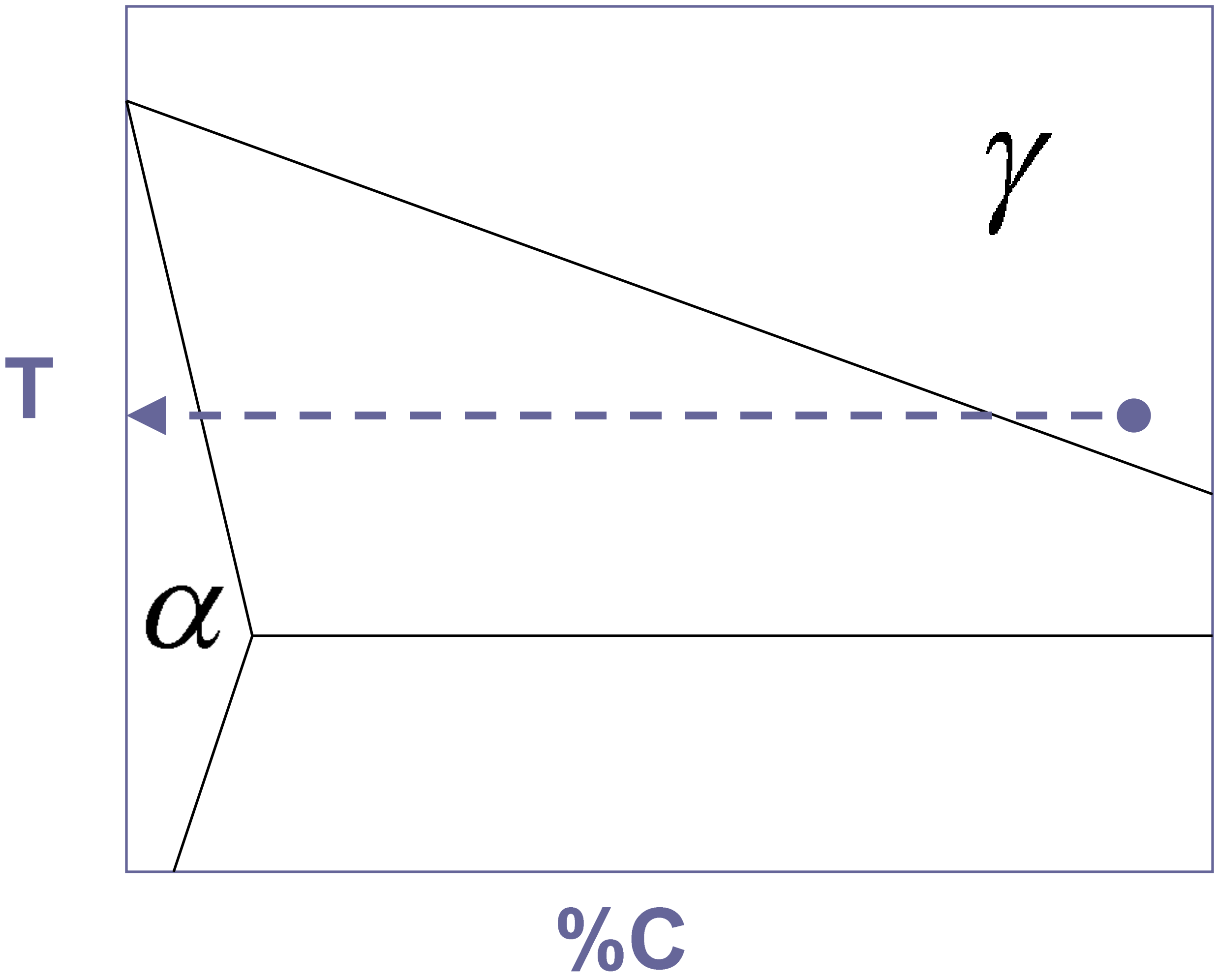
Investigation of the $\gamma \rightarrow \alpha$ Transformation in Fe-C-X Alloys Using Decarburization

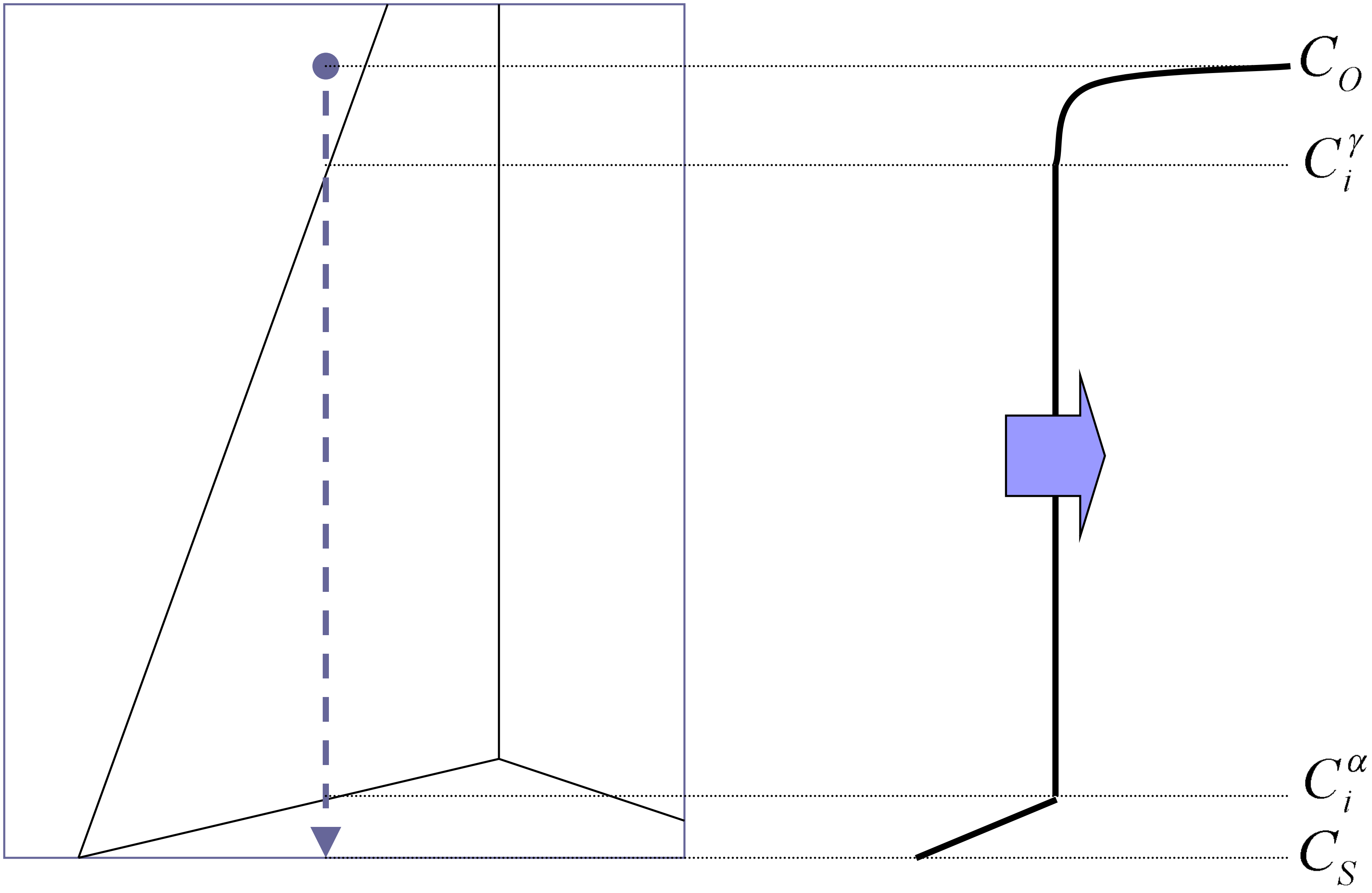
Compiled by Hatem Zurob from works done at McMaster University and LTPCM by:

Gary Purdy, Jinichiro Nakano, Andre Phillion, Chris Hutchinson, Yves Brechet and Armand Beche.

- **Decarburization Method**.
- **Summary of Results**:
  - Fe-C
  - Fe-C-Ni
  - Fe-C-Mn
  - Fe-C-Cr
  - Fe-C-Mo
  - Fe-C-Si and Fe-C-Si-Mn
  - Fe-C-Nb
- **Future Work**.

