Interfaces and Materials Propert

Press Esc to exit full screen

Lecture 17

Recap

Original

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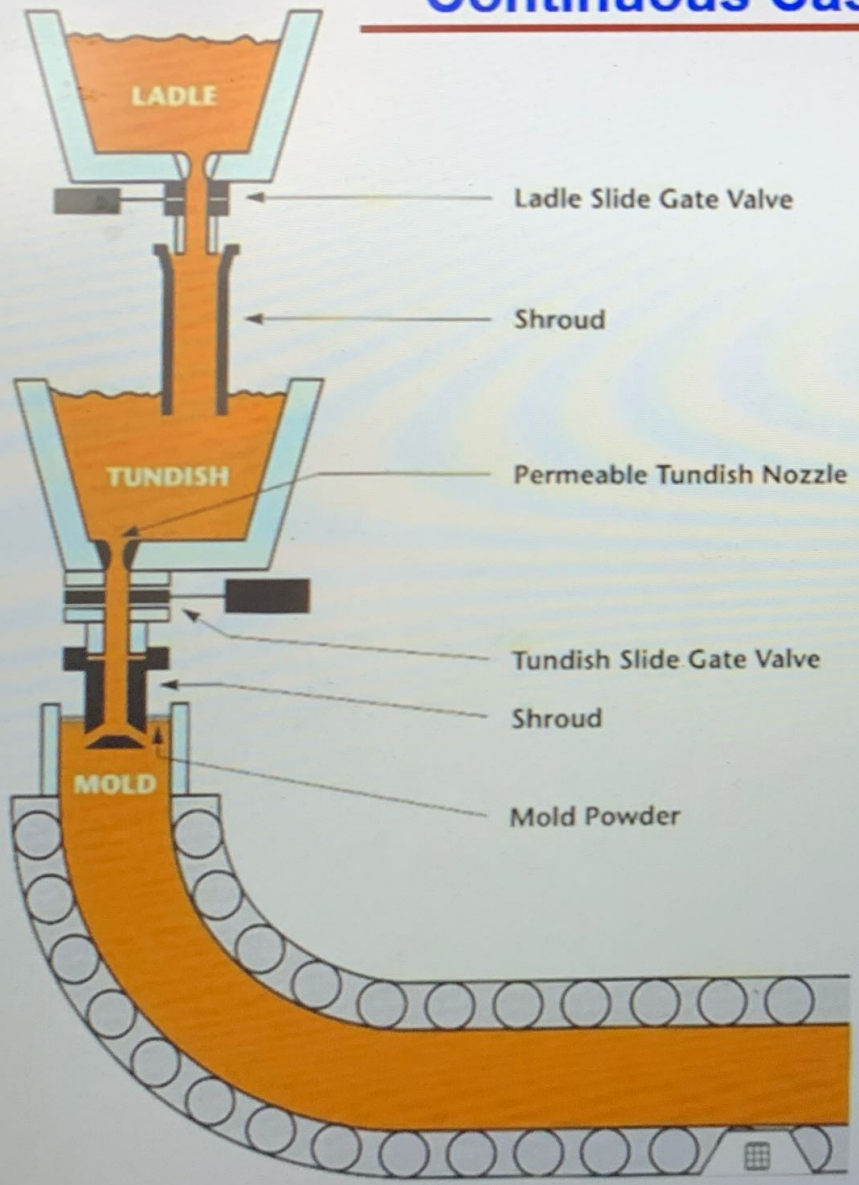
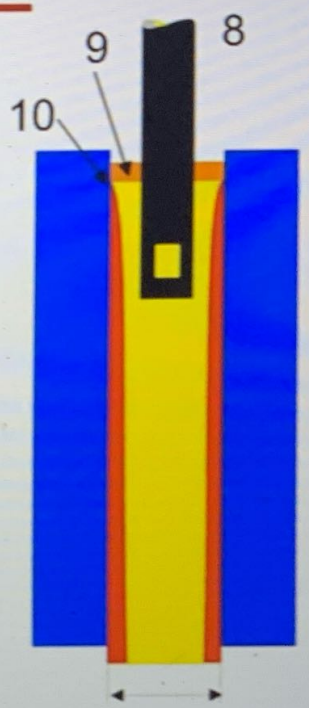
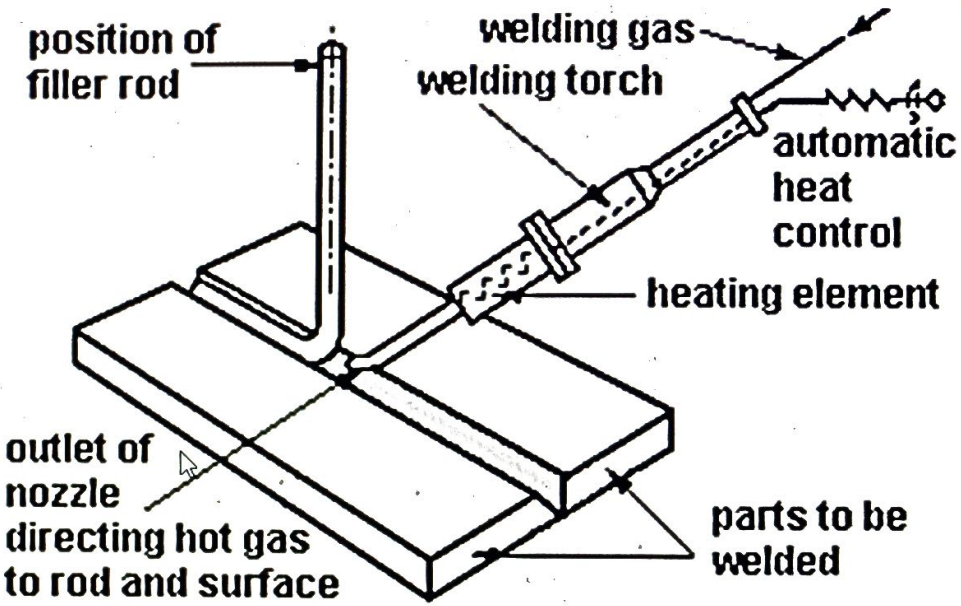
Continuous Casting



