The effect of interface conditions on the γ to α transformation in Fe-C-Mn and Fe-C-Ni alloys

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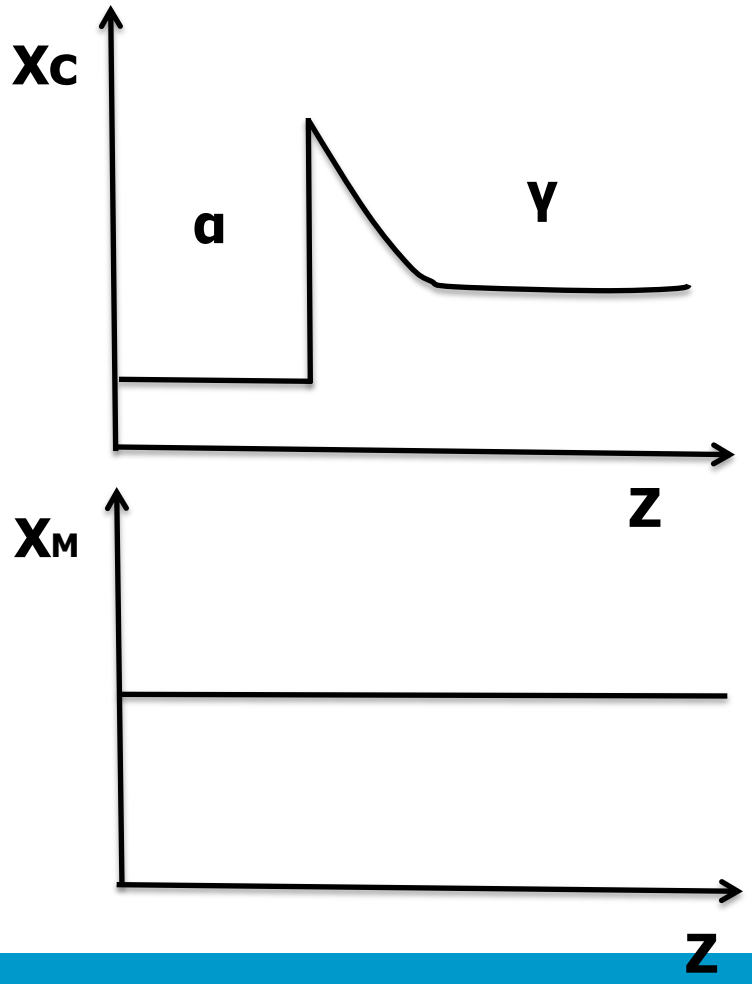
Paraequilibrium Model

$$\mu_C^{\gamma} = \mu_C^{\alpha}$$

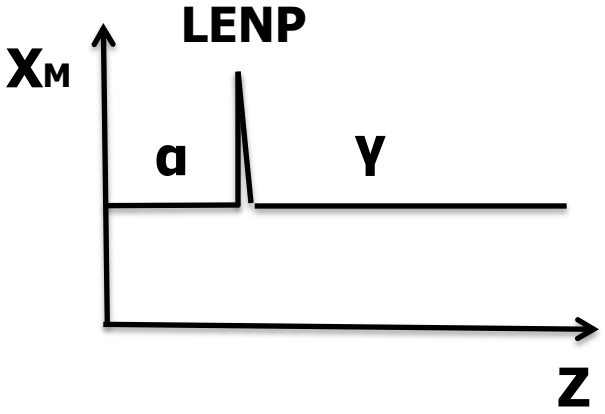
$$\left(\mu_M^{\gamma} - \mu_M^{\alpha}\right) = -\frac{X_{Fe}}{X_M}\left(\mu_{Fe}^{\gamma} - \mu_{Fe}^{\alpha}\right)$$

