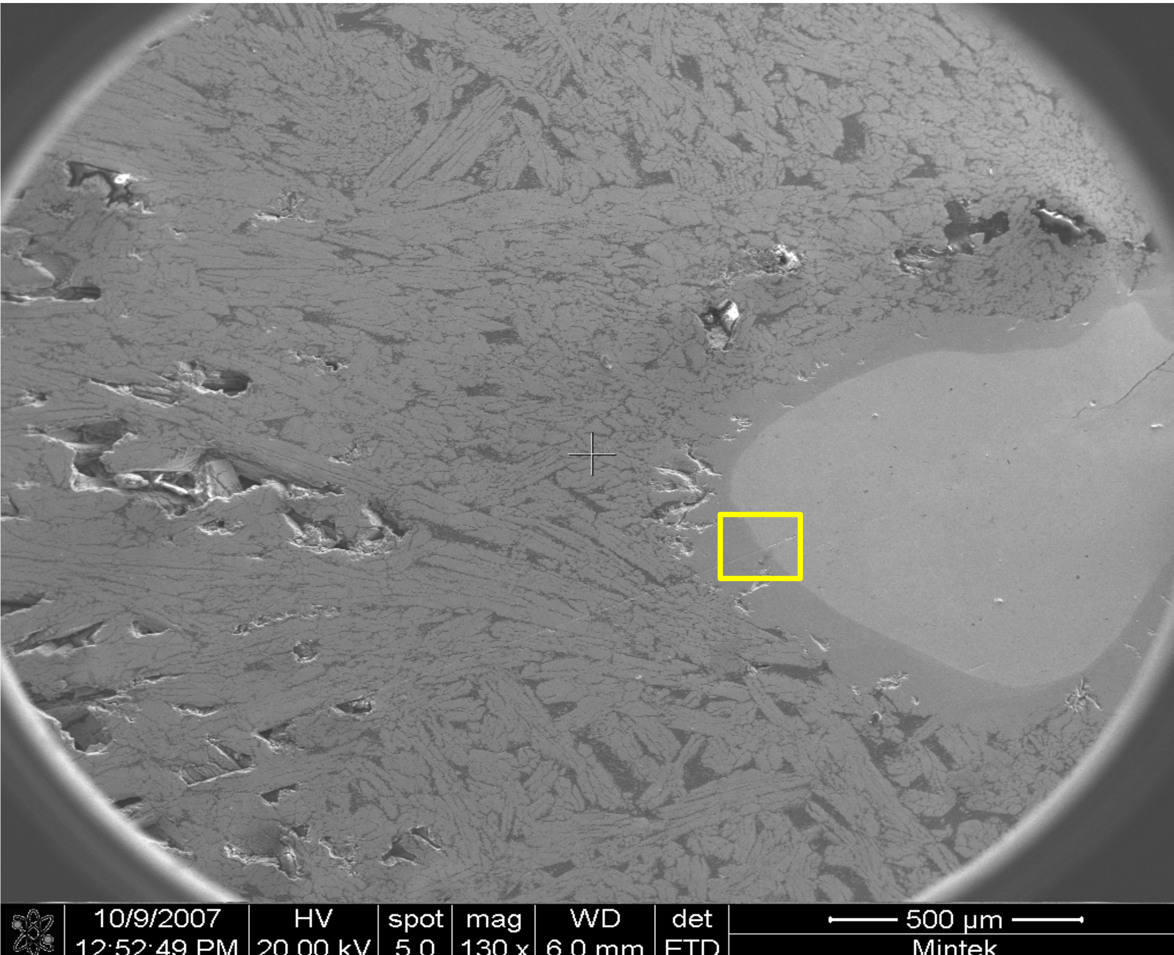
Thermal analysis → reaction temperatures

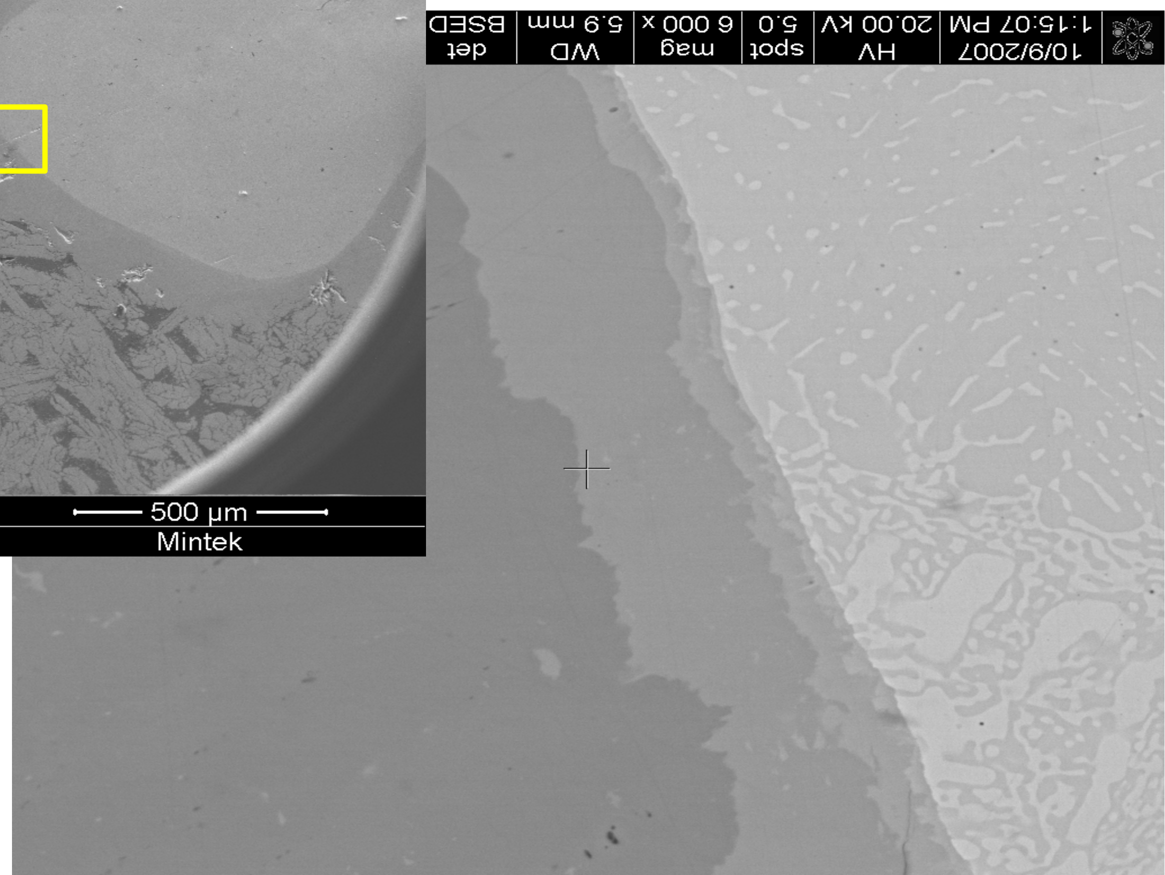
Check that all EDX peaks are accounted for….