1. The Decarburization Method




C_O
C_i^{γ}
C_i^{α}
C_S

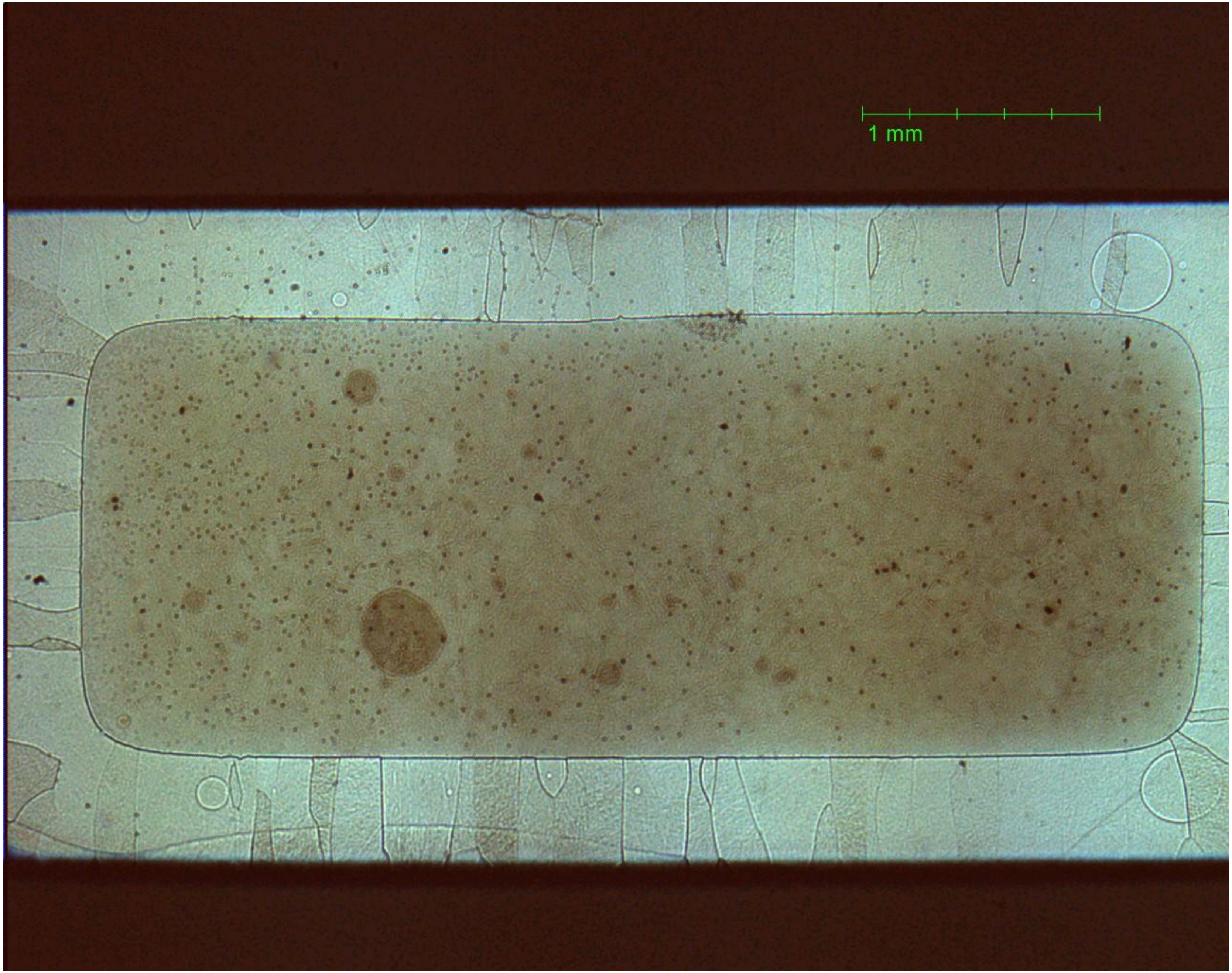
The rate of interface motion is given by:

$$\frac{dz}{dt} = \frac{J_i^{\alpha} - J_i^{\gamma}}{C_i^{\gamma} - C_i^{\alpha}}$$

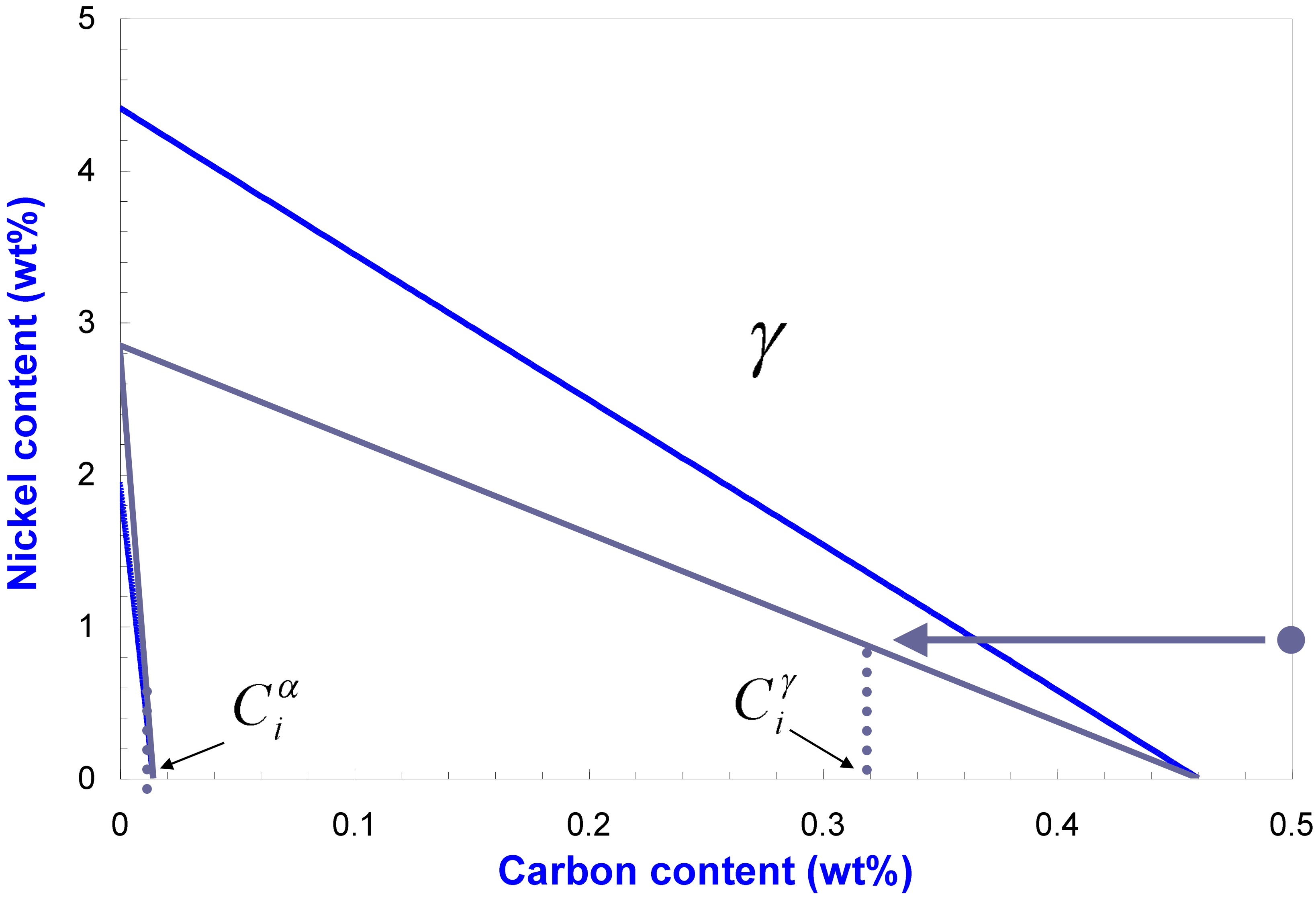
This differential equation has an analytical solution of the form:

$$z = B\sqrt{t}$$

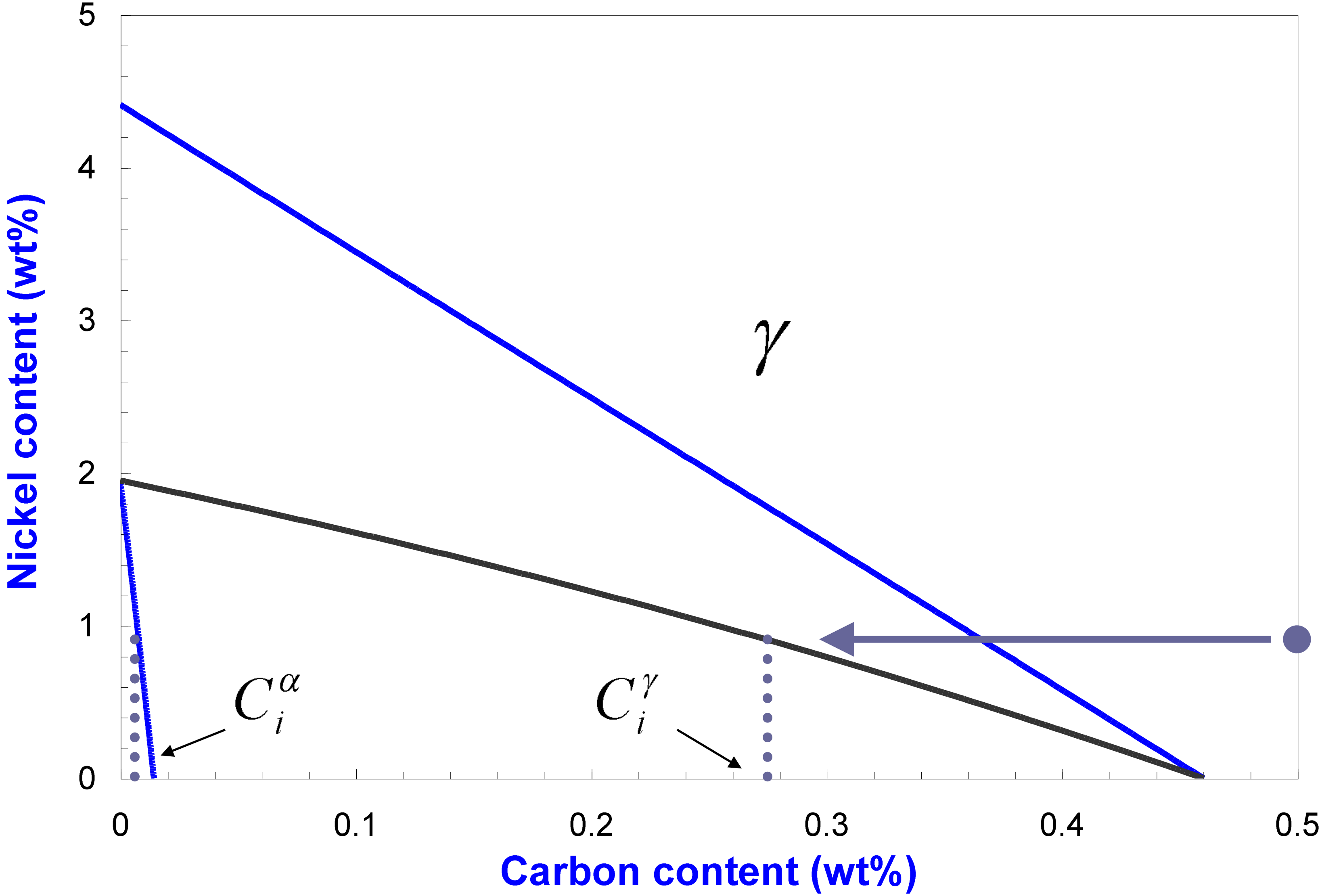
$$B = f(C_i^{\alpha}, C_i^{\gamma}, C_O)$$


1 mm

> Ternary Alloys: ParaEquilibrium Limit.



