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?
Must be able to understand phase diagrams

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

Fig. 9. Modified Al–Ru phase diagram.
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!
Dendrite grows into its shape because the atoms add more easily on the tips than on the sides in specific directions for different structures.

$r^* = \text{critical radius for growth to occur}$

Table 3.1 DENDRITE GROWTH DIRECTIONS

<table>
<thead>
<tr>
<th>Crystal structure</th>
<th>Dendrite direction</th>
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<tbody>
<tr>
<td>f.c.c.</td>
<td>$\langle 100 \rangle^{11}$</td>
</tr>
<tr>
<td>b.c.c.</td>
<td>$\langle 001 \rangle$</td>
</tr>
<tr>
<td>h.c.p.</td>
<td>$\langle 10 \bar{1}0 \rangle^{12}$</td>
</tr>
<tr>
<td>b.c.tet.</td>
<td>$\langle 110 \rangle^{12}$ or $13^\circ$ from $\langle 110 \rangle^{13}$</td>
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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
Dendrites →
Most metals form dendrites

Facetted crystals
Often compounds, and Bi
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) 55 at % Al; (d) 10 at % Al.

Figure 3.15 Examples of solid–liquid interface structure in metallic systems. (a) Non-faceted dendrites of silver in a copper–silver eutectic matrix (x 300); (b) faceted cuboids of β-SnSb compound in a matrix of Sn-rich material (x 100).
Rejection of solute...
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 $k \ll 1$, 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.
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)