A new heat treatment design for medium Mn steel: the austenitization from pearlite

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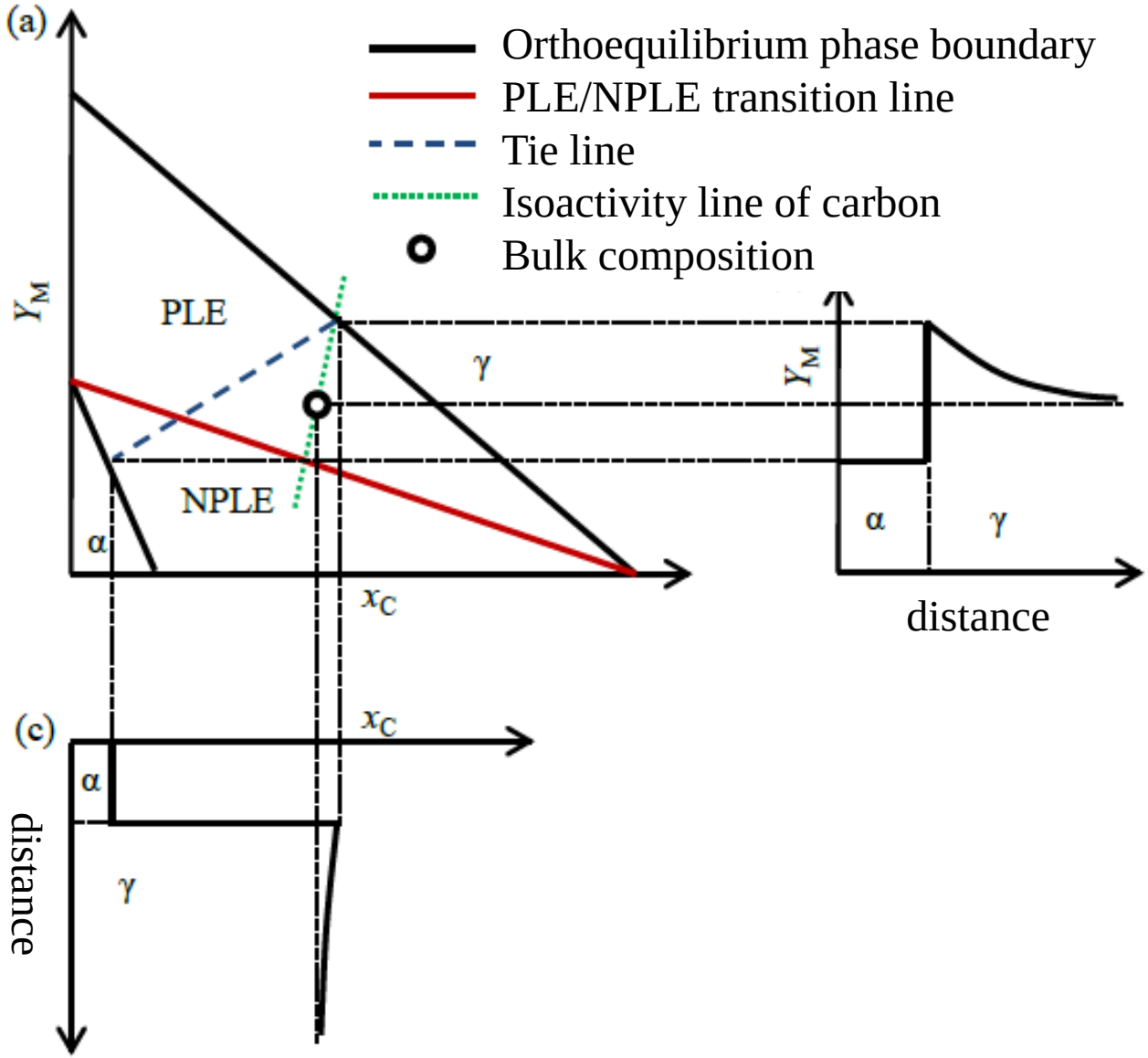
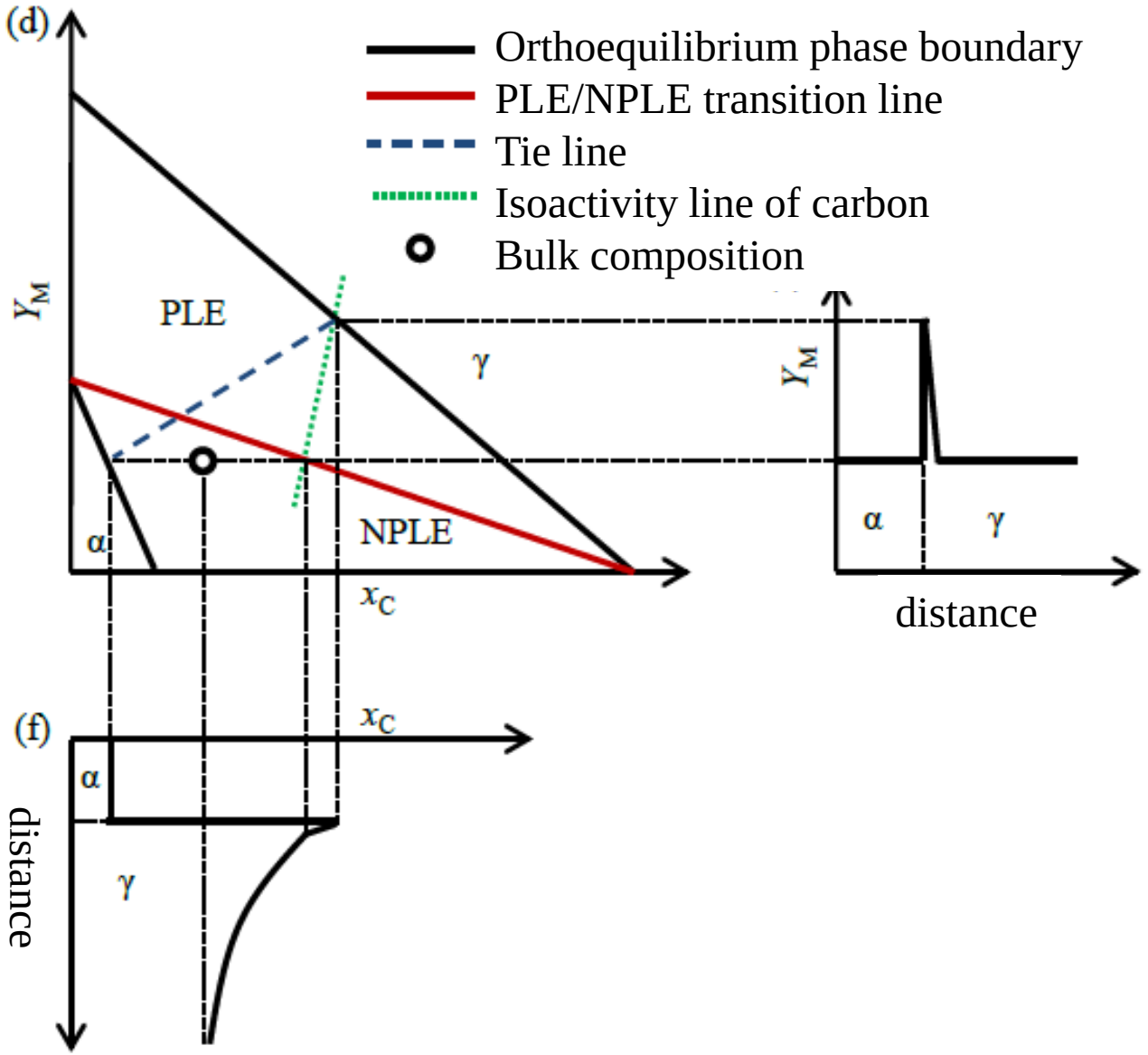
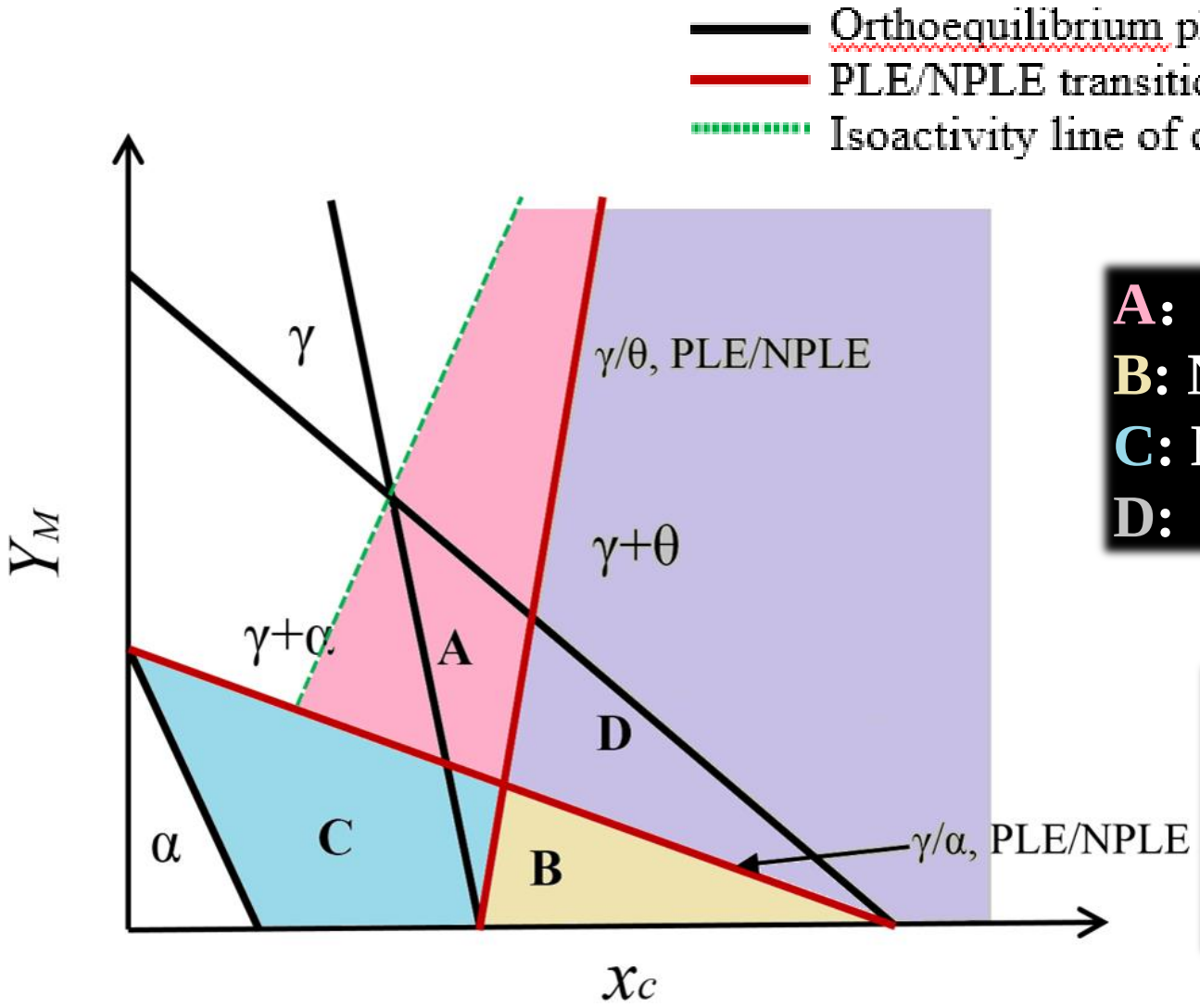
Ferrite Transformation-PLE mode



Ferrite Transformation-NPLE mode



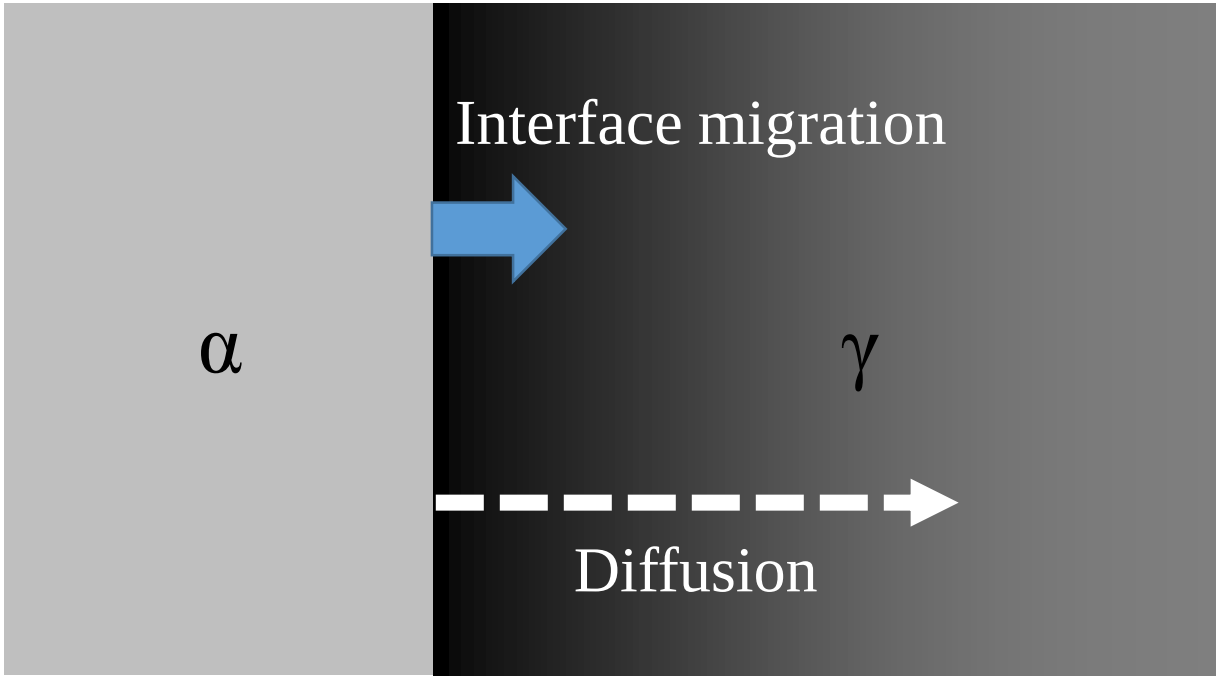
Pearlite Transformation



A: PLE-α + PLE-θ
B: NPLE-α + NPLE-θ
C: NPLE-α + PLE-θ
D: PLE-α + NPLE-θ

A: Ortho-pearlite
B : Para-pearlite
C : Proeutectiod α
D : Proeutectiod θ

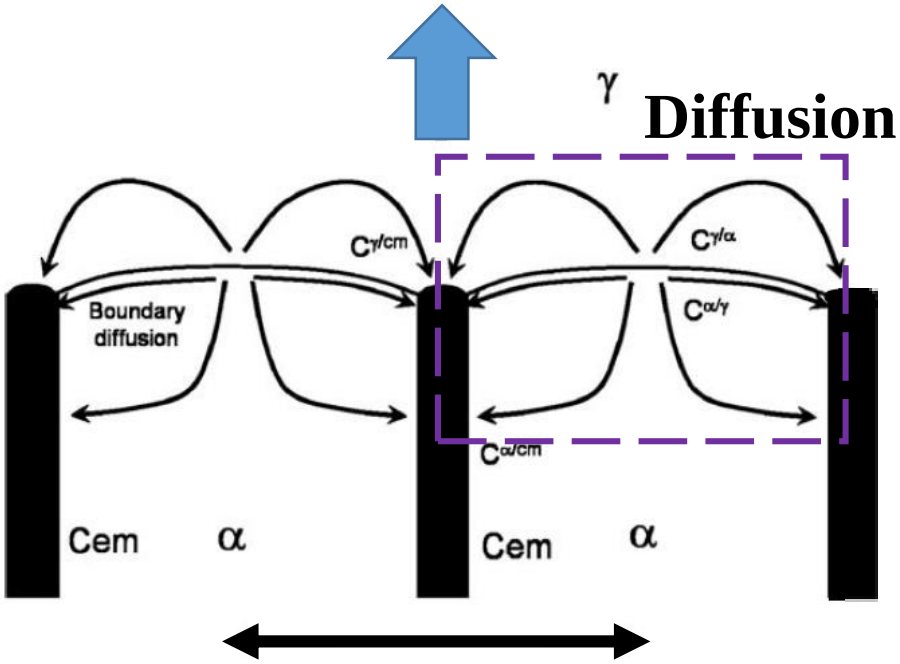
Ferrite Transformation



1D model

Pearlite Transformation

Interface migration



Lamellar Spacing

Diffusional path

γ

$$v = \frac{2D^{\gamma}S}{S^{\alpha}S^{\theta}}\left(\frac{c_e^{\gamma/\alpha}-c_e^{\gamma/\theta}}{c^{\theta/\gamma}-c^{\alpha/\gamma}}\right)\left(1-\frac{S_C}{S}\right)$$

