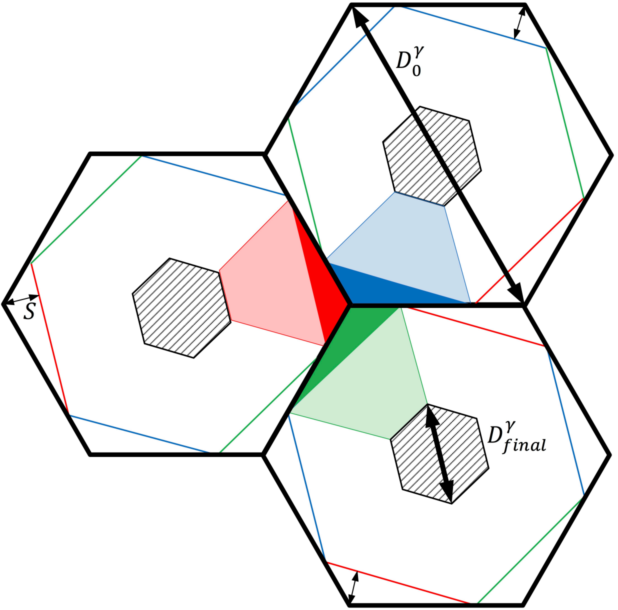
Agenda

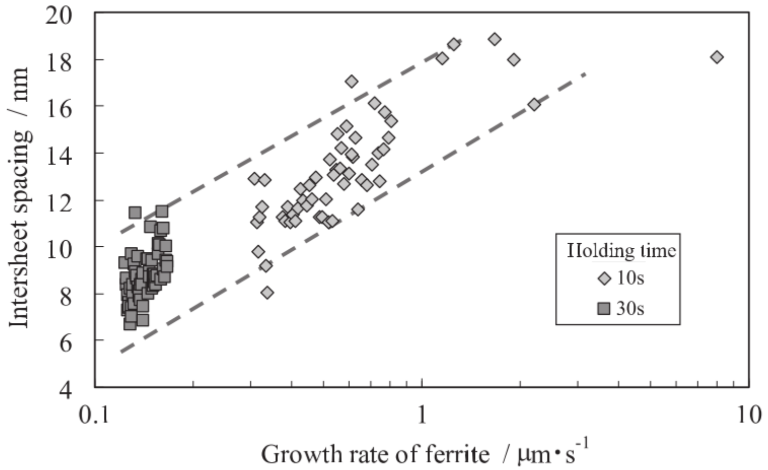


- **Interphase Precipitation Model**

S. Clark, V. Janik, Y. Lan, and S. Sridhar: *ISIJ Int.*, **57**, (2017), 524–532.

Modelling of Interphase Precipitation – Experimental Facts

- **Interphase precipitation refines with reducing interphase velocity.** (T. Murakami, H. Hatano, G. Miyamoto, and T. Furuhara: *ISIJ Int.*, **52**, (2012), 616–25.)



Prediction of Inter-Sheet Spacing

WMG
THE UNIVERSITY OF WARWICK

Interfacial Energy of the γ/α interface

Molar Volume

Inter-Sheet Spacing

$$\lambda = \frac{\sigma V_m}{\Delta G_m^{\gamma \to \alpha}}$$

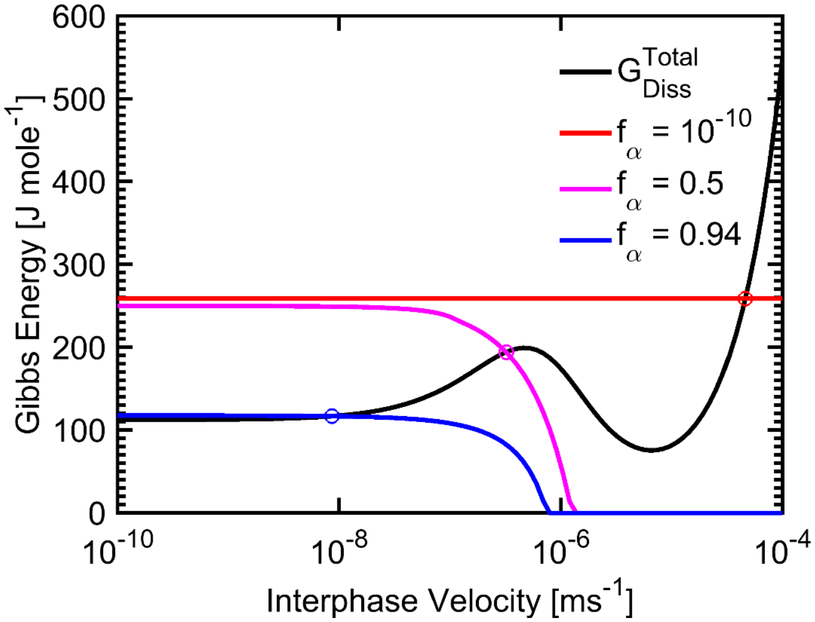
Driving Force

We have evaluated this using the GEB concept incorporating 'solute drag'