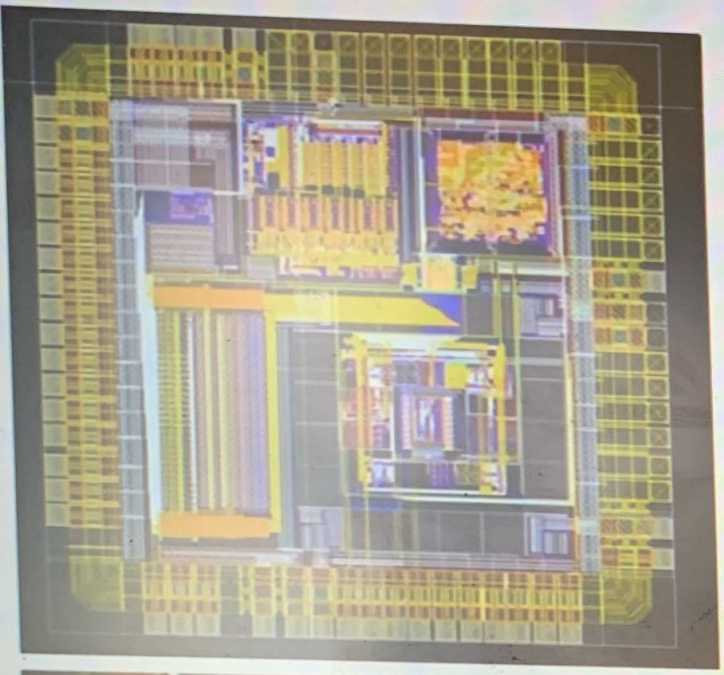


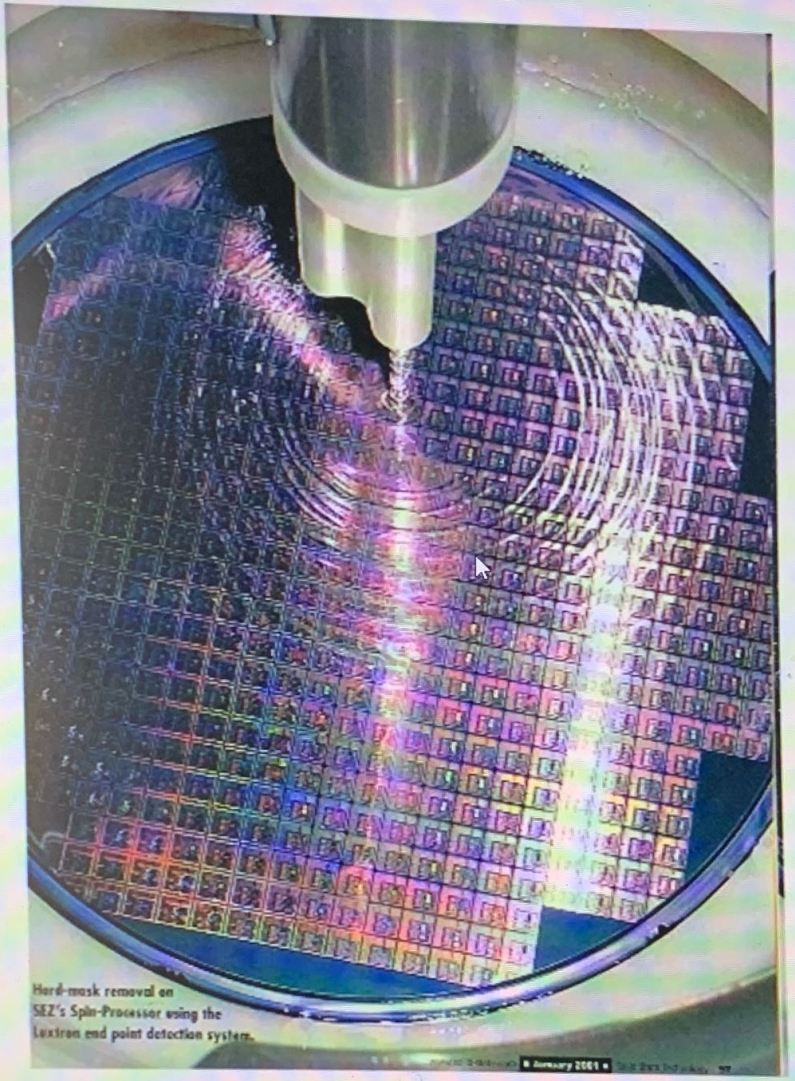
Gas Welding



M.C. Flemings, Solidification Processing,

