Kinetic Transitions in Fe-Mn-C Alloys

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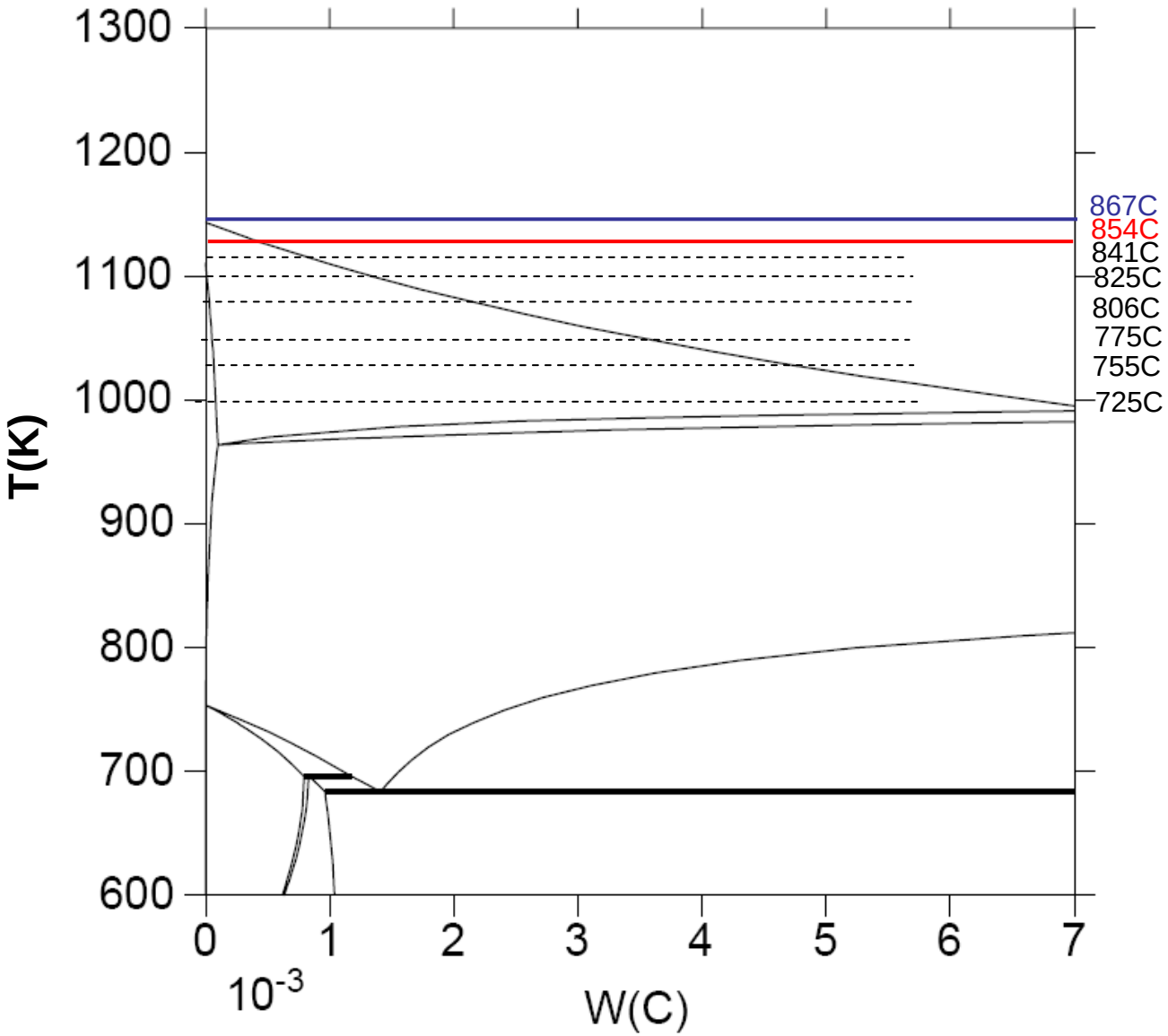