Bhadeshia assumed parequilibrium

H. K. D. H. Bhadeshia: *Phys. Status Solidi a-Applied Res.*, **69**, (1982), 745–50.

Gibbs Energy Balance Model

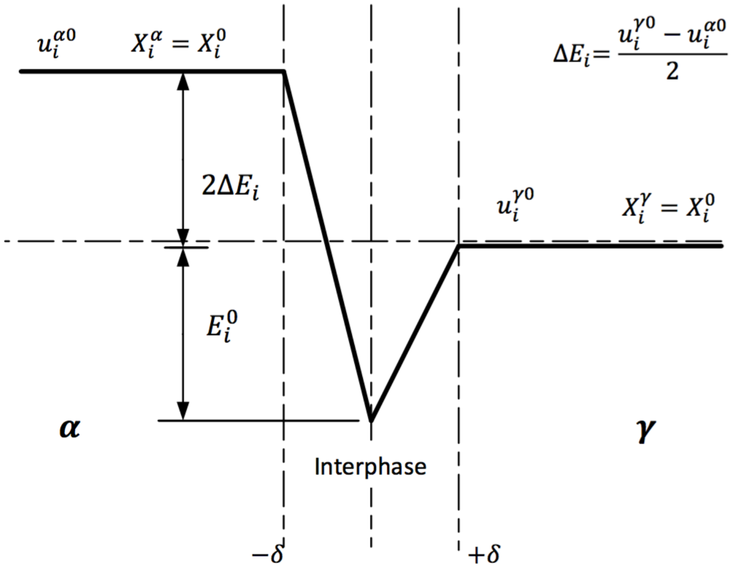


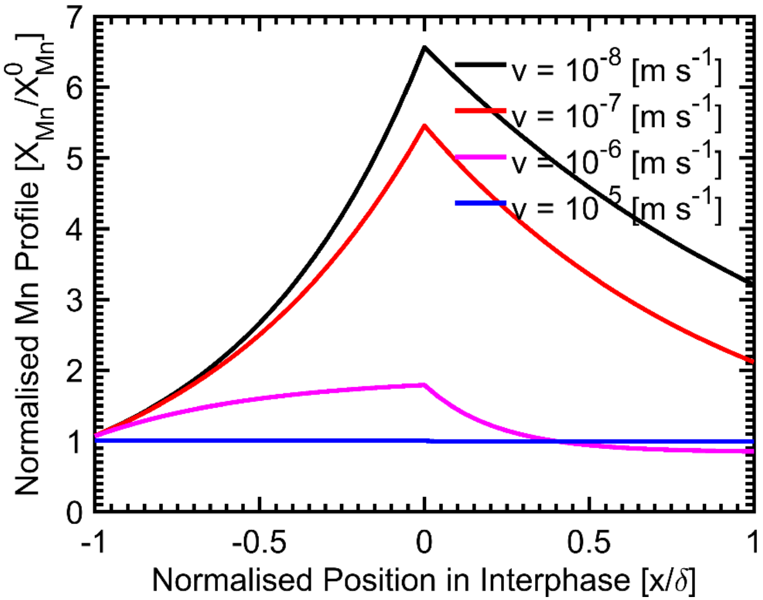
Chemical Driving Force

$$\Delta G_m^{\gamma\to\alpha} = \underbrace{\Delta G_m^{diff} + \Delta G_m^{frict}}_{\text{Dissipation Inside the Interphase}}$$