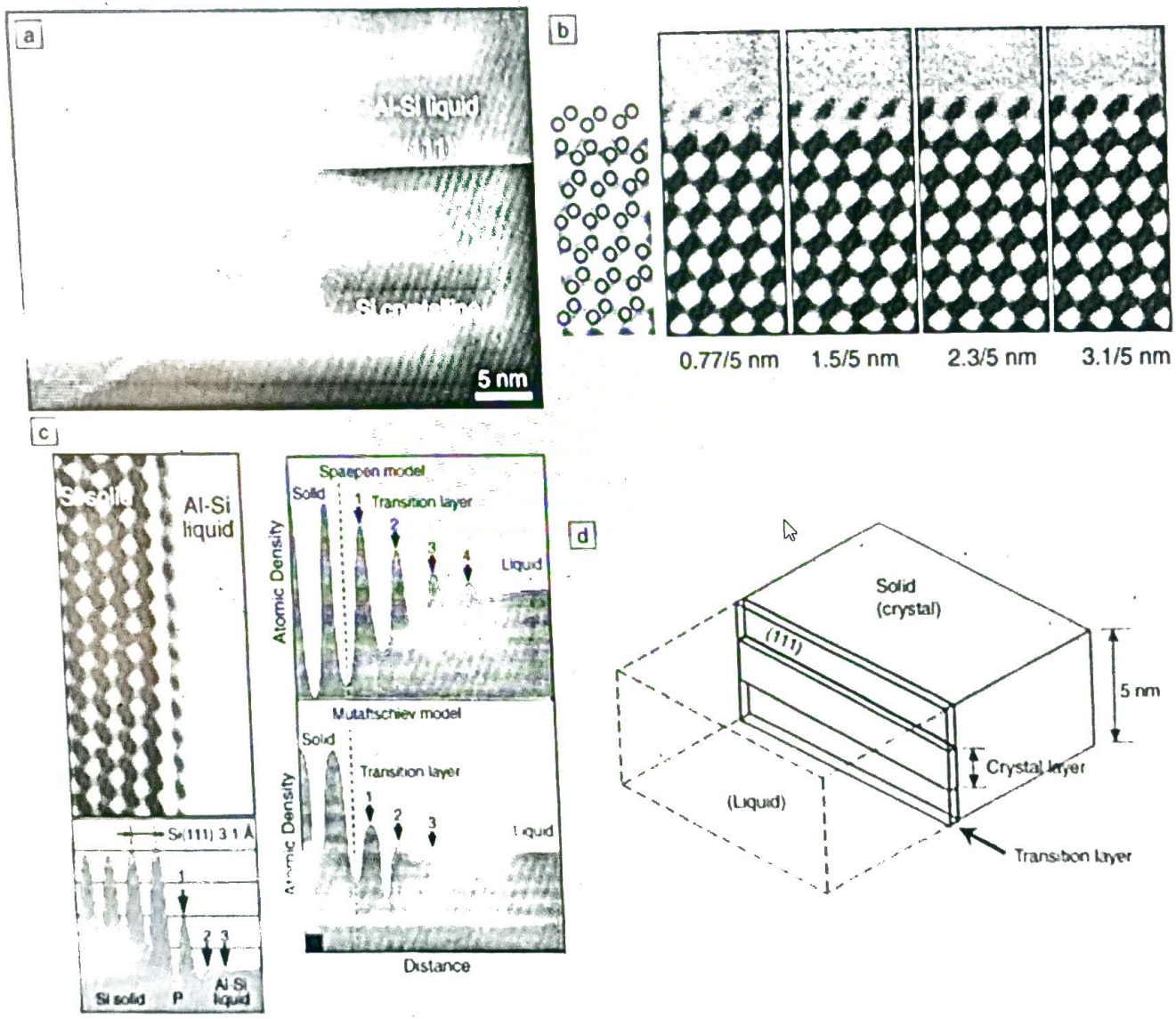
Microelectronics





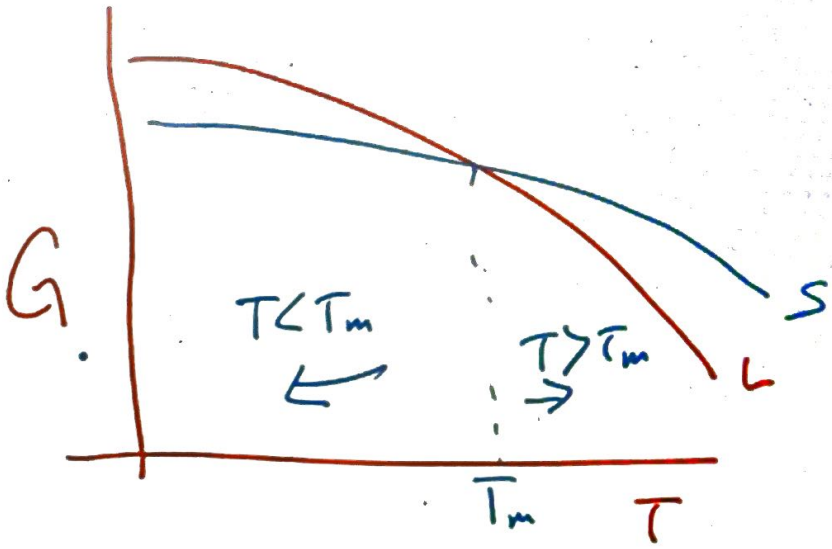
https://www.generalfilter.com/en/sectors/microel...ss/