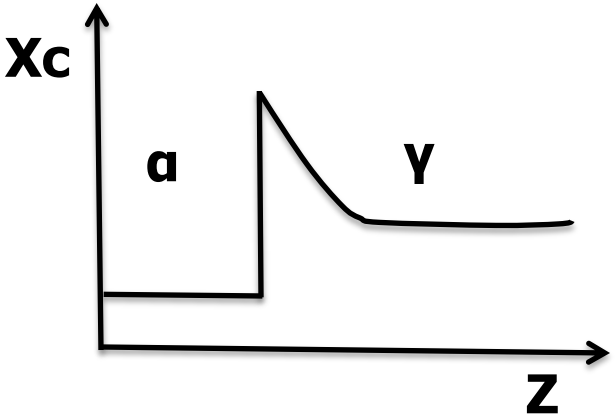


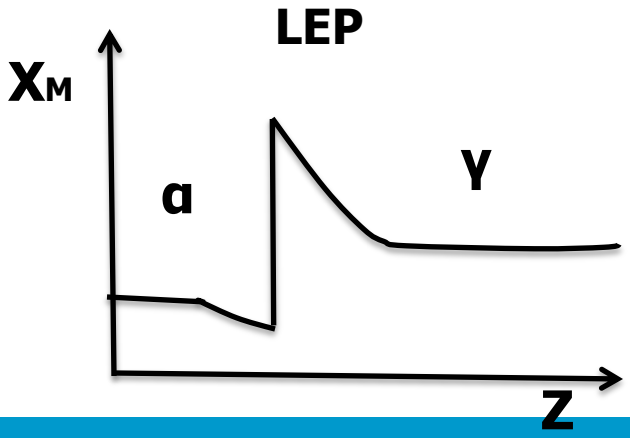
Local Equilibrium model

$$\mu_C^{\gamma} = \mu_C^{\alpha}$$

$$\mu_M^{\gamma} = \mu_M^{\alpha}$$







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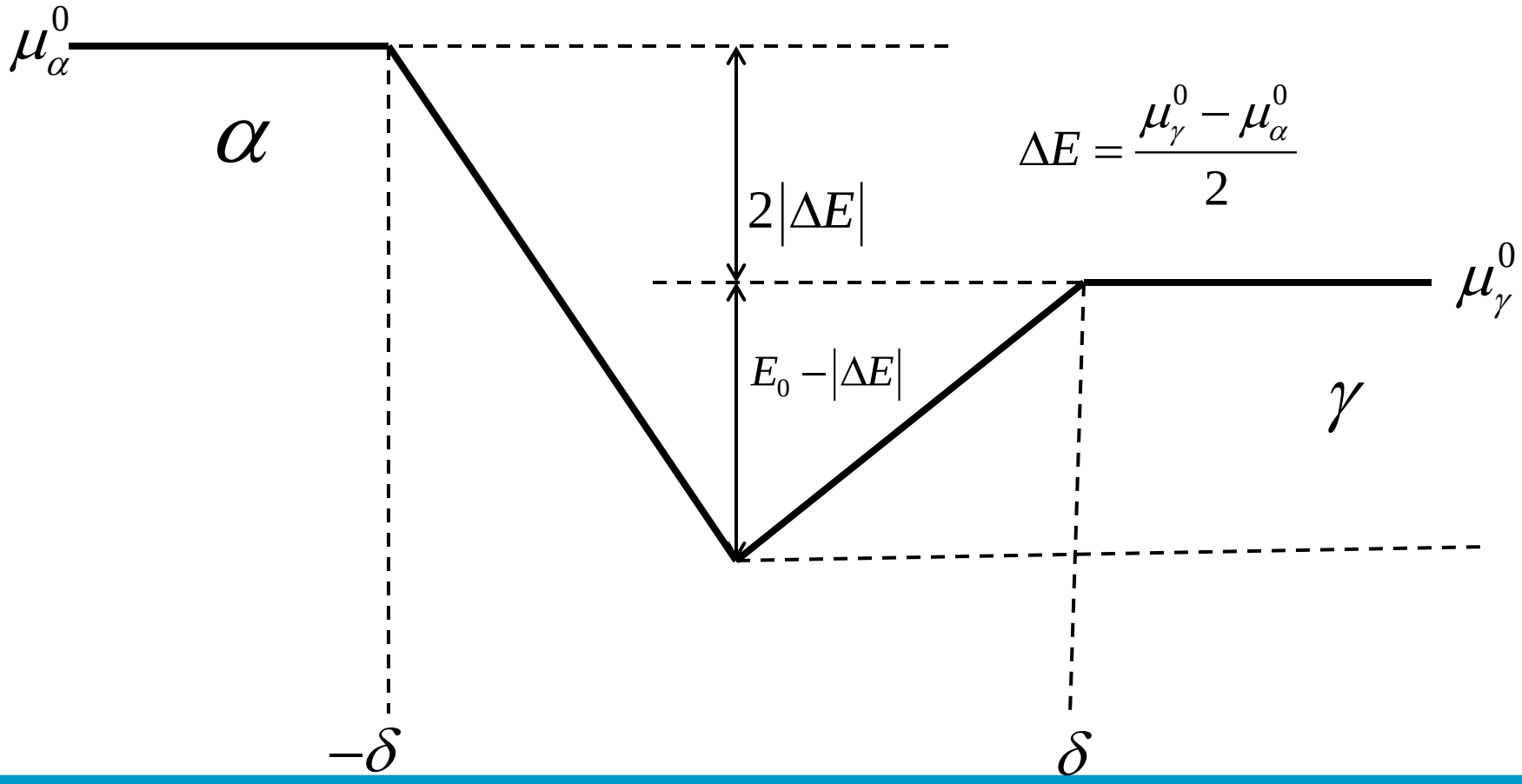
Motivation of this work

- Can we apply the GEB model to the austenite to ferrite transformation??
- Is there transformation stasis phenomenon during the isothermal austenite to ferrite transformation??
- What's the relationship among LE, PE and GEB model??