H. Chen and S. van der Zwaag: *Acta Mater.*, **72**, (2014), 1–12.

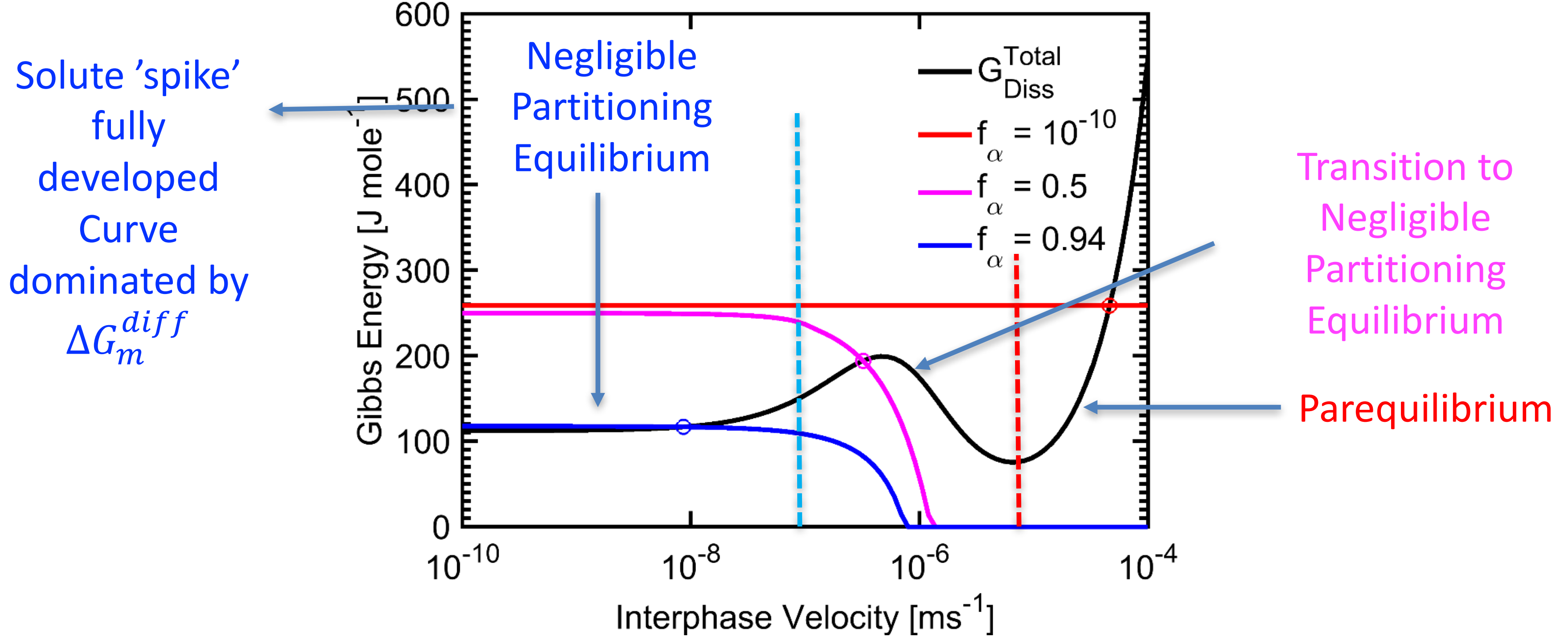
Solute Drag – Purdy and Brechét





G. R. Purdy and Y. J M Bréchet: *Acta Metall. Mater.*, **43**, (1995), 3763–74.

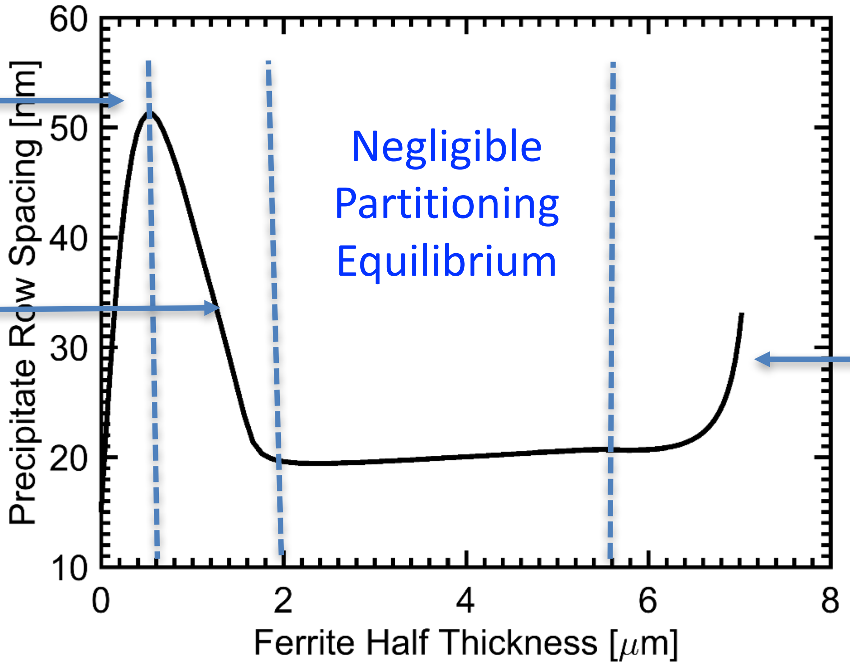
Gibbs Energy Balance Model



Modelled Inter-sheet Spacing