Experimentations: Structure of liquids- In-situ studies



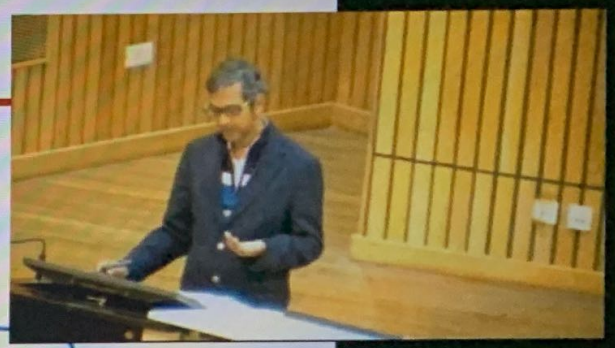
H.Saka, MRS Bulletin

Solidification

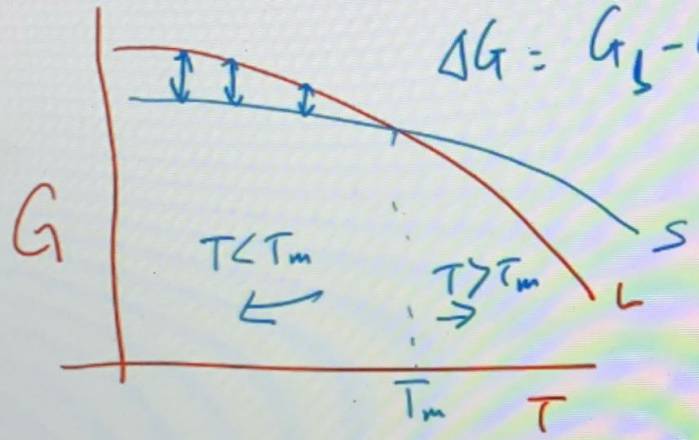


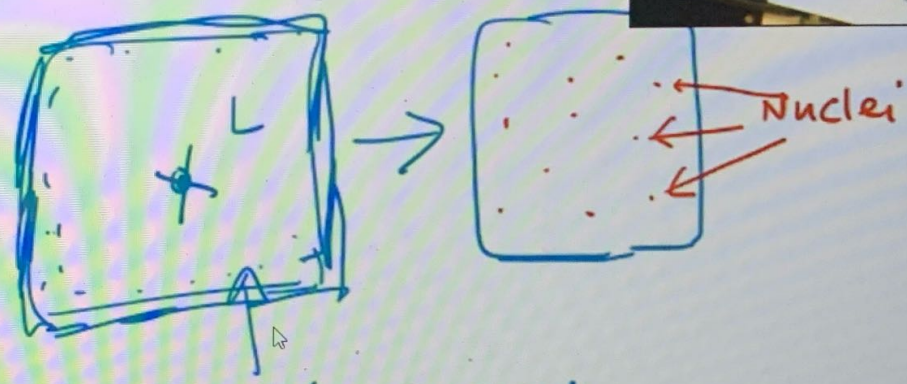
D A Porter and K.E. Easterling, Phase Transformations in Metals and A