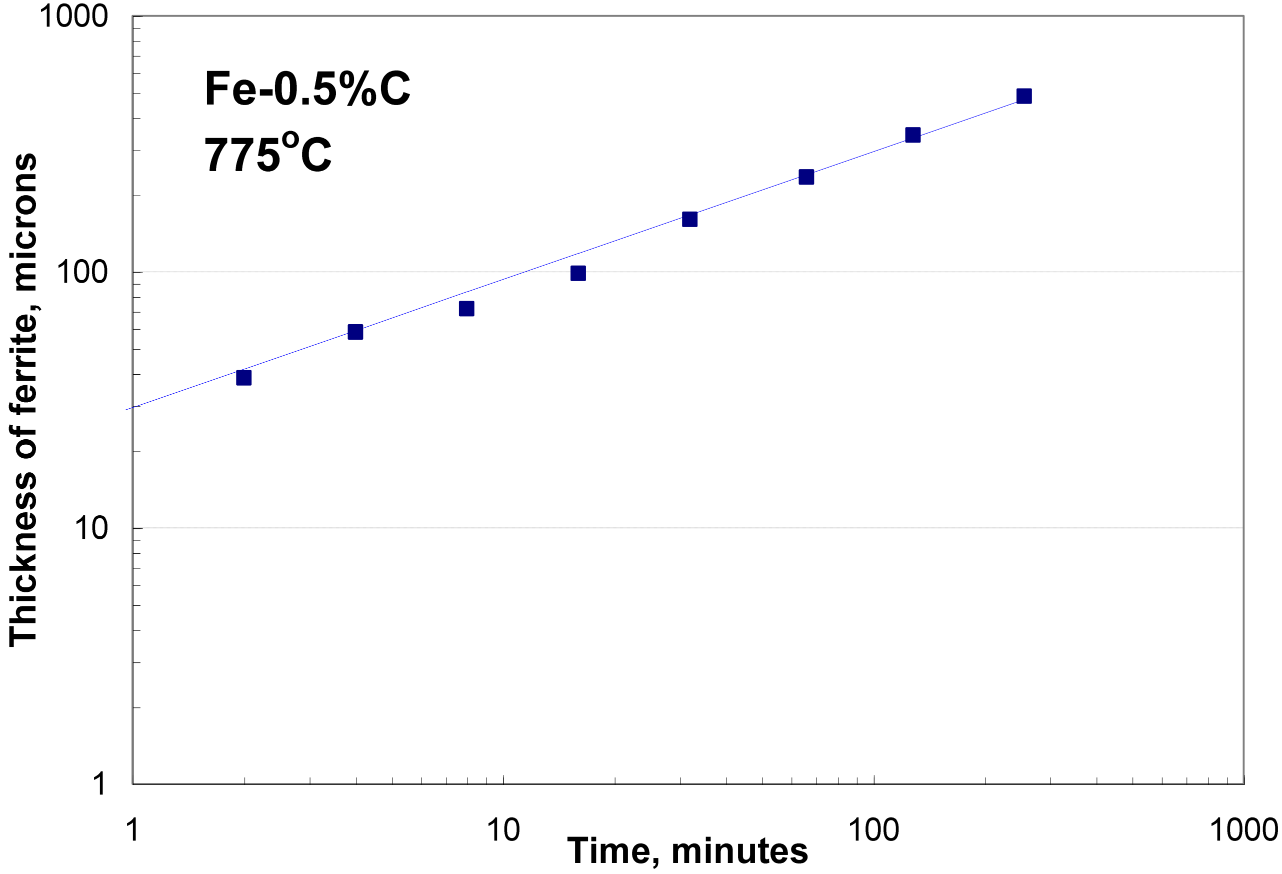
> *Ternary Alloys: LENP Limit.*



2. **Summary of Results**:

2.1. Fe-C (diffusion coefficient).
2.2. Fe-C-Ni (the LE-NP limit).
2.3. Fe-C-Mn (possible transition).
2.4. Fe-C-Cr (solute drag).
2.5. Fe-C-Mo (dissipation are not created equal).
2.6. Fe-C-Si and Fe-C-Si-Mn (combined effects).
2.7. Fe-C-Nb (precipitation).

2.1. Binary Fe-C System:

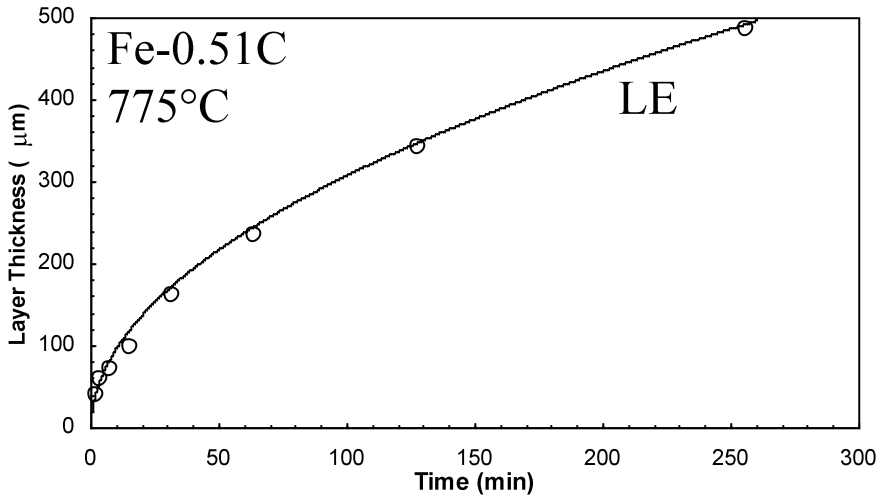


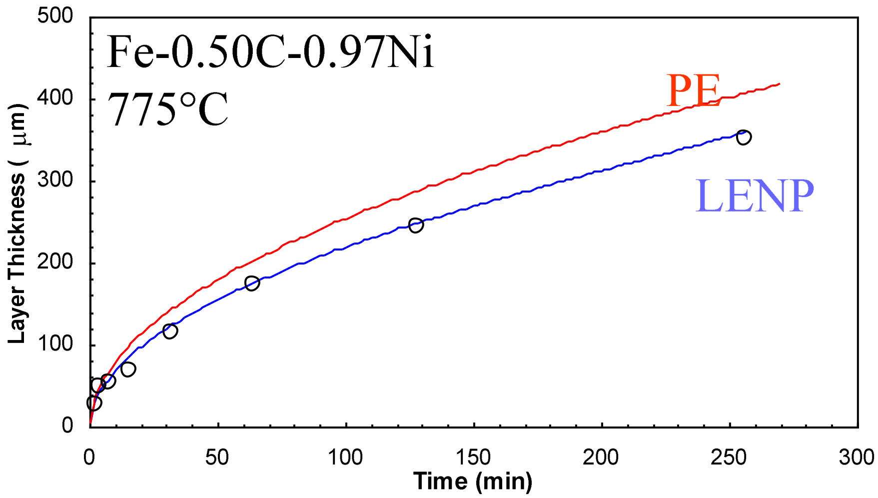
T (°C)	D/D_A
775	1
806	0.8
825	0.8
850	0.8

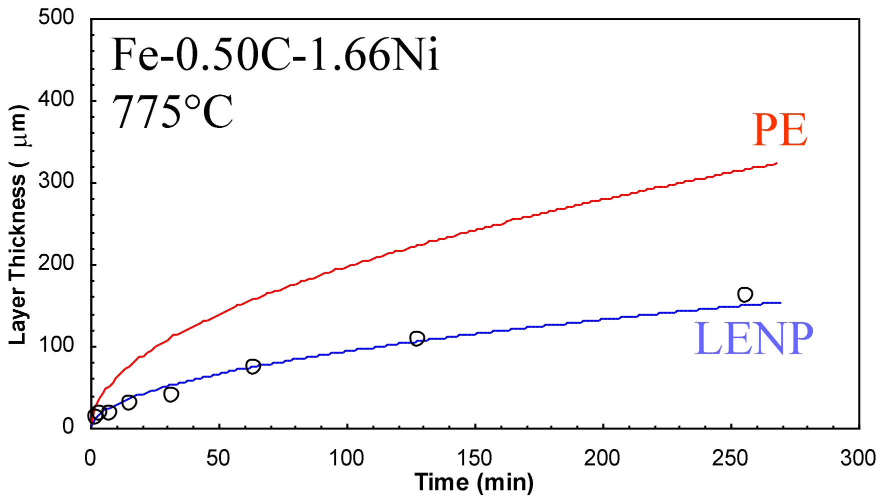
$$D_C^{\alpha} = 2.63 \times 10^{-10} m^2/s \quad vs. \quad D_C^{\alpha} = 2.68 \times 10^{-10} m^2/s$$