Very light bits are contamination (gold)

Observe in low magnification **first**





Very inhomogeneous specimen!

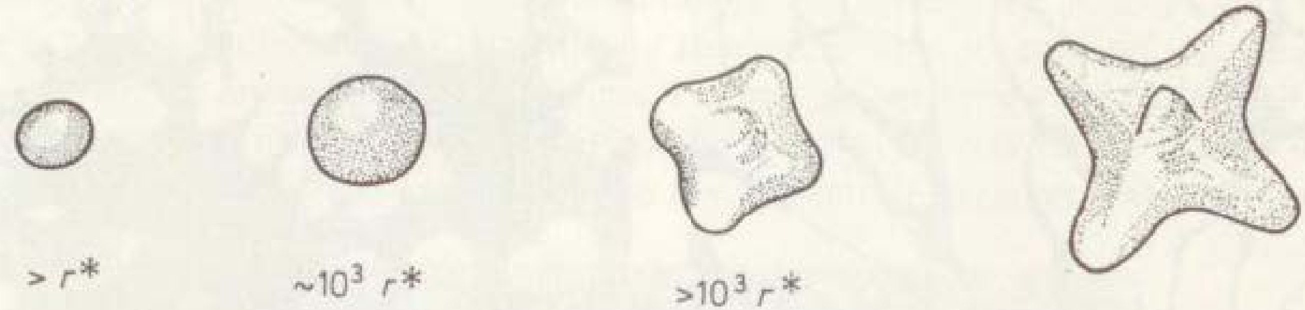


Figure 3.20 Schematic drawings of the development of a dendrite from the initial solid nucleus

r* = critical radius for growth to occur

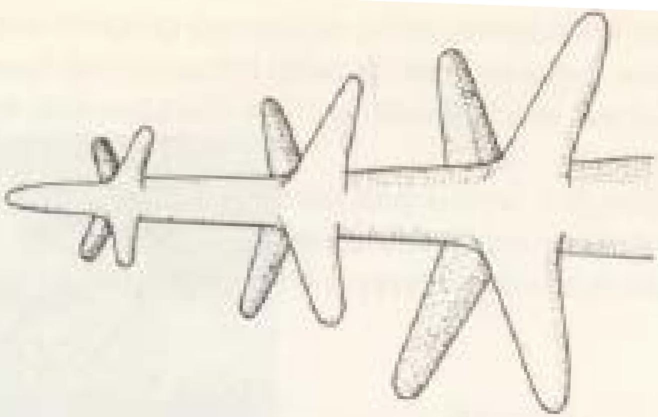


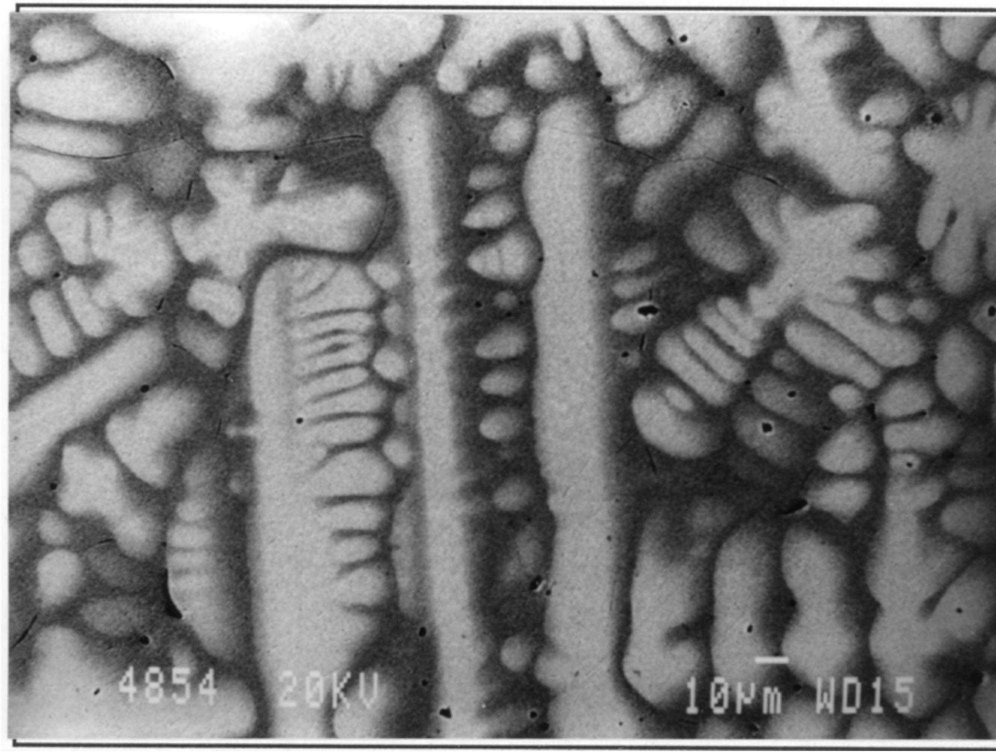
Figure 3.18 Idealised drawing of a dendrite

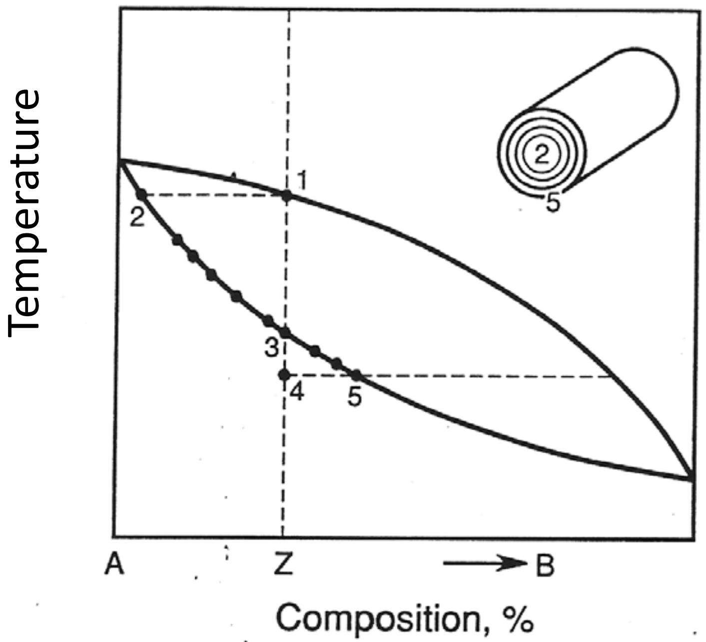
Dendrite grows into its shape because the atoms add more easily on the tips than on the sides in specific directions for different structures