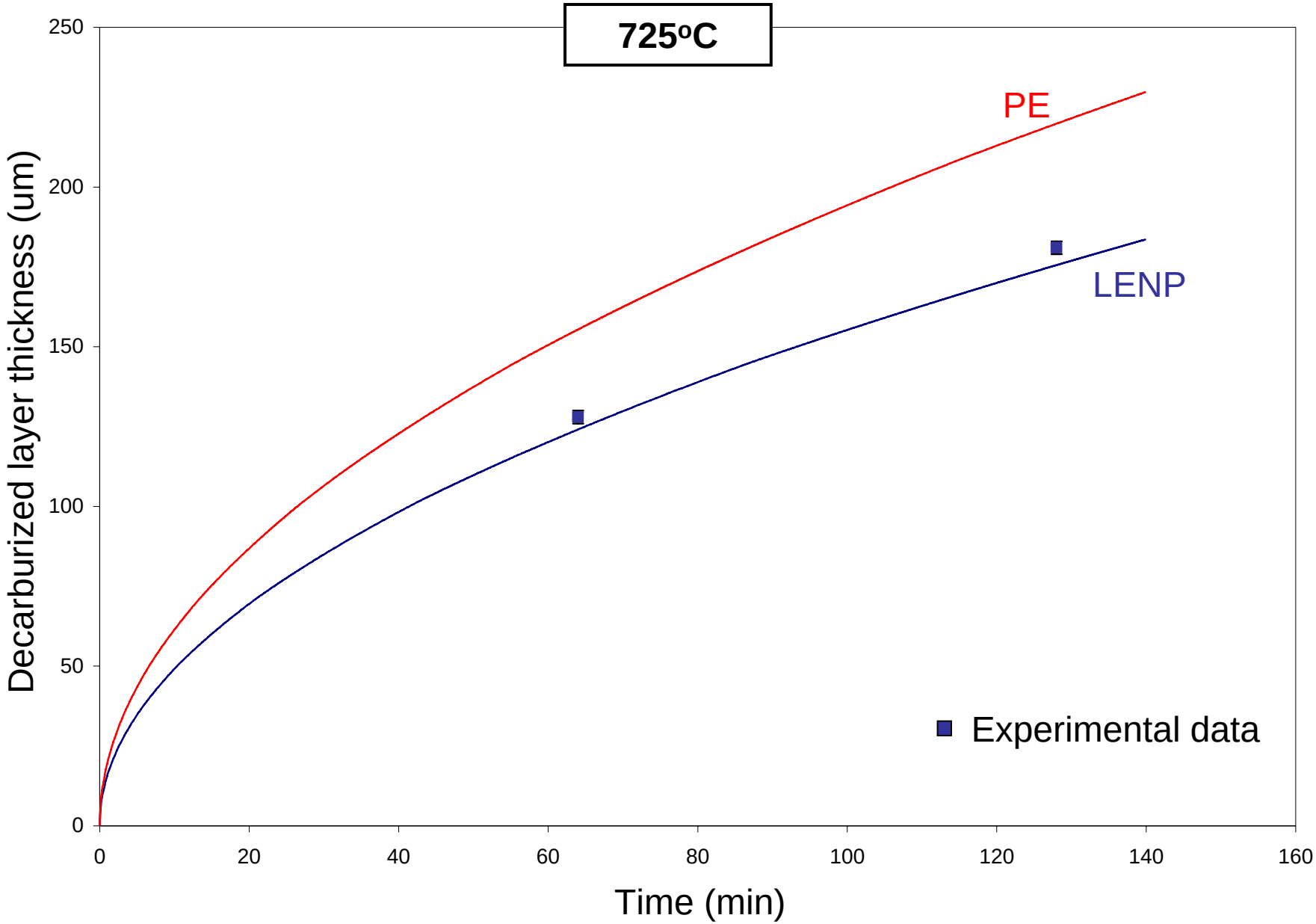
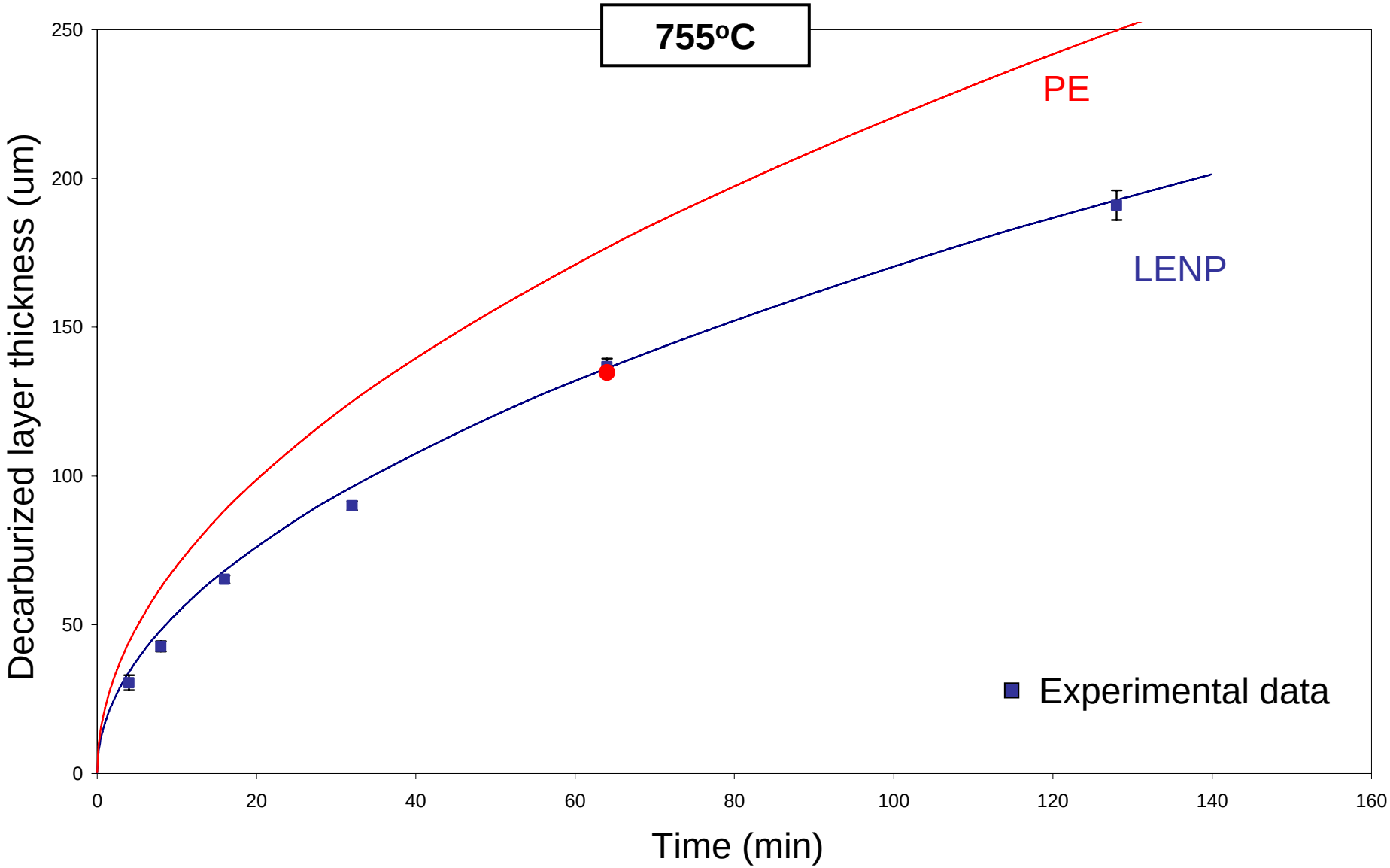
Experiments