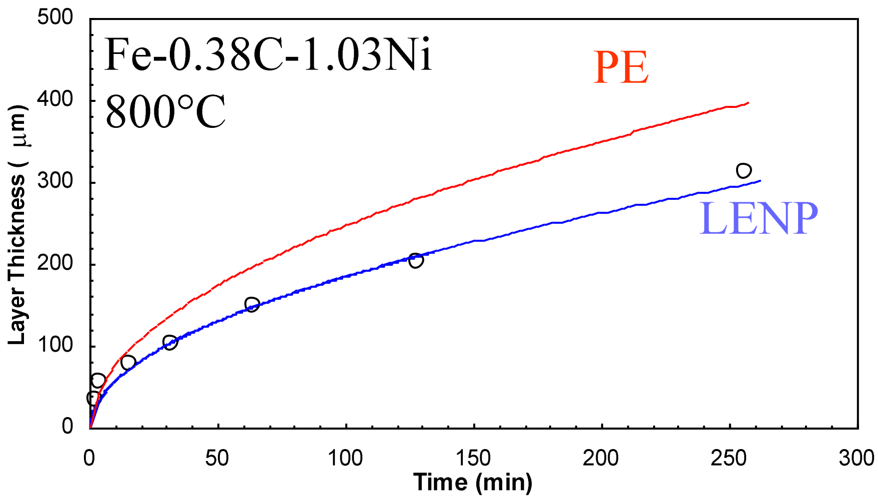
2.2. Fe-C-Ni Decarburization Experiments (ideal case)

Phillion, Zurob, Hutchinson, Guo, Malakhov, Nakano and Purdy, *Metall Trans*., 35A, 1237-1242, 2004.

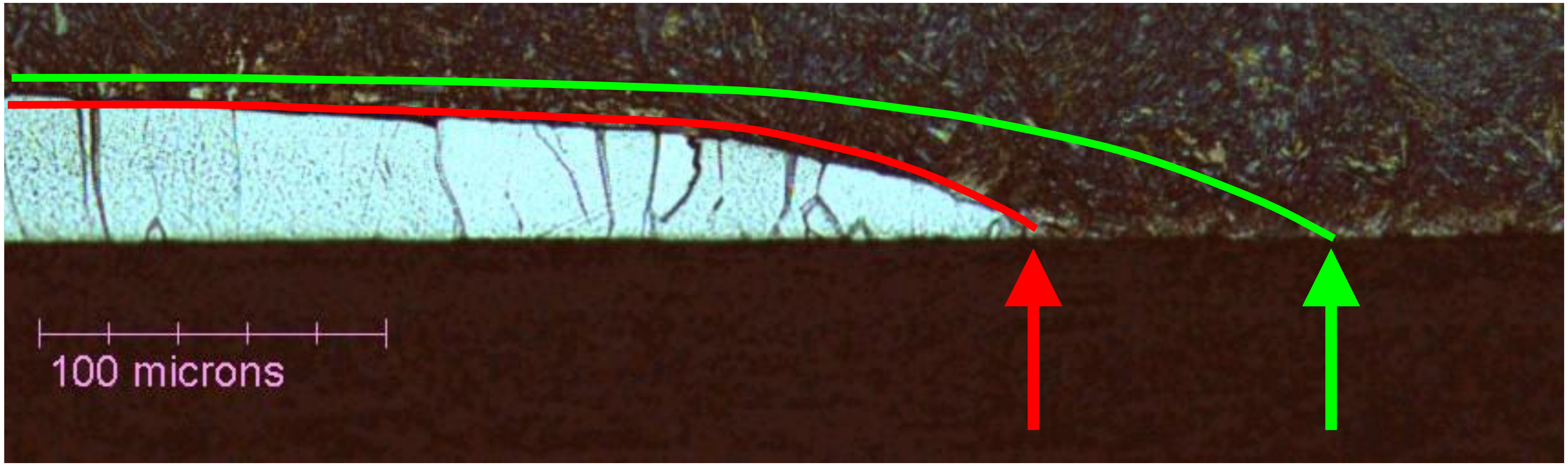






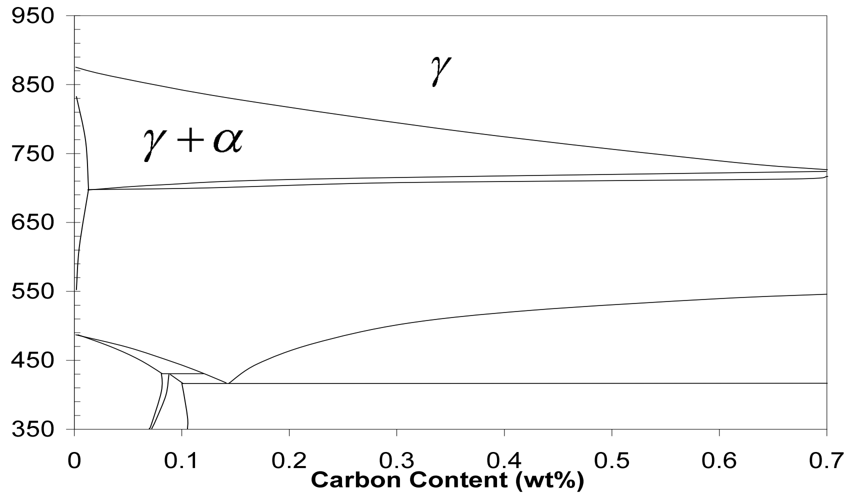


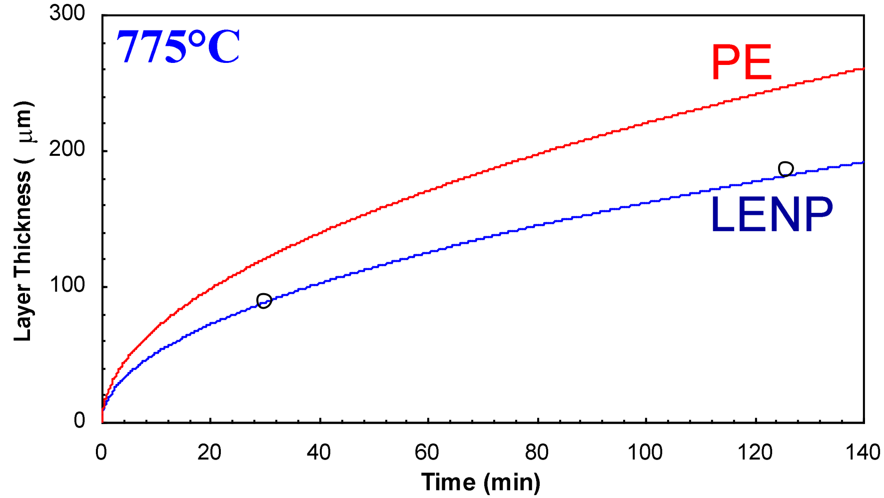
Fe-Ni diffusion couple: 775°C for 4 min.

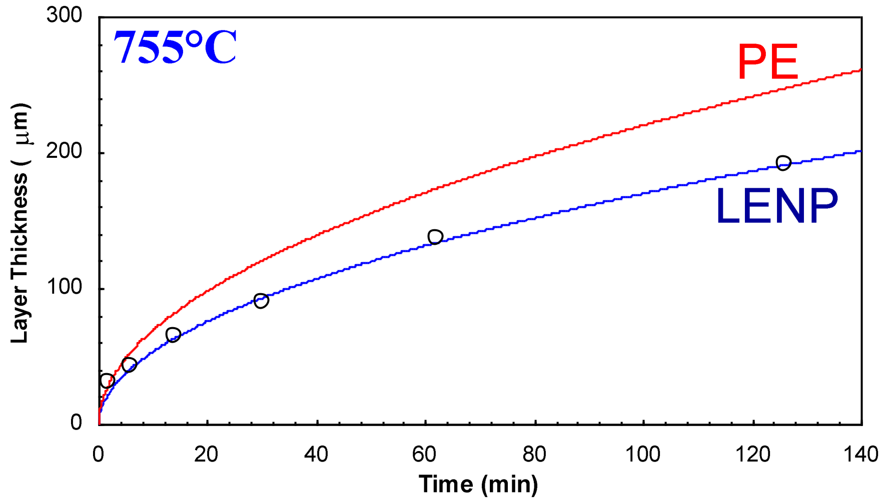


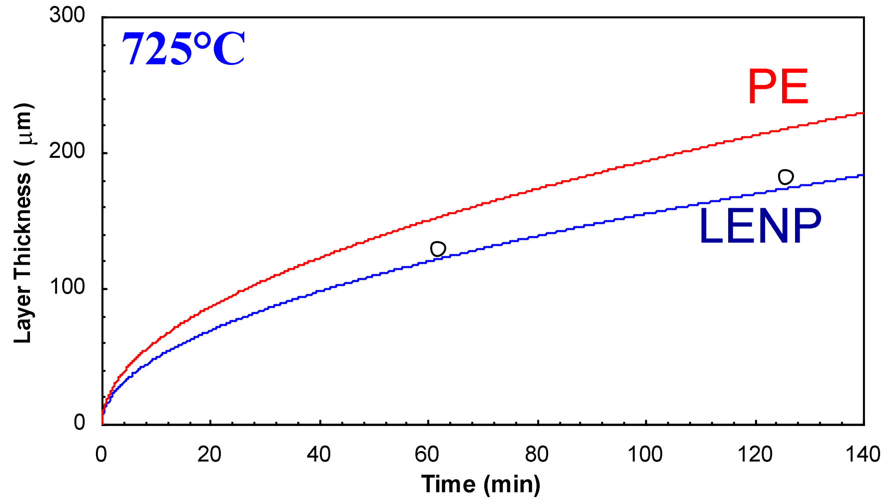
2.3. Fe-C-Mn Decarburization Experiments

Fe-0.57C-0.94Mn (wt. %)