Table 3.1 DENDRITE GROWTH DIRECTIONS

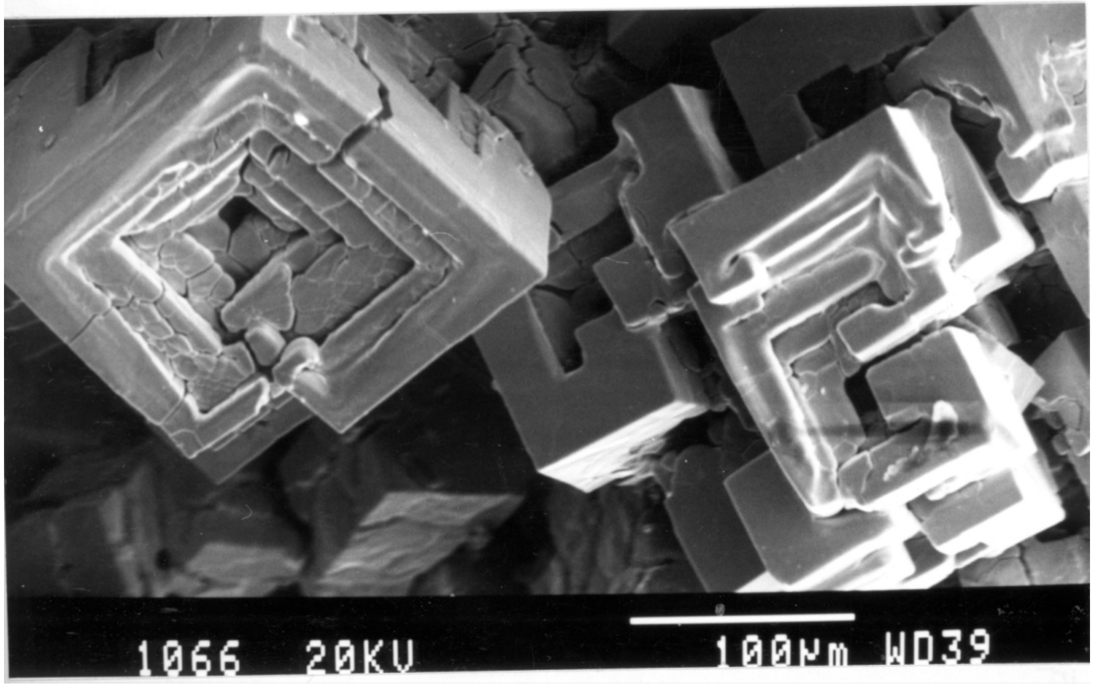
Crystal structure	*Dendrite direction*
f.c.c.	⟨100⟩[11]
b.c.c.	⟨100⟩
h.c.p.	$\langle 10\bar{1}0 \rangle$[12]
b.c.tet.	⟨110⟩[12] or 13° from ⟨110⟩[13]

Coring:
Solidification of
the same phase with different
compositions

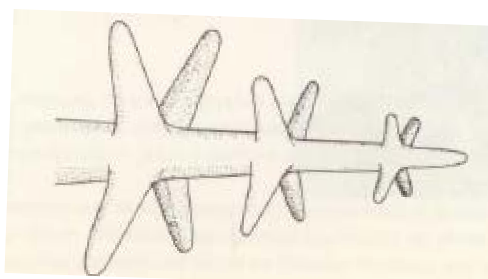




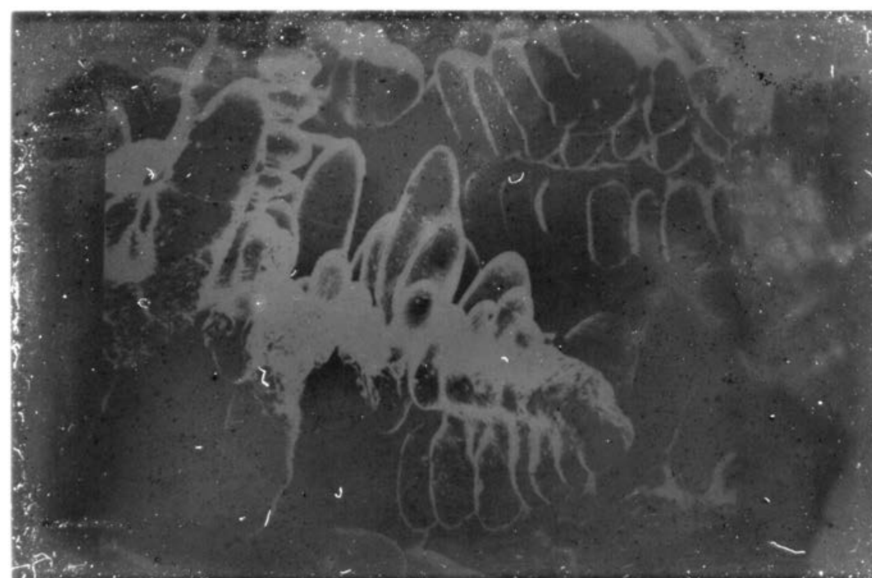
Phase diagram of two components with complete solubility both in the liquid and the solid state