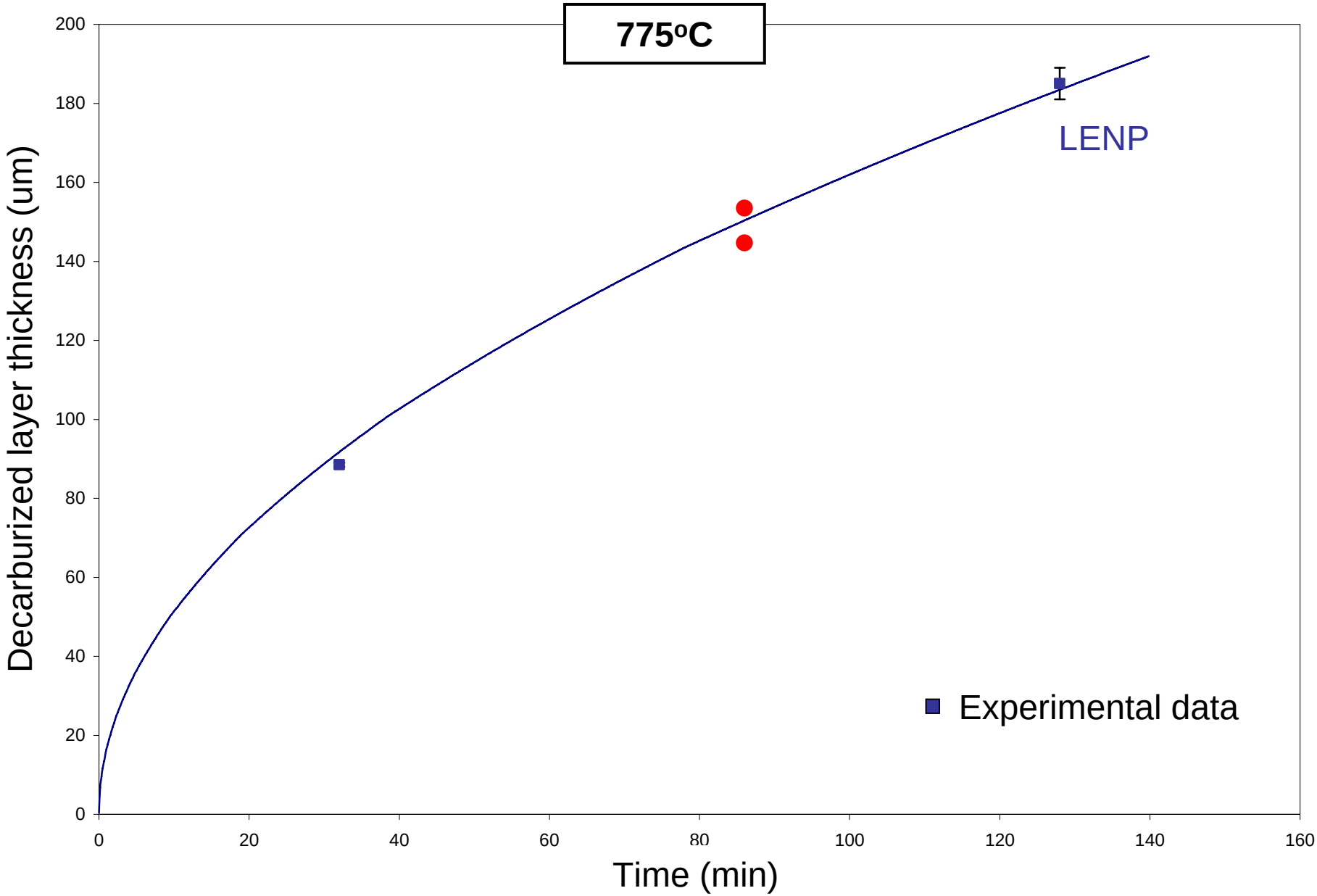
A steel with 0.94 wt% Mn and 0.57% C was decarburized at:

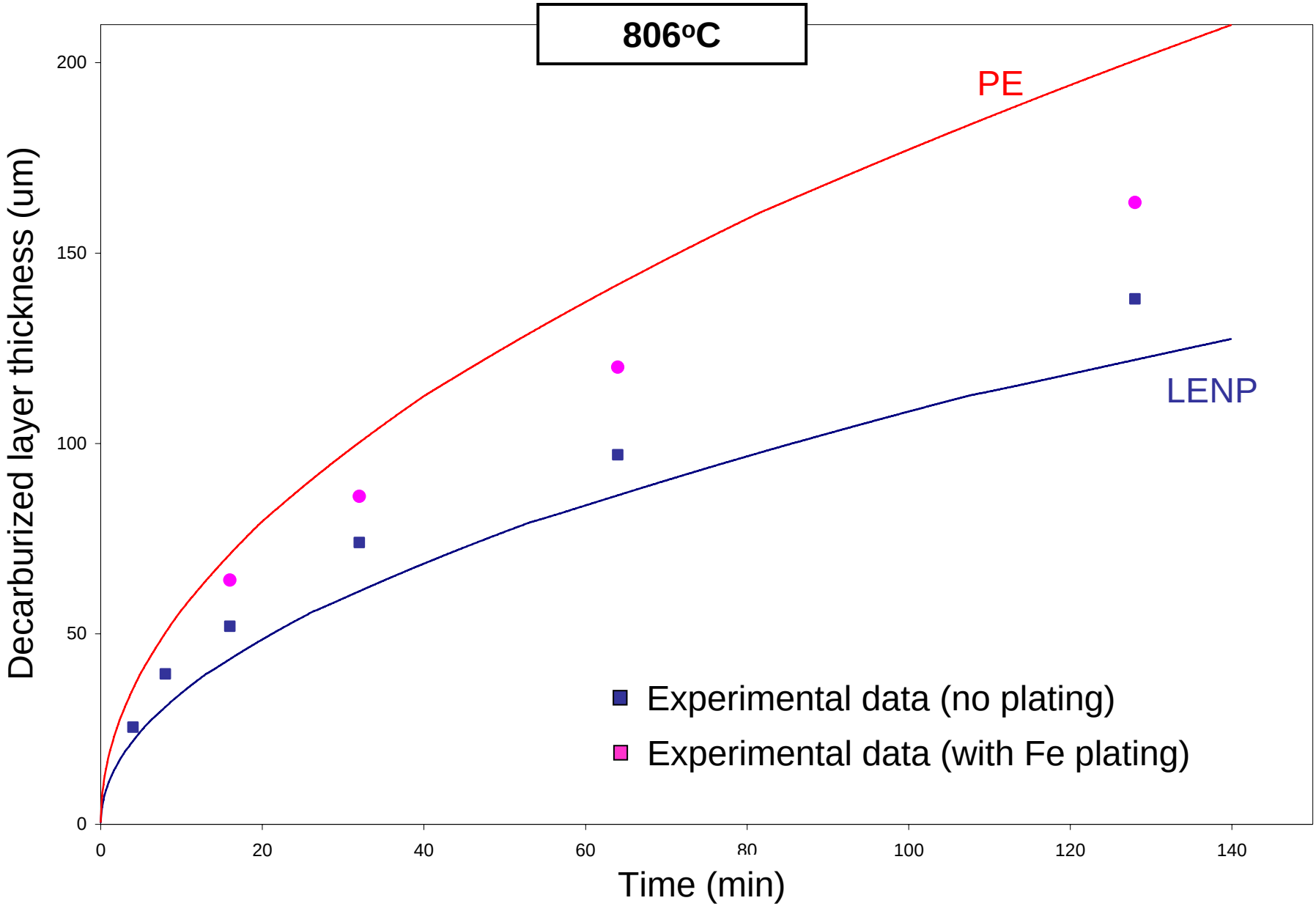
- 725°C
- 755°C
- 775°C
- 806°C
- 825°C
- 841°C