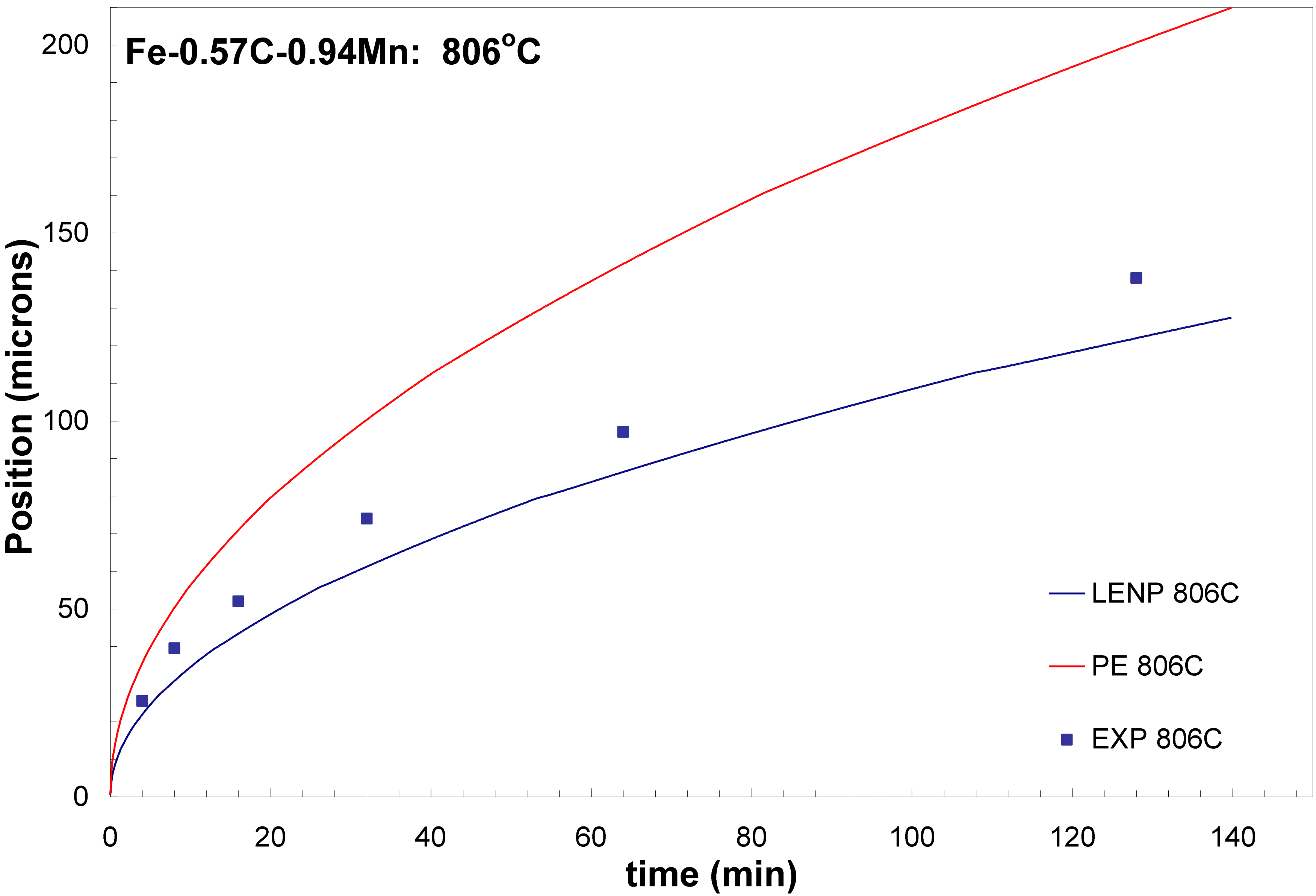








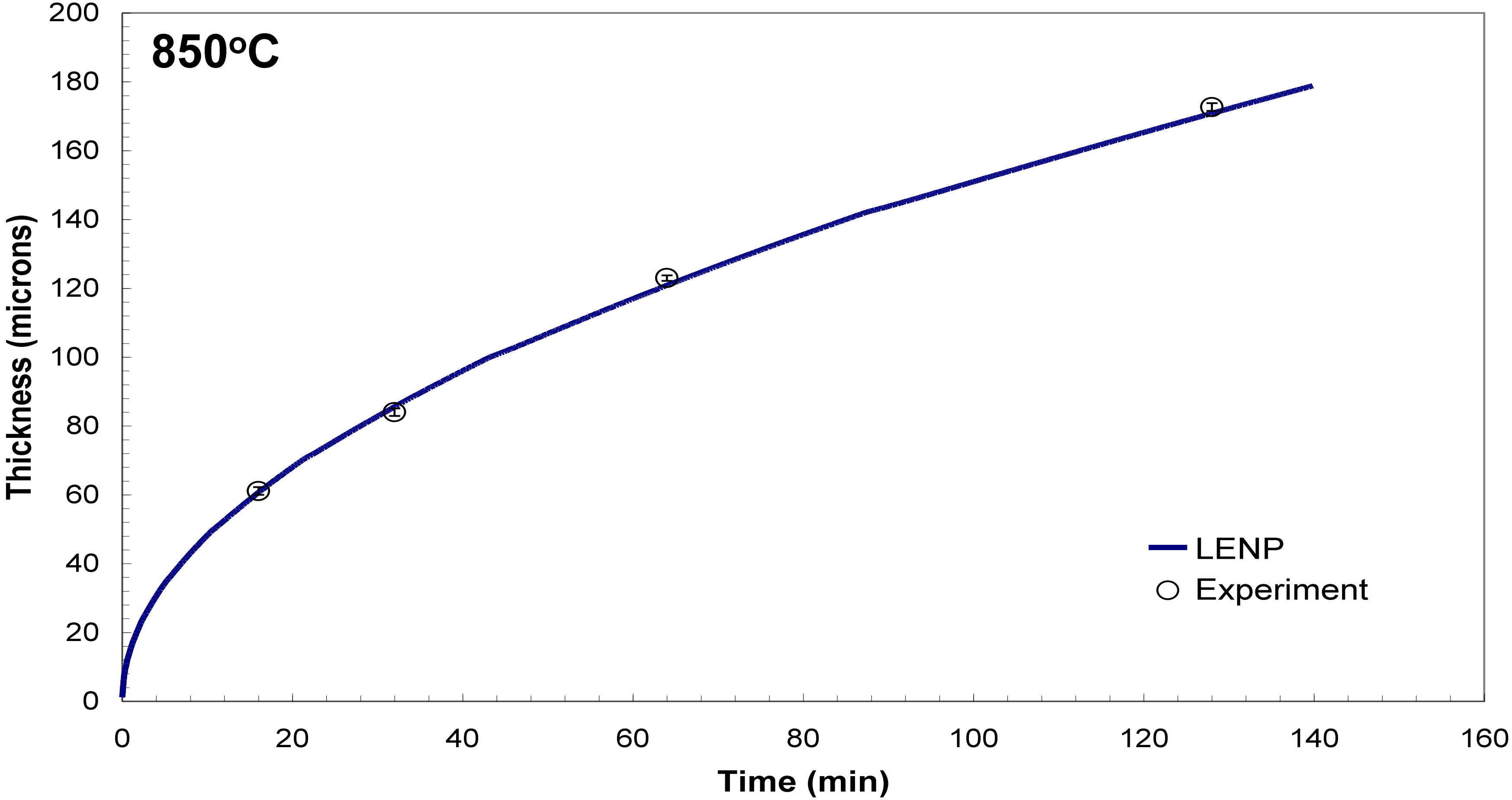
H. S. Zurob, C. R. Hutchinson, Y. Brechet and G. R. Purdy, PTM'05.



Fe-0.57C-0.94Mn: 806°C
Position (microns)
200
150
100
50
0
0
20
40
60
80
100
120
140
time (min)
LENP 806C
PE 806C
EXP 806C