←Facetted crystals
Often compounds, and Bi



Dendrites →
Most metals form dendrites



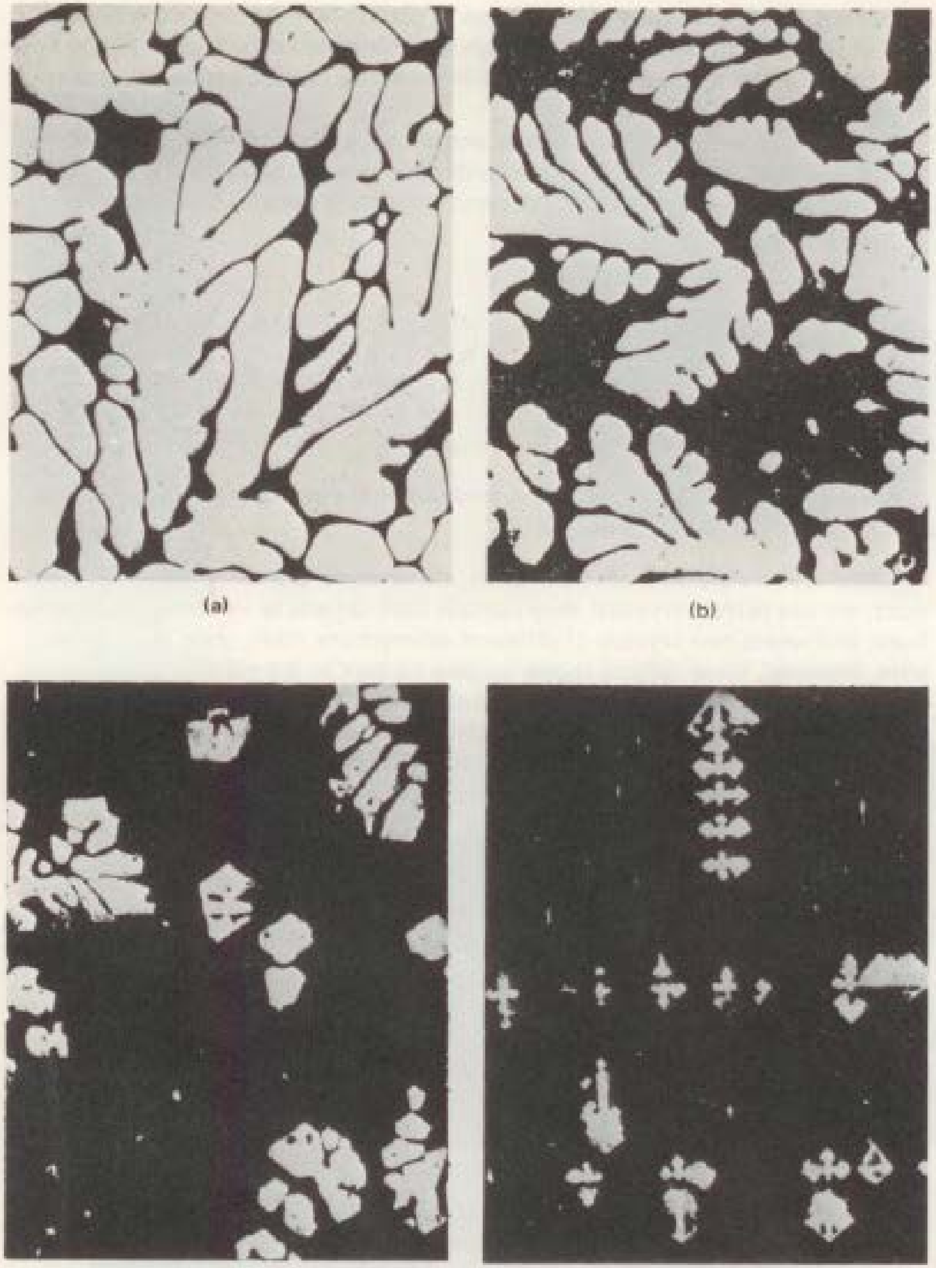
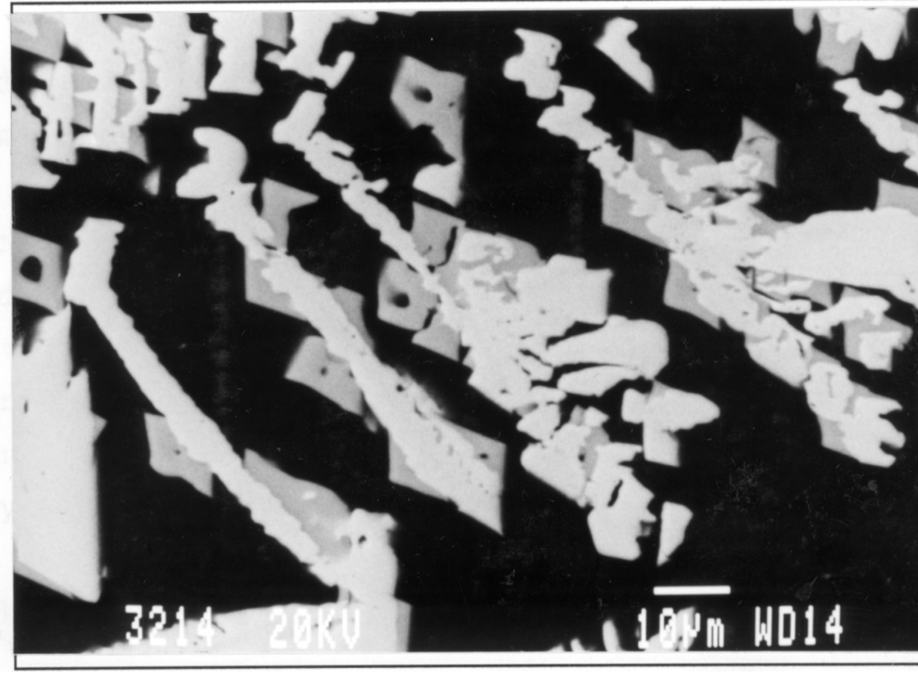
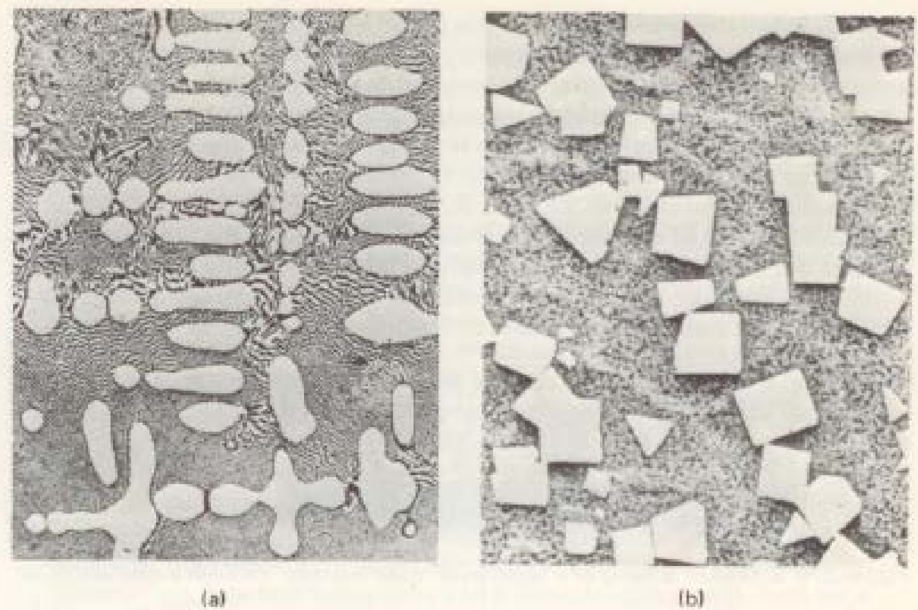


Figure 3.22 *Change in morphology of the primary crystals of Al in Al–Sn alloys with decreasing amounts of primary phase. (a) 85 at % Al; (b) 65 at % Al; (c) 33 at % Al; (d) 10 at % Al*