B

$$v = \frac{16D^{B}\delta}{S^{\alpha}S^{\theta}}\left(\frac{c_e^{\gamma/\alpha}-c_e^{\gamma/\theta}}{c^{\theta/\gamma}-c^{\alpha/\gamma}}\right)\left(1-\frac{S_C}{S}\right)$$

α

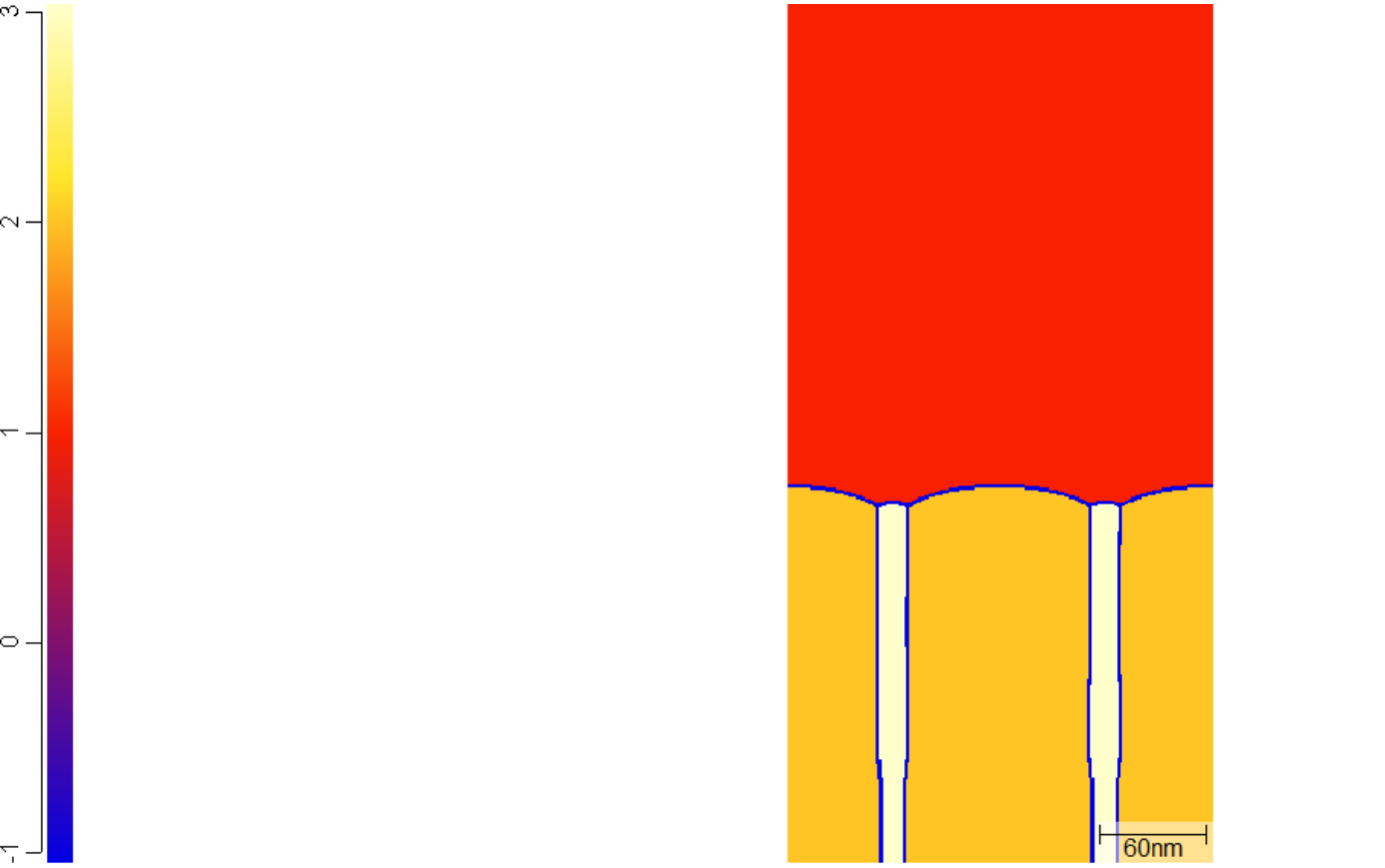
?

1. Which path works for carbon? Which for alloying elements?

2. Is there transition between different modes?

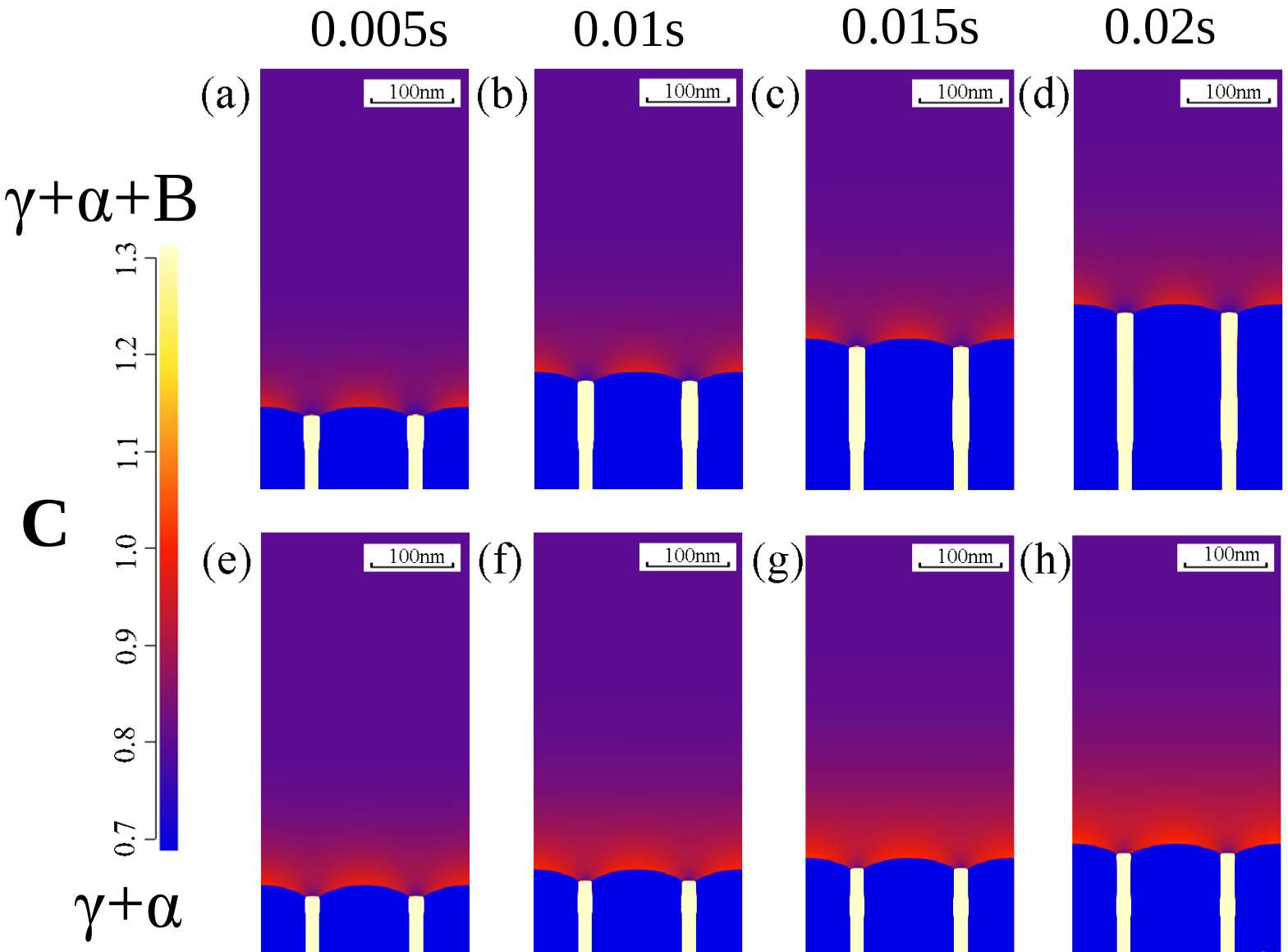
PFM_Phase Field

Fe-0.81C T=675ºC t= 0s 0.25s

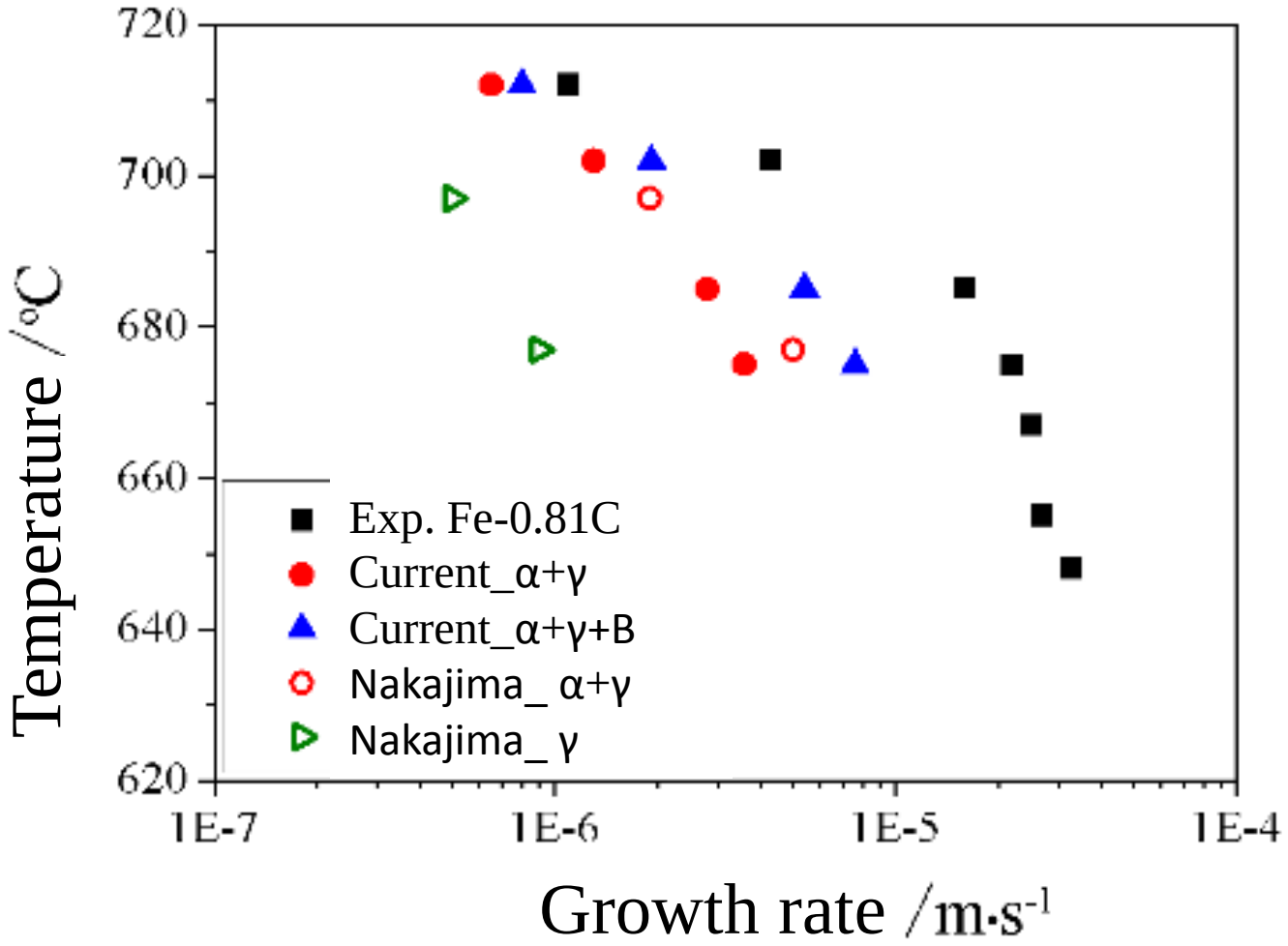


per_Fe-0.81C_675_GB_96851_phas.mcr, X: 1 to 238, Y: 1 of 1, Z: 1 to 480, Time: 0s

PFM_Conc. Field



PFM_Diffusion Path



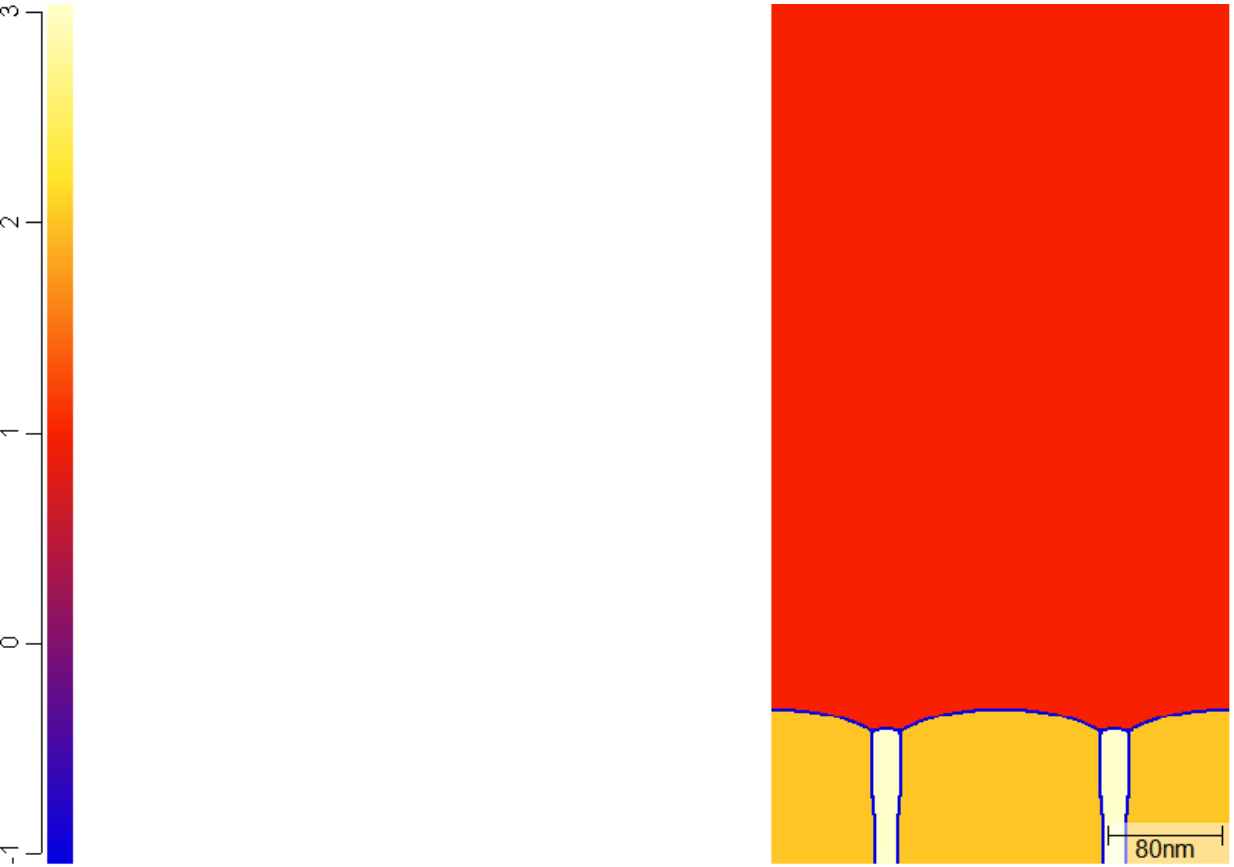
PFM_Phase Field

Fe-0.69C-1.80Mn T=650℃ t=0s

per_923_Fe-0.69C-1.8Mn_Dgb-Mn155000-C96851_phas.mcr, X: 1 to 320, Y: 1 of 1, Z: 1 to 600, Time: 0s