2.4. Fe-C-Cr Decarburization Experiments

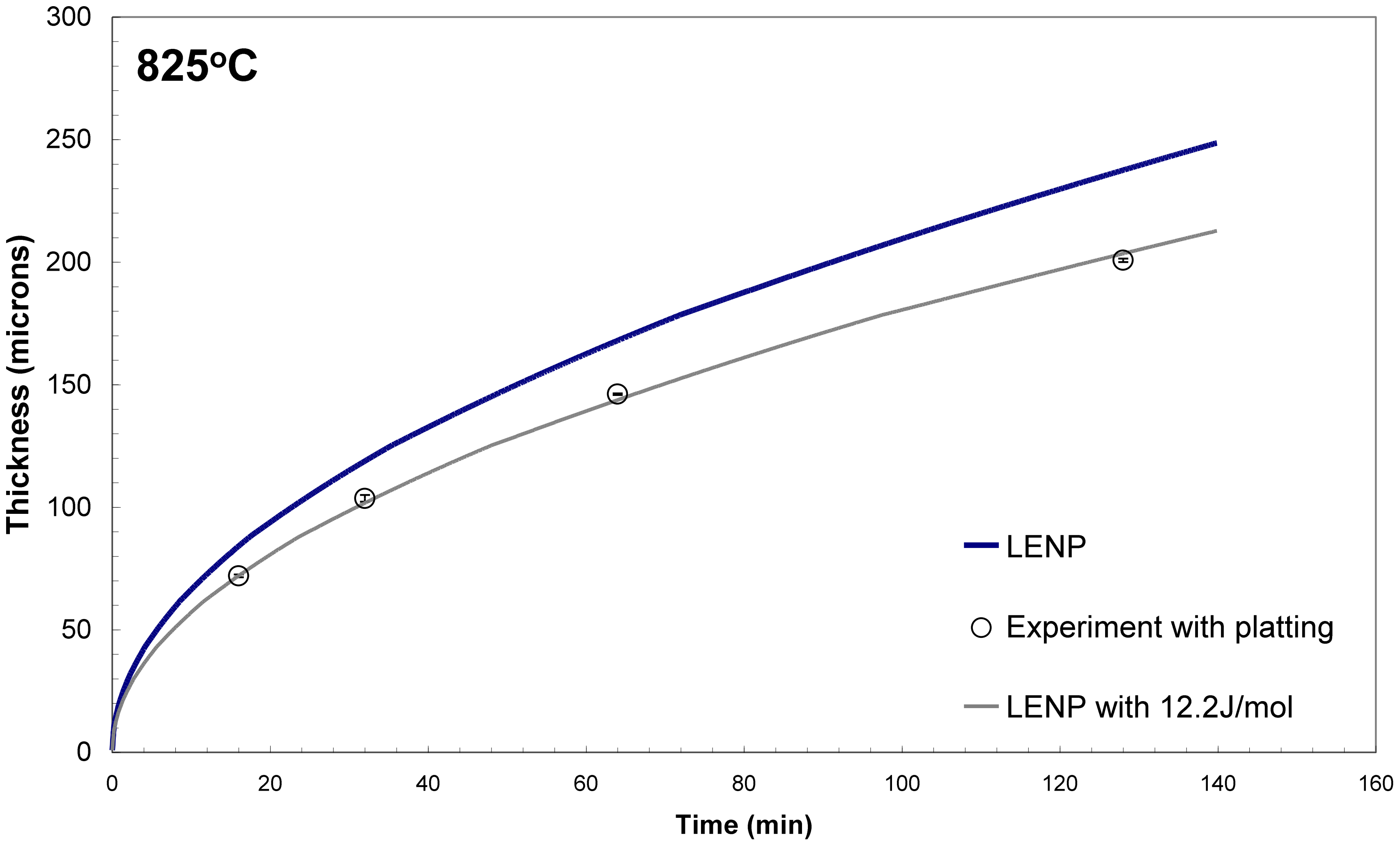
Fe-0.58C-1.99Cr (wt. %)



A. Beche, senior thesis.

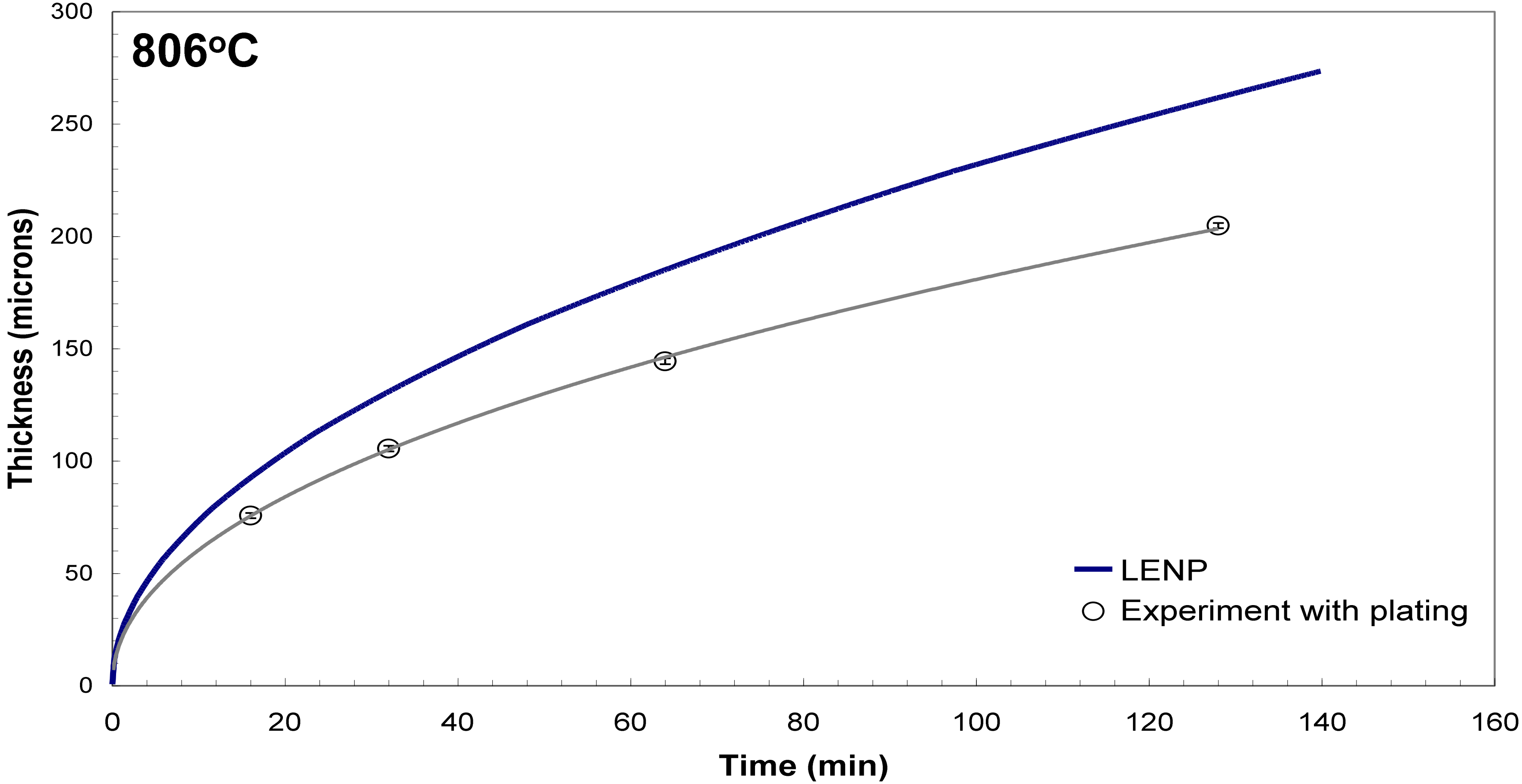
2.4. Fe-C-Cr Decarburization Experiments

Fe-0.58C-1.99Cr (wt. %)

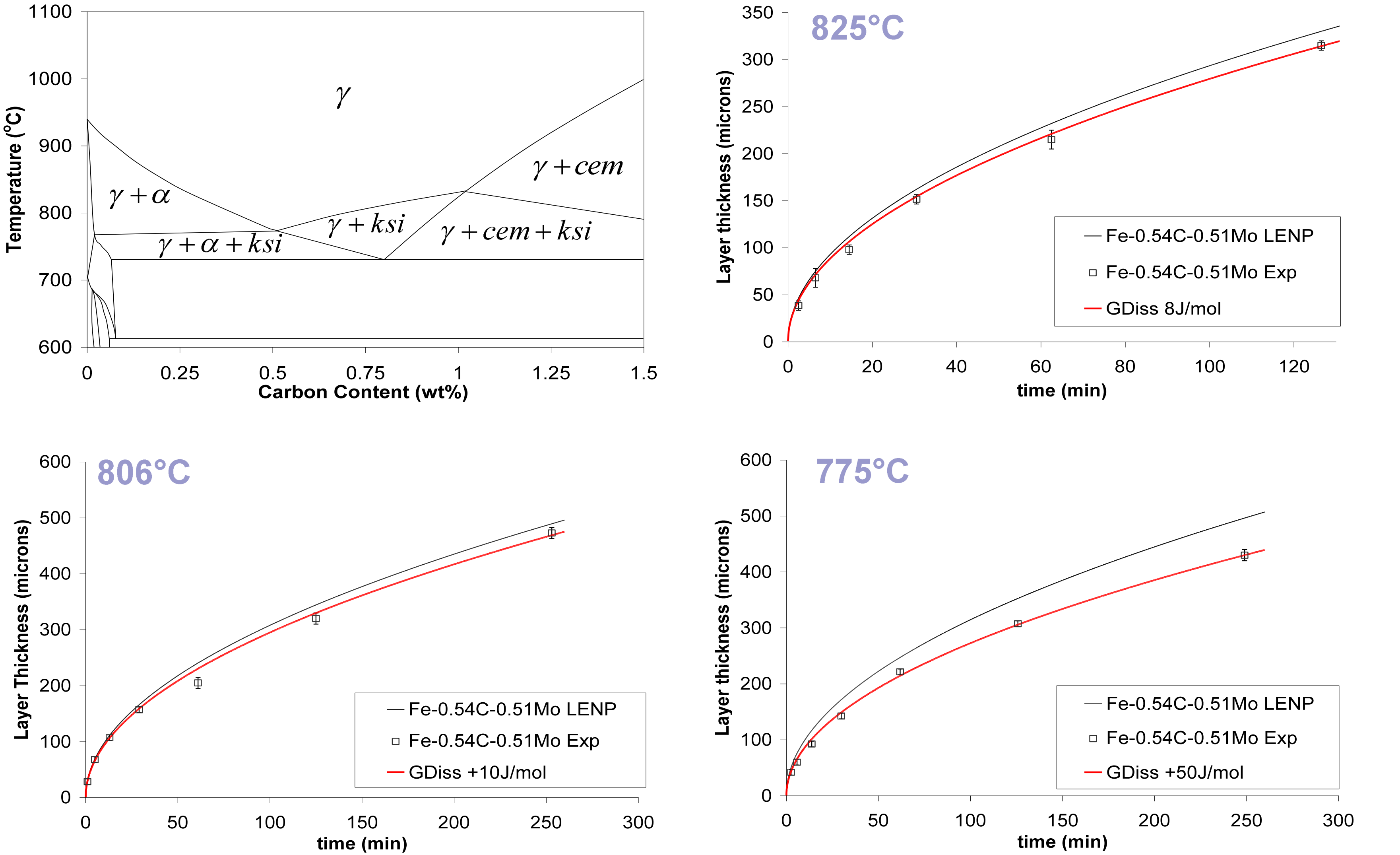


2.4. Fe-C-Cr Decarburization Experiments

Fe-0.58C-1.99Cr (wt. %)