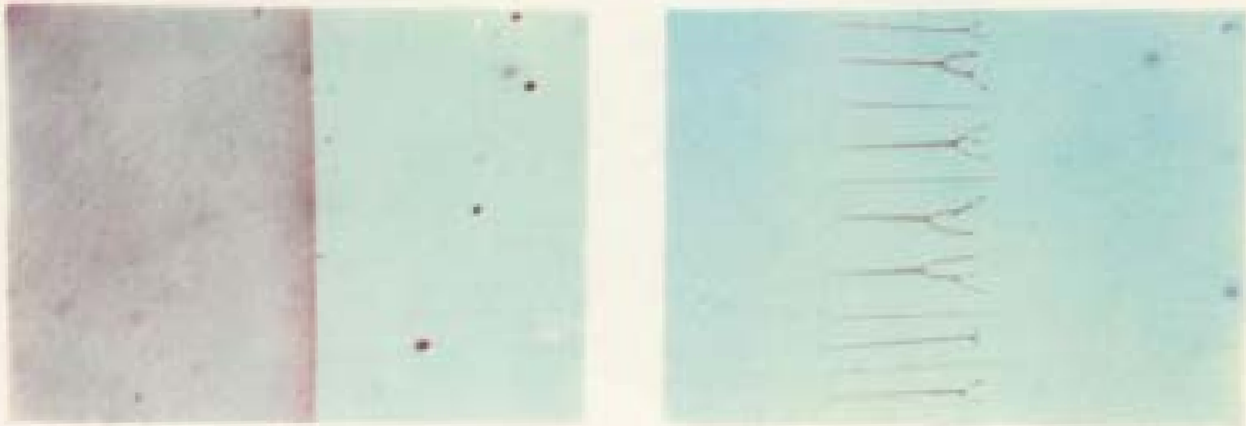




(a) (b)

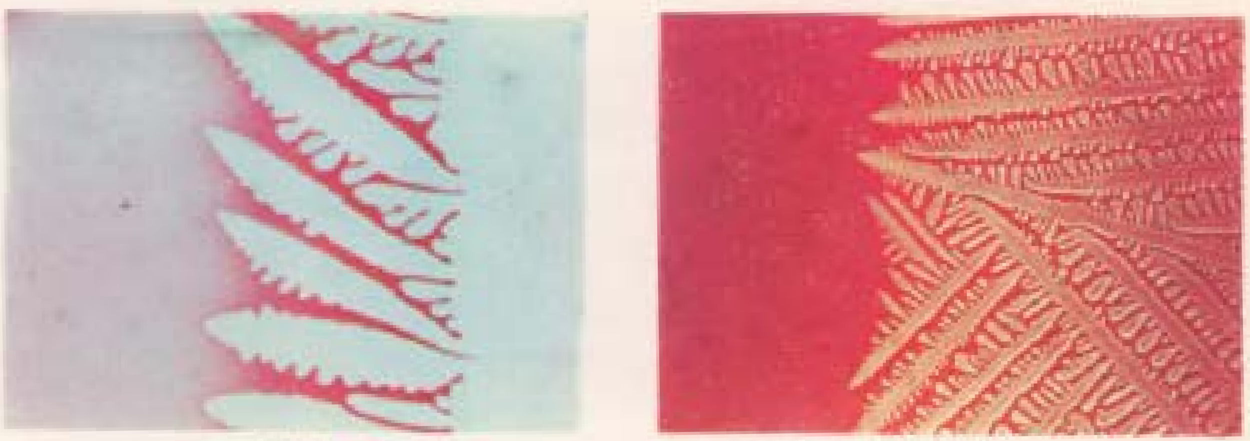
Figure 3.15 *Examples of solid–liquid interface structure in metallic systems. (a) Non-faceted dendrites of silver in a copper–silver eutectic matrix (× 300); (b) faceted cuboids of β′-SnSb compound in a matrix of Sn-rich material (× 100)*

Rejection of solute…



(a) (b)

Figure 4.14. Two photomicrographs of the solid–liquid interface in the carbon tetra-bromide–oil red mixture showing the development of a cellular interface. (a) Solute rejection at the interface leads to growth in stabilities; (b) cellular growth, showing the redistribution of solute (Courtesy of K. A. Jackson)



(a) (b)

Figure 4.18. Two photomicrographs illustrating the nature of cellular-dendritic growth in the system carbon tetrabromide–oil red. (a) Initiation of dendritic growth from a planar interface; (b) well-established cellular-dendritic growth, showing the inter-dendritic segregation (Courtesy of K. A. Jackson)

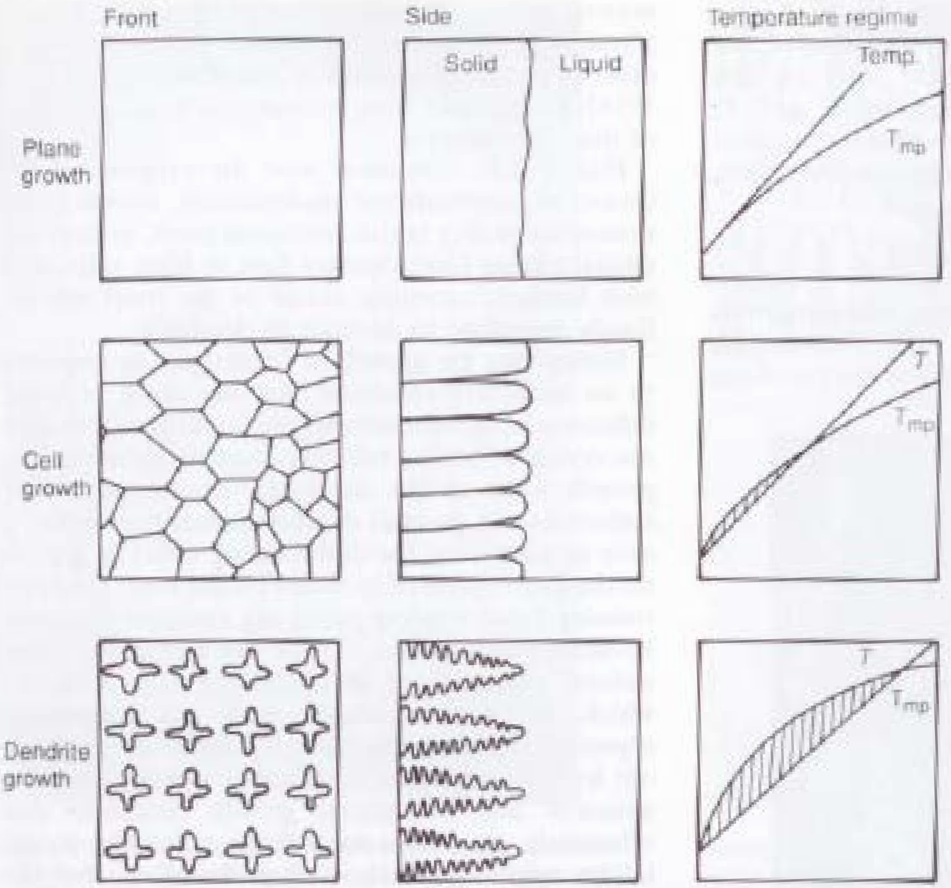


Figure 4.20 *The transition of growth morphology from planar, to cellular, to dendritic, as compositionally induced undercooling increases (equivalent to G/R being reduced).*