PFM_Phase Field

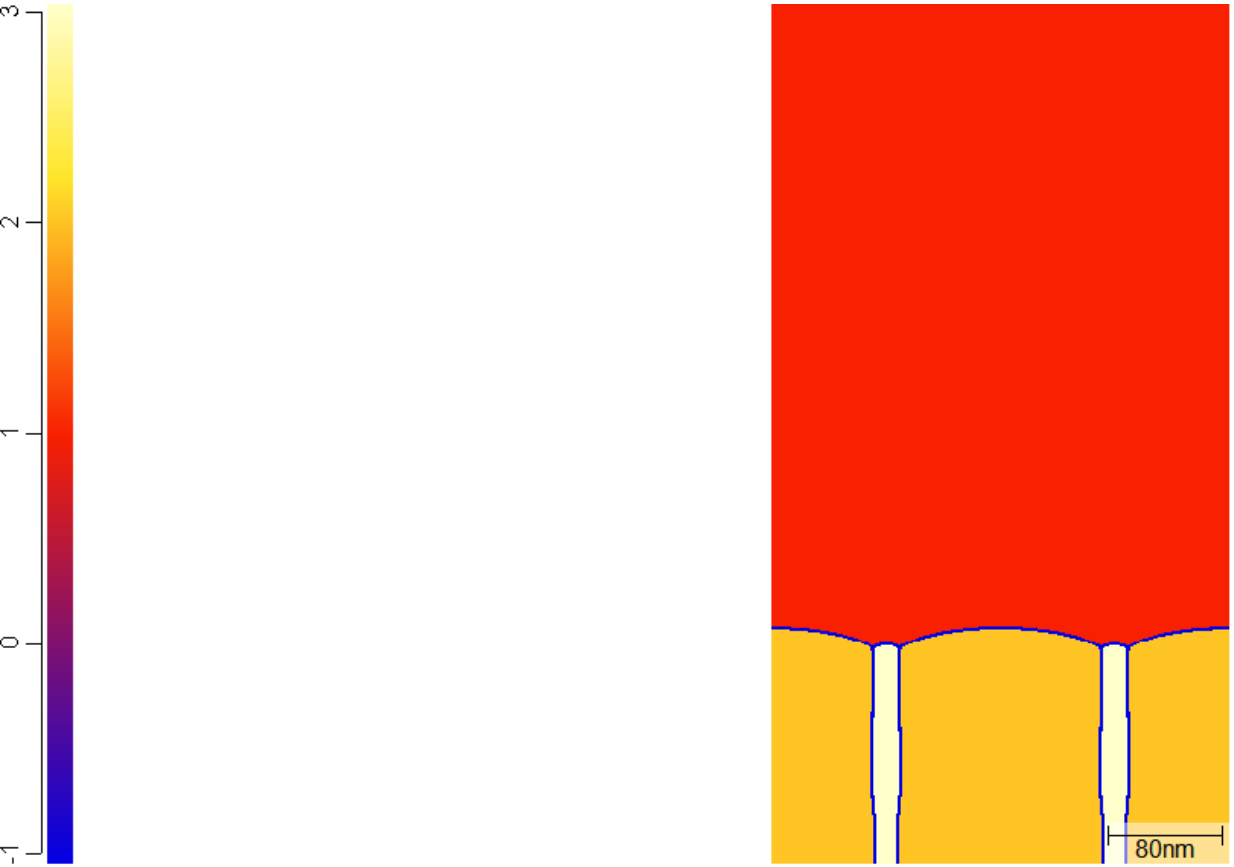
Fe-0.69C-1.80Mn T=650℃ t=0.02s



per_923_Fe-0.69C-1.8Mn_Dgb-Mn155000-C96851_phas.mcr, X: 1 to 320, Y: 1 of 1, Z: 1 to 600, Time: 0s

PFM_Phase Field

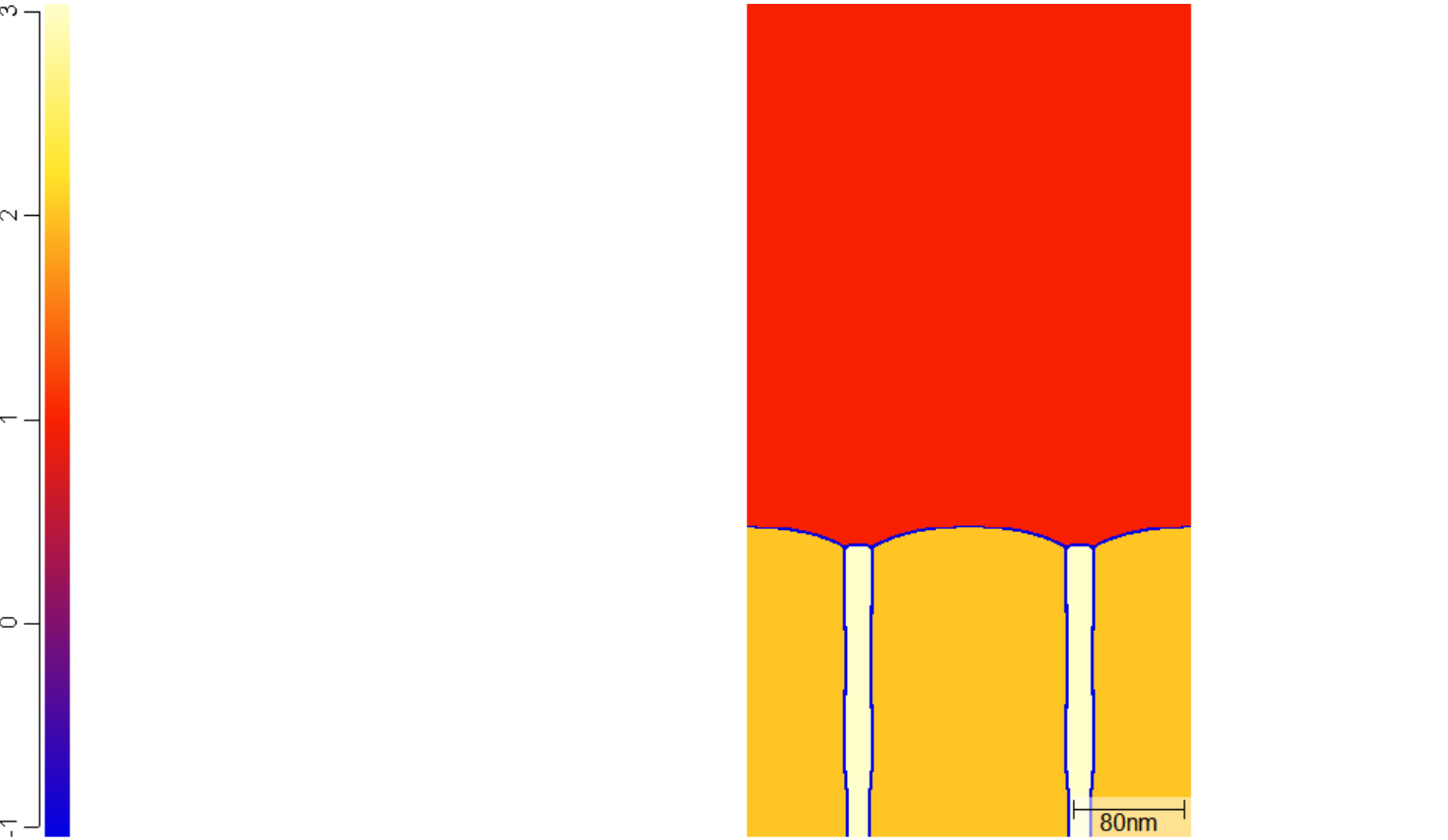
Fe-0.69C-1.80Mn T=650℃ t=0.04s



per_923_Fe-0.69C-1.8Mn_Dgb-Mn155000-C96851_phas.mcr, X: 1 to 320, Y: 1 of 1, Z: 1 to 600, Time: 0s

PFM_Phase Field

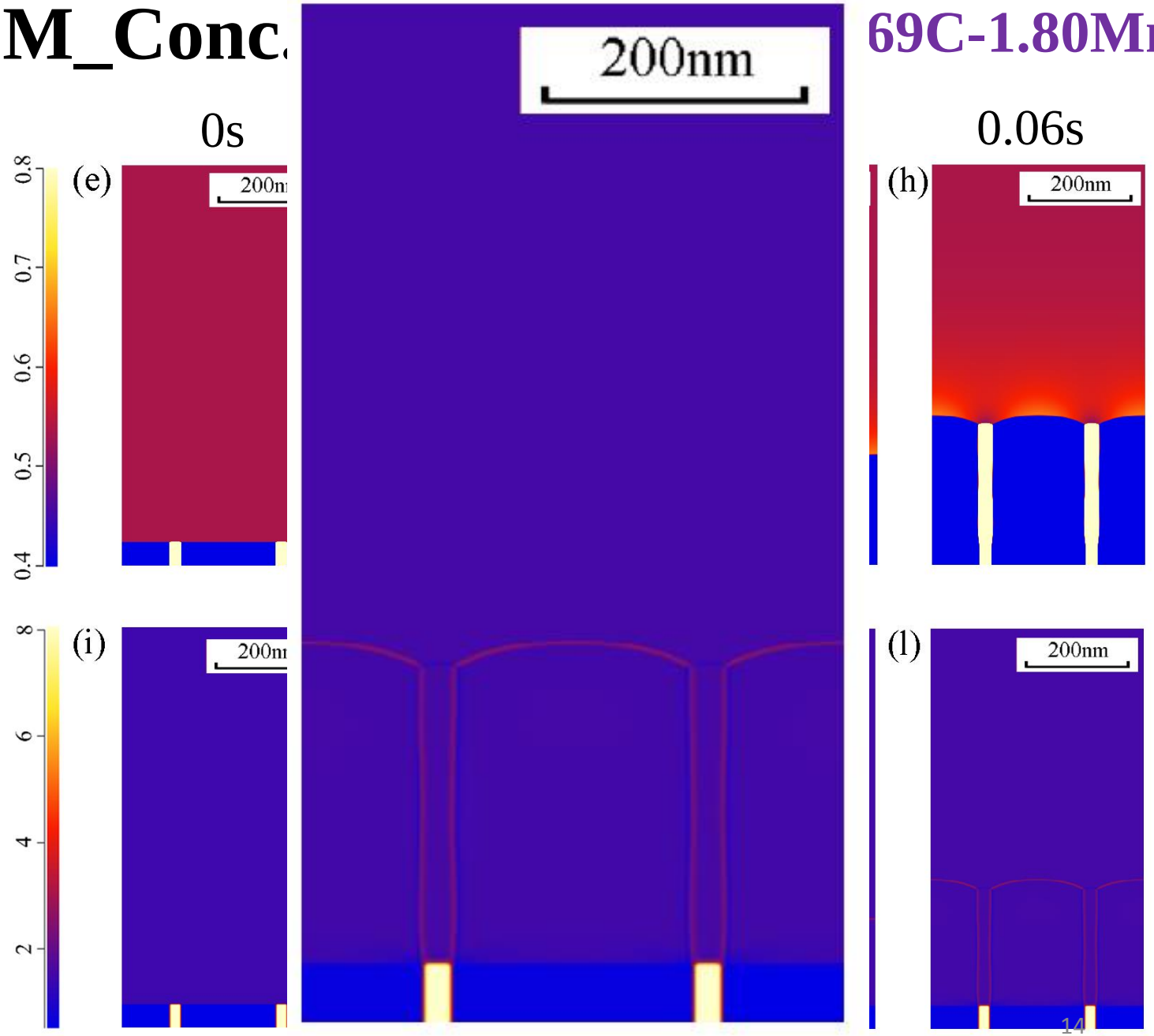
Fe-0.69C-1.80Mn T=650℃ t=0.06s



per_923_Fe-0.69C-1.8Mn_Dgb-Mn155000-C96851_phas.mcr, X: 1 to 320, Y: 1 of 1, Z: 1 to 600, Time: 0s