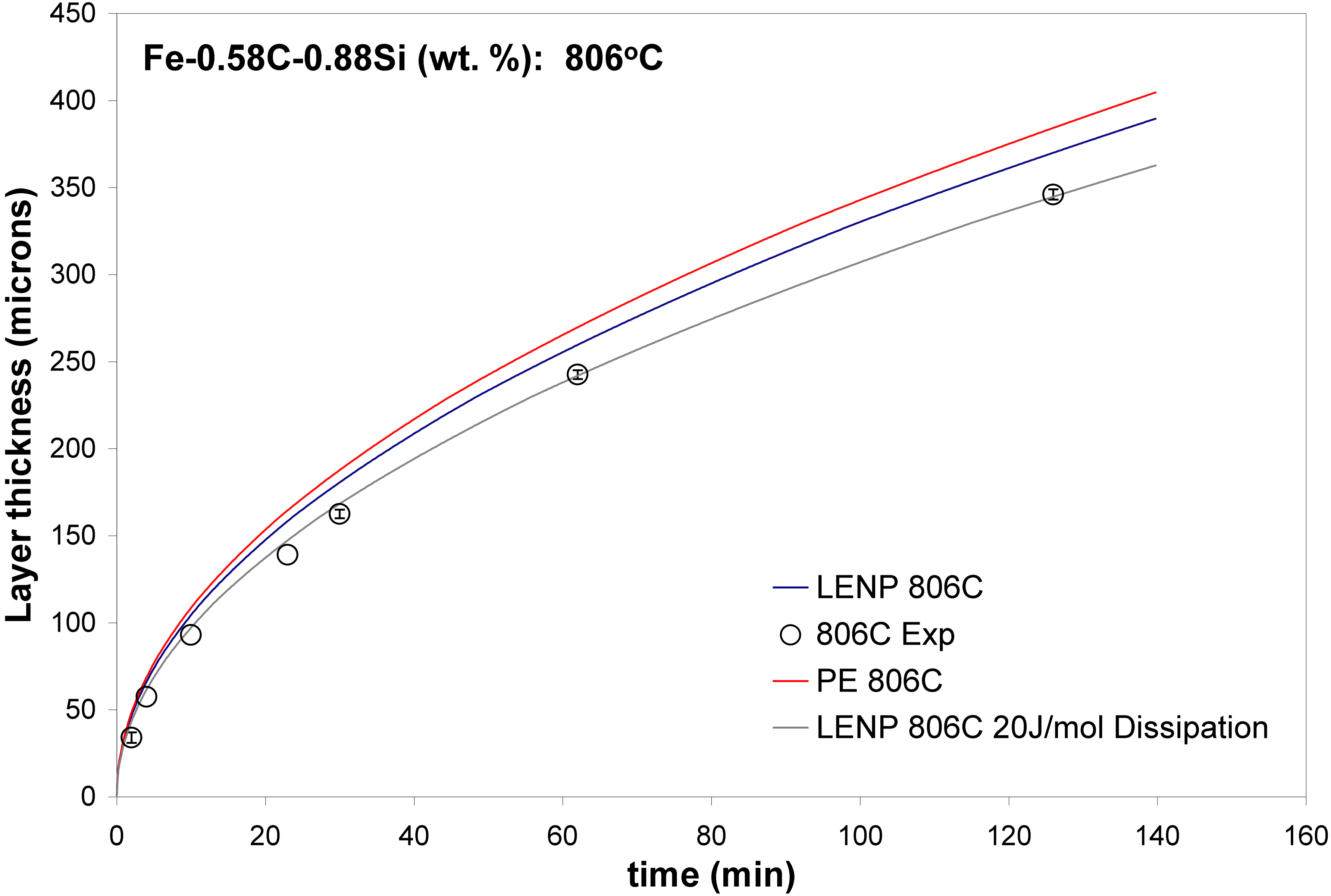


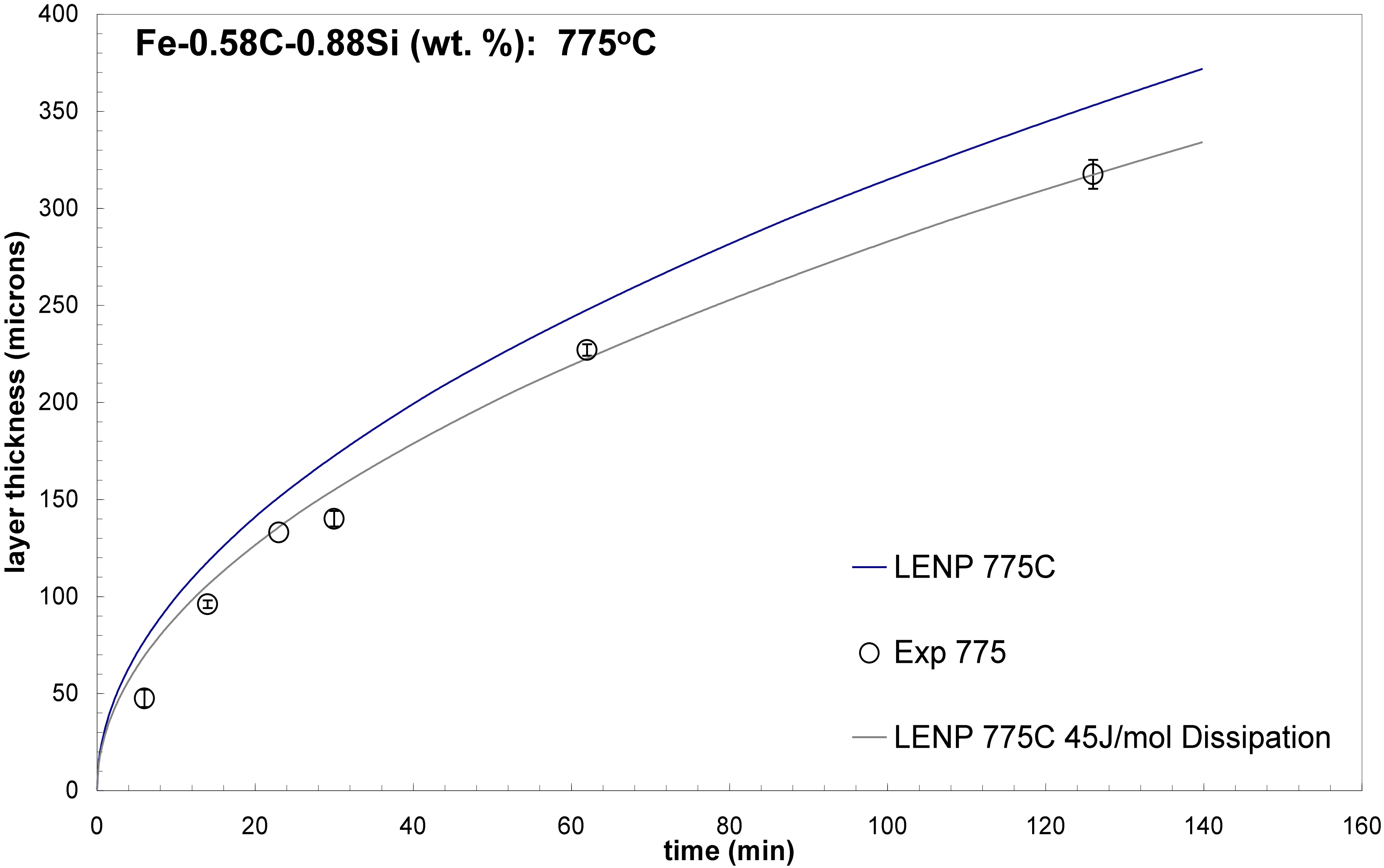
2.5. Fe-C-Mo Decarburization Experiments