Pareqilibrium

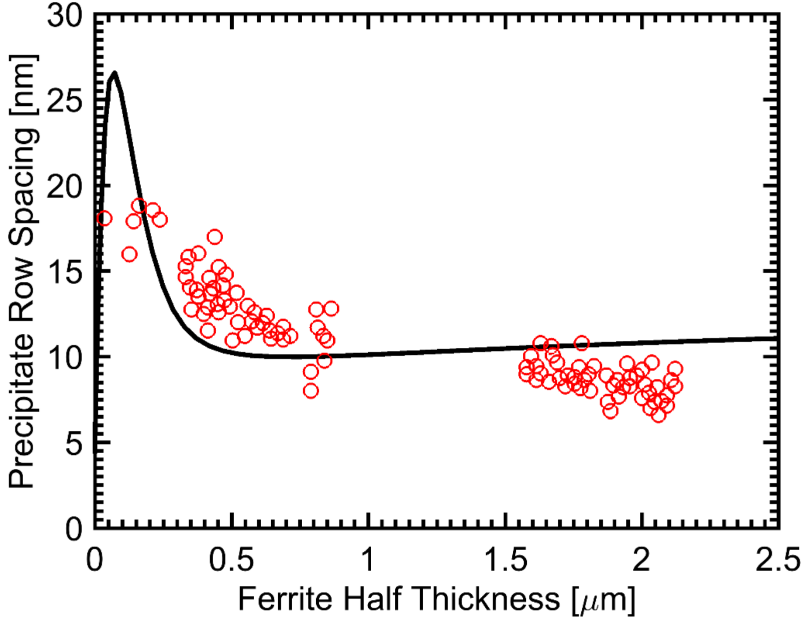
Transition to Negligible Partitioning Equilibrium



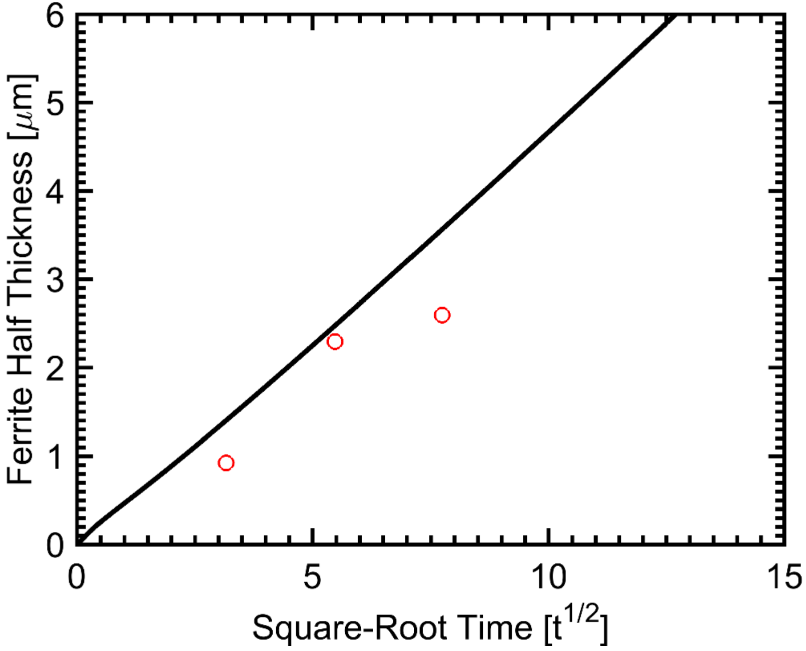
Soft Impingement

Testing the Model

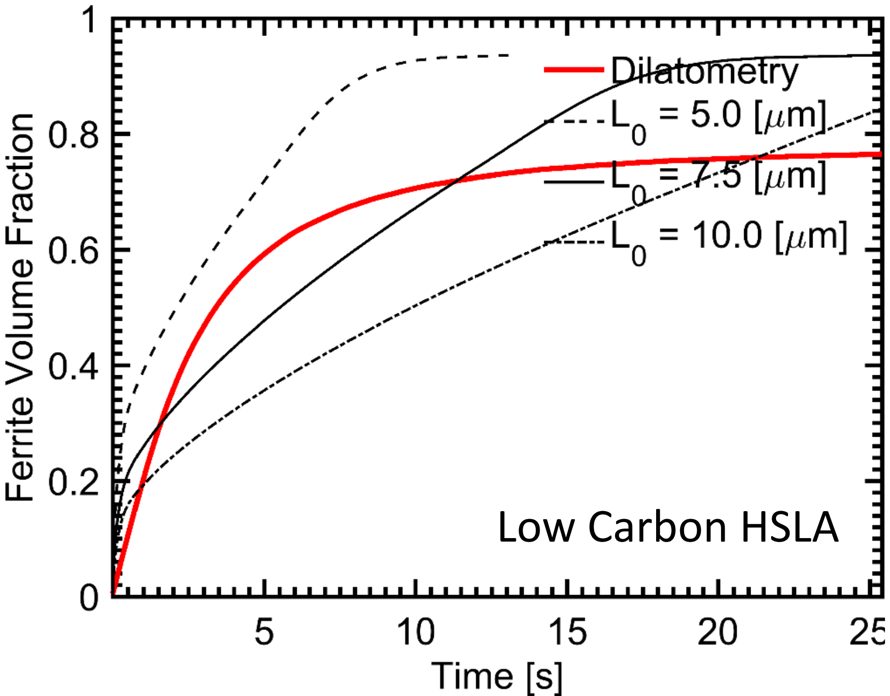
Data from: . Murakami, H. Hatano, G. Miyamoto, and T. Furuhara: *ISIJ Int.*, **52**, (2012), 616–25.