PFM_Conc

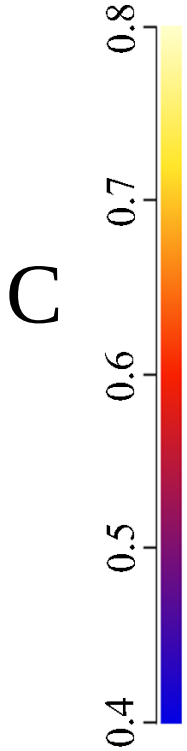
69C-1.80Mn

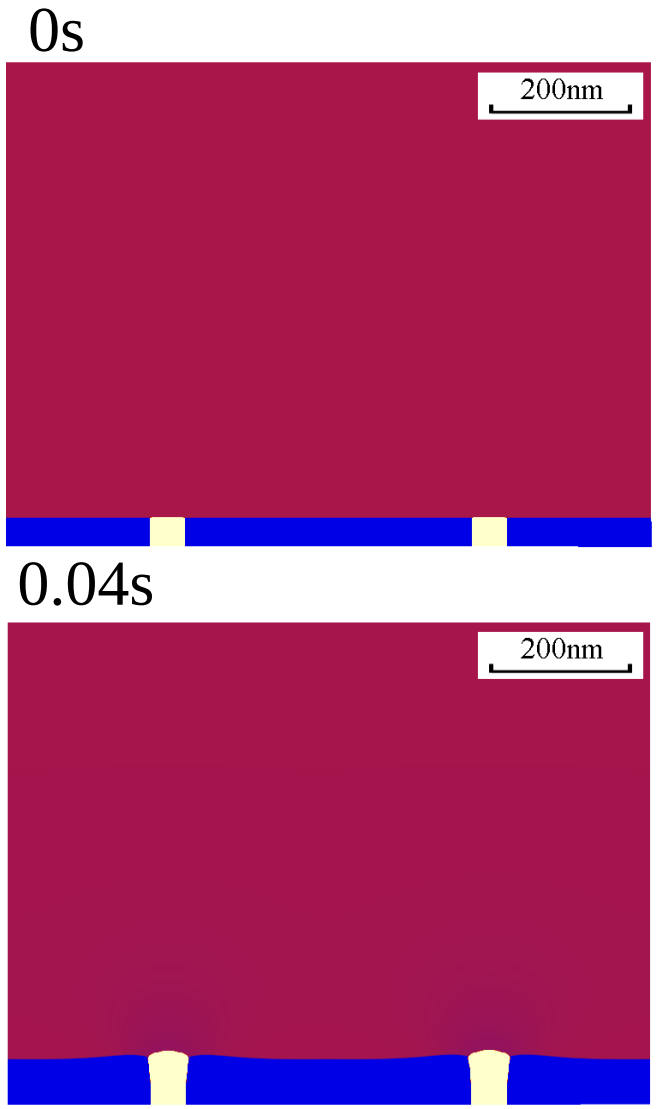


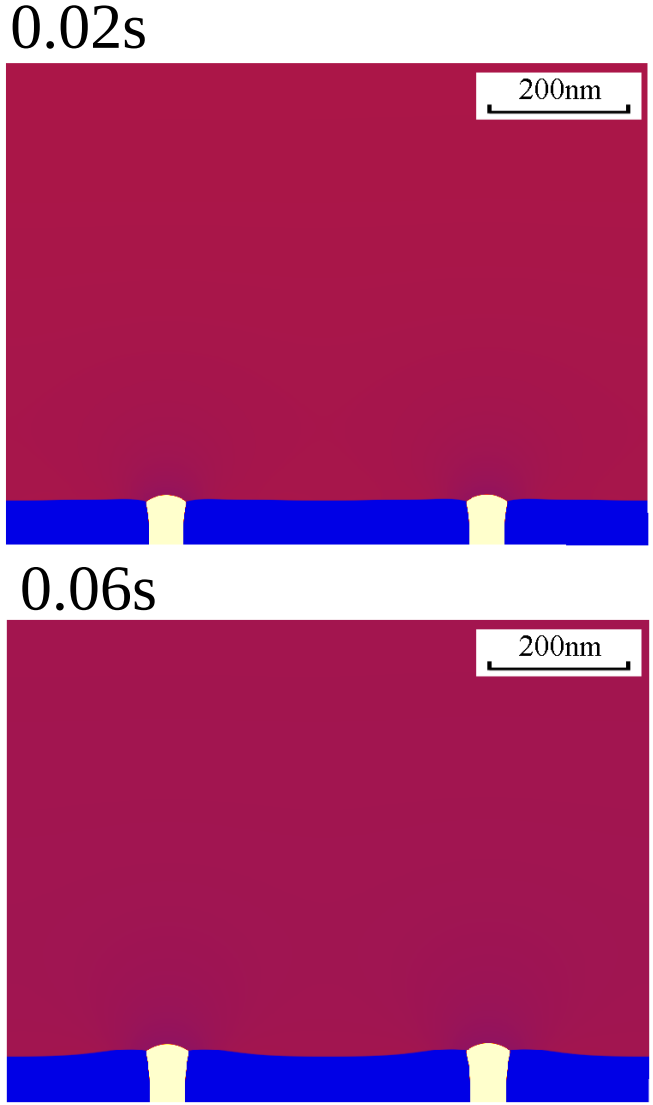
PFM_Conc. Field

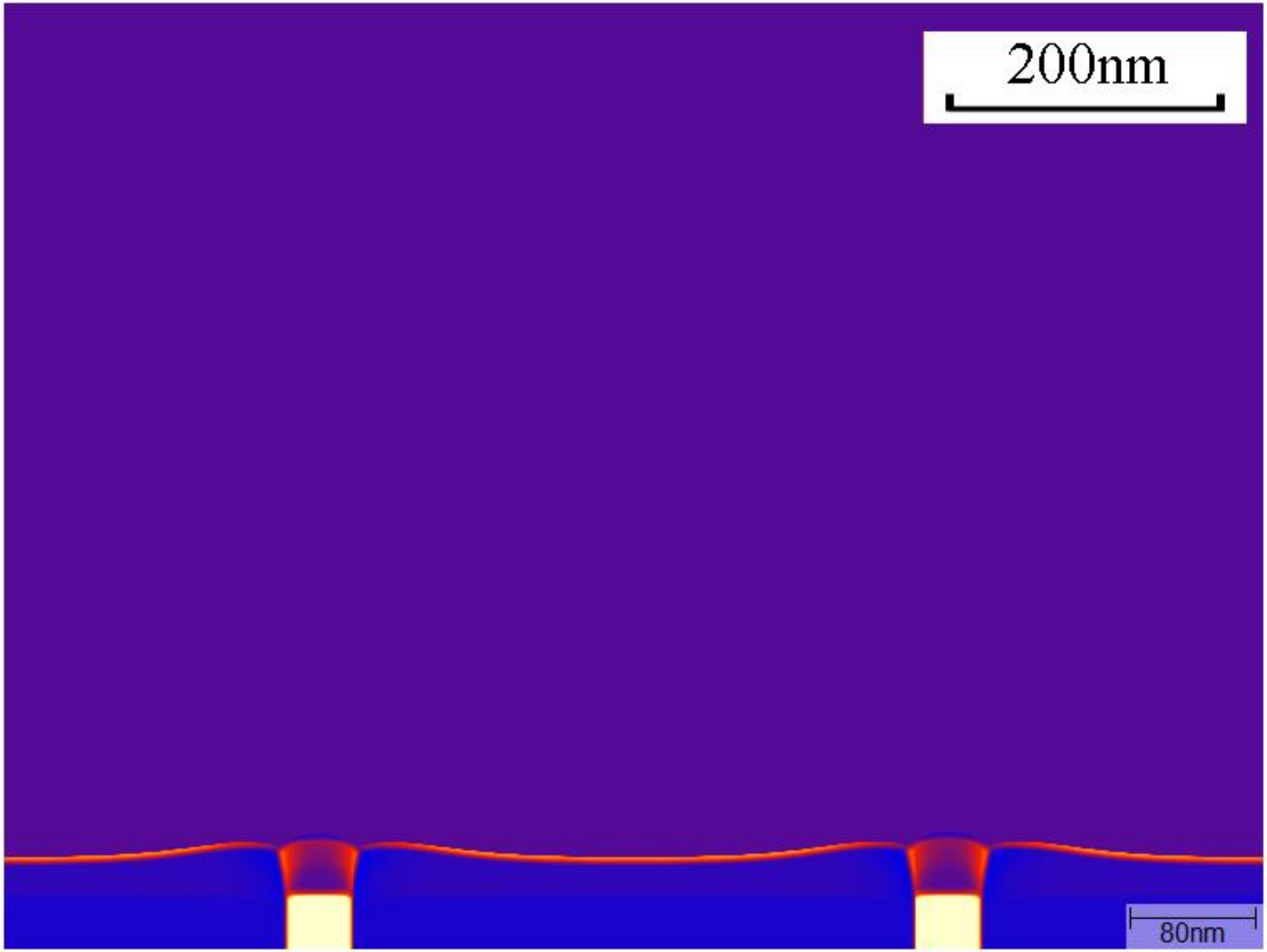
Fe-0.69C-1.80Mn

T=670^{o}C

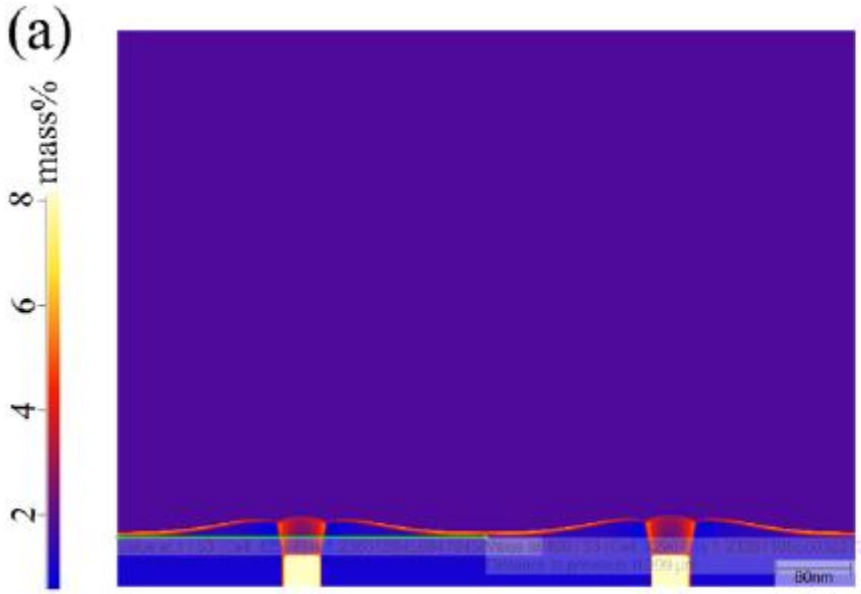


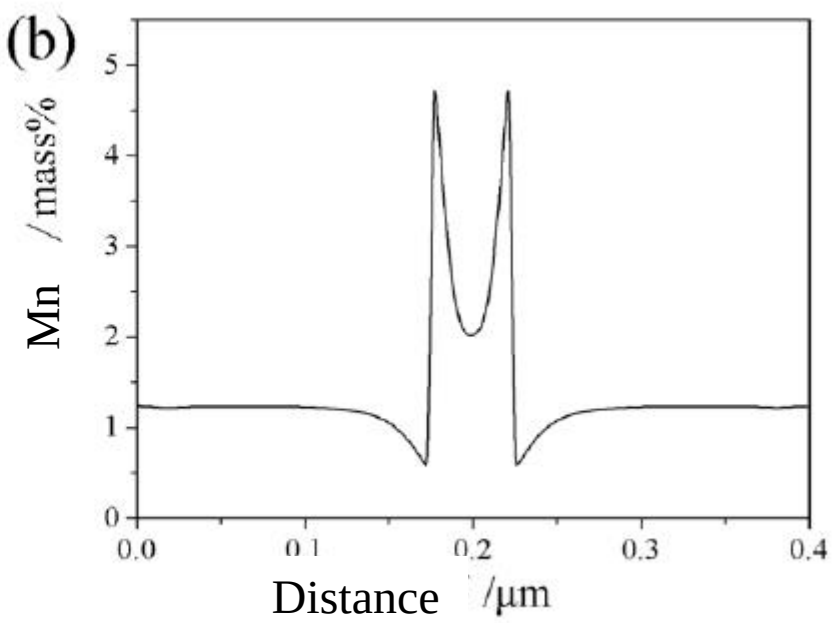





200nm
80nm

PFM_Conc.





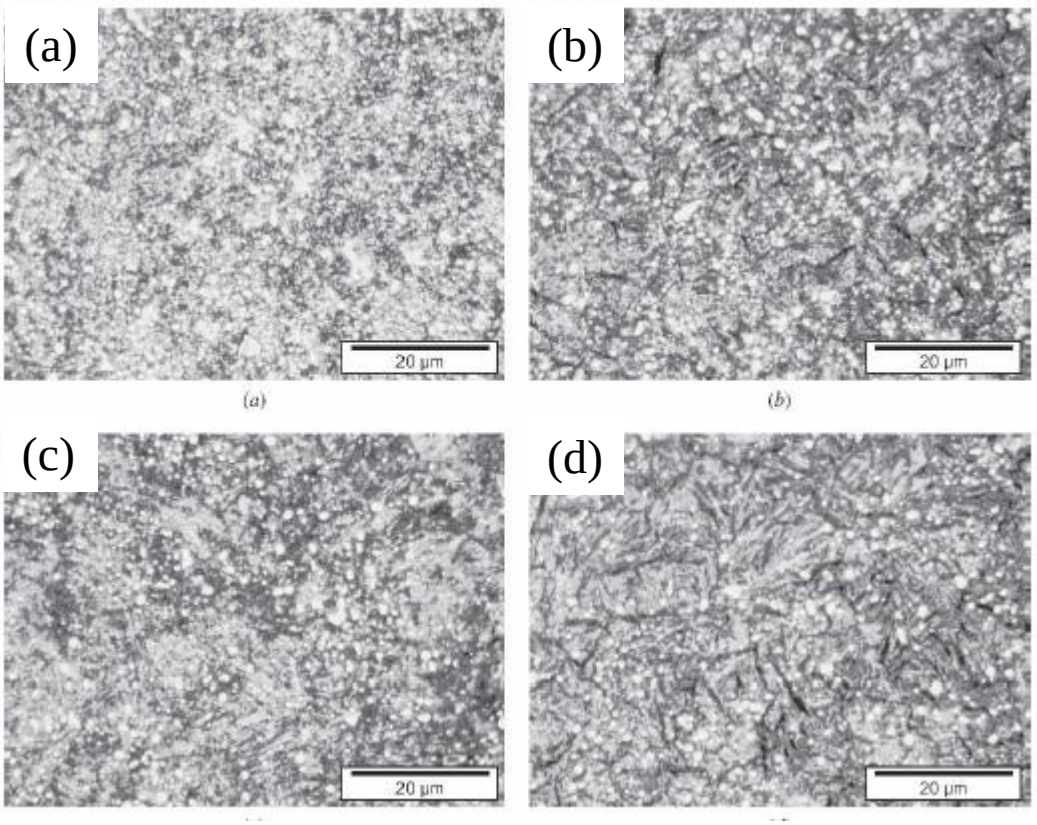
Temperature /°C	Growth rate /μm•s^{-1}		Partition coeffcient $k^{\theta/\alpha}$	
	Exp.	Sim.	Exp.	Sim.
650	0.15	2.95	1.3	1.1
660	0.042	0.11	2	2.36
670	0.01	0.024	3.4	3

PFM_Summary

1. In Fe-C binary system, the diffusion path of carbon includes austenite, ferrite and γ/p interface. Bulk diffusion dominates the transformation at higher temperature, while boundary diffusion becomes important at lower temperature.

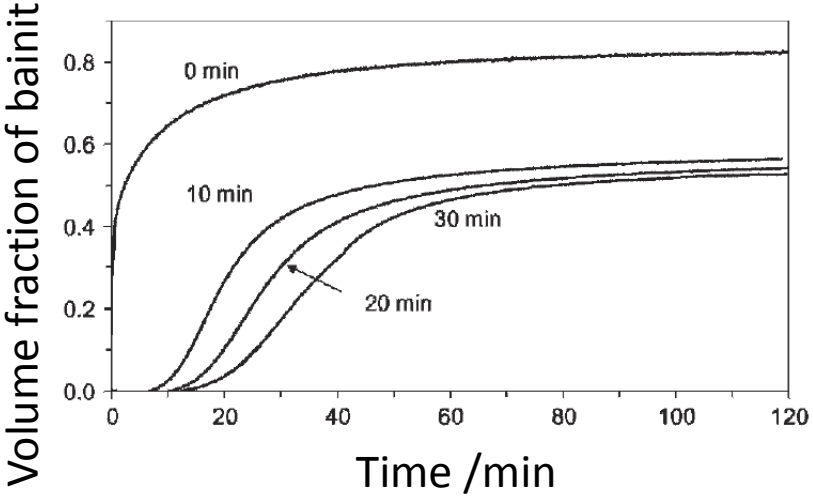
2. The pearlite transformation of Fe-0.69C-1.80Mn ternary system is controlled by C diffusion at 650^{o}C , while by Mn (boundary) diffusion at 670^{o}C.