Dissipation due to M diffusion



Dissipation due to M diffusion

Solute profile:

$$\frac{\partial}{\partial x}\left(D\frac{\partial C}{\partial x}+\frac{CD}{RT}\frac{\partial E}{\partial x}+\mathbf{v}C \right)=0$$

v is interface velocity

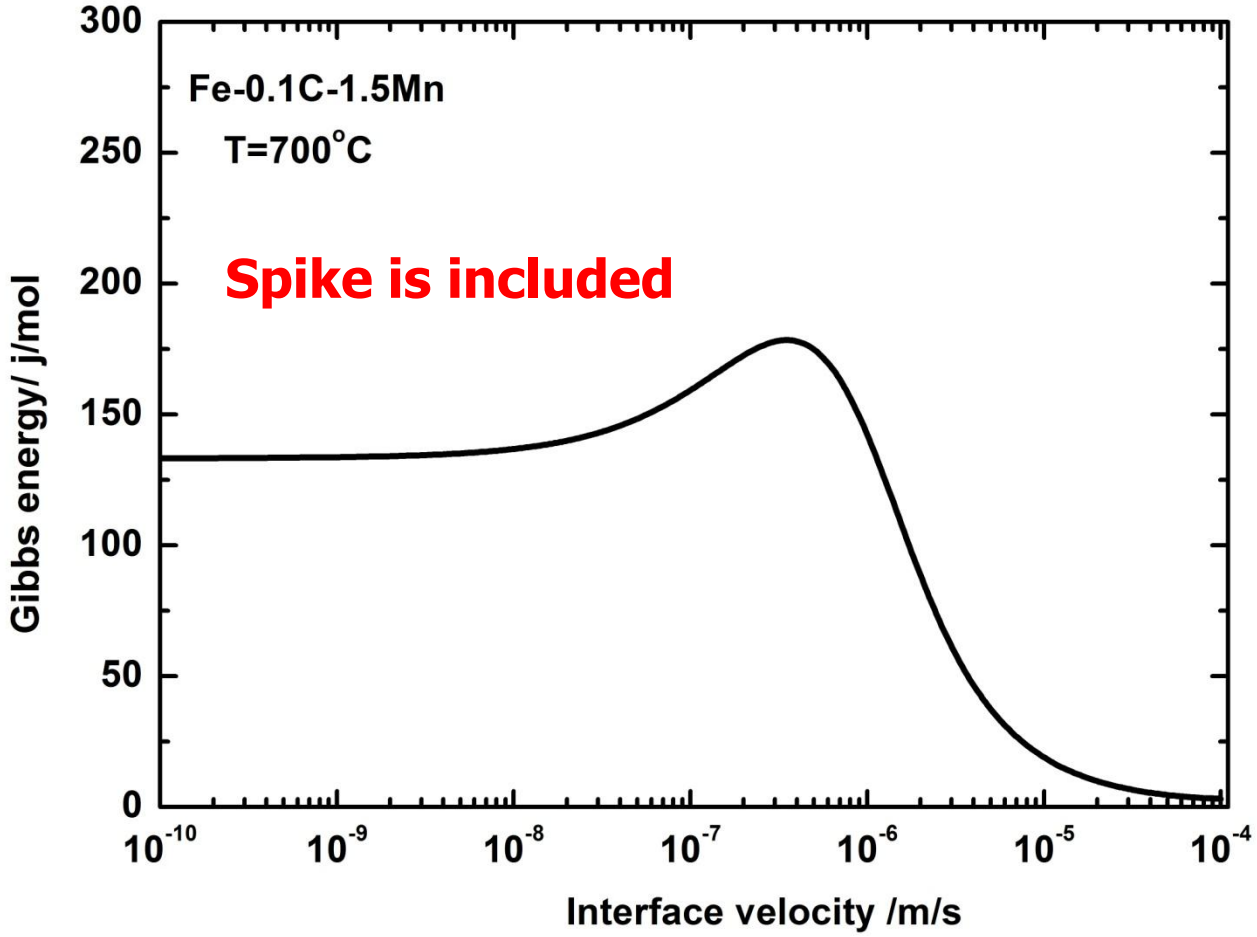
Hillert's Model:

$$\Delta G^{diff} = -\int_0^{\delta} (x_B - x_B^0)\frac{d\left(\mu_B - \mu_A\right)}{d\xi}d\xi$$

Cahn Model:

$$P^{sd}V_m = -\int_{-\infty}^{+\infty} \left(x_B - x_B^0\right)\frac{dE}{d\xi}d\xi$$

Dissipation due to M diffusion



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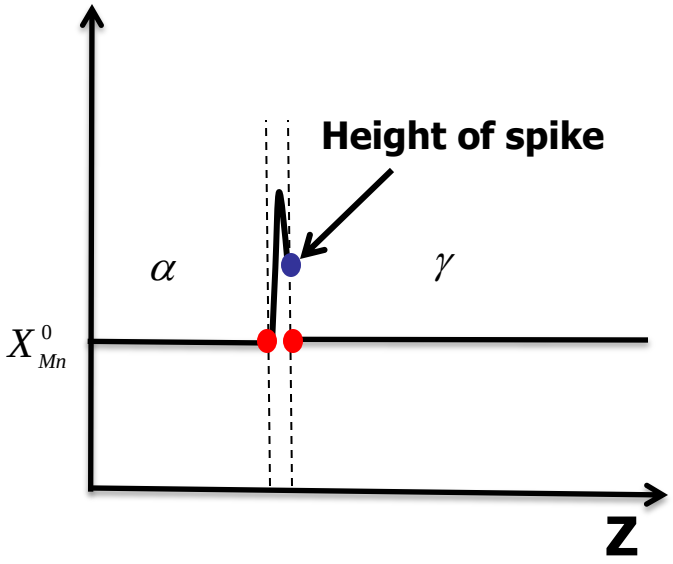
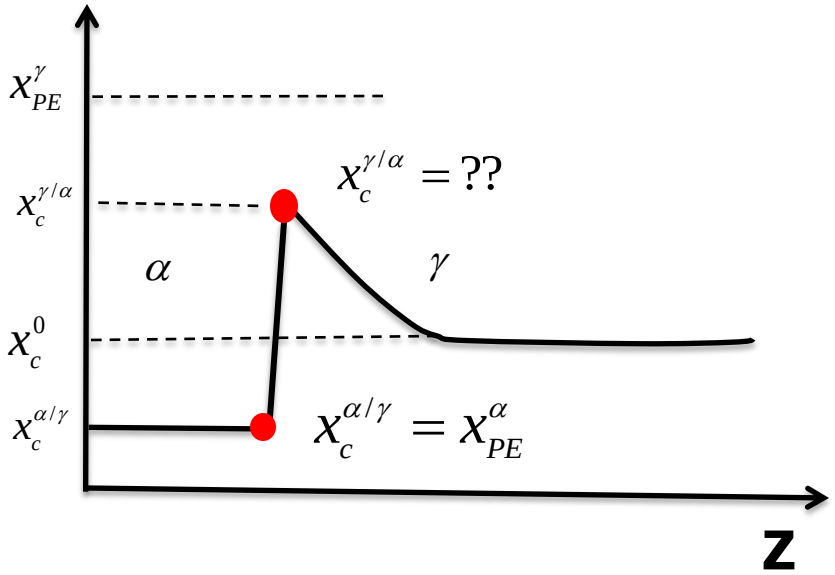
Chemical driving force

