

Phase Transformations: Solidification



Today's topics:

- **Solidification of superheated liquid against a cooled mold wall**
- **Solidification of supercooled liquid by a nucleation event in the liquid**
- **Shape stability of the solid/liquid interface**
- **Constitutional supercooling of an alloy**
- **Casting microstructures**



Solidification of superheated liquid

- **Heat removed through mold wall at $T < T_m$**

Figure removed due to copyright restrictions.

See Figure 20.10 in Balluffi, Robert W., Samuel M. Allen, and W. Craig Carter.
Kinetics of Materials. Hoboken, NJ: J. Wiley & Sons, 2005. ISBN: 0471246891.

- **Interface *stable* with respect to shape variations**

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See Figure 20.11 in Balluffi, Robert W., Samuel M. Allen, and W. Craig Carter.
Kinetics of Materials. Hoboken, NJ: J. Wiley & Sons, 2005. ISBN: 0471246891.



Solidification of supercooled liquid

- **Latent heat removed into liquid at $T < T_m$**

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See Figure 20.12 in Balluffi, Robert W., Samuel M. Allen, and W. Craig Carter.

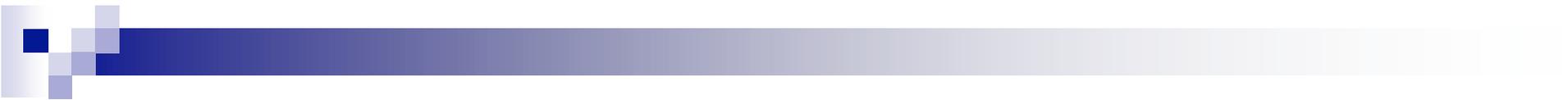
Kinetics of Materials. Hoboken, NJ: J. Wiley & Sons, 2005. ISBN: 0471246891.

- **Interface *unstable* with respect to shape variations**

Figure removed due to copyright restrictions.

See Figure 20.11b in Balluffi, Robert W., Samuel M. Allen, and W. Craig Carter.

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Constitutional supercooling in alloys

- **Solute enrichment ahead of an advancing solid/liquid interface can effectively supercool the adjacent liquid by forming liquid compositions that are below their melting temperature. This commonly results in dendrite formation in alloys.**

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See Figure 20.13 in Balluffi, Robert W., Samuel M. Allen, and W. Craig Carter.

Kinetics of Materials. Hoboken, NJ: J. Wiley & Sons, 2005. ISBN: 0471246891.



Cells and dendrites

■ Features resulting from shape instability

**Cells &
Dendrites**
~10 μm

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See Figure 20.3 in Balluffi, Robert W., Samuel M. Allen, and W. Craig Carter.
Kinetics of Materials. Hoboken, NJ: J. Wiley & Sons, 2005. ISBN: 0471246891.

**Macro grain
structure of
a casting**
**~0.1 – 10 mm
grains**

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See Figure 20.5 in Balluffi, Robert W., Samuel M. Allen, and W. Craig Carter.
Kinetics of Materials. Hoboken, NJ: J. Wiley & Sons, 2005. ISBN: 0471246891.



SEM View of Dendrites in Cu–Ni–Mn Alloy

- **These dendrites are very large because the liquid metal was cooled very slowly.**

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See Figure 20.9 in Balluffi, Robert W., Samuel M. Allen, and W. Craig Carter.

Kinetics of Materials. Hoboken, NJ: J. Wiley & Sons, 2005. ISBN: 0471246891.

- **When a material solidifies dendritically and forms a polycrystal, the grain size is generally *much larger* than the dendrite spacing.**
- **Alloy solidification via dendrite formation leads to compositionally inhomogeneous material.**



Microsegregation

- **Alloy solidification via dendrite formation leads to compositionally inhomogeneous material.**

Figure removed due to copyright restrictions.

See Figure 22.4 in Balluffi, Robert W., Samuel M. Allen, and W. Craig Carter.

Kinetics of Materials. Hoboken, NJ: J. Wiley & Sons, 2005. ISBN: 0471246891.