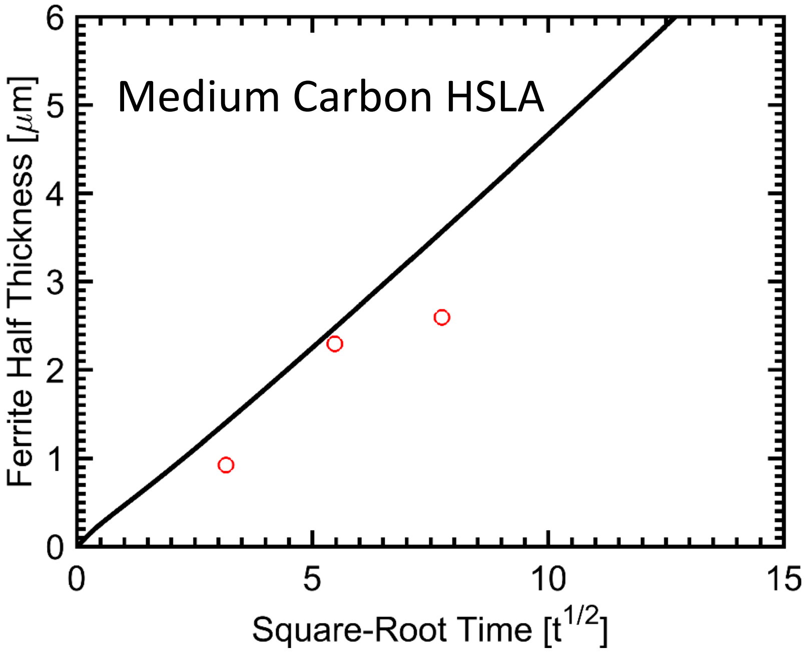


$$\sigma = 0.17 \ [Jm^{-2}]$$

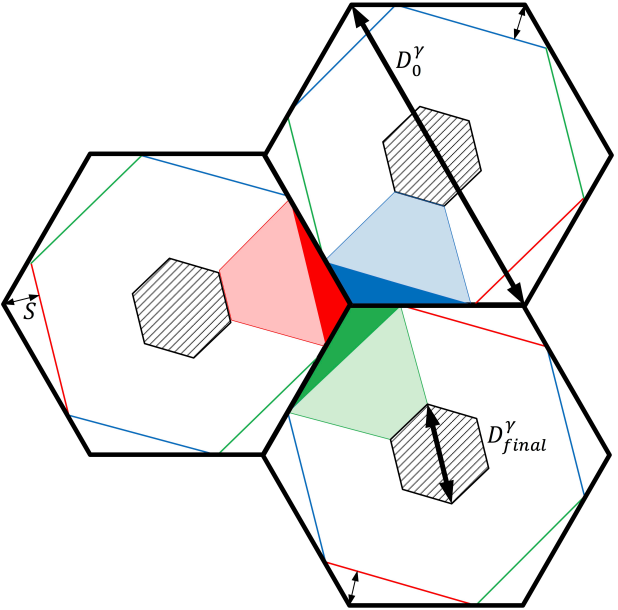


Prediction of Transformation Kinetics



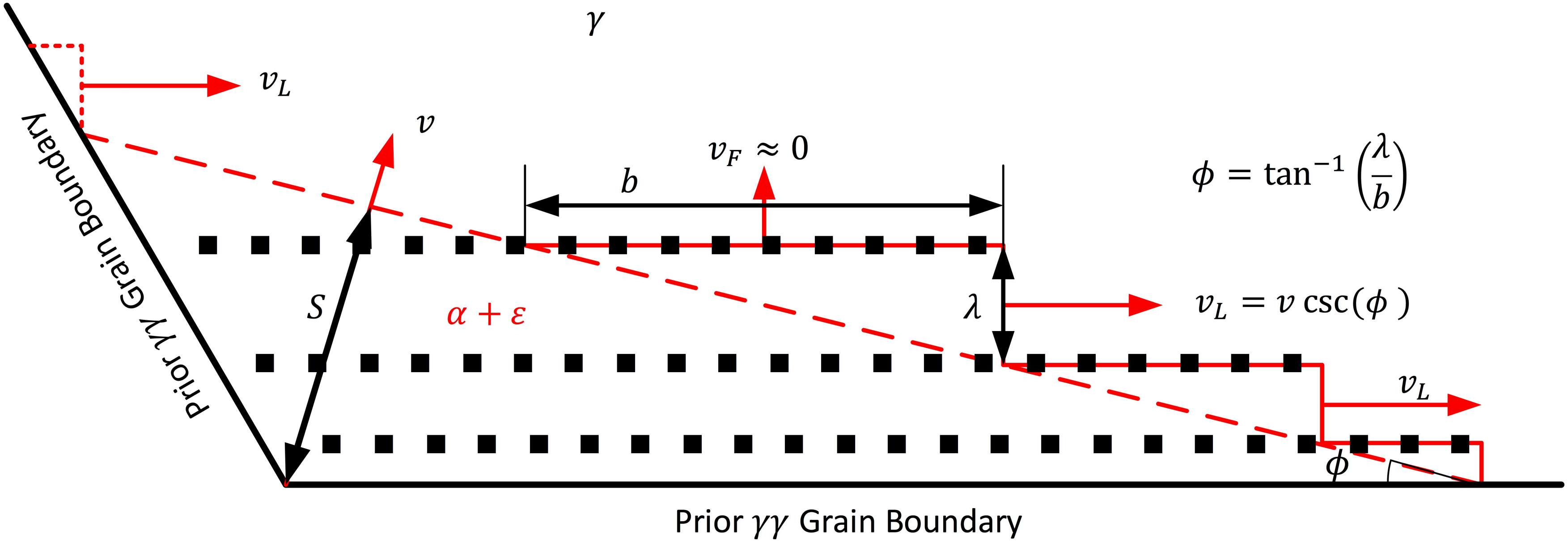


Agenda

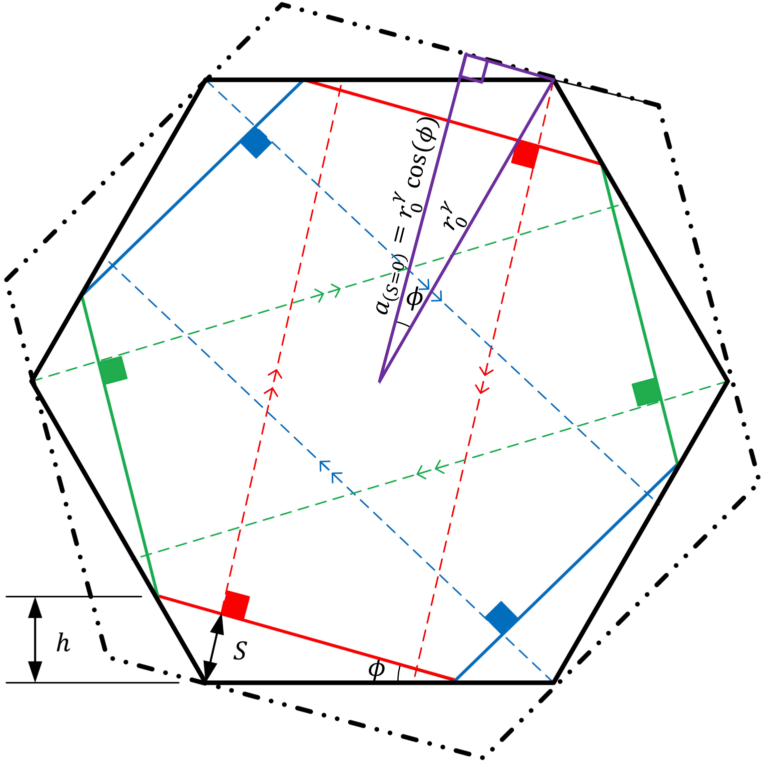


- Interphase Precipitation Model
- **New improvements**
- Summary

Improved GEB Model



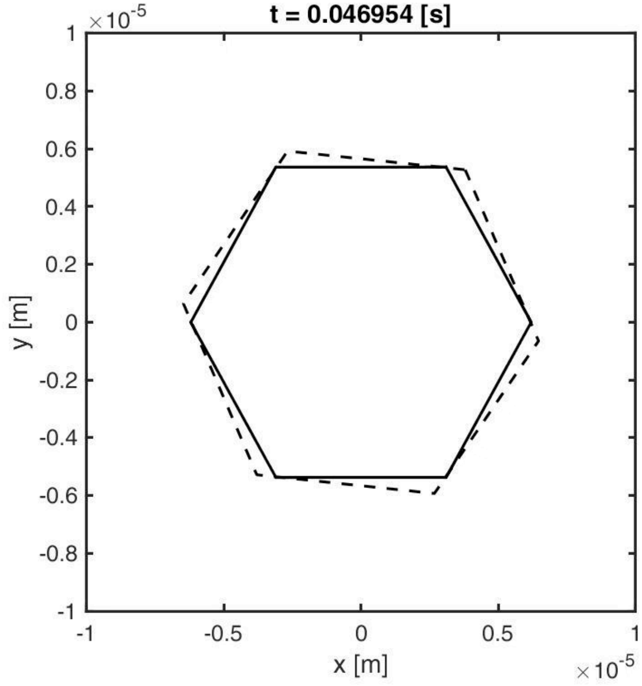
Improved GEB Model



Hexagon Representing Austenite Grain

Hexagon Representing Forming Ferrite Grains When $S = 0$

Hexagon Representing Forming Ferrite Grains.