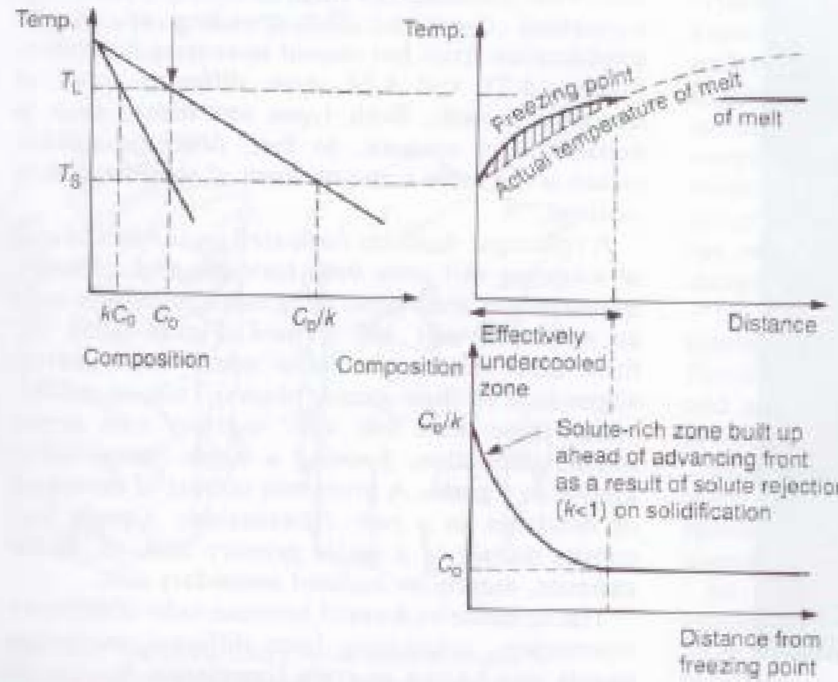


Figure 4.21 *The link between the constitutional phase diagram for a binary alloy, and constitutional undercooling on freezing.*

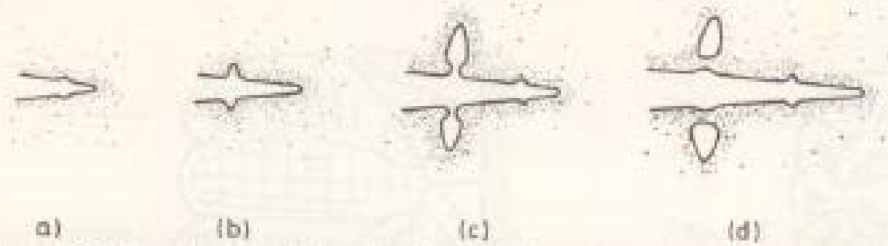


Figure 4.25 Growth of a cellular dendrite showing schematically the detachment of secondary branches due to remelting

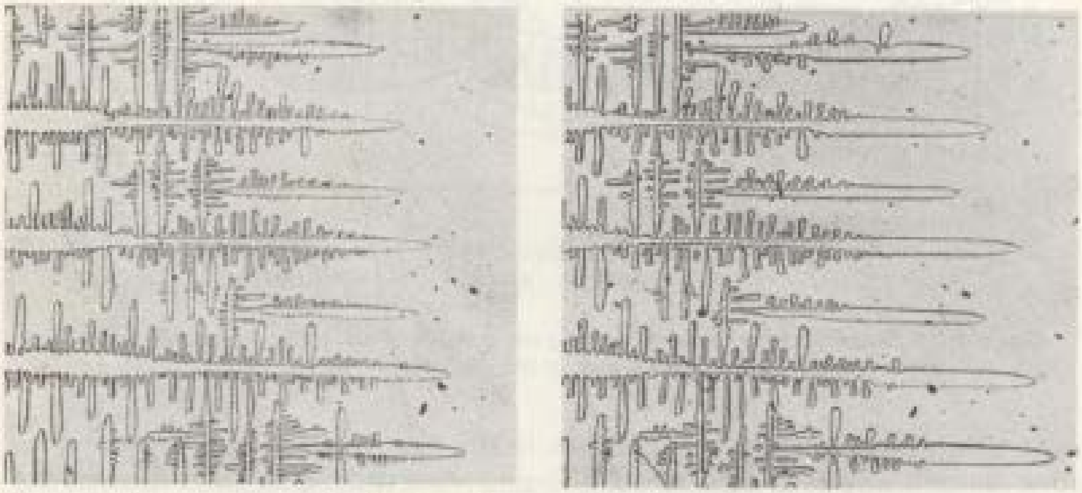


Figure 4.26 Two micrographs showing the successive stages of growth and remelting of cellular dendrites in impure camphene. (Courtesy of K. A. Jackson)

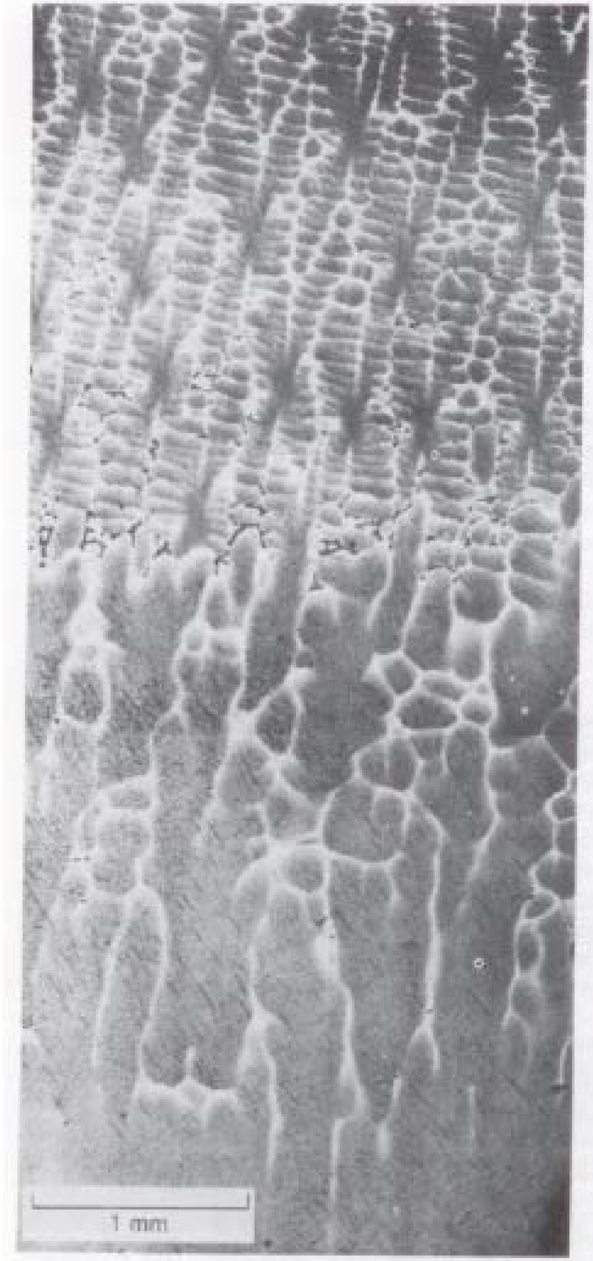


Figure 4.22 *The structure of a low-alloy steel subjected to accelerating freezing from bottom to top, changing from planar, through cellular, to dendritic growth.*