Austenitization from pearlite



Fe-1C-1.36Cr alloy austenized at 860 ^{0}C for (a)0min (b)10min (c)20min (d)30min

230^{0}C



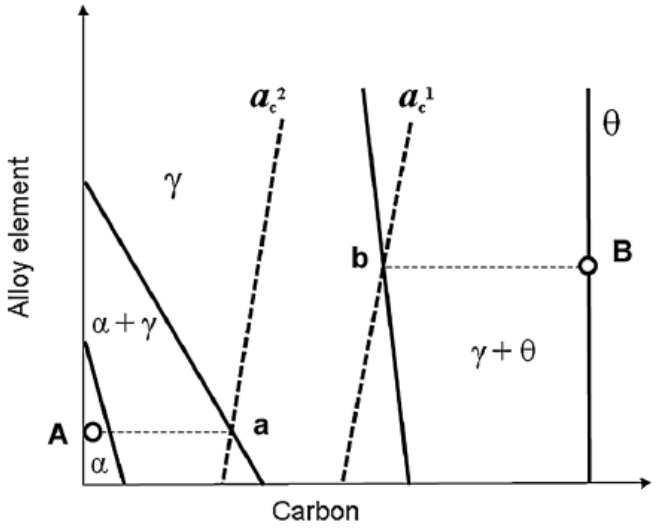
Incomplete dissolution of cementite particles

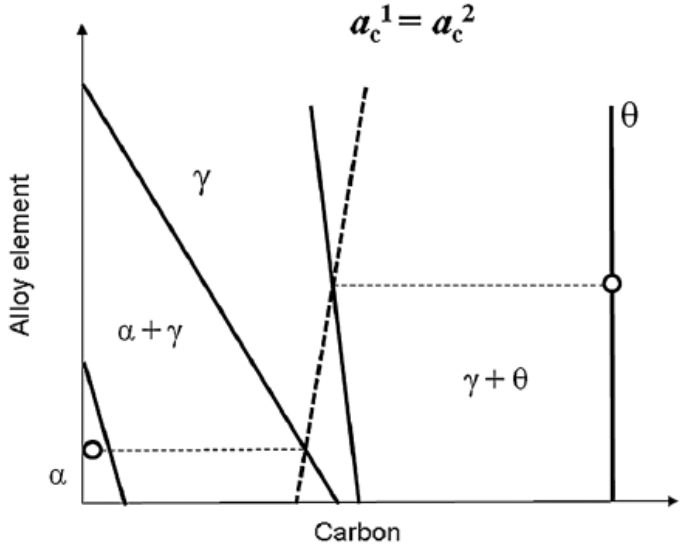
Enrichment of C in austenite

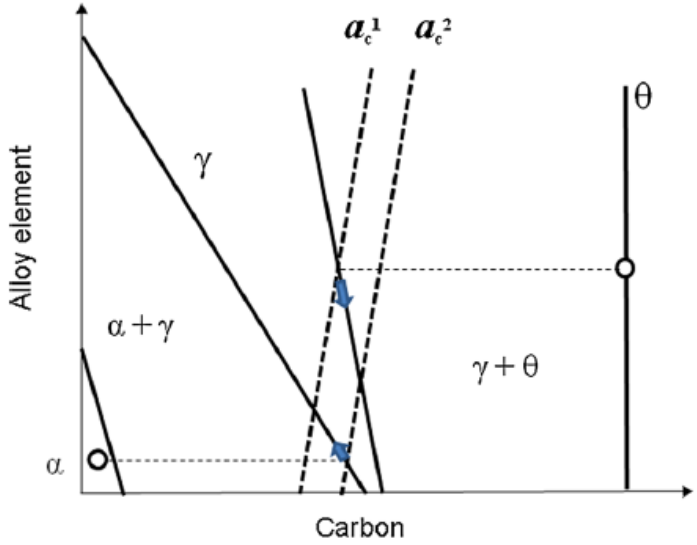
Nucleation site for Decomposition products

Zhao L, Vermolen F J, Sietsma J, et al. MMTA, 2006, 37(6): 1841-1850.