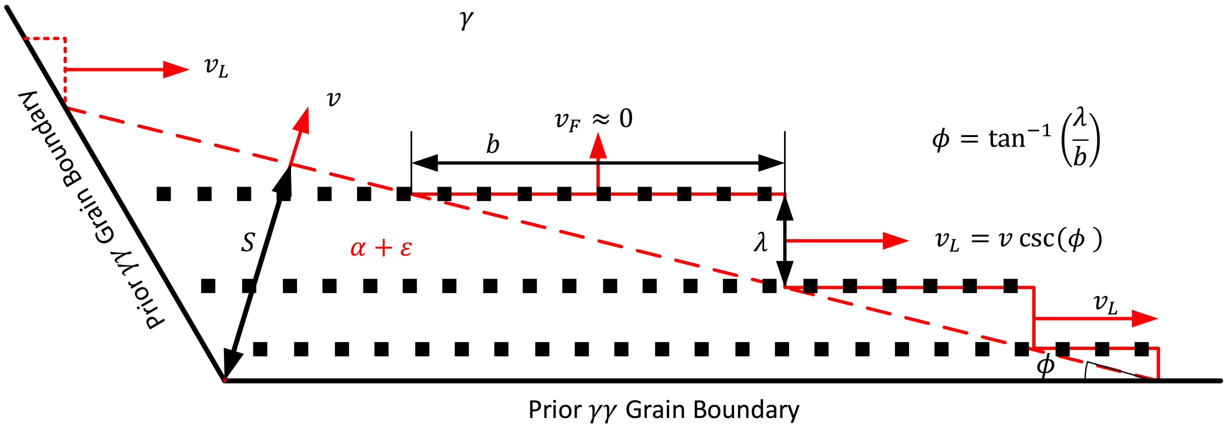


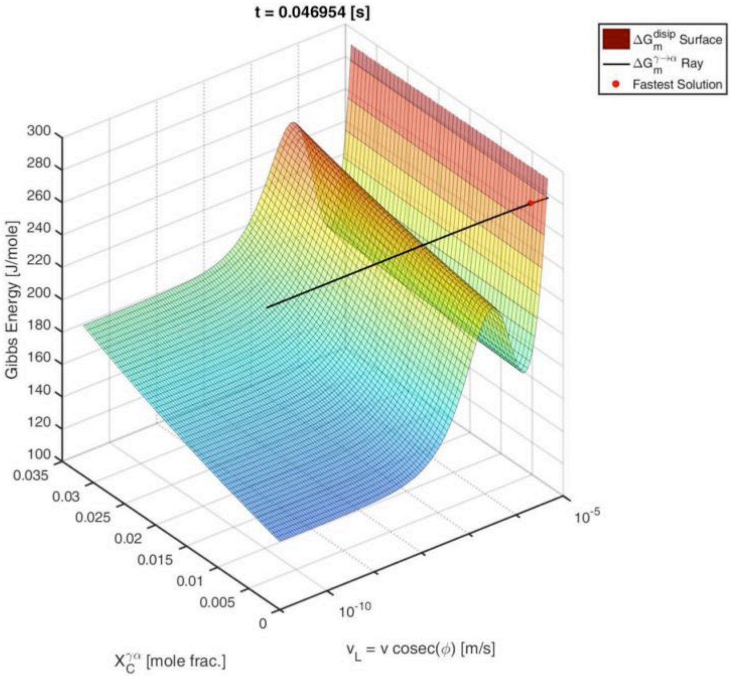
Intrinsic Mobility of Ledge Risers

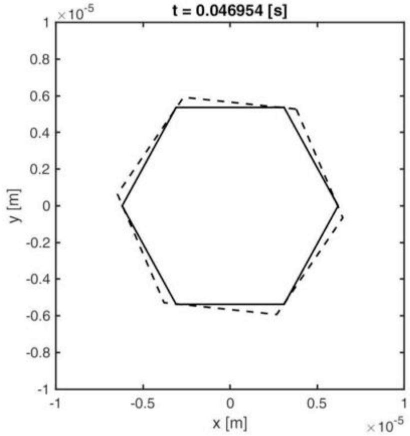
$$\Delta G_m^{frict} = \frac{v_L}{M_m^{\gamma\alpha R}} \approx \frac{v}{M_m^{\gamma\alpha^*}}$$

$$M_m^{\gamma\alpha^*} = 0.058exp\left(\frac{-140\times10^3}{RT}\right) \quad [mmol.J^{-1}\, s^{-1}]$$

G.P. Krielaart, J. Sietsma, and S. van der Zwaag: *Mater. Sci. …*, (1997).




t = 0.046954 [s]
ΔG_m^disip Surface
ΔG_m^γ→α Ray
Fastest Solution
Gibbs Energy [J/mole]
300
280
260
240
220
200
180
160
140
120
100
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
10^-10
10^-5
X_C^γα [mole frac.]
v_L = v cosec(ϕ) [m/s]

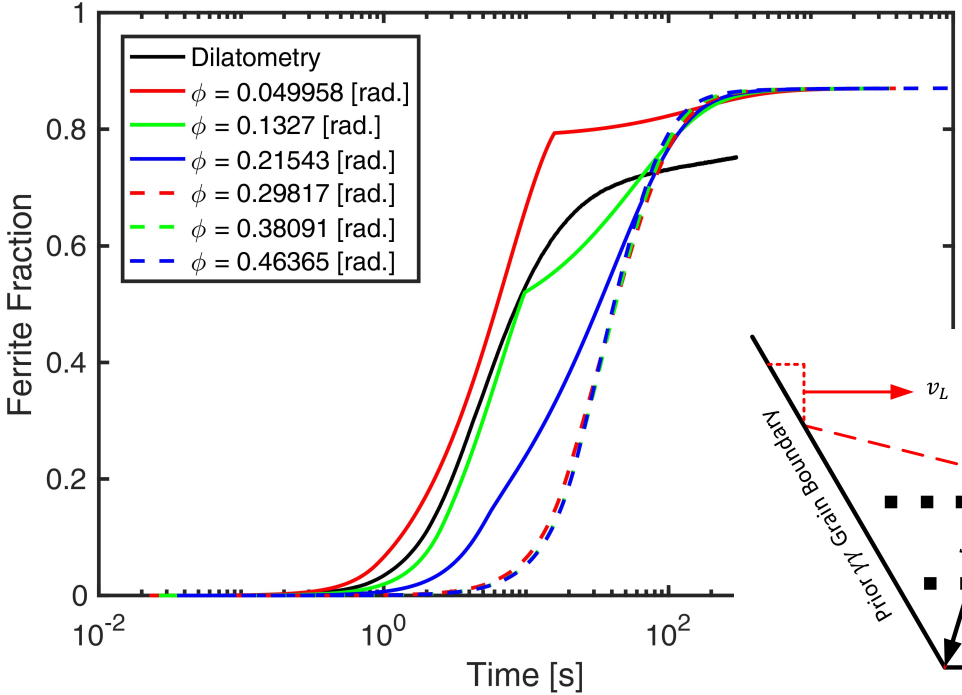

t = 0.046954 [s]
×10^-5
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
y [m]
-1
-0.5
0
0.5
1
x [m]
×10^-5

Case Studies

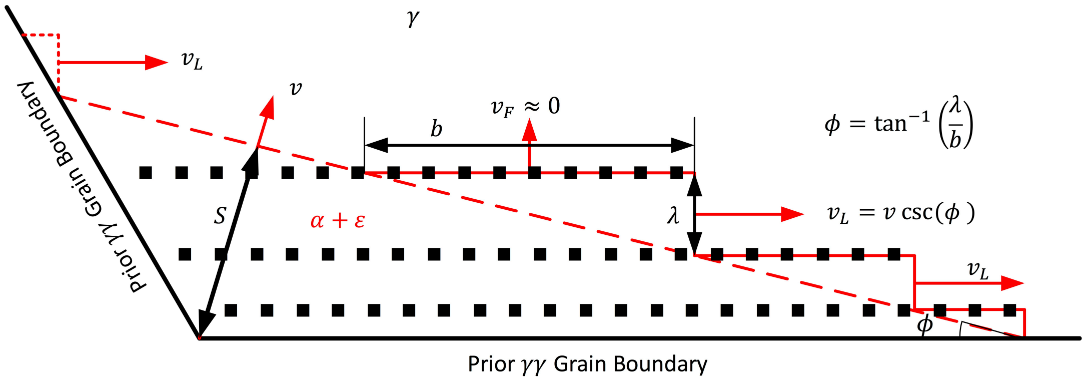
Element	Ref. HSLA $[wt\%]$	V HSLA $[wt\%]$
Mn	1.60	1.60
Si	0.20	0.18
V	~	0.20
C	0.038	0.047