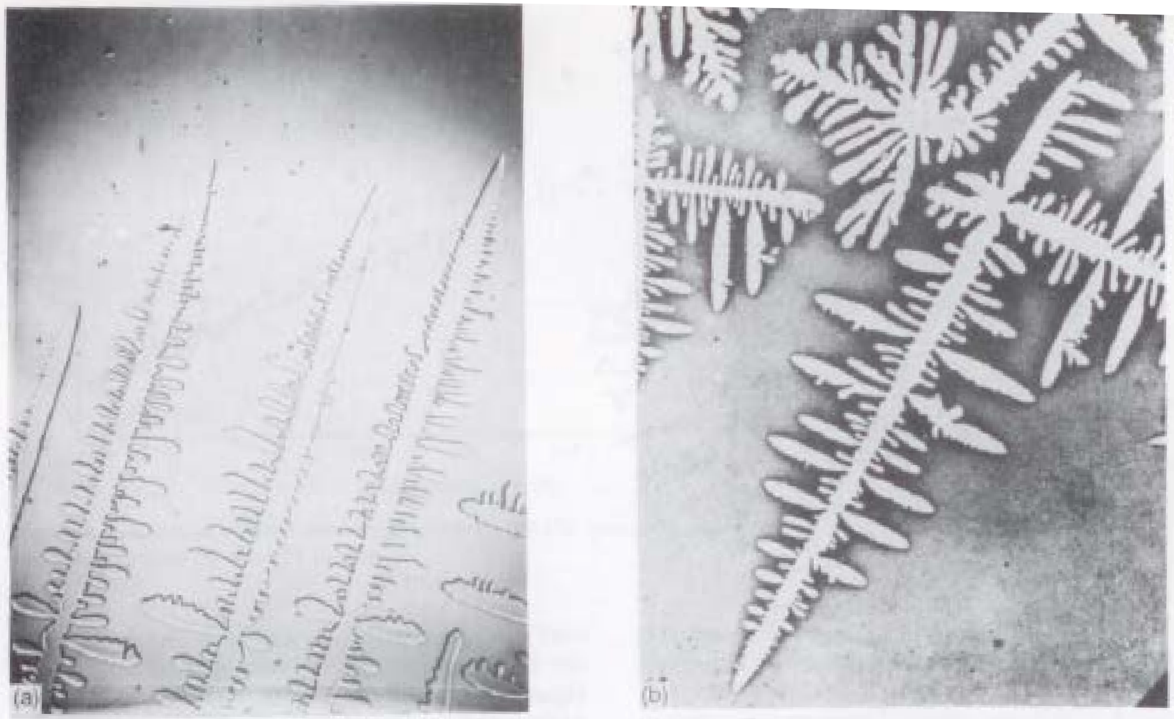


Figure 4.23 *A transparent organic alloy showing dendritic solidification. Columnar growth (a) and equiaxed growth (b) with a modification to the alloy by the addition of a strongly partitioning solute, with k ≪ 1, which can be seen to be segregated ahead of the growing front. Courtesy J. D. Hunt; see Jackson et al. (1966).*

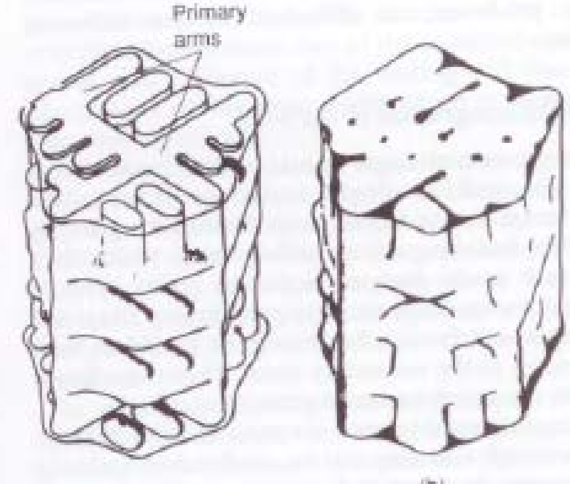


Figure 4.24 *The rather irregular dendrites common in aluminium alloys at (a) 50 and (b) 90 per cent solidified. The secondary arms spread laterally, joining to form continuous plates. After Singh et al. (1970).*

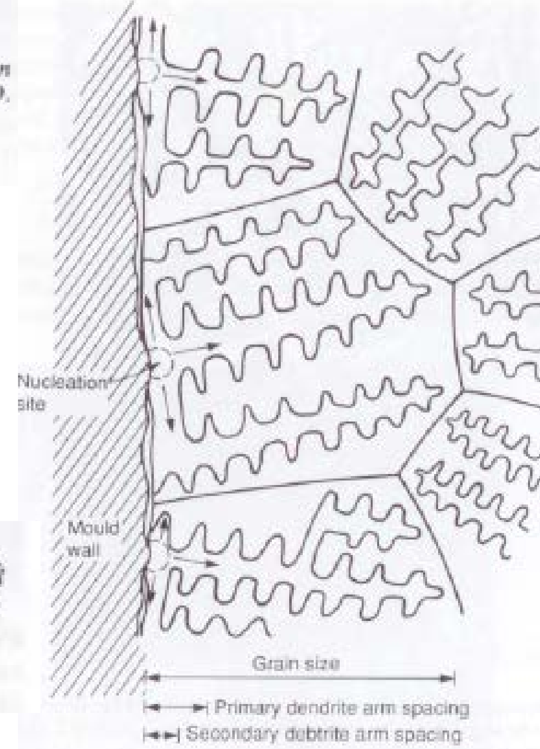
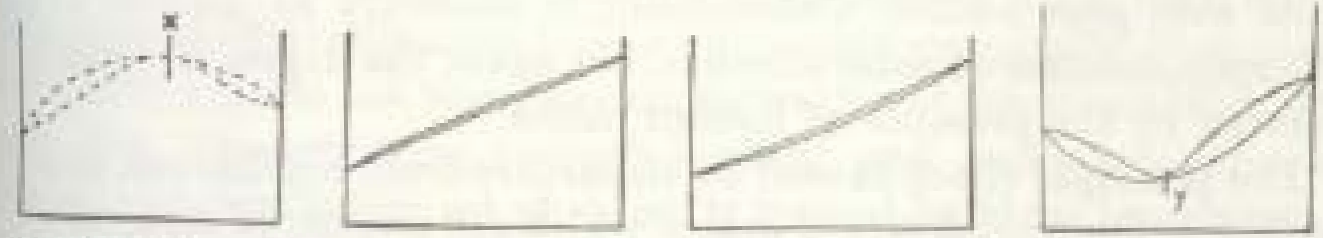