Solidification



$\Delta G = G_s - G_L$





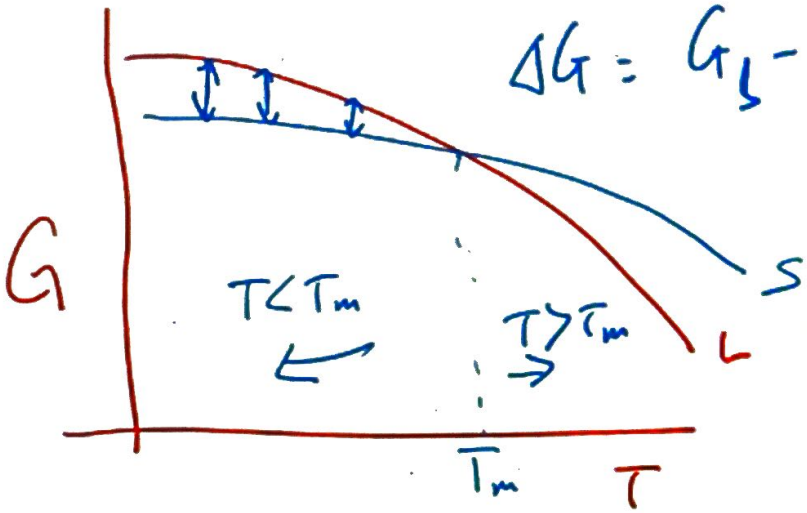
Heterogeneous Nucleation

1453
−250 — Undercooling
1203

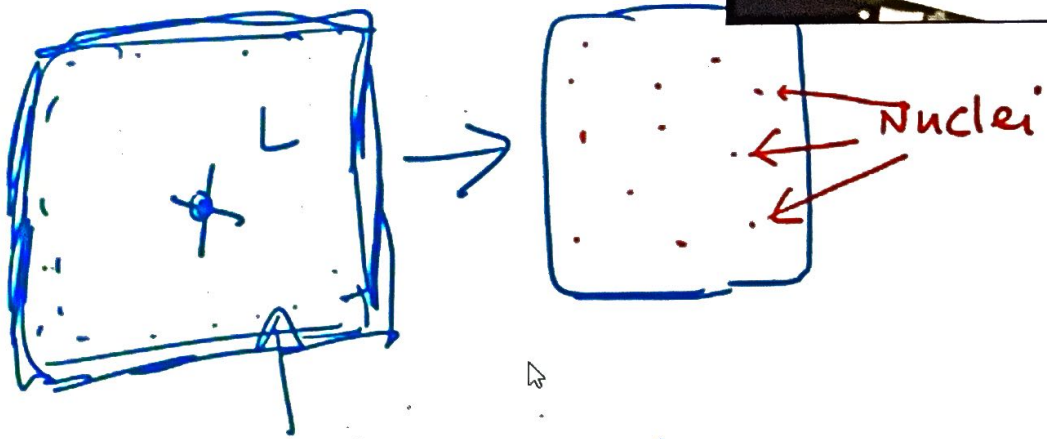
$\Delta T = T_m - T$
$= 1453 - 1203$
$= 250K$

D A Porter and K.E. Easterling, Phase Transformations in Metals and A

Solidification



$\Delta G = G_s - G_l$



Heterogeneous Nucleation

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$\Delta T = T_m - T$
$= 1453 - 1203$
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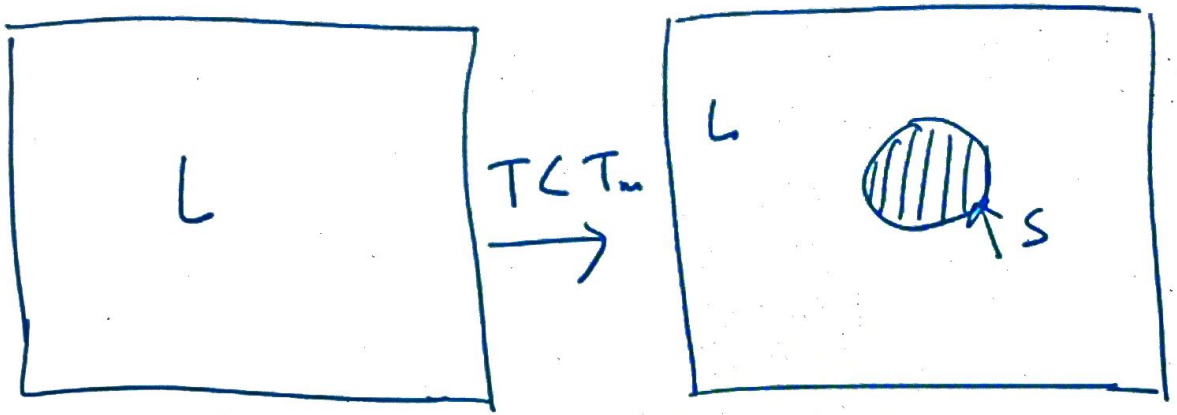
Solid/Liquid Interface