Austenitization_PNTT-I







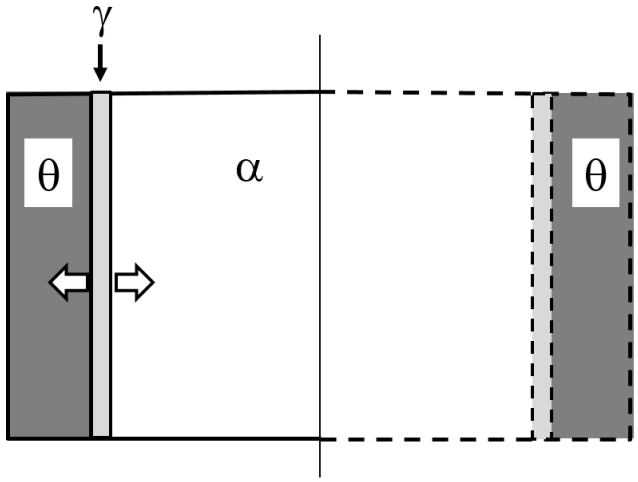
Austenitization_Dictra

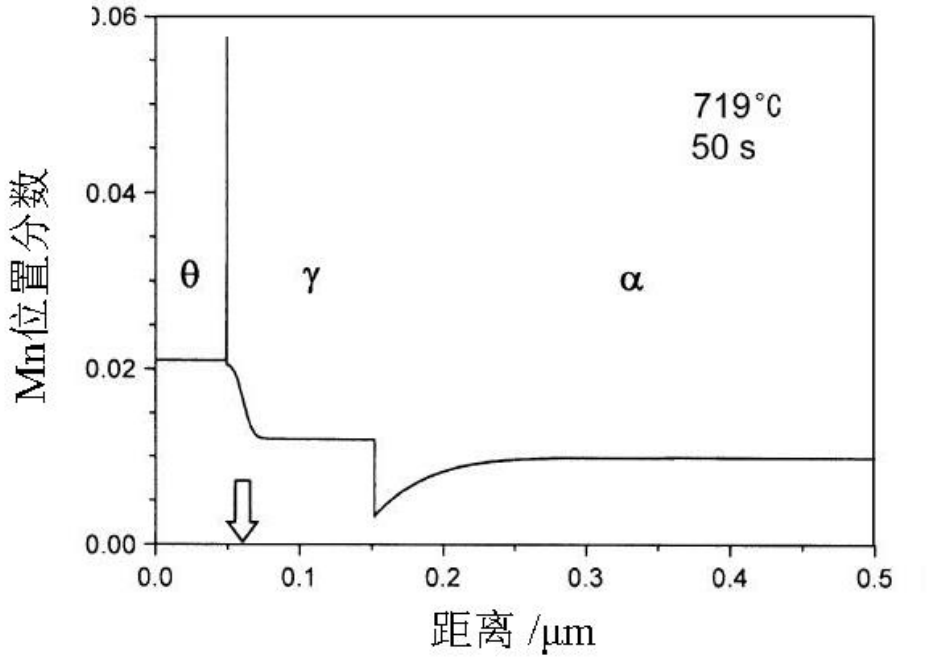
Fe-0.80C-1.08Mn

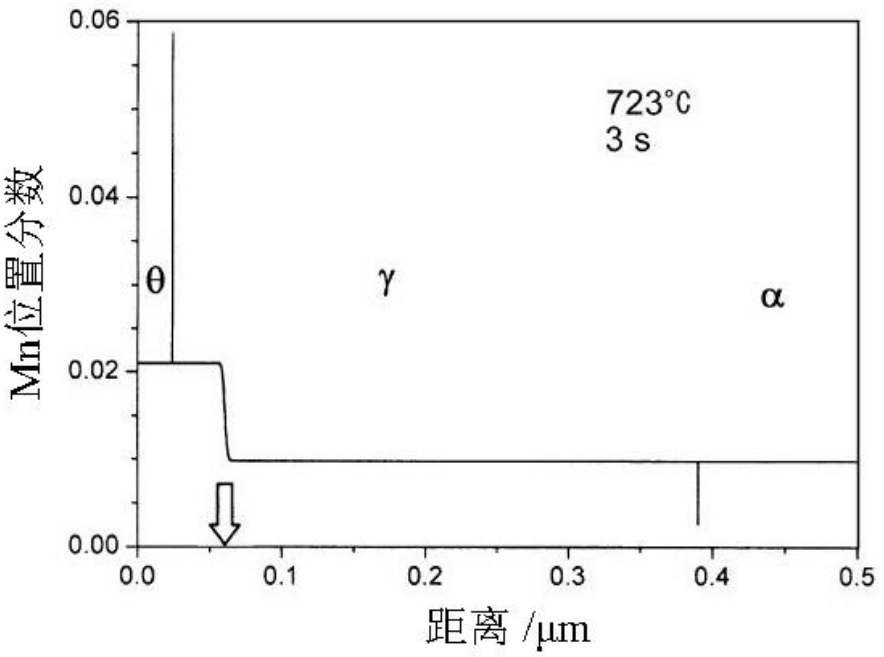
T_{ptr}=692^{0}C

Lamellar pearlite

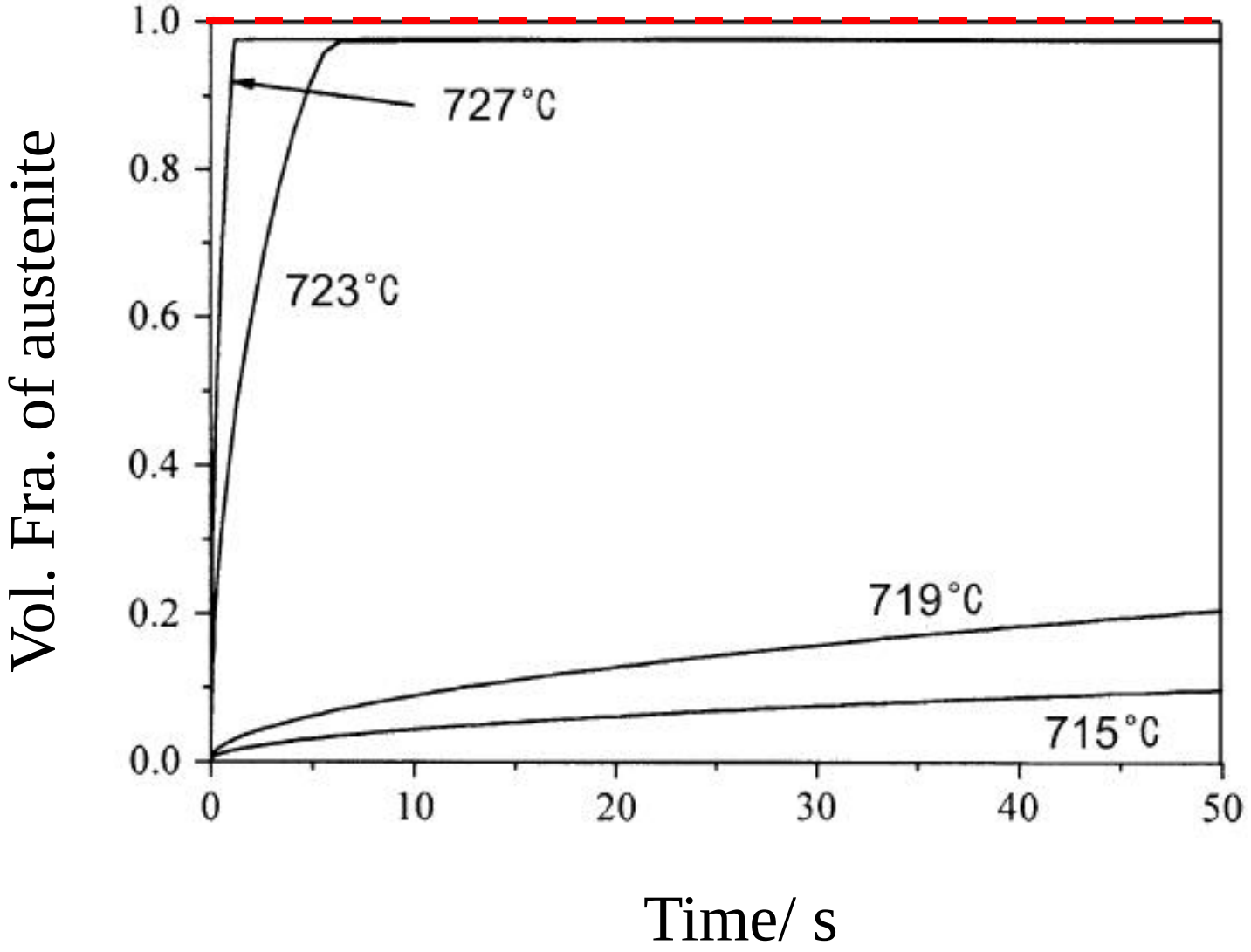
PNTT-I=721^{0}C







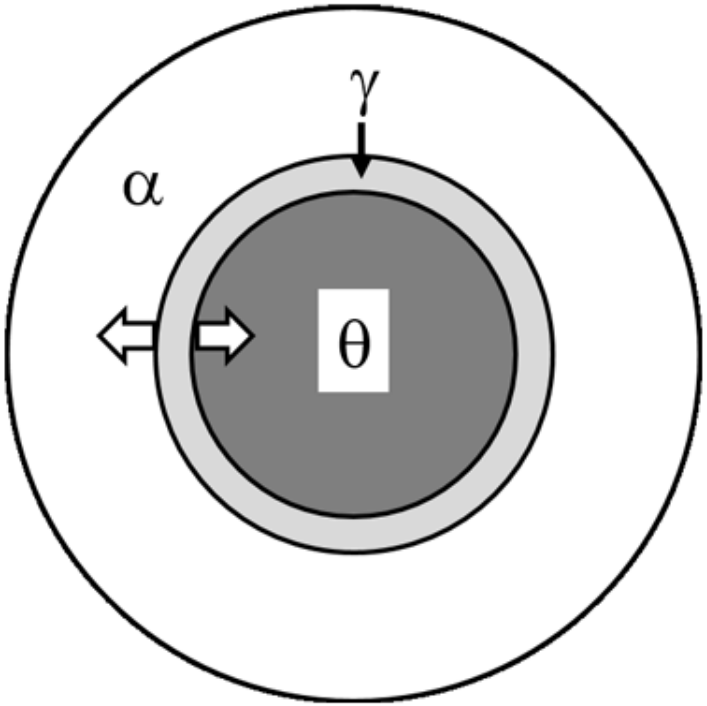
Austenitization_Dictra

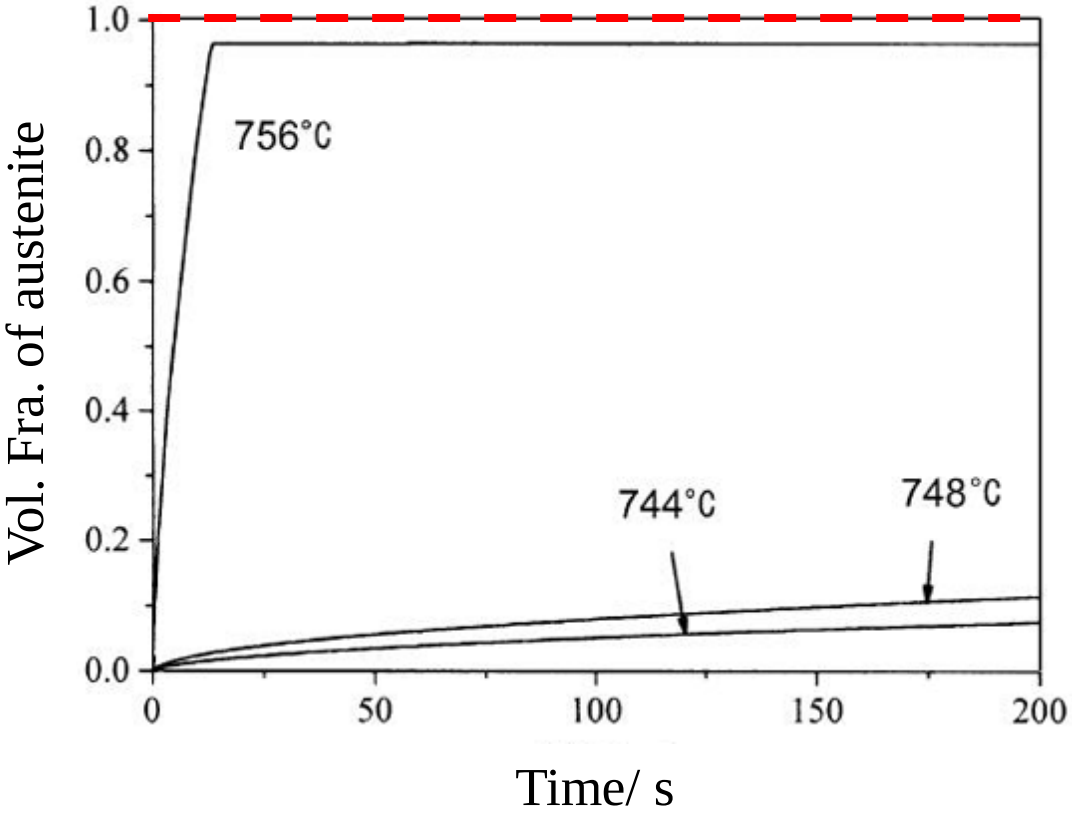


Austenitization_Dictra

Fe-0.69C-1.80Mn **Spherodized pearlite**

T_{ptr}=660^{0}C **PNTT-I=750^{0}C**

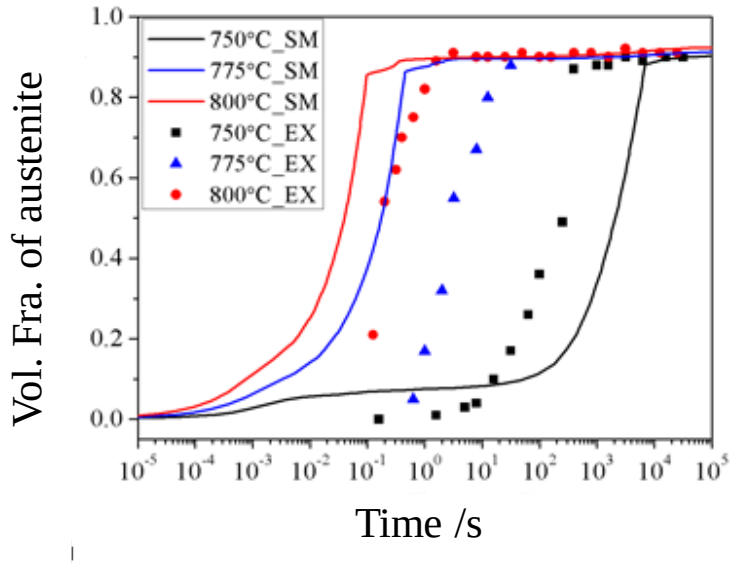


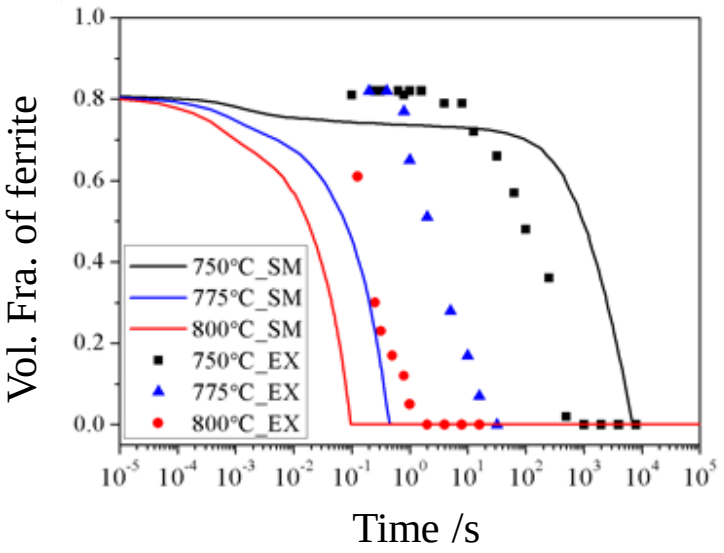


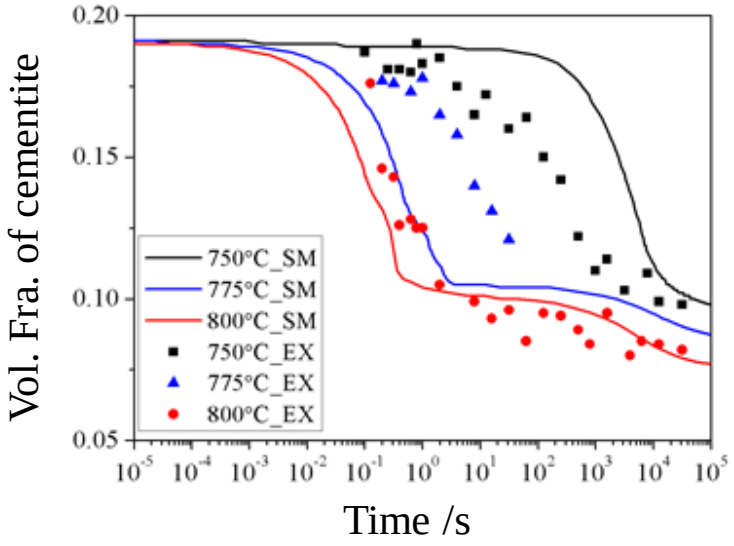
Austenitization_Exp.

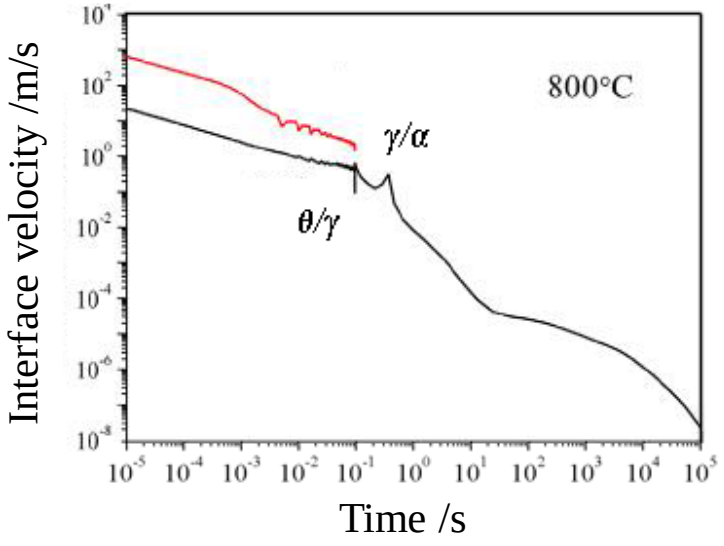
Fe-1.27 C-0.36Mn-0.19Cr

PNTT-I=756^{0}C

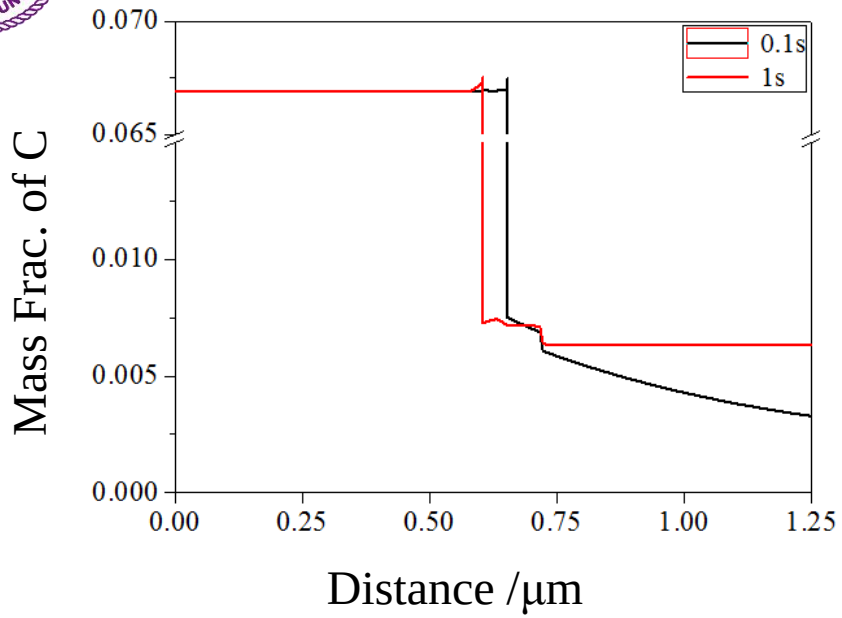


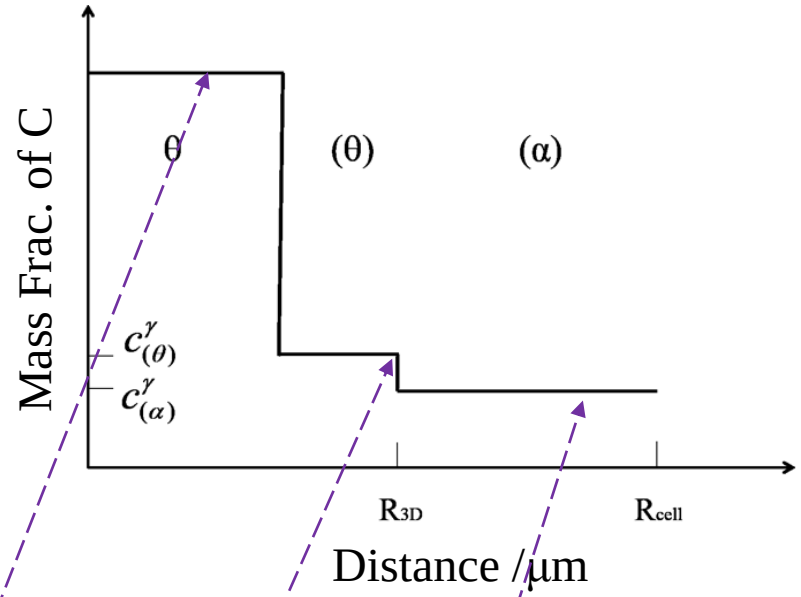


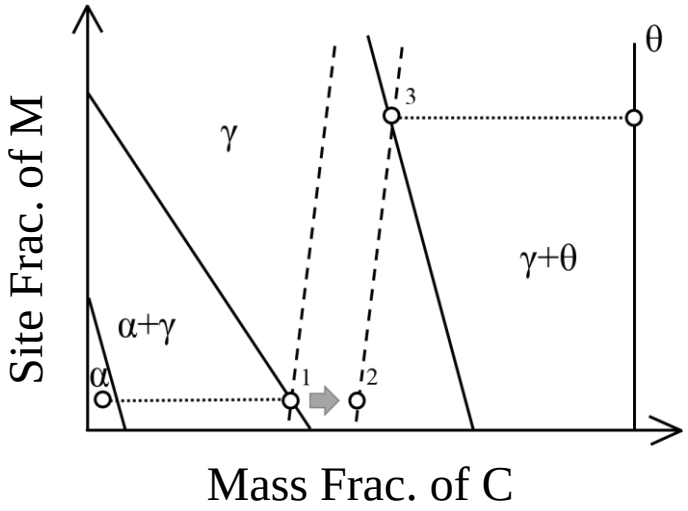




Austenitization_PNTT-II





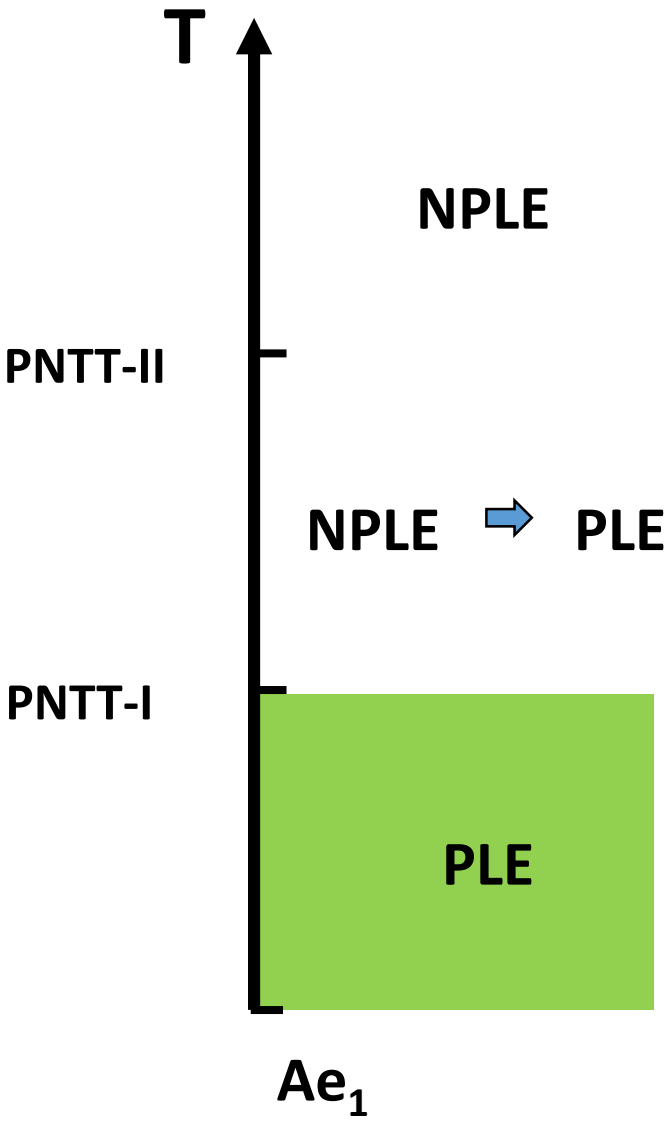


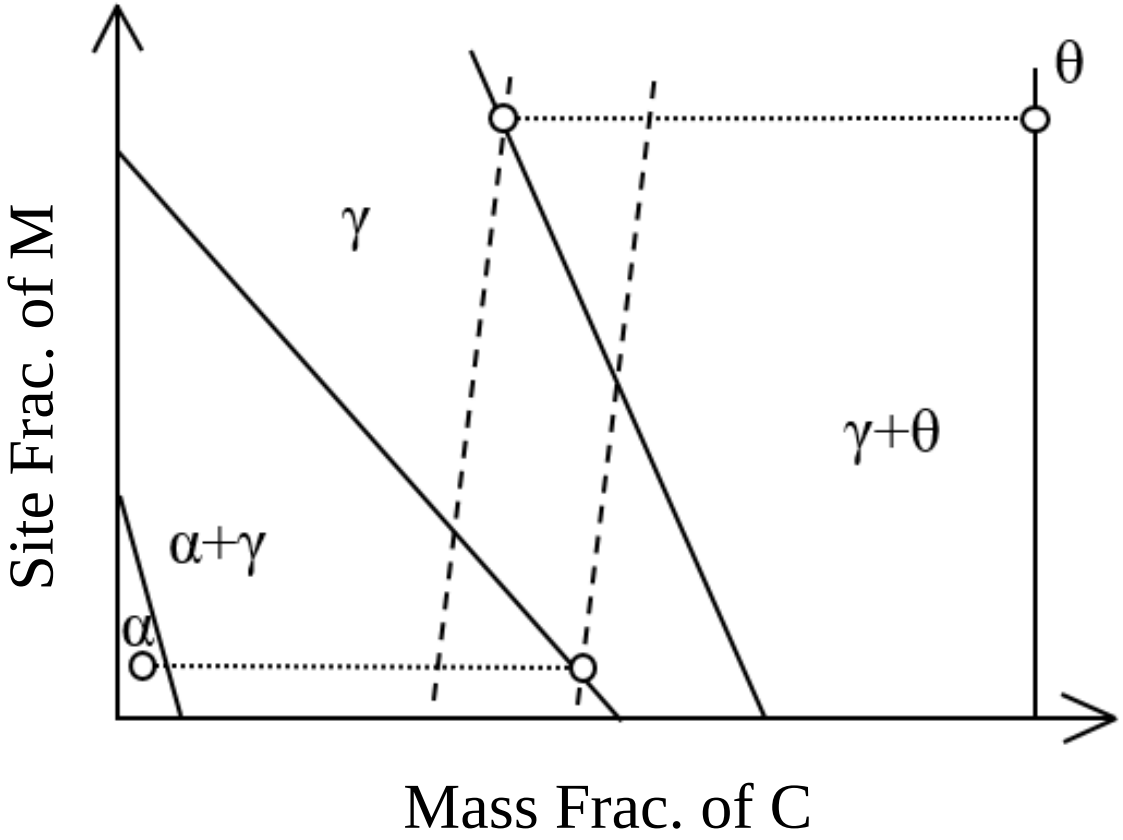
$$C_C^{\theta} \cdot f^{\theta} + C_C^{(\theta)} \cdot f^{(\theta)} + C_C^{(\alpha)} \cdot f^{(\alpha)} = C_C^0$$

