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3.205 Thermodynamics and Kinetics of Materials—Fall 2006

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Kinetics Lecture 9: Solidification

Lecture References

1. Balluffi, Allen, and Carter, *Kinetics of Materials*, Section 20.3, "Morphological Stability of Moving Interfaces," and Chapter 22, "Solidification."

2. Porter and Easterling, *Phase Transformations in Metals and Alloys*, Van Nostrand Reinhold (International), Wokingham, 1988, pp. 213–222, on alloy solidification.

3. M.C. Flemings *Solidification Processing*, Mc-Graw Hill, 1974. This is a very good reference on solidification.

Key Concepts

- Solidification rates are controlled by the rate of removal of latent heat from the solidifying material.

- Solidification modes are governed by a variety of factors, including the rate of heat extraction, alloy content, and available sites for nucleation of the solid.

- A typical solidification process involves heat extraction through a mold wall from liquid that is initially above its melting temperature. In pure materials, this will result in a stable solid/liquid interface shape. In alloy solidification, *constitutional supercooling* may occur—particularly when the temperature gradient in the liquid is shallow.

- Solidification into an *undercooled* melt promotes interface shape instability, even in a pure material.

- Solid/liquid interface shape instability results in the formation of cellular and dendritic crystal growth forms. Dendrites have the shape of fir trees, often with well-formed branches and sub-branches.

- In a given region of a casting, dendrites tend to grow parallel to one another in the same crystallographic orientation. When the region is entirely solidified, it forms a single grain. Thus, the grain size in a casting that solidifies dendritically is much larger than the dendrite spacing within a grain.

- The solute segregation that occurs during dendritic alloy solidification remains in the resulting solid. If the alloy composition lies in a range where a single solid phase is stable, the material can be homogenized, typically by a combination of forging and annealing.