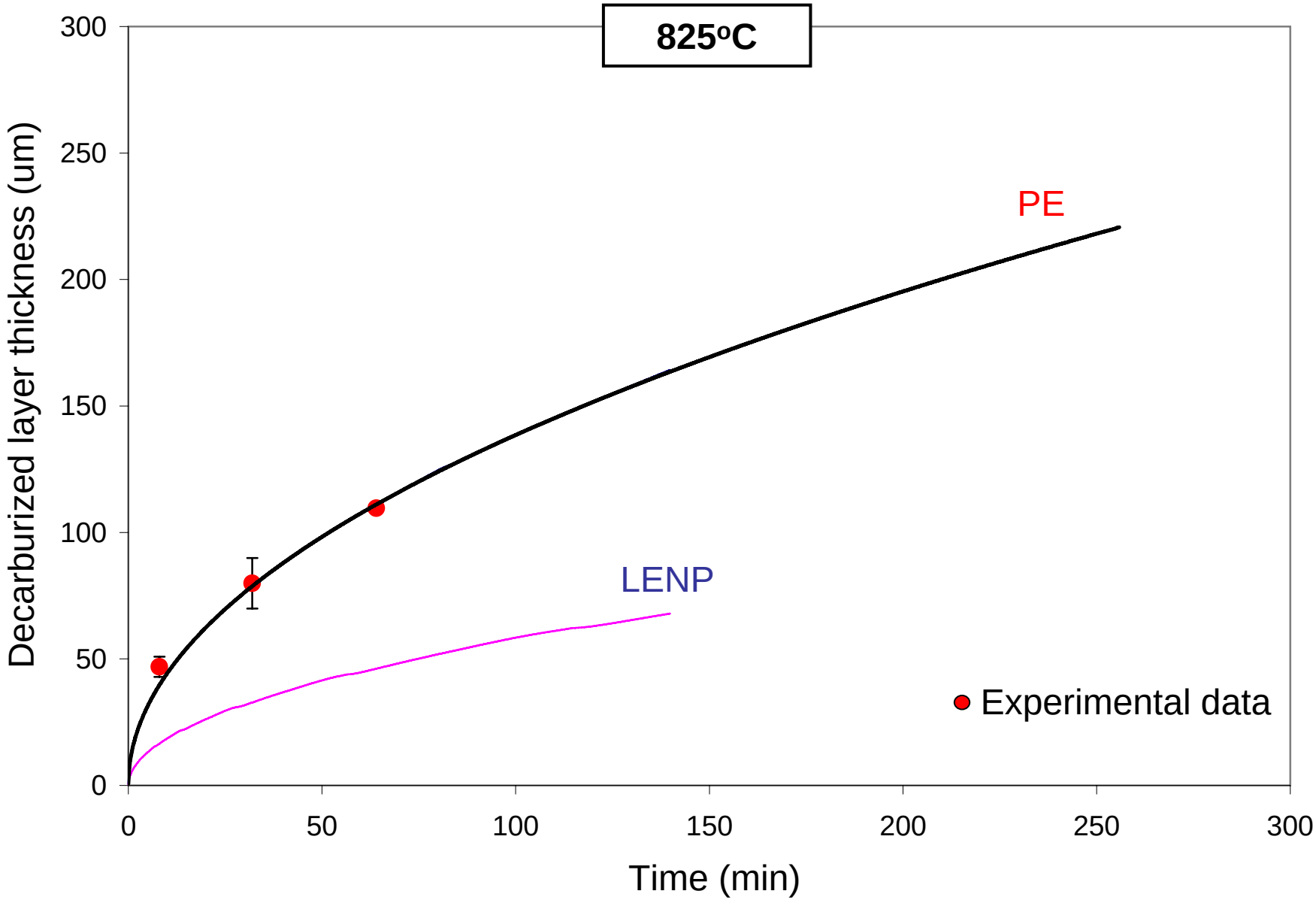


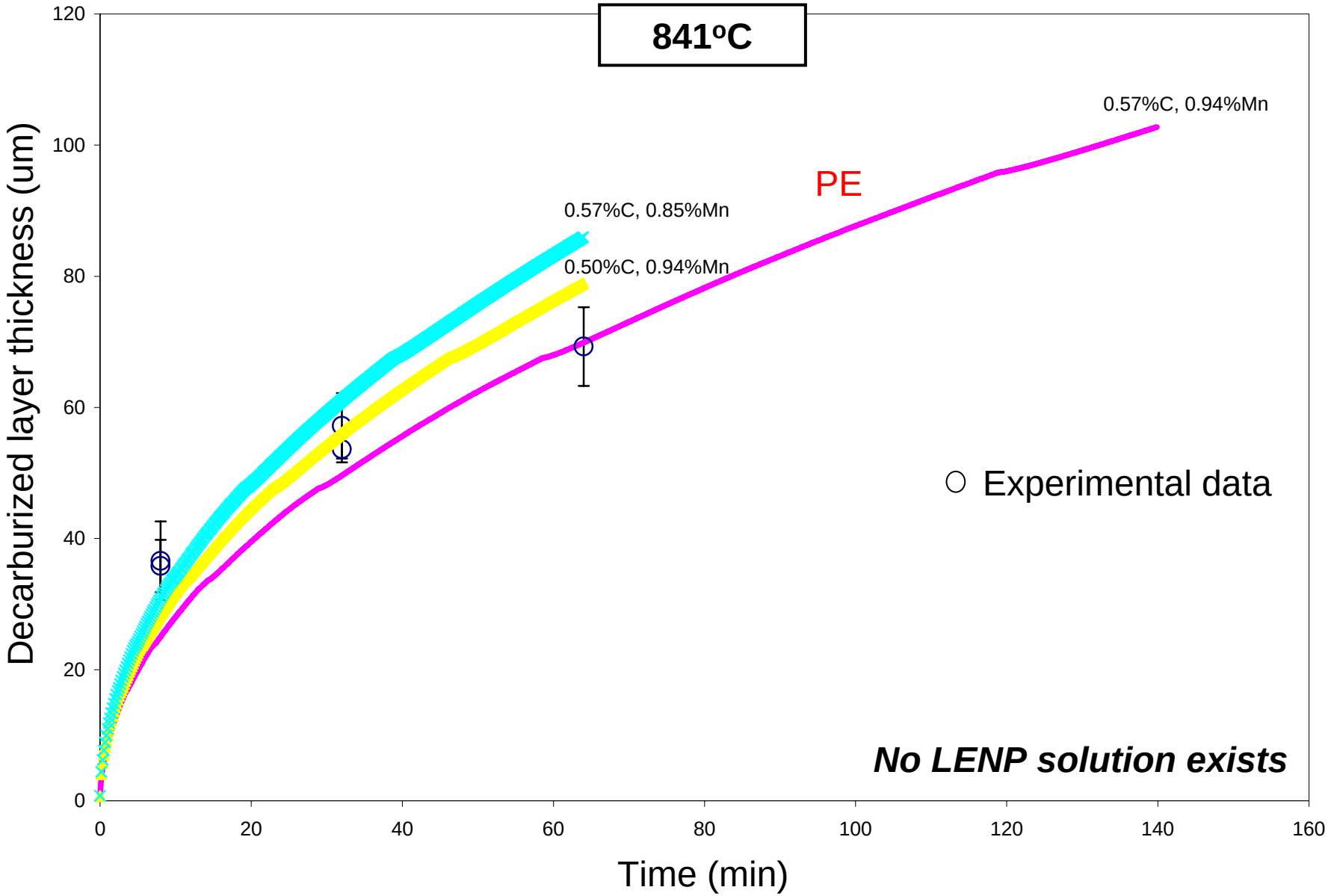

725°C
PE
LENP
Experimental data
Decarburized layer thickness (um)
Time (min)
0
50
100
150
200
250
0
20
40
60
80
100
120
140
160


755ºC
PE
LENP
Experimental data
Decarburized layer thickness (um)
Time (min)
0
50
100
150
200
250
0
20
40
60
80
100
120
140
160