Figure 4.25 *Schematic illustration of the formation of a raft of dendrites to make grains. The dendrite stems within any one raft or grain are all crystallographically related to a common nucleus.*



Possible although no metallic examples can be given

Examples : Au-Pd Ag-Au

Cu-Pd
Cu-Pt

Cu-Au Au-Ni to be expected when the atomic sizes differ by 8–14 per cent

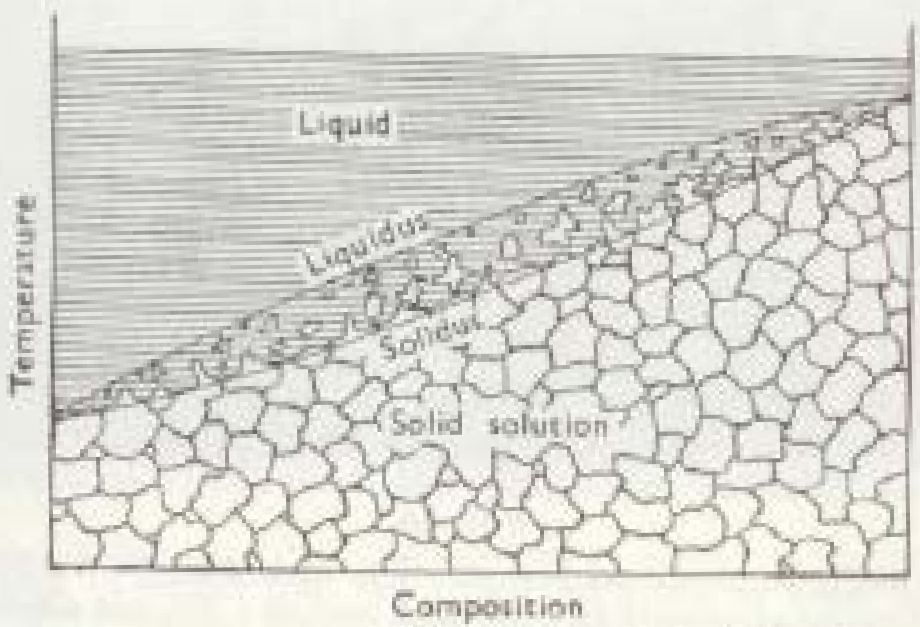
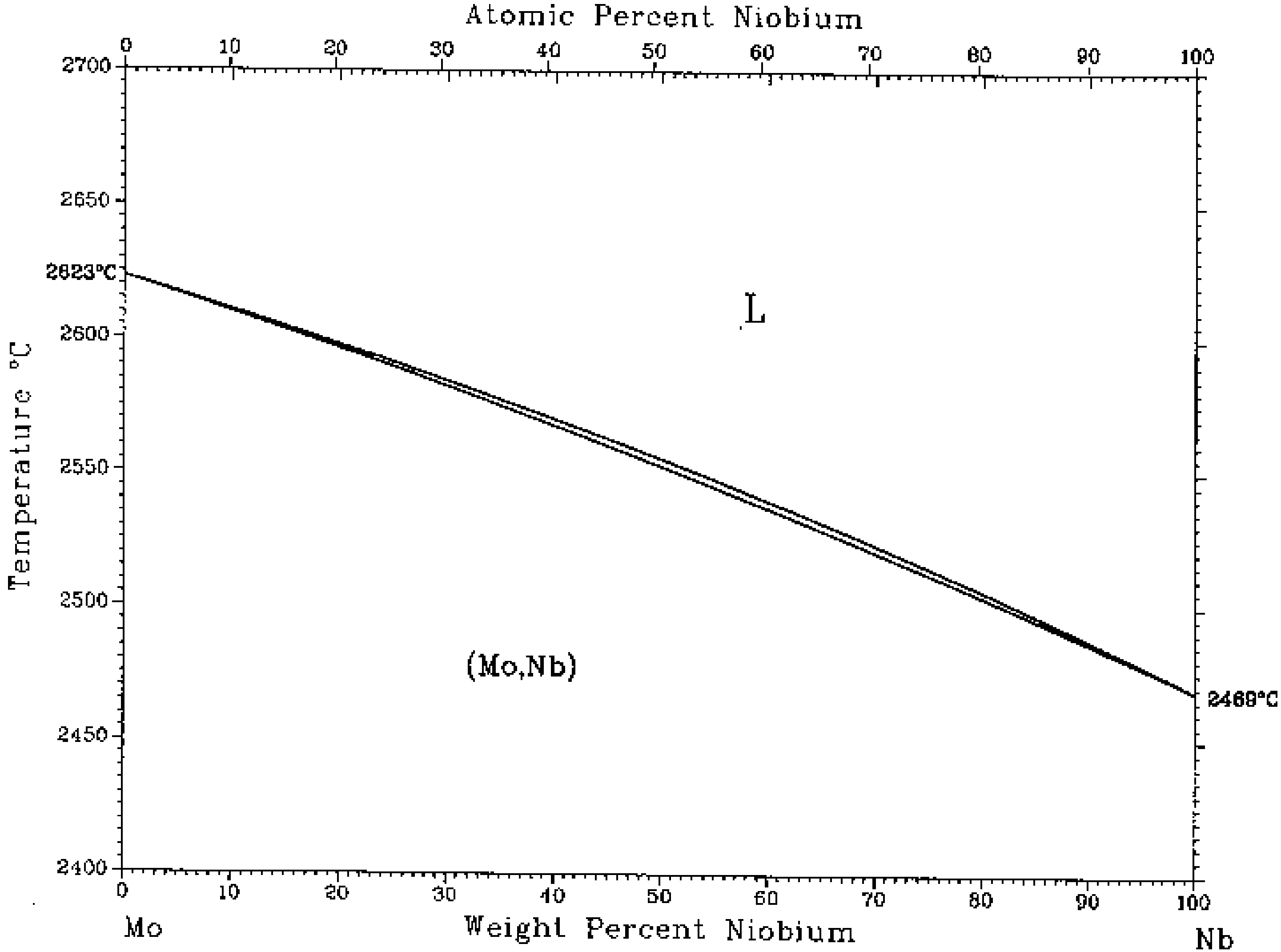


FIG. 37. Sketch illustrating microstructures in solid solution alloys.

Mo-Nb



Atomic Percent Niobium
0
10
20
30
40
50
60
70
80
90
100
2700
2650
2623°C
2600
2550
2500
2450
2400
Temperature °C
L
(Mo,Nb)
2469°C
Mo
Weight Percent Niobium
Nb

Hume-Rothery rules for extended isomorphous solid solutions

- Same structure
- Atom size within 15%
- Similar valencies (i.e. to bond with the same number of atoms – else form compound)
- Similar electronegativities (else form compound)