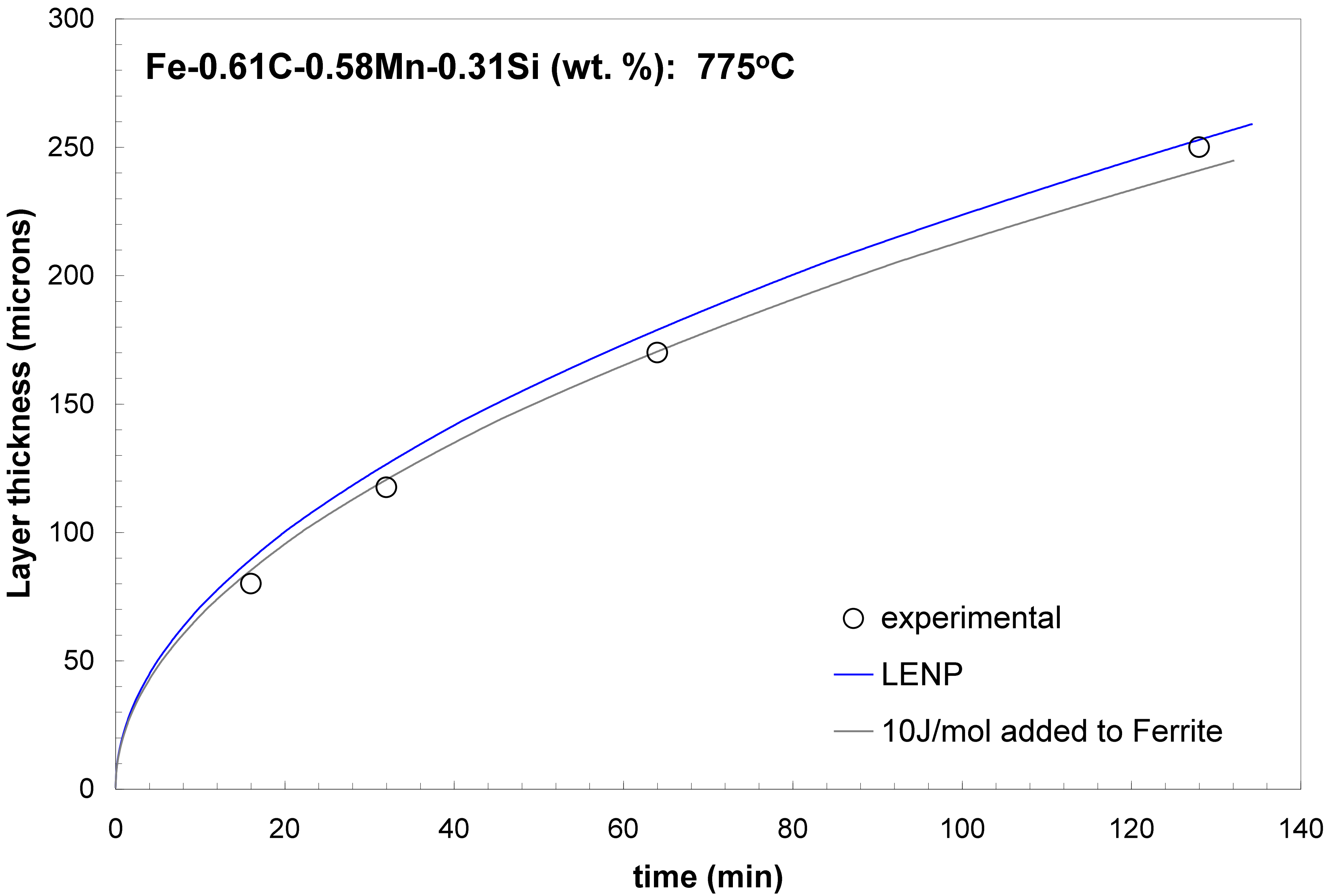
C. R. Hutchinson, H. S. Zurob and Y. Brechet, Met Trans A.

2.6. Fe-C-Si Decarburization Experiments

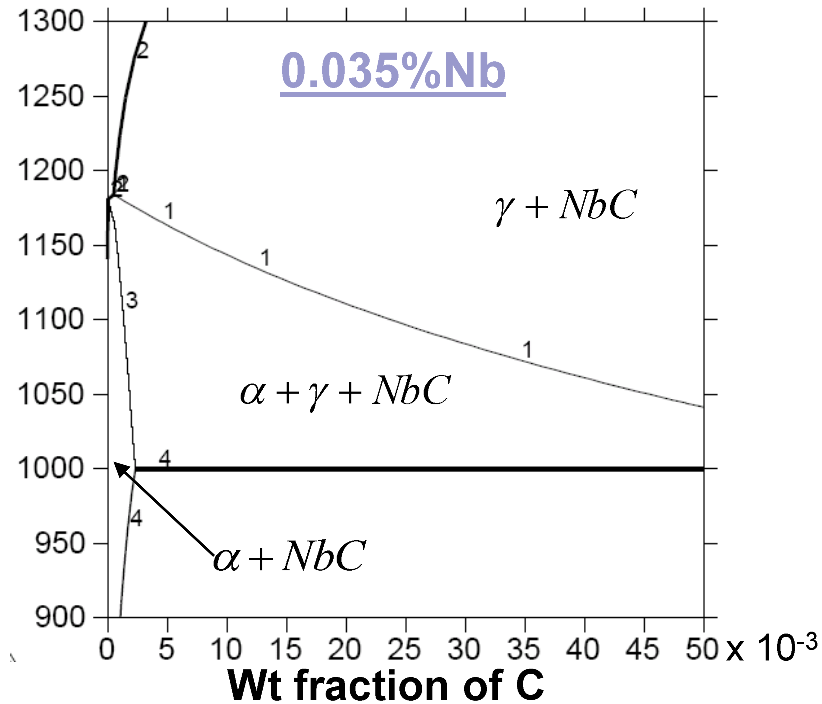



Fe-0.58C-0.88Si (wt. %): 775°C
layer thickness (microns)
0
50
100
150
200
250
300
350
400
time (min)
0
20
40
60
80
100
120
140
160
LENP 775C
Exp 775
LENP 775C 45J/mol Dissipation

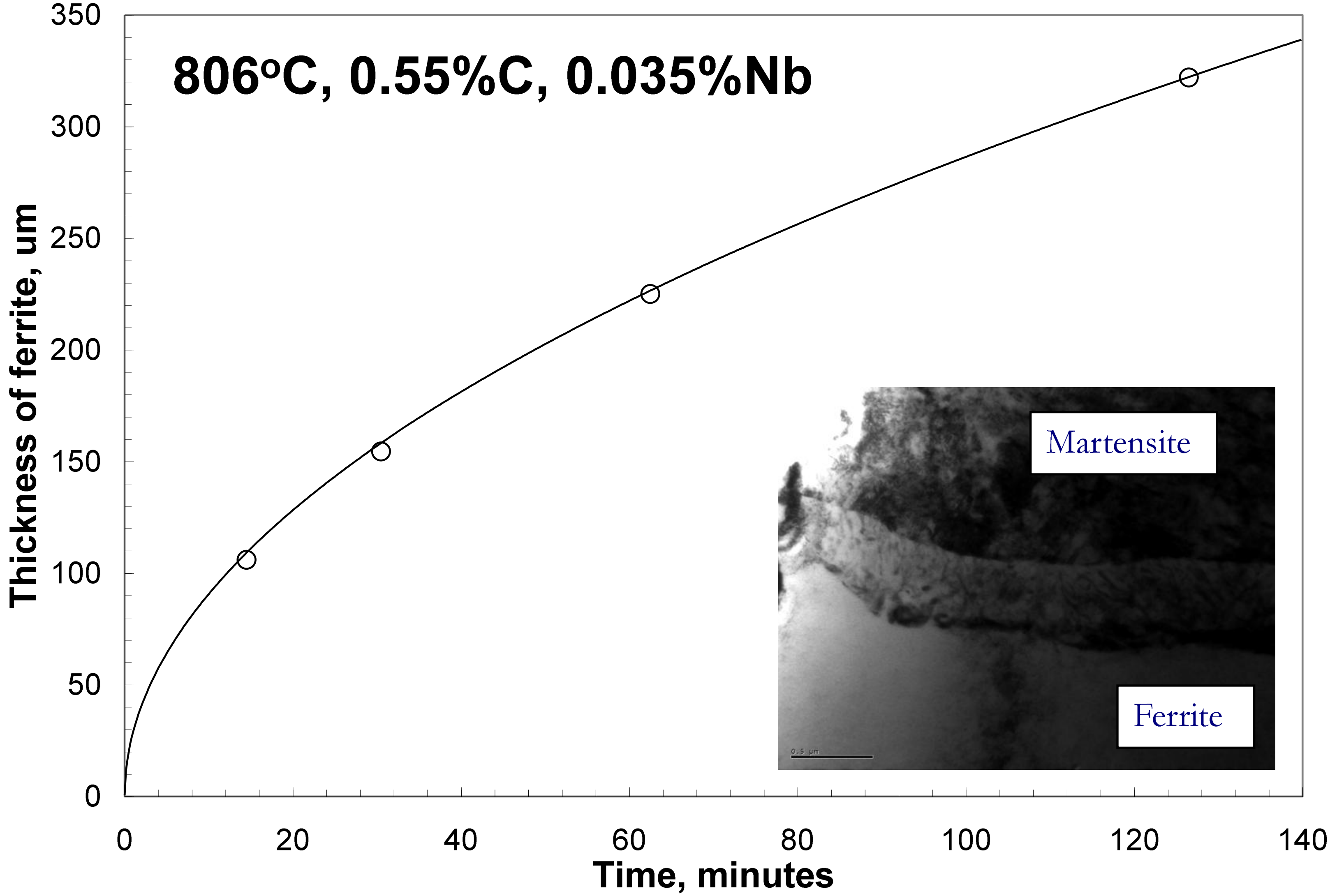
Fe-C-Si-Mn Decarburization Experiments



2.7. Fe-C-Nb Decarburization Experiments



2.7. Fe-C-Nb Decarburization Experiments



Summary

Alloy (wt. %)	Treat. Temp (^oC)	Interfacial Compositions	Exp. observed excess dissipation	
			(J/mole)	(MPa)
Fe-0.50C-0.97Ni Fe-0.50C-1.66Ni Fe-0.38C-1.03Ni	775 775 800	LENP LENP LENP	- - -	- - -
Fe-57C-0.94Mn	806 775 755 725	LENP+ LENP LENP LENP	- - - -	- - - -
Fe-0.54C-0.51Mo	825 806 775	LENP- LENP- LENP-	8 10 50	1.1 1.4 7.4
Fe-0.58C-0.88Si	806 775	LENP- LENP-	20 45	2.9 6.4
Fe-0.61C-0.58Mn-0.31Si	775	LENP-	10	1.4
Fe-0.56C-1.97Cr	850 825 806	LENP LENP- LENP-	- 12 30	- 1.7 4.2

3. Future Work:

- Search for Transition in Fe-Mn-C at high temperatures.
- More detailed investigation of the quaternary Fe-C-Mn-Si.
- One more temperature in Fe-C-Cr.
  - Question: If we use 775^{o}C, will precipitation be a problem?
- Denitriding of Fe-N-Cr down to 675^{o}C.
  - Question: will denitriding be controlled by N diffusion? How can we check?