$$\Delta G^{Chem} = \sum_i x_i^{\alpha} \left[\mu_i^{\gamma/\alpha}(x_i^{\gamma/\alpha}) - \mu_i^{\alpha/\gamma}(x_i^{\alpha/\gamma}) \right]$$ (Spike is included)





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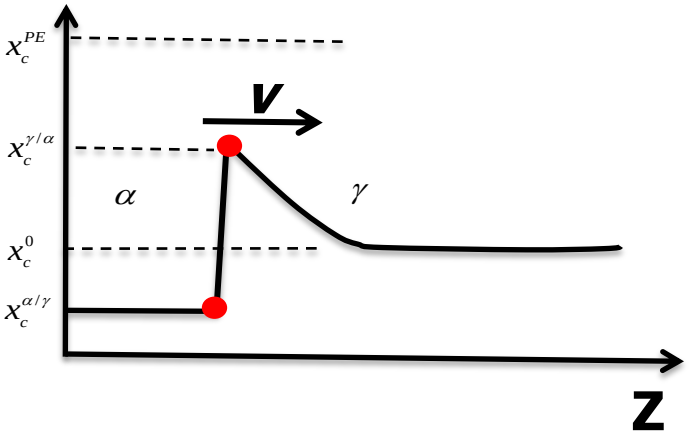
Chemical driving force



Before soft impingement:

$$v = \frac{2D_C^{\gamma}(x_C^{\gamma/\alpha} - x_C^0)}{L(x_C^{\gamma/\alpha} - x_C^{\alpha/\gamma})}$$

$$L = \frac{3S(x_C^0 - x_C^{\alpha/\gamma})}{(x_C^{\gamma/\alpha} - x_C^0)}$$

After soft impingement:

$$v = \frac{2D_C^{\gamma}(x_C^{\gamma/\alpha} - x_C^m)}{L(x_C^{\gamma/\alpha} - x_C^{\alpha/\gamma})}$$

$$x_C^m = \frac{(3S(x_C^0 - x_C^{\alpha/\gamma})/L + 3x_C^0 - x_C^{\gamma/\alpha})}{2}$$

$$L = L_0 - S$$

$$\Delta G^{Chem} = f\left(x_c^{\gamma/\alpha}\right)$$

$$v = f\left(x_c^{\gamma/\alpha}\right)$$

$$\Delta G^{Chem} = f(v)$$

Chen, van der Zwaag, J of Mater Sci 2011, (46)1328-1336.