$$G_1 = (V_s + V_l)\, G^l$$

$$G_2 = V^s G^s + V^l G^l + A_{SL}\gamma_{SL}$$

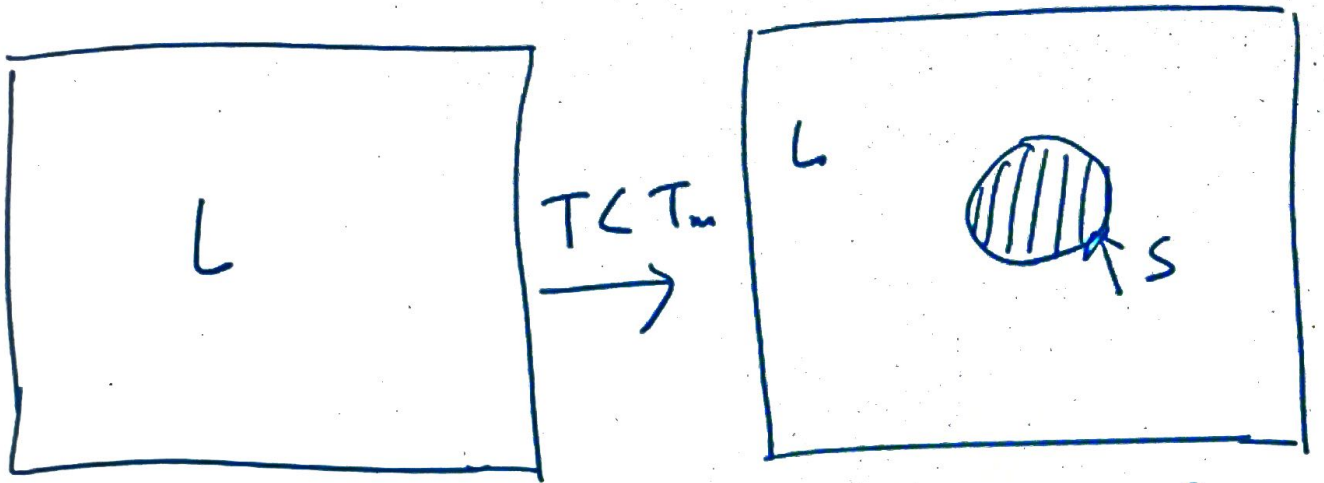
$$\Delta G = G_1 - G_2$$

$$\Delta G = -V_s \Delta G + A_{SL}\gamma_{SL}$$

$$\Delta G = G_V^L - G_V^S$$

Laser Pointer
Pen
Highlighter
Eraser
Erase All Ink on Slide

D.A. Porter and K.E. Easterling, Phase Transformations in Metals and A



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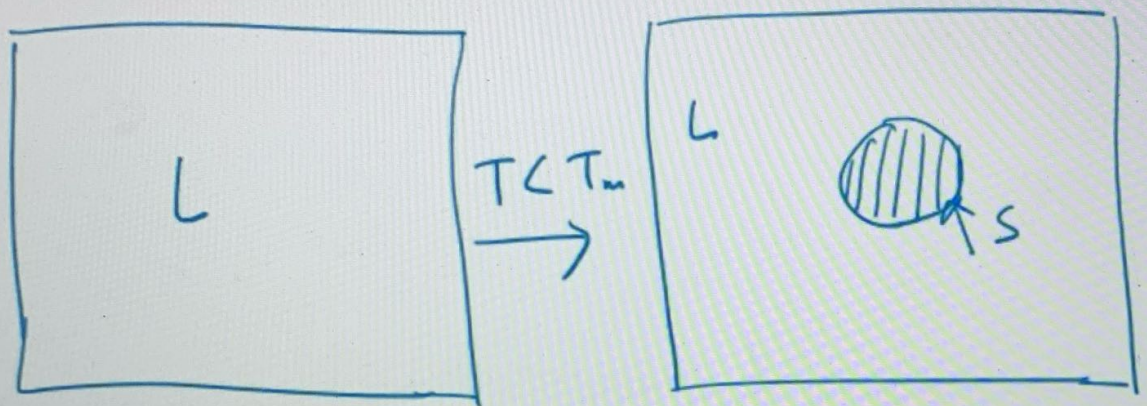
Solid/Liquid Interface



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$$\Delta G = G_1 - G_2$$

$$\Delta G = -V_s \Delta G + A_{SL}\, \gamma_{SL}$$

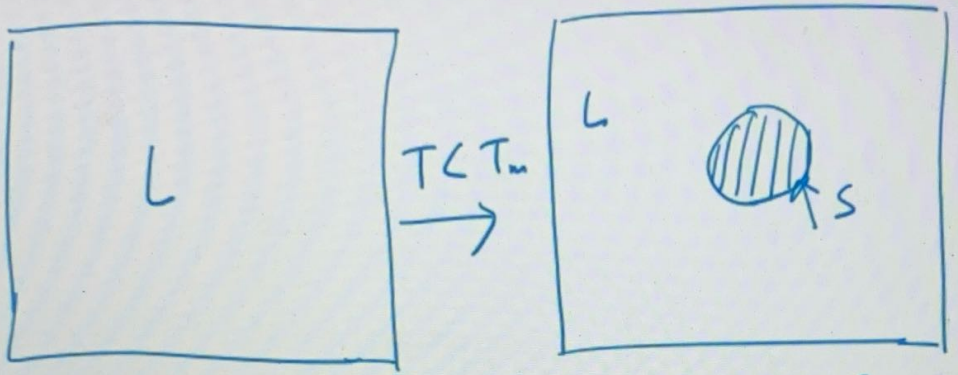
$$\Delta G = G^L - G^S$$

$$\approx \frac{L \Delta T}{T_m}$$

$$\Delta G \cdot$$

D A Porter and K.E. Easterling, Phase Transformations in Metals and A

Solid/Liquid Interface



$$G_1 = (V_s + V_l)\, G^l$$

$$G_2 = V^s G^s + V^l G^l + A_{sL}\, \gamma_{sL}$$

$$\Delta G = G_1 - G_2$$

$$\Delta G = -V_s \Delta G + A_{sL}\, \gamma_{sL}$$

$$\Delta G = G^L - G^S$$

$$\approx \frac{L \Delta T}{T_m}$$

$$\Delta G = \Delta H - T \Delta S$$

At $T = T_m$, $\Delta G = 0$

$$\Delta H = L = T_m \Delta S$$

$$\Delta S = L / T_m$$

$$\Delta G \approx L - \frac{L}{T_m}$$

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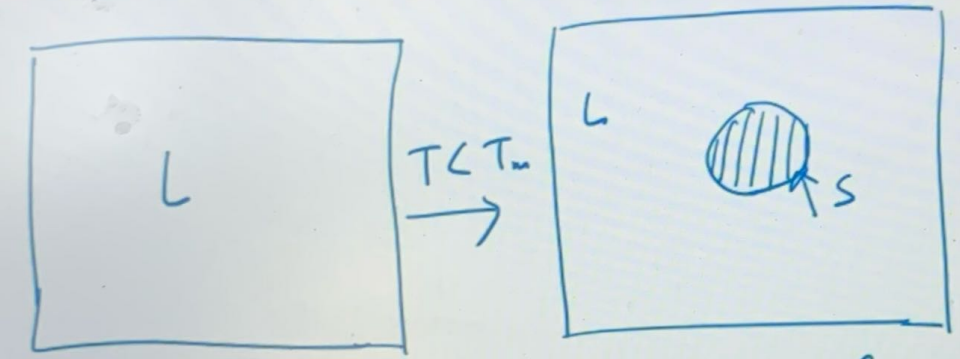
Solid/Liquid Interface