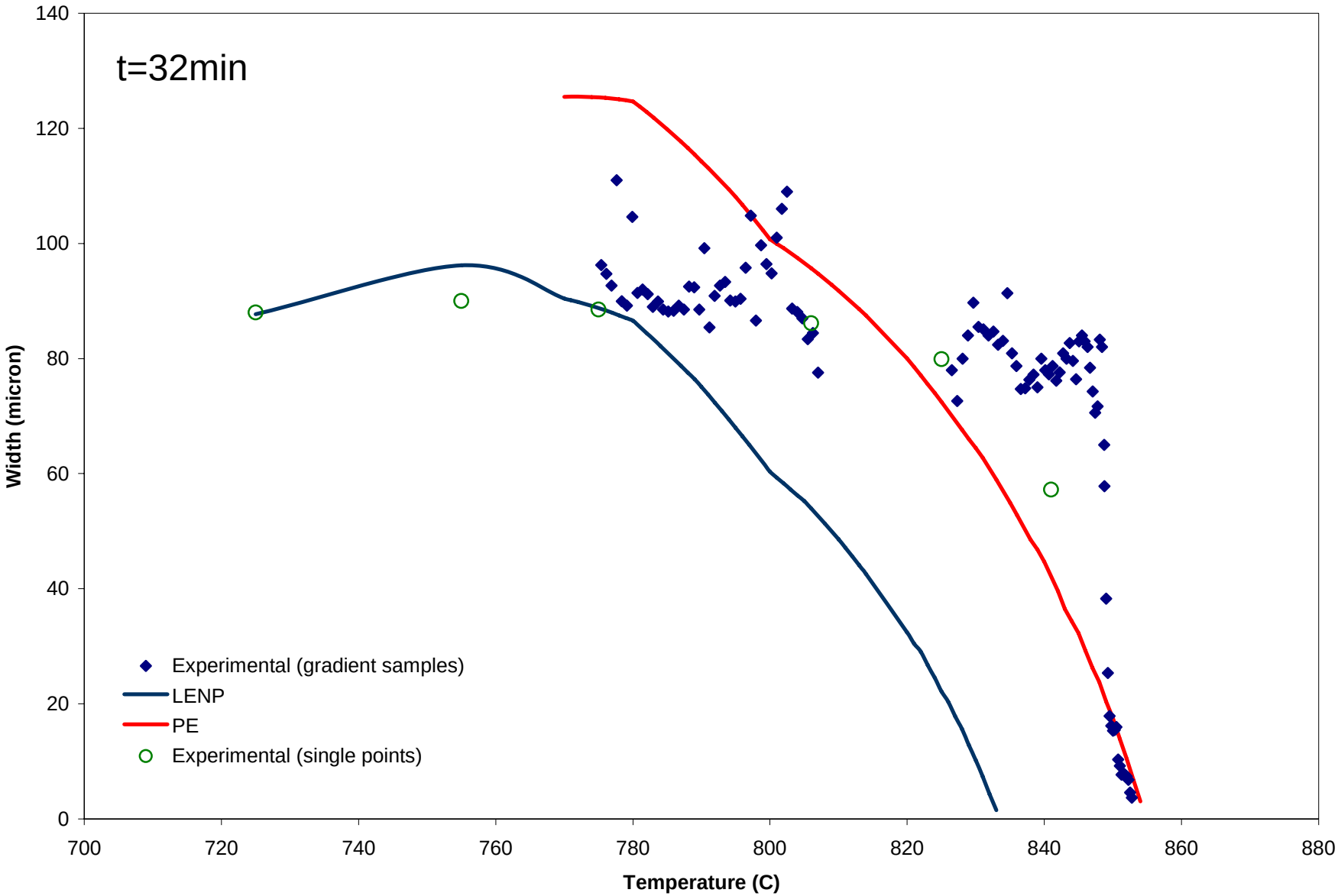

775ºC
LENP
Experimental data
Decarburized layer thickness (um)
Time (min)
0
20
40
60
80
100
120
140
160
180
200


806°C
PE
LENP
Experimental data (no plating)
Experimental data (with Fe plating)
Decarburized layer thickness (um)
Time (min)
0
50
100
150
200
0
20
40
60
80
100
120
140


825ºC
Decarburized layer thickness (um)
Time (min)
PE
LENP
Experimental data
0
50
100
150
200
250
300


841°C
0.57%C, 0.94%Mn
PE
0.57%C, 0.85%Mn
0.50%C, 0.94%Mn
Experimental data
No LENP solution exists
Decarburized layer thickness (um)
Time (min)
0
20
40
60
80
100
120
140
160