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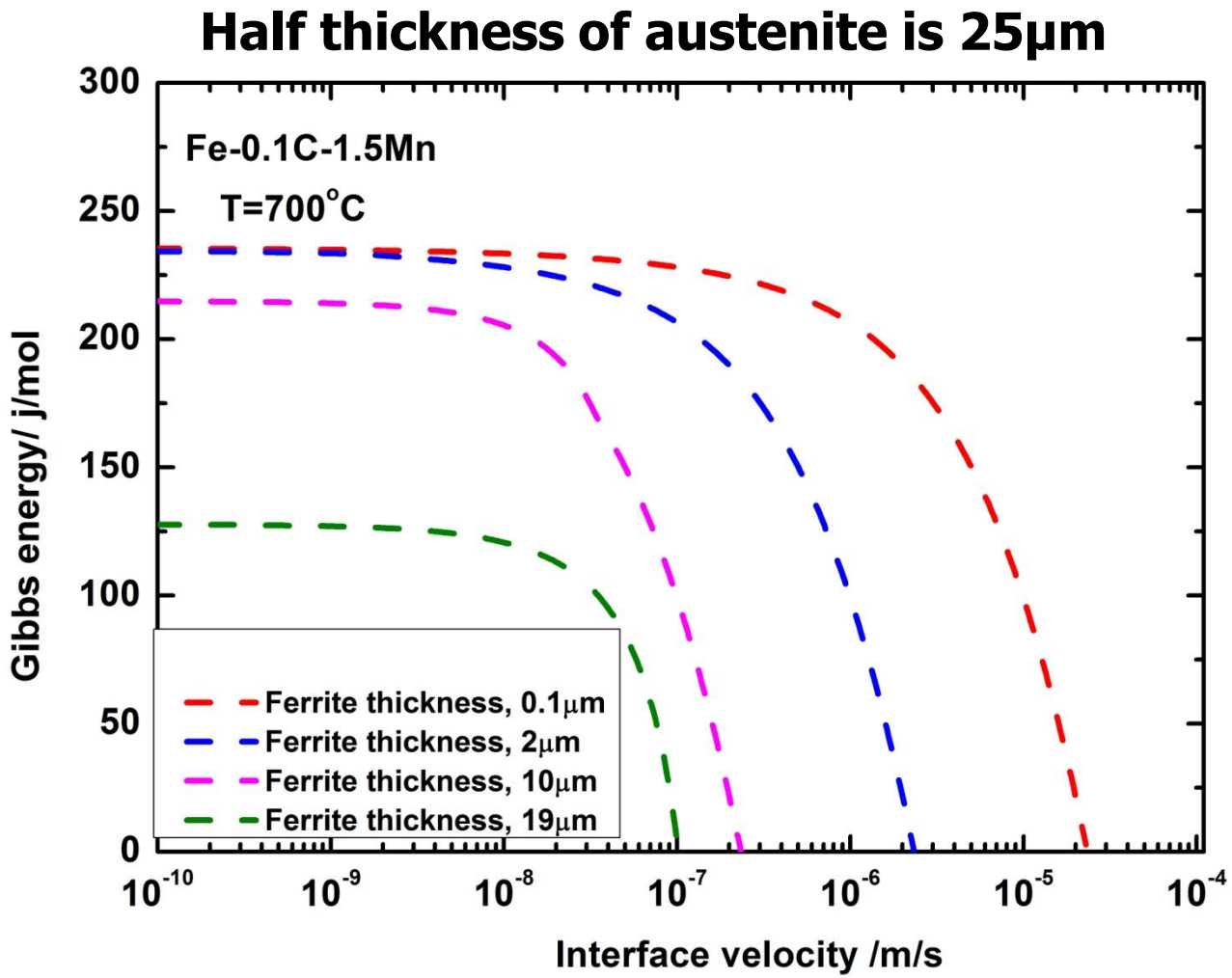
Chemical driving force



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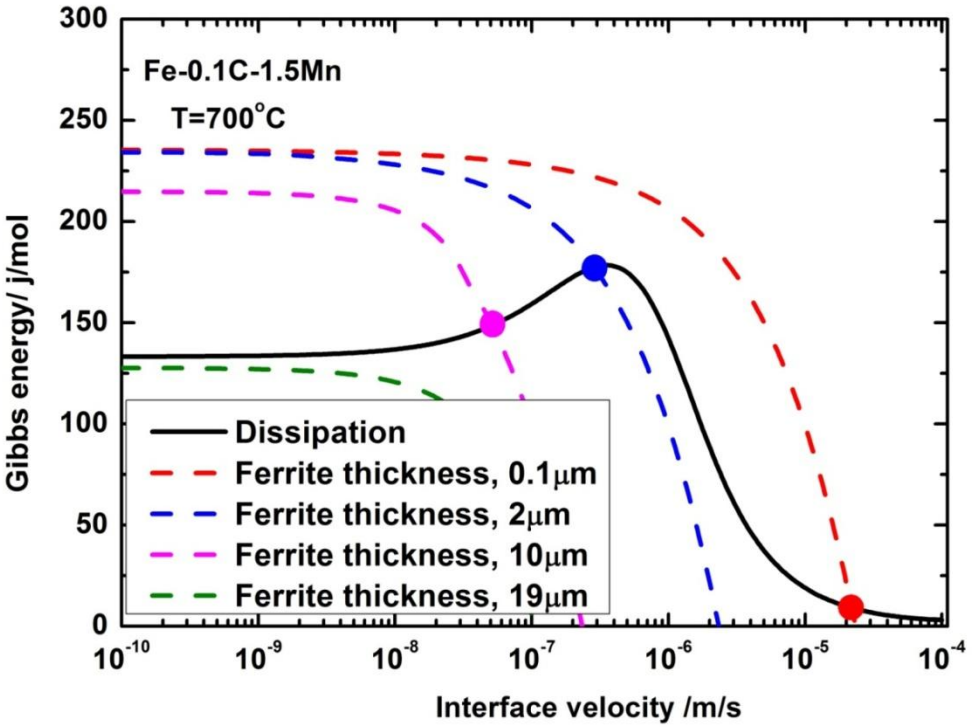
Gibbs Energy Balance (GEB)

$$\Delta G^{Chem} = \Delta G^{Diff} + \Delta G^{Friction}$$

$$E_0 = 9.9kJ/mol \qquad D_{Mn}^{Int} = \sqrt[3]{D_{Mn}^{\alpha} \times D_{Mn}^{\gamma} \times D_{Mn}^{GB}} \qquad 2\delta = 0.5nm$$

Interface mobility is infinite



No partitioning of Mn (PE)