Samples were isothermally transformed at $973\ [K]$ for $300\ [s]$. The austenite grain size was estimated to be $15.2 \pm 9.6\ [\mu m]$ and $12.4 \pm 6.5\ [\mu m]$, for the Ref-HSLA and V-HSLA respectively. **Measured using *in-situ* EBSD.**

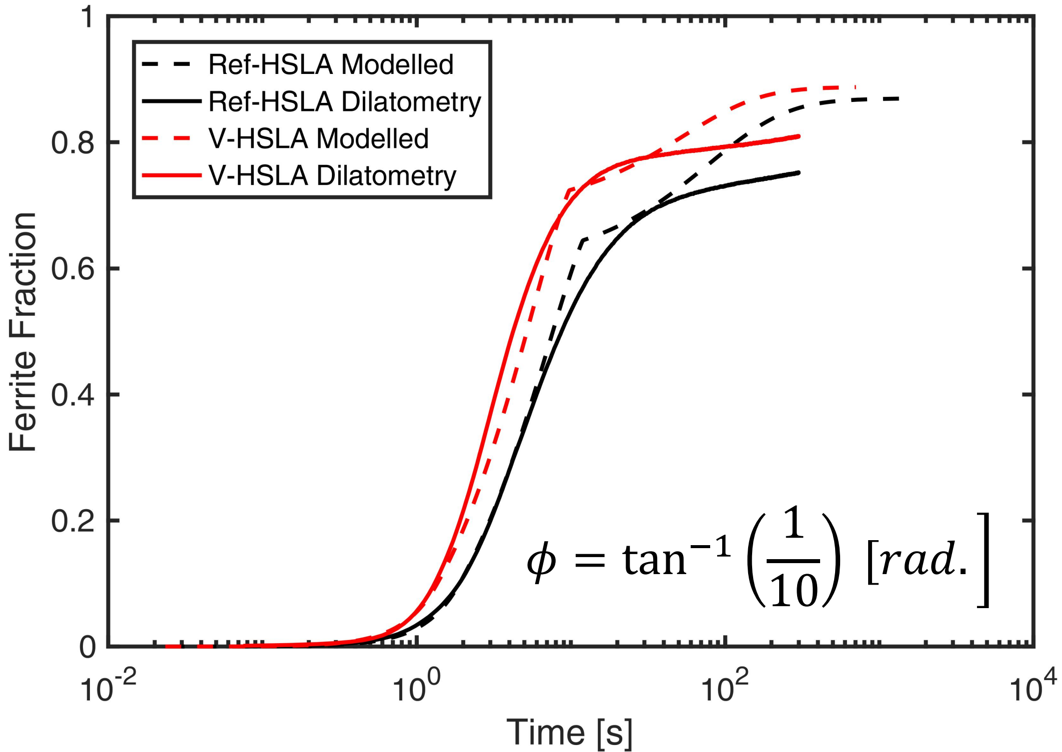
Adapted GEB Model - Fitting



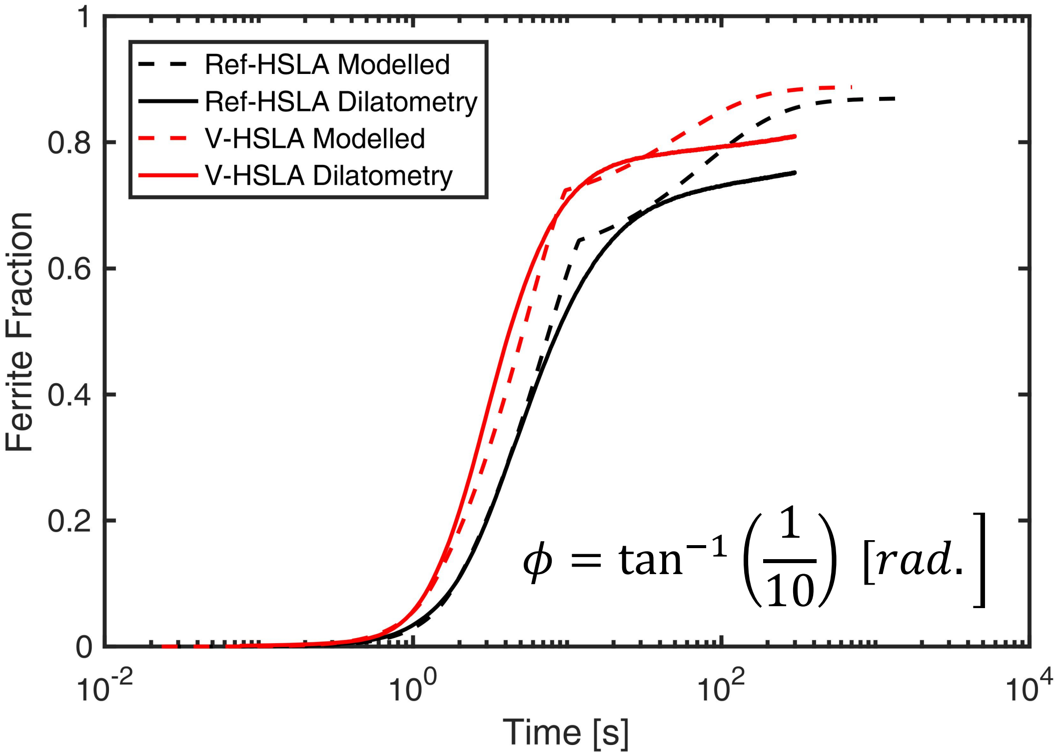
ϕ has been systematically varied until a reasonable match with the experimental kinetics has been achieved with the Ref-HSLA.