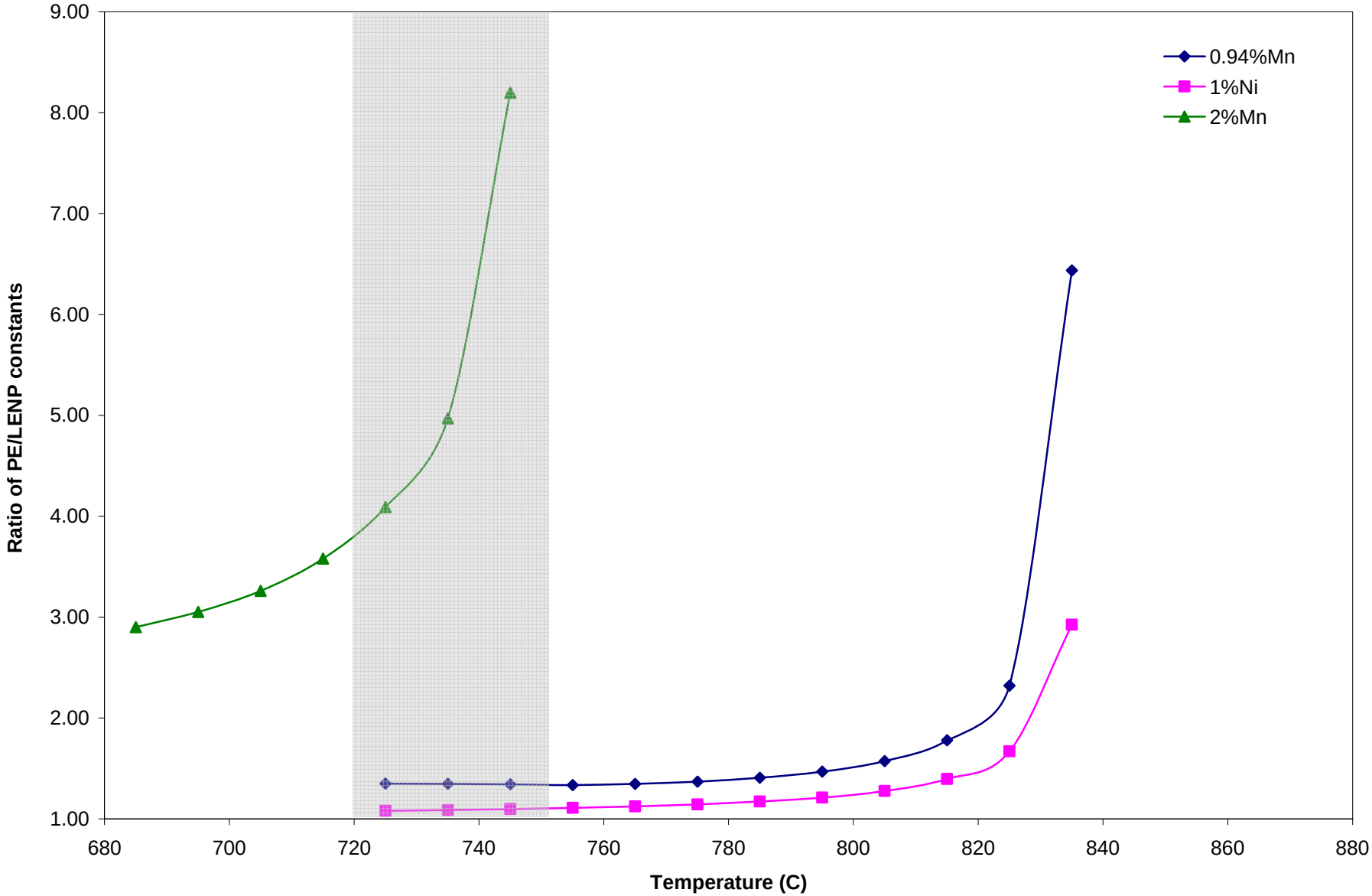
Blue dots show experimental data obtained by decarburizing a long sample in a temperature gradient for 32 min.



Additional Results

- Fe-0.94%Mn-0.27%C give at ***806C***, gives something very close to PE.

- Fe-2%Mn-0.6%C at ***736C***, gives LENP, possibly something much faster at the corners.


9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
Ratio of PE/LENP constants
680
700
720
740
760
780
800
820
840
860
880
Temperature (C)
0.94%Mn
1%Ni
2%Mn

Reminder

- Fe-Ni-C followed the LENP model under all conditions.
- This was checked with Fe → Fe-5%Ni diffusion couple. Ferrite growth stopped at the LENP limit.
- We also tried to decarburize above the LENP limit and no ferrite was formed.

Key Issues

- What is the difference between Ni and Mn?
- How do we explain the PE state at high temperatures in Fe-Mn-C.
- How can we capture the transition?
- How do we account for long-lived intermediate states between LENP and PE?

Discussion

- We tried a Global Dissipation approach but found that LENP always dissipates more energy than PE. As such a transition could not be explained.

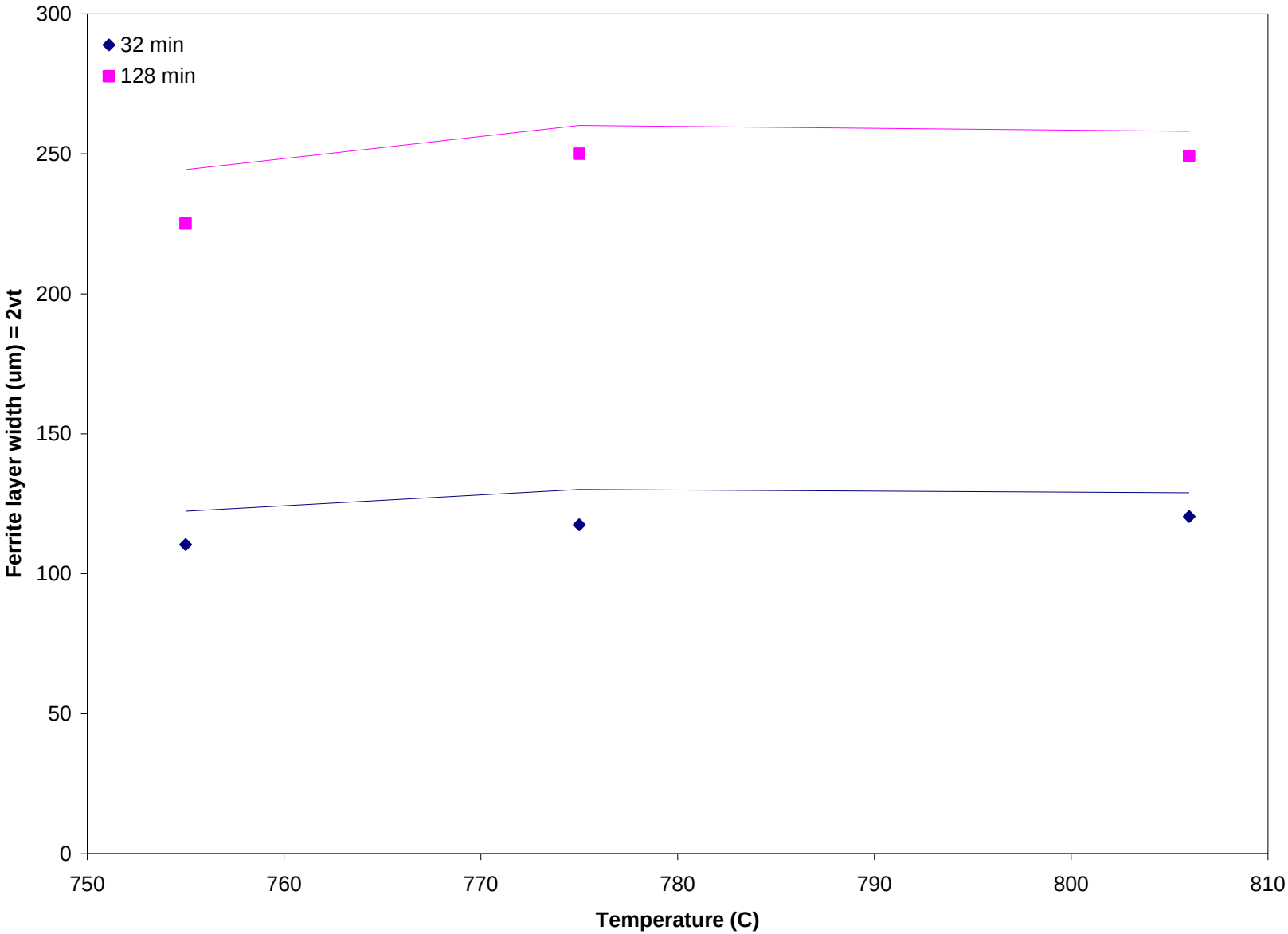
- Hillert's Approach (Phoenix) involving a diffusive flux and a diffusionless flux (due to interface motion) could also be used, but it requires four cross interface parameters for which we don't have any estimates.