↓

Negligible partitioning of Mn (LENP)

↓

Partitioning of Mn (LEP)

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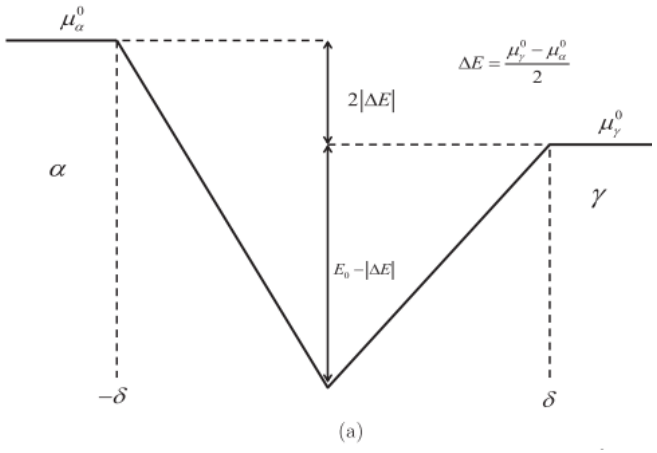
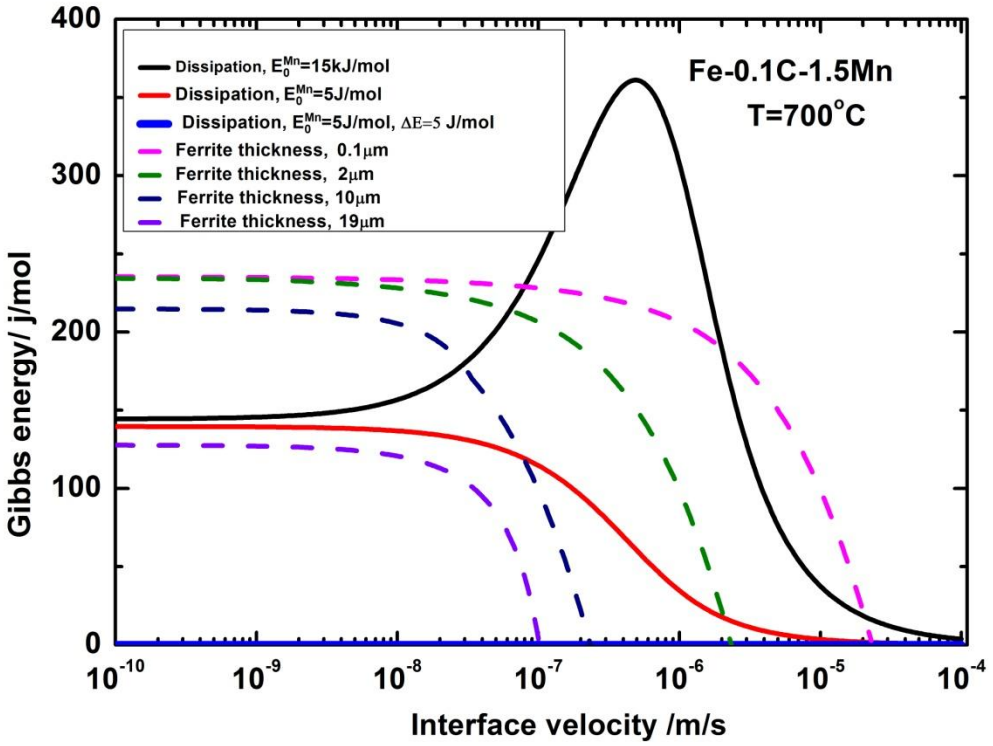
The effect of binding energy



$$\Delta E = \frac{\mu_\gamma^0 - \mu_\alpha^0}{2}$$

E_0 ???



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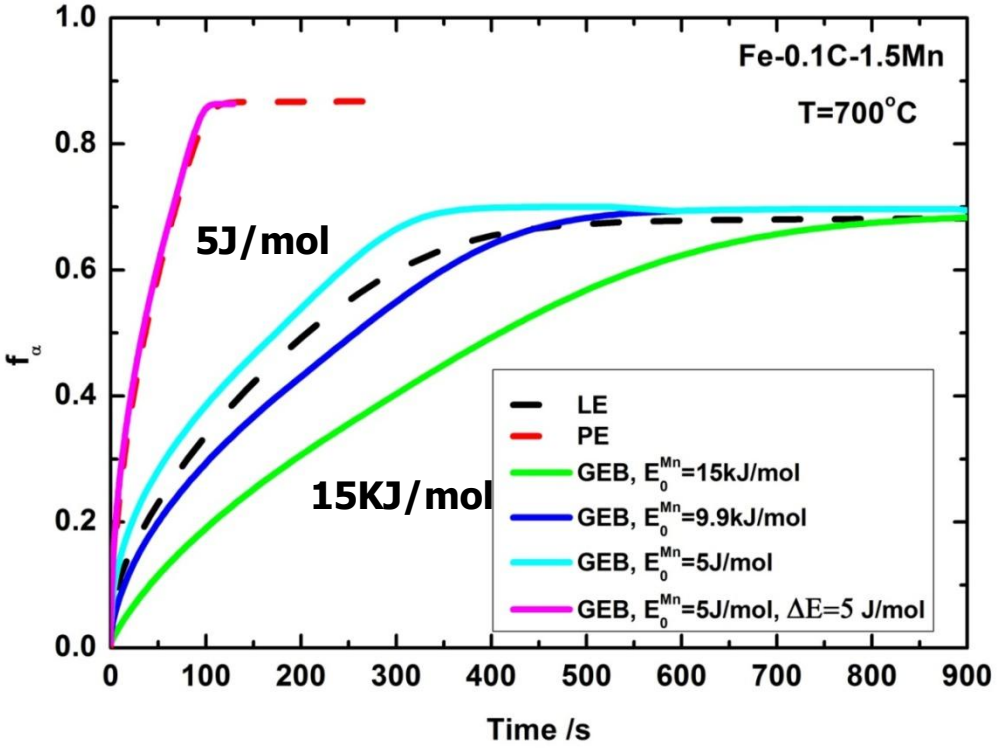
Transformation kinetics