$$G_1 = (V_s + V_l)\, G^l$$

$$G_2 = V^s G^s + V^l G^l + A_{SL}\gamma_{SL}$$

$$\Delta G = G_1 - G_2$$

$$\Delta G = -V_s \Delta G_v + A_{SL}\gamma_{SL}$$

$$\Delta G_v = G_v^L - G_v^S \approx \frac{L\Delta T}{T_m}$$

$$\Delta G_v = \Delta H - T\Delta S$$

At $T = T_m$, $\Delta G_v = 0$

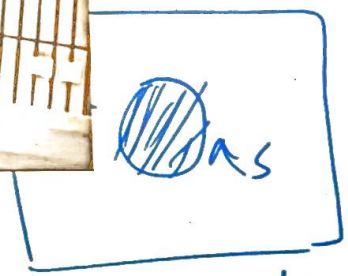
$$\Delta H = L = T_m \Delta S$$

$$\Delta S = L/T_m$$

$$\Delta G \approx L_v - \frac{L_v}{T_m}\cdot T = \frac{L\Delta T}{T_m}$$

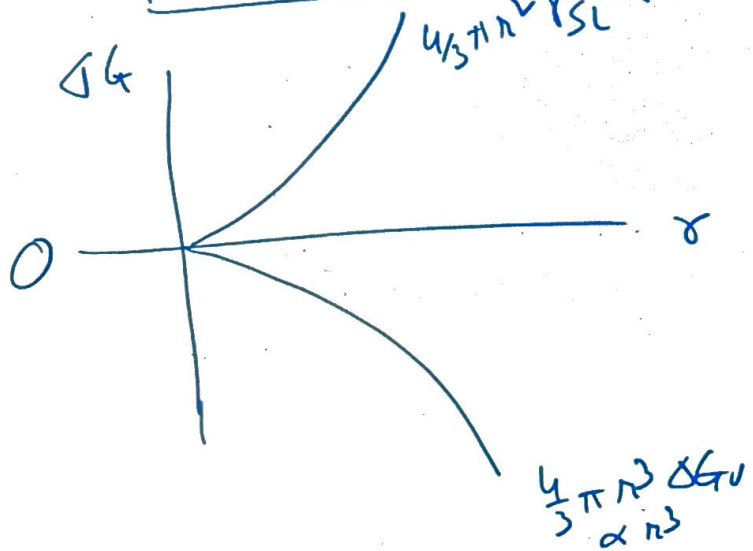
D A Porter and K.E. Easterling, Phase Transformations in Metals and A

uid Interface



$$\Delta G = -V_s G_s + \gamma_{SL} A_{SL}$$

$$\Delta G_{pr} = -\frac{4}{3}\pi r^3 \Delta G_V + 4\pi r^2 \gamma_{SL}$$



D A Porter and K.E. Easterling, Phase Transform... in Metals and A

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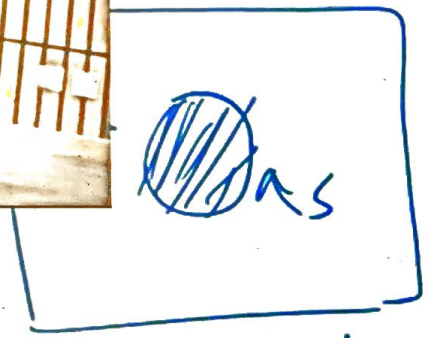
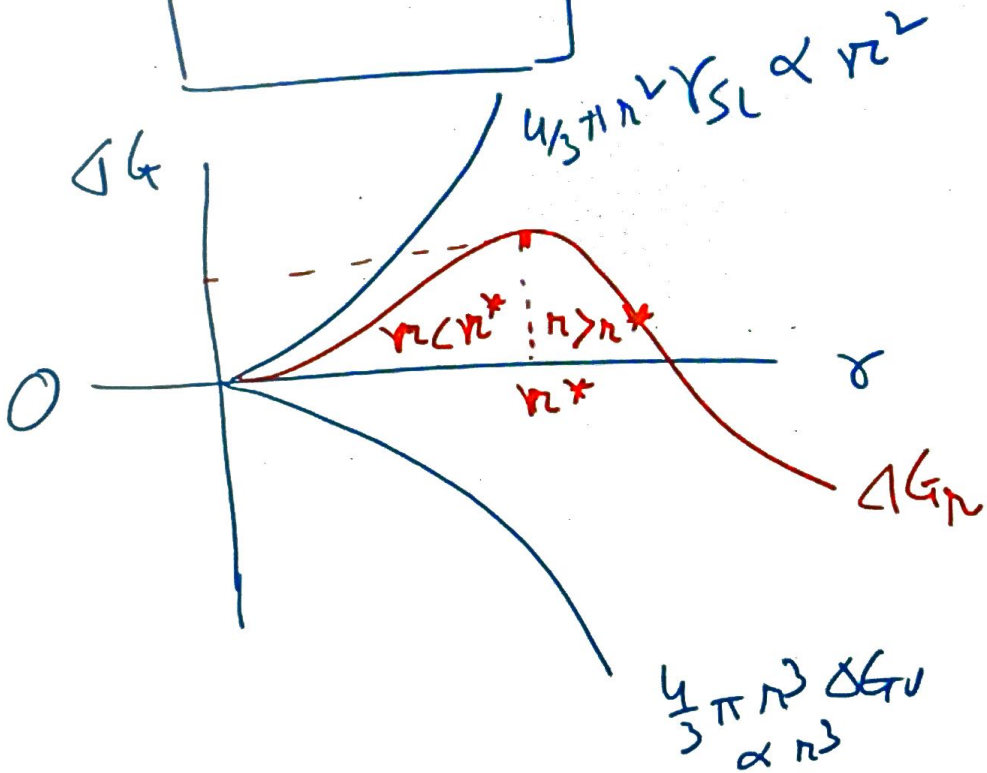
LEGION