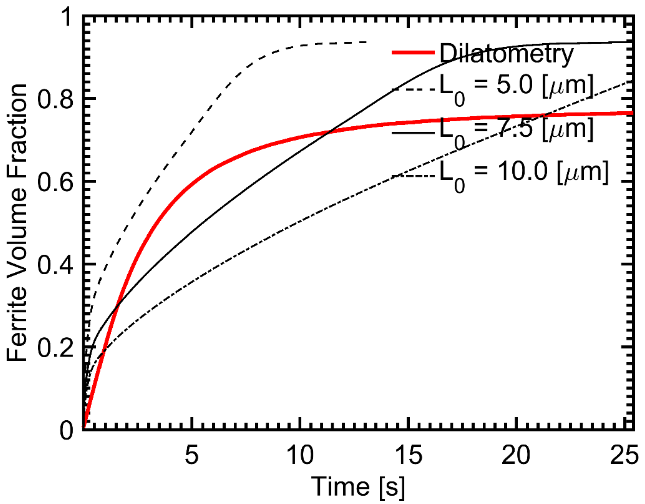
Adapted GEB Model - Kinetics



Adapted GEB Model - Comparison



Previous – V-HSLA

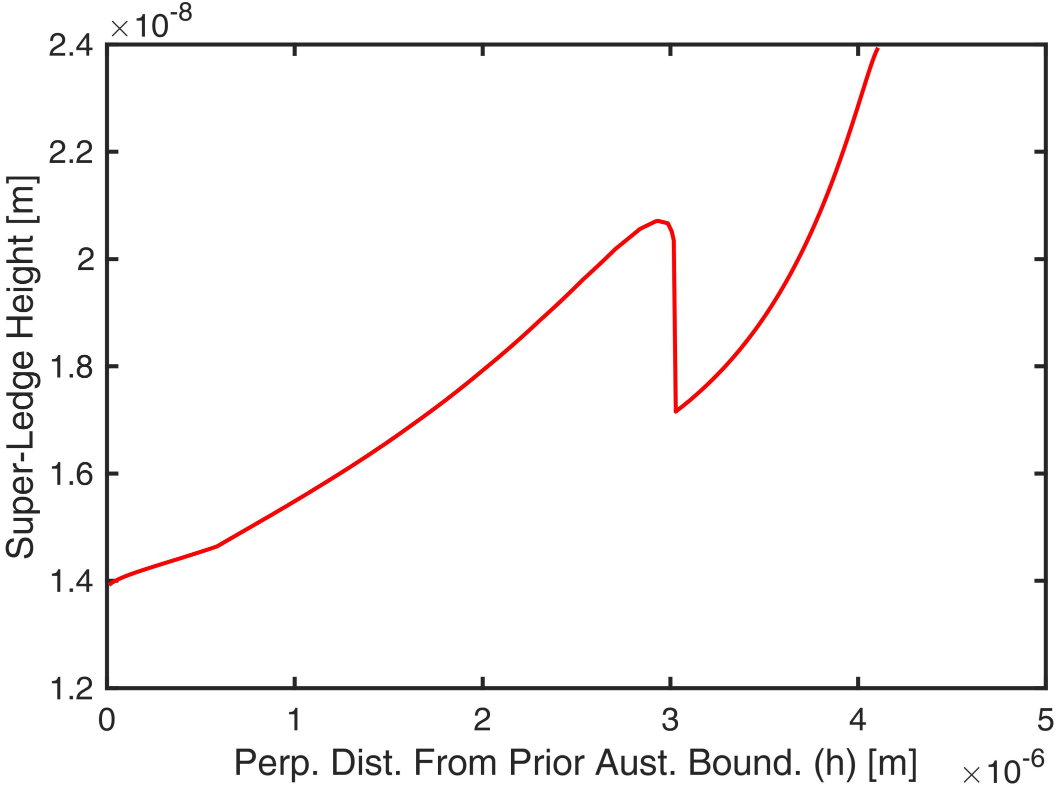


Intrinsic Mobility

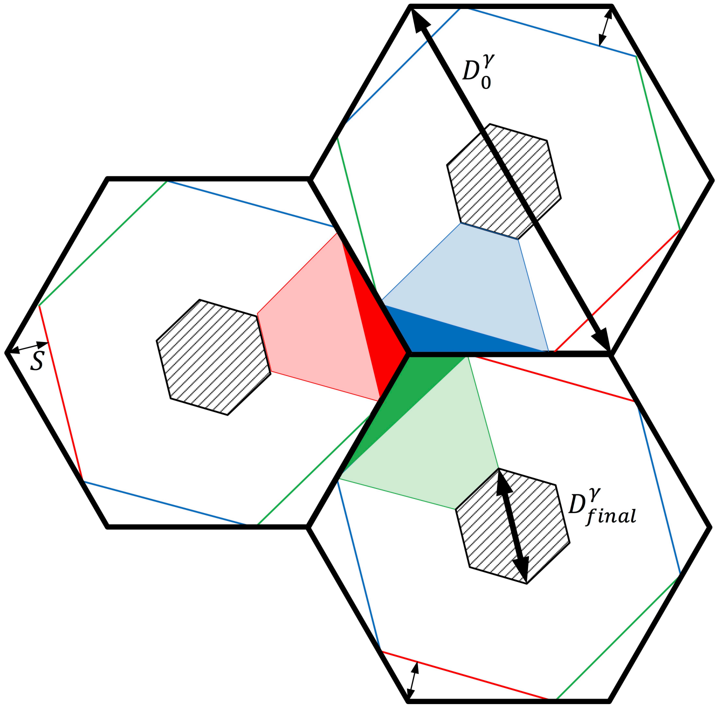
$$\Delta G_m^{frict} = \frac{v_L}{M_m^{\gamma\alpha R}} \approx \frac{v}{M_m^{\gamma\alpha^*}}$$

$$M_m^{\gamma\alpha R} = \mathbf{0.58} exp\left(\frac{-140\times10^3}{RT}\right) \quad [mmol.J^{-1}\ s^{-1}]$$

Inter-sheet Spacing



Improved Model - Possibilities



- Combine many ‘unit models’ to account for factors such as heterogeneous austenite grain size.

Summary

THE UNIVERSITY OF WARWICK

1. A model is presented using the solute drag model of Purdy and Bréchet, the GEB concept, and the theory of the diffusional formation of super-ledges by Bhadeshia.
2. Rather the inter-sheet spacing is controlled by a complex interplay between the factors of interfacial energy, interfacial segregation.
3. The intrinsic mobility of ledge risers us estimated to be 10 times greater than previously suggested relationships for planar disordered interphases.