1. The GEB model is equal to PE when the dissipation is assumed to be zero.

2. The GEB model predicts that ferrite fraction at the stasis is not affected by the value of binding energy.

3. The ferrite fraction predicted by LE and GEB model are almost the same.

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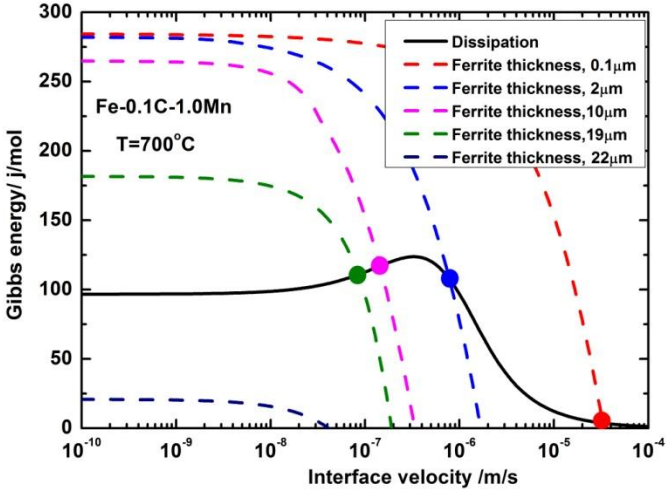
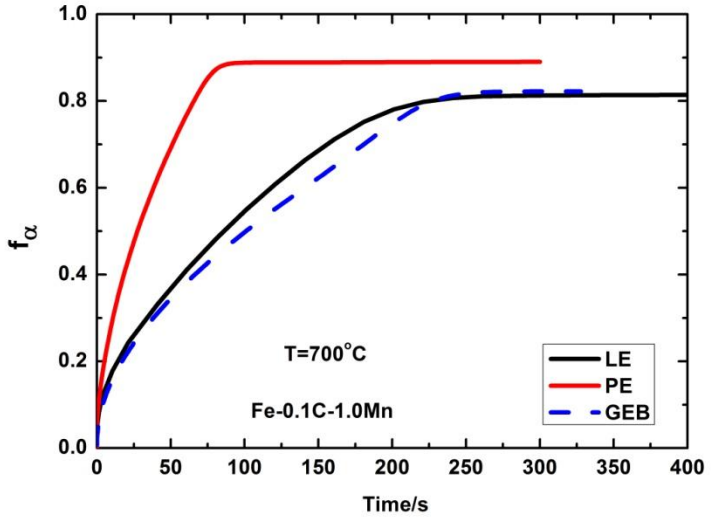
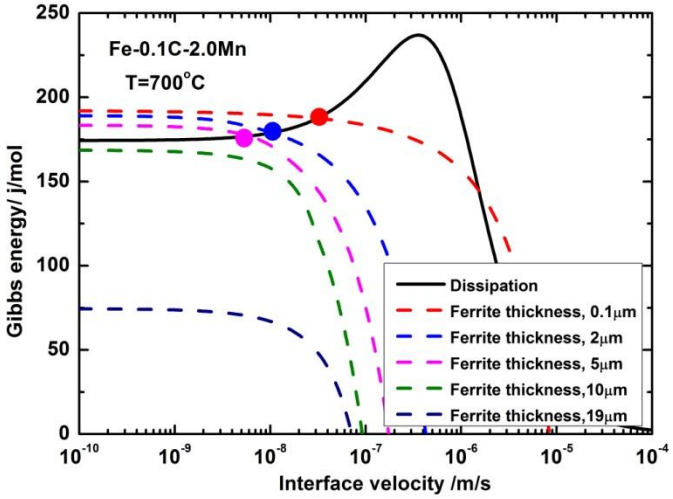
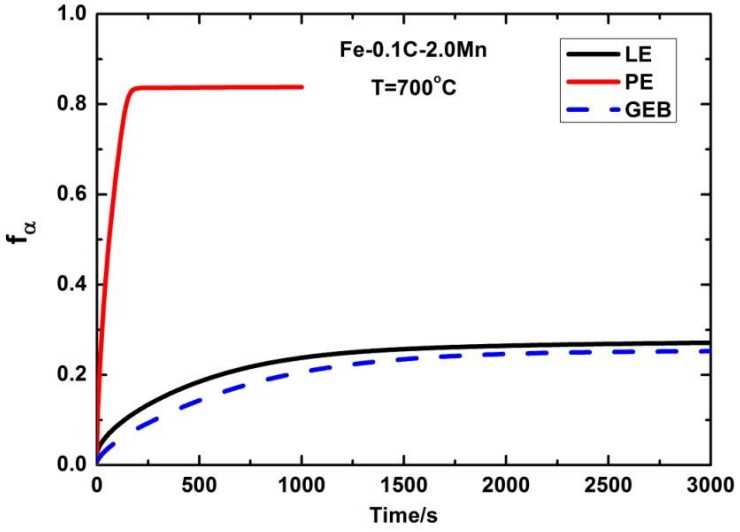
The effect of Mn concentration