$$=$$

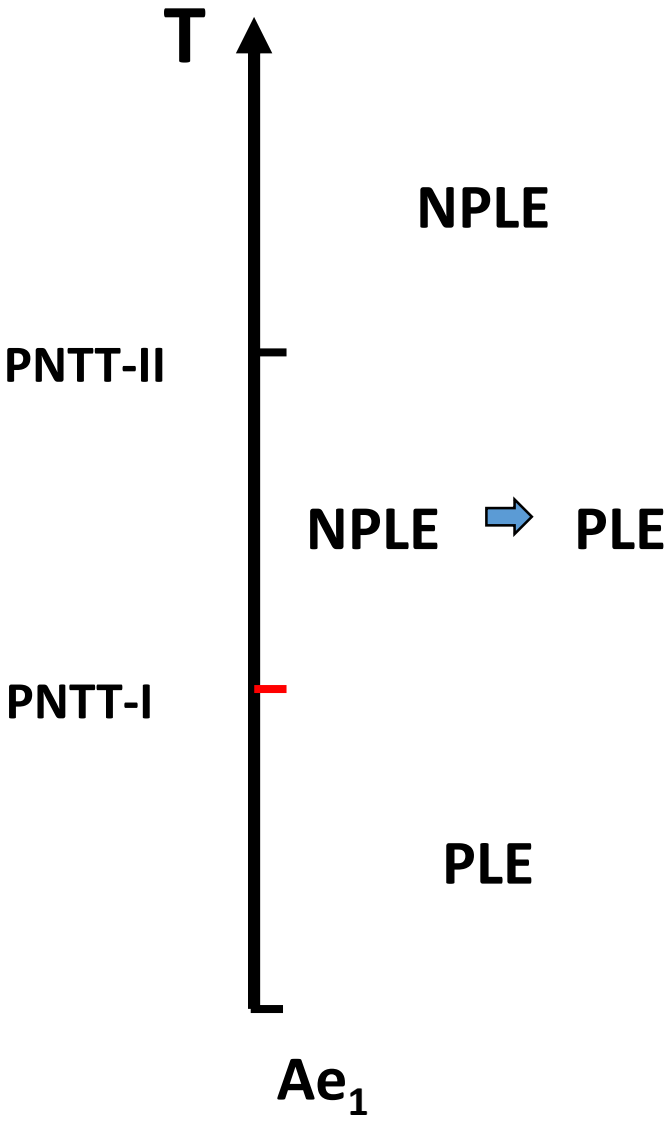
$$\boldsymbol{0}$$

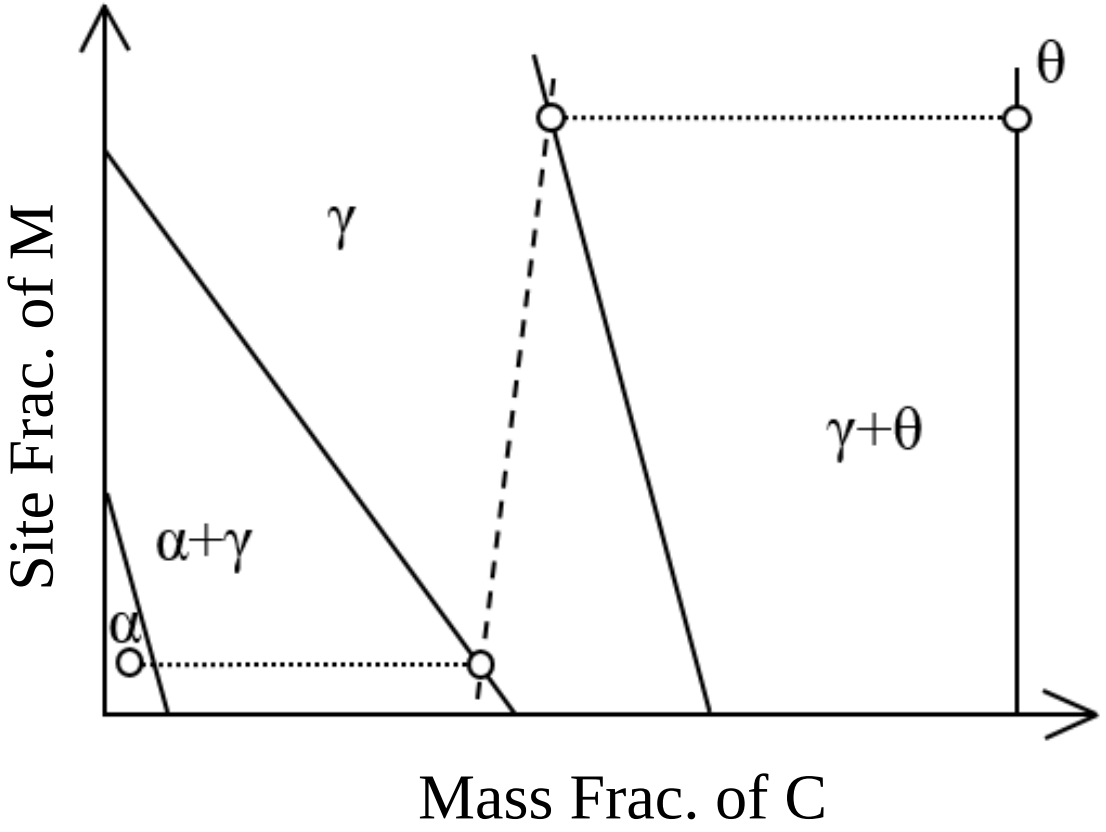
Austenitization_PNTTs



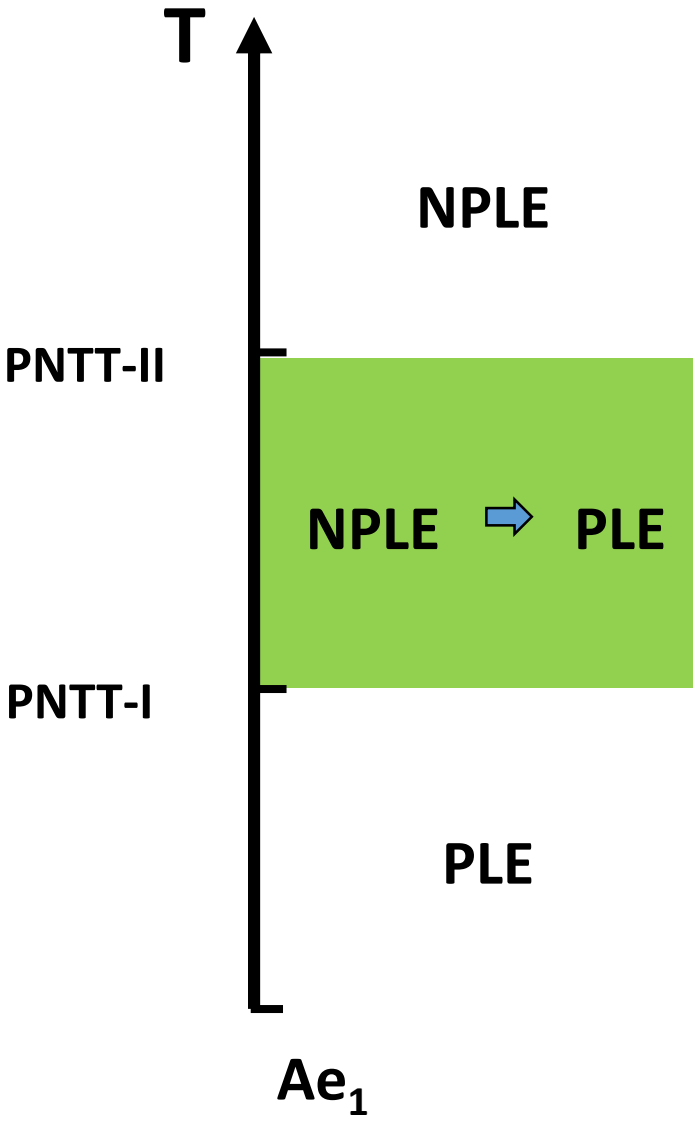


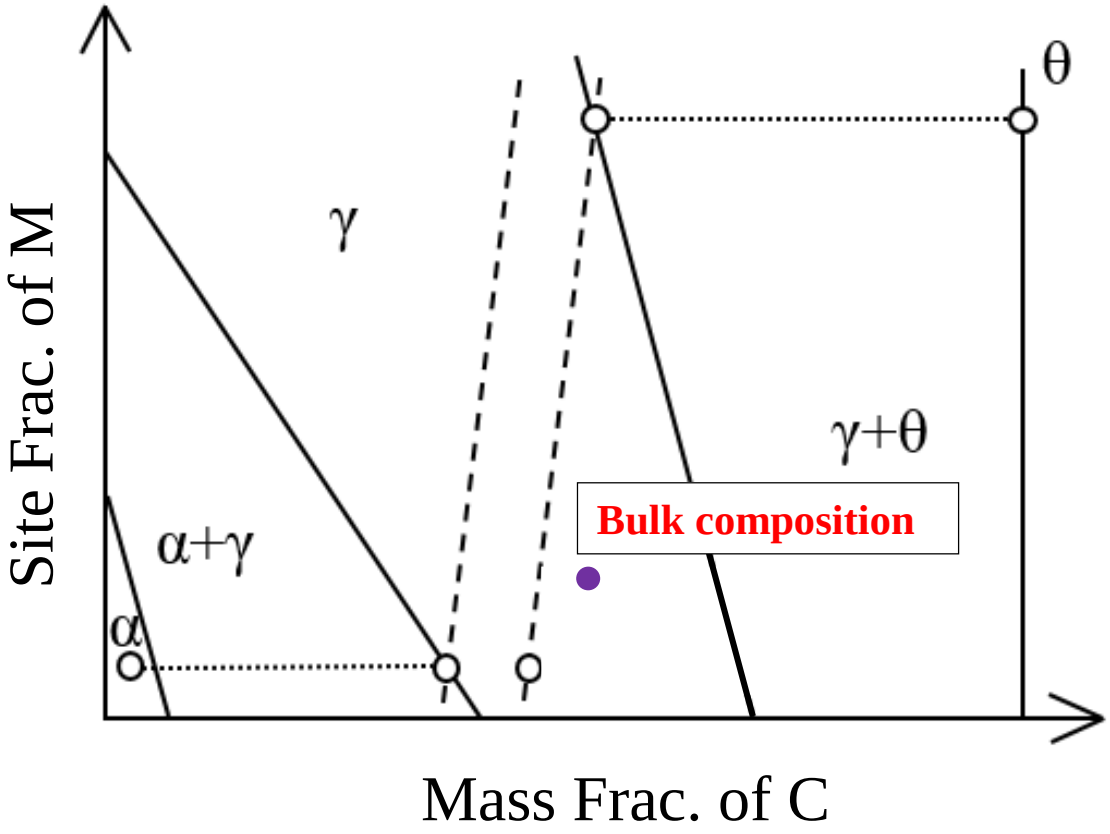
Austenitization_PNTTs



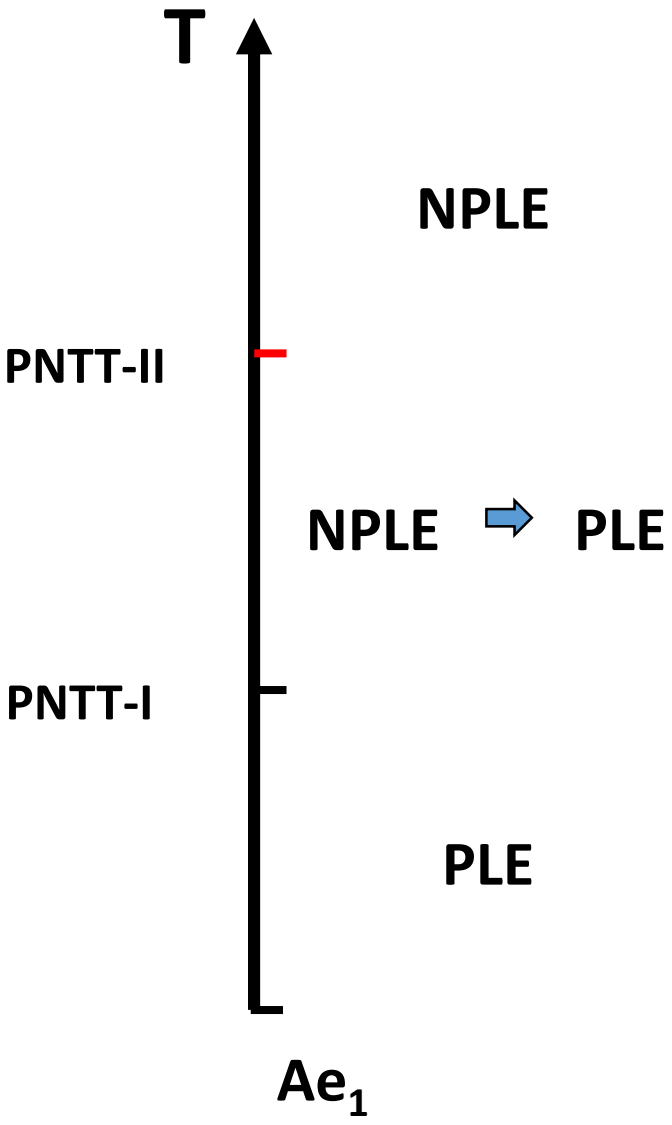


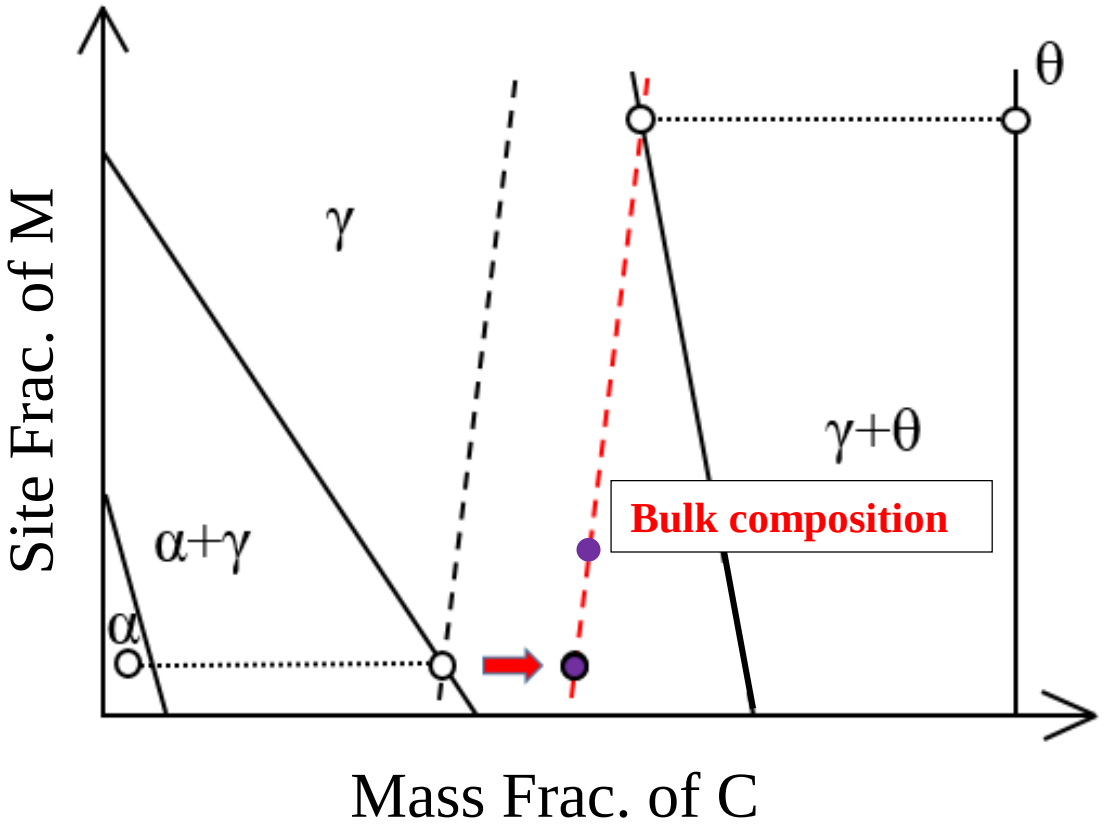
Austenitization_PNTTs



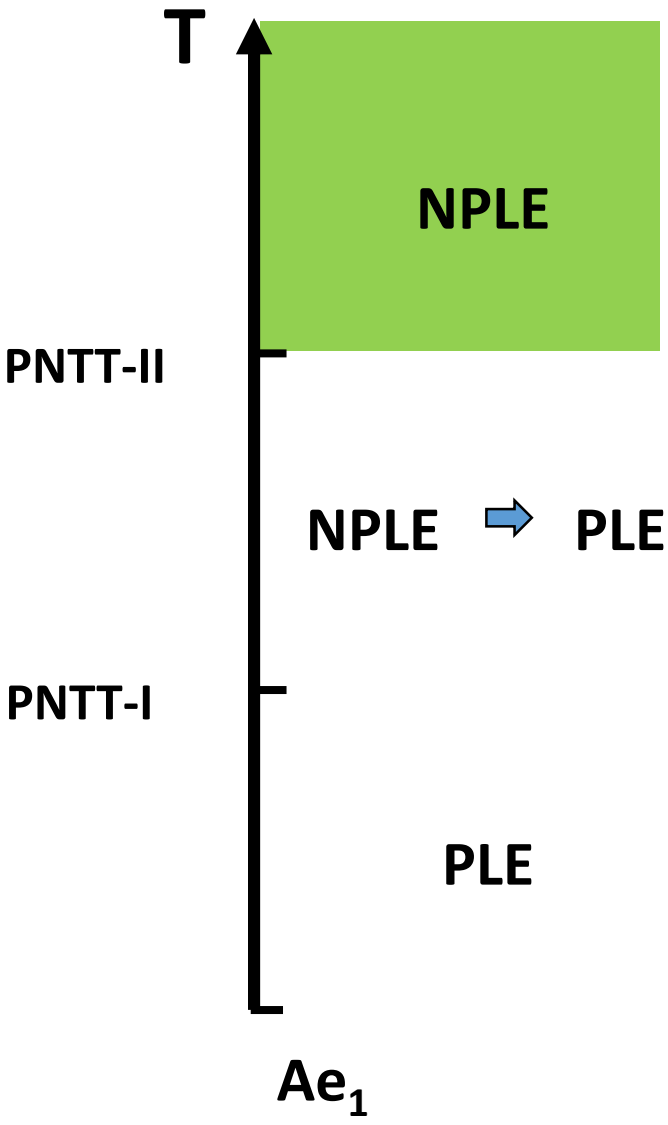


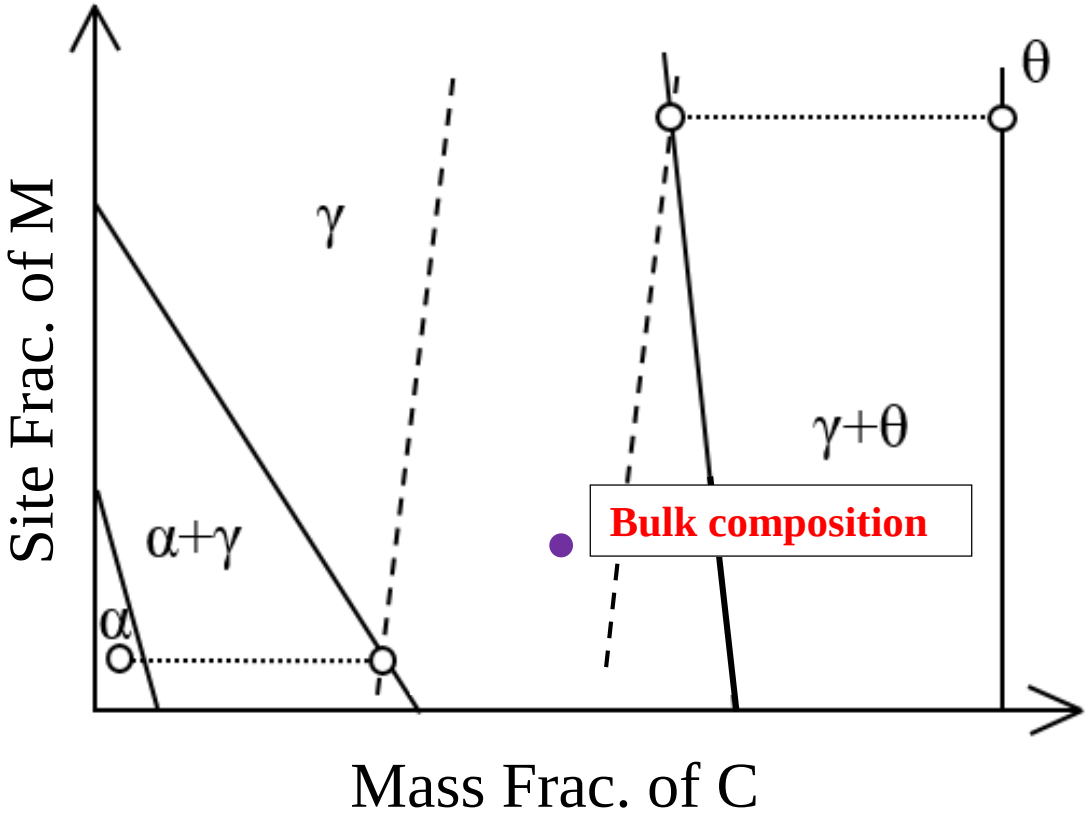
Austenitization_PNTTs



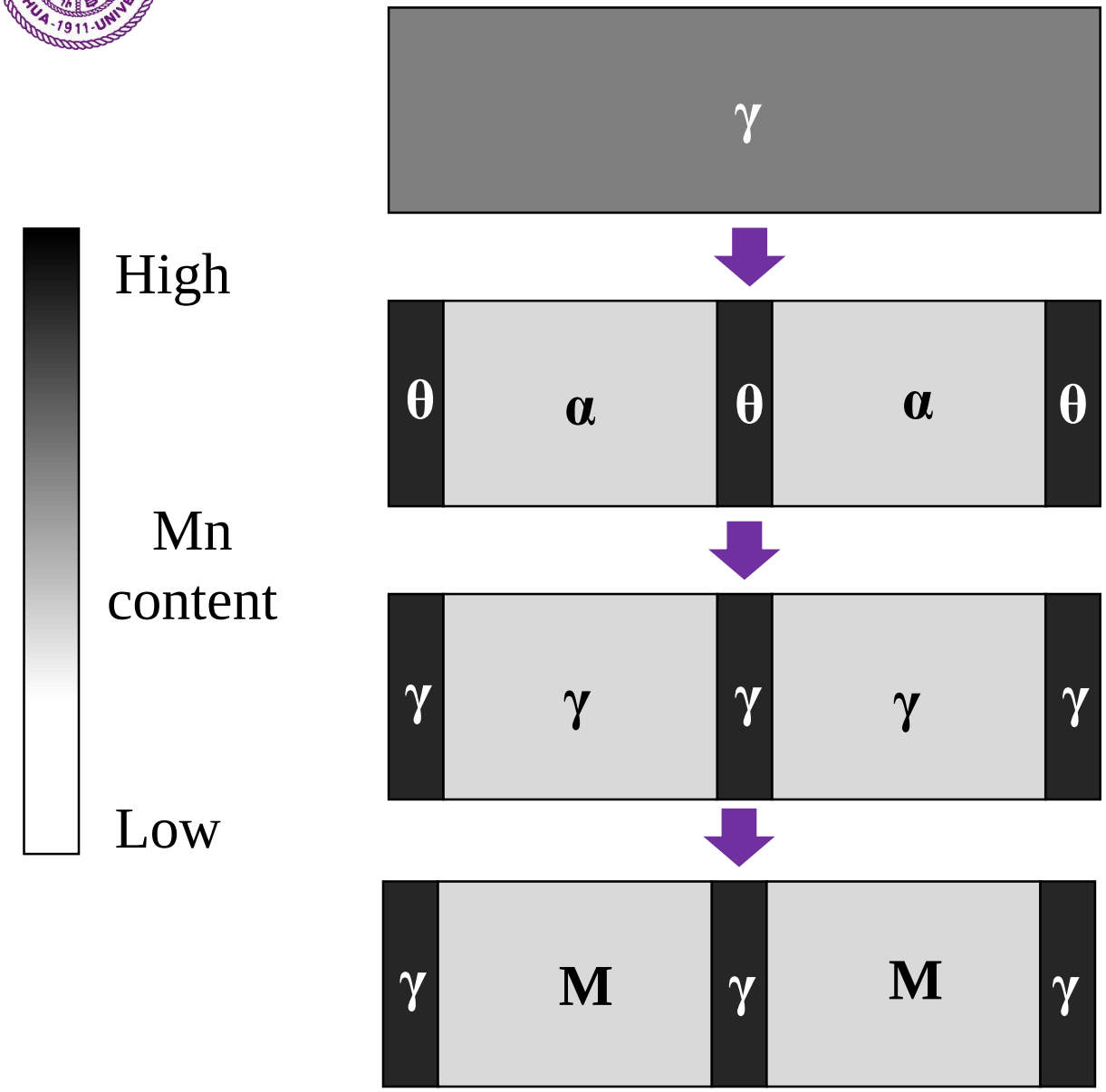


Austenitization_PNTTs





Medium Mn steel



Pearlite transformation

Partition of Mn

Austenitization T>PNTT-II

Non-uniform distribution

Quench