quid Interface



$$\Delta G = -V_S G_S + \gamma_{SL} A_{SL}$$

$$\Delta G_r = -\frac{4}{3}\pi r^3 \Delta G_V + 4\pi r^2 \gamma_{SL}$$



$r < r^*$ - Embryo

$r > r^*$ - Nucleus

r^*

$$\left.\frac{\partial \Delta G}{\partial r}\right|_{r=r^*} = 0$$

$$\boxed{r^* = +\frac{2\gamma_{SL}}{\Delta G_V}}$$

$$\Delta G^* = \frac{16}{3}\pi \frac{\gamma^3}{(\Delta G_V)^2}$$

D A Porter and K.E. Easterling, Phase Transform... in Metals and A

Solid/Liquid Interface

$$r^* = \left(\frac{2\gamma_{SL} T_m}{L_v}\right) \times \frac{1}{\Delta T}$$

$$\Delta G^* = \frac{16\pi \gamma_{SL}^3 T_m^2}{3 L_v^2} \cdot \left(\frac{1}{\Delta T}\right)^2$$

$$\Delta G_v \simeq \frac{L_v \Delta T}{T_m}$$

D A Porter and K.E. Easterling, Phase Transformations in Metals and A

Solid/Liquid Interface

$$r^* = \left(\frac{2\gamma_{SL} T_m}{L_v}\right) \times \frac{1}{\Delta T}$$

$$\Delta G^* = \frac{16\pi \gamma_{SL}^3 T_m^2}{3 L_v^2} \cdot \left(\frac{1}{\Delta T}\right)^2$$

$$\Delta G_v \simeq \frac{L_v \Delta T}{T_m}$$

$$\boxed{\Delta G_v \simeq \frac{2\gamma_{SL}}{r^*}}$$

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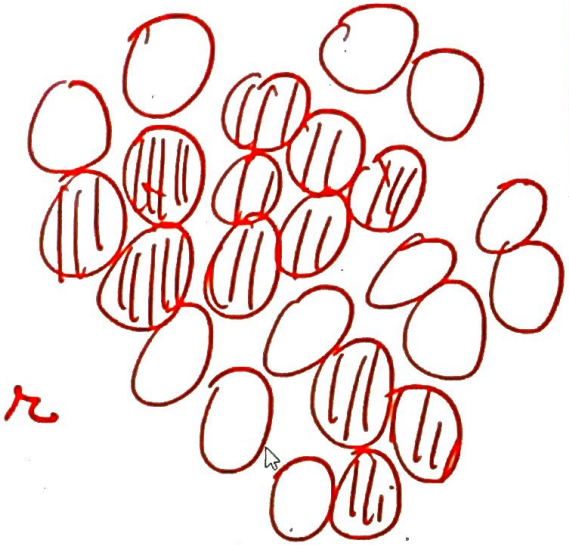
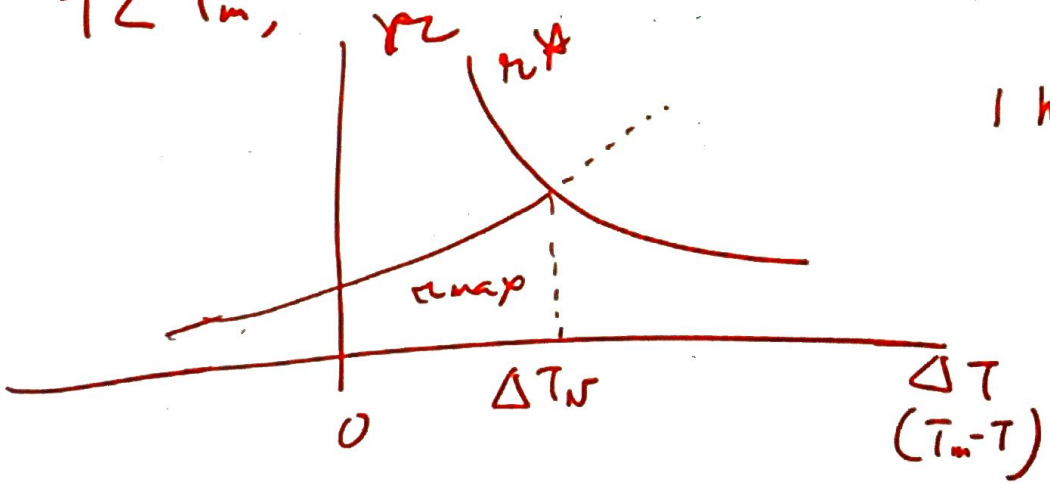
Solid/Liquid Interface

$$n_r = n_0 \exp\left(-\frac{\Delta G_r}{kT}\right)$$



$T > T_m$, valid for all r

$T < T_m$,



1 mm^3 Cu at $T = T_m$

10^{20} atoms

- 10^{14} clusters of 0.3nm (10 atoms)

~10 clusters of 0.6nm (600 atoms)