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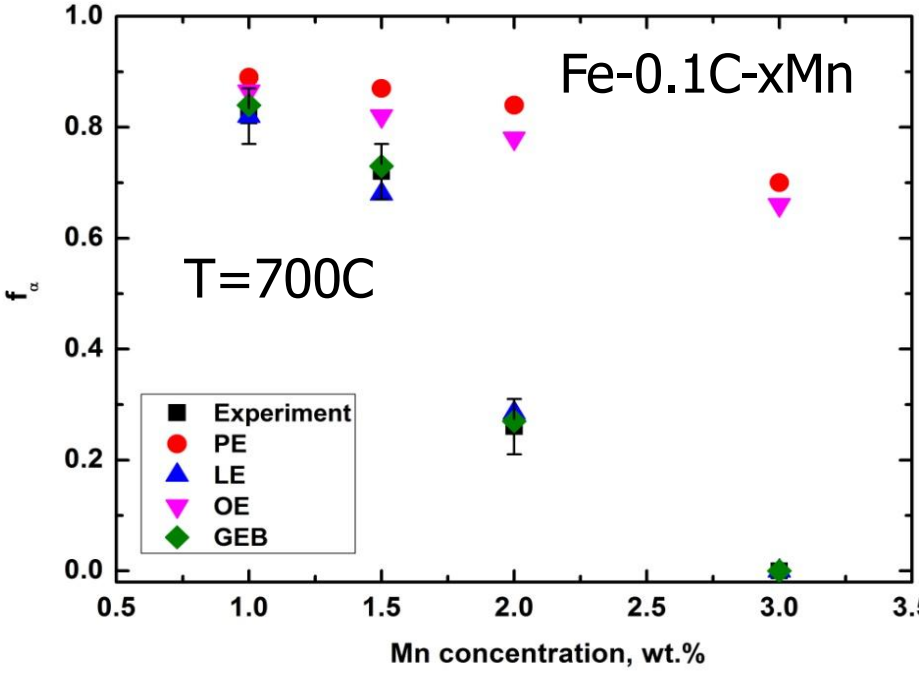
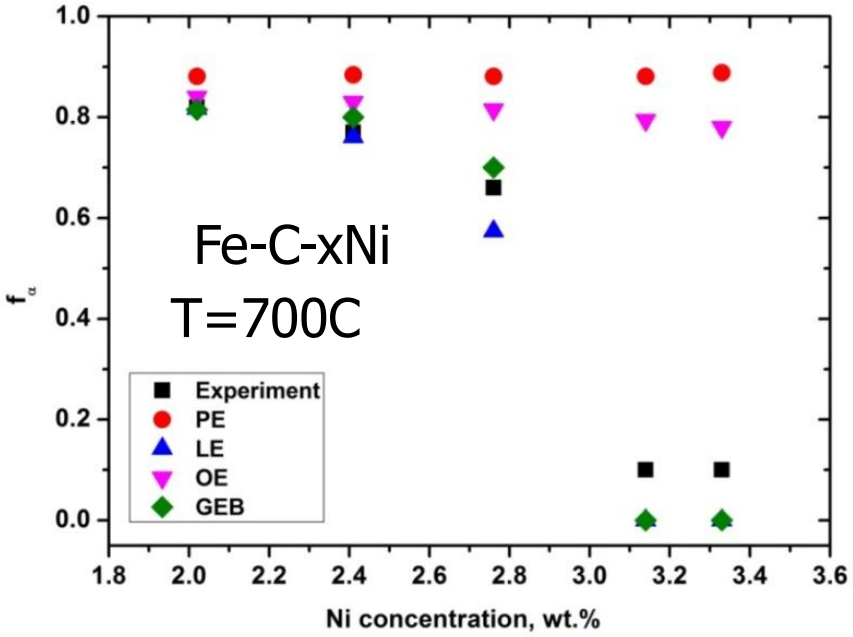
Transformation stasis phenomenon





Both LE and GEB can well predict the ferrite fraction at the stasis!!!!

Experimental data for Fe-C-Ni alloys is from Hutchinson, et.al, MMTA 2004.

Summary

- The GEB model can well predict the growth mode transition between no partitioning (i.e. PE) and Negligible partitioning(i.e. LENP) during the austenite to ferrite transformation. The PE and LENP model are two specific cases of the GEB model.

- The transformation stasis phenomenon during the austenite to ferrite transformation in Fe-C-Mn and Fe-C-Ni can be well described by the GEB model.

- The transformation kinetics is affected by the value of binding energy, while the ferrite fraction at the stasis is mainly determined by ΔE