MA dual phase

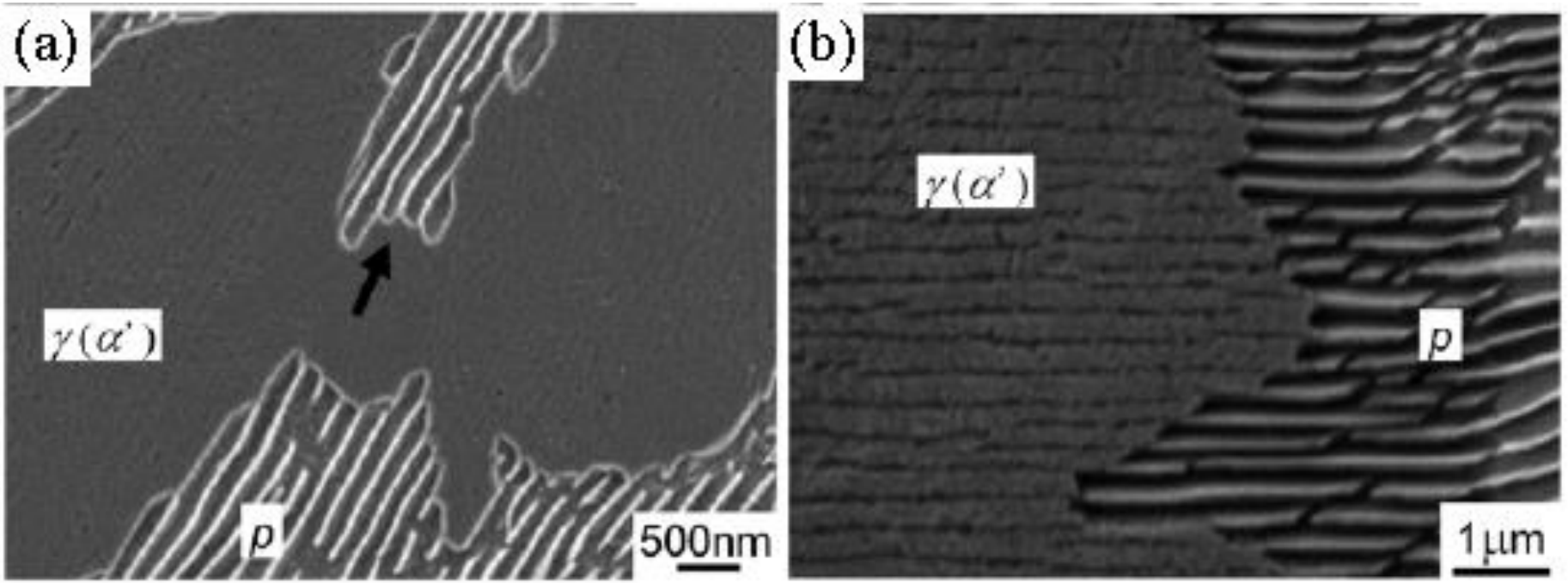
Medium Mn steel

Fe-0.6C-1Mn

800^{0}C-1.1s

Fe-0.6C-2Mn

800^{0}C-1.4s



李昭东. 变形和合金元素对钢中奥氏体组织形成和分解相变的影响: 清华大学, 2012.

Conclusion

1. Pearlite transformation is simulated via PFM. Compared with bulk diffusion, boundary diffusion of C and Mn plays an important role in the kinetics of transformation and partition of Mn between ferrite and cementite

2. A new heat treatment design for medium Mn steel is proposed. A non-uniform distribution of Mn is created by austenitization from pearlite, and the subsequent quenching may lead to a M&A dual phase microstructure.

Thanks for your attention