- Segregation to the interface may explain the difference between Mn and Ni. It may also delay the transition from PE to LENP leading to a long-lived PE state.

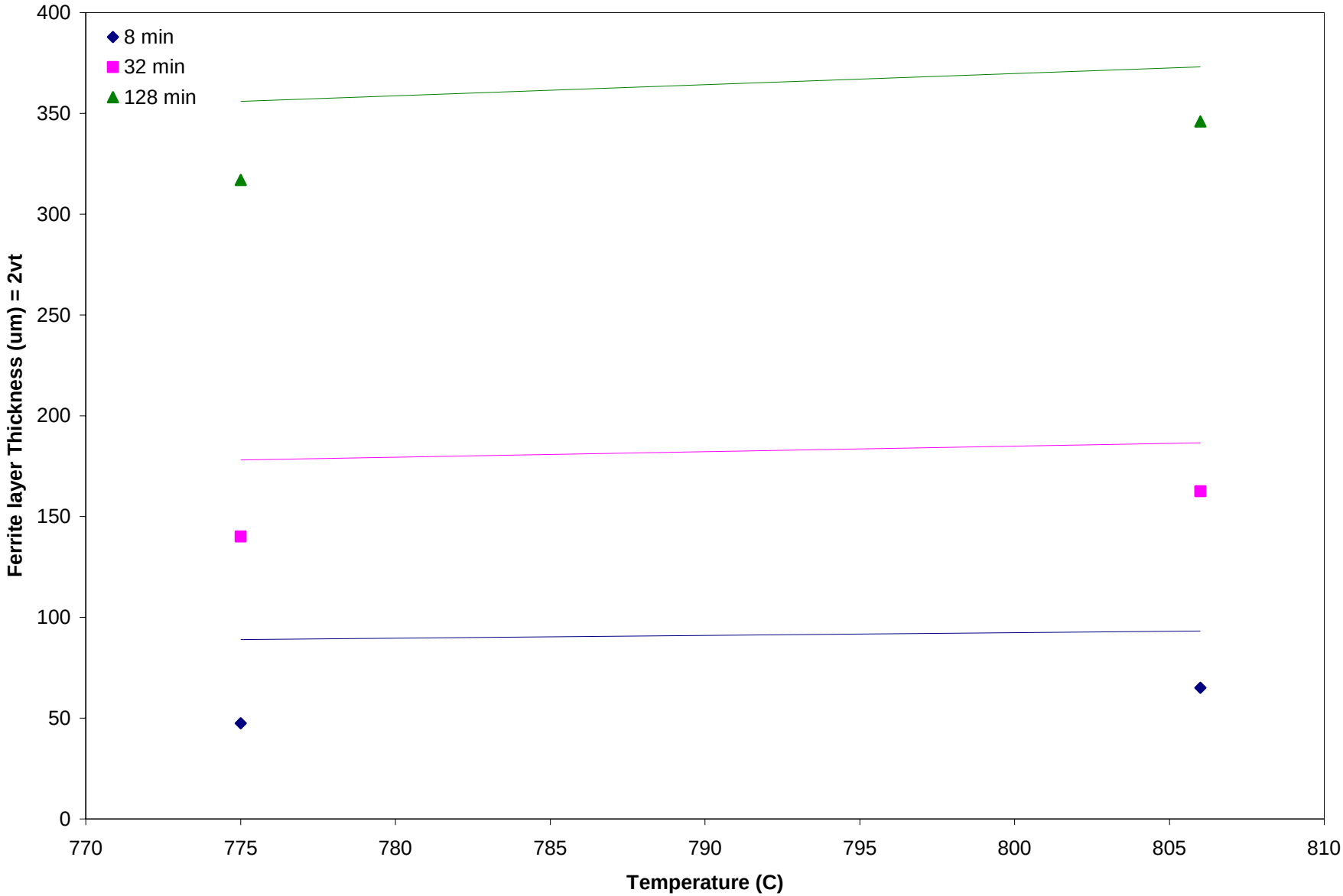
- Kirkendall Effect. The difference in temperature dependence of the mobilities of Mn and Fe in the interface might explain the transition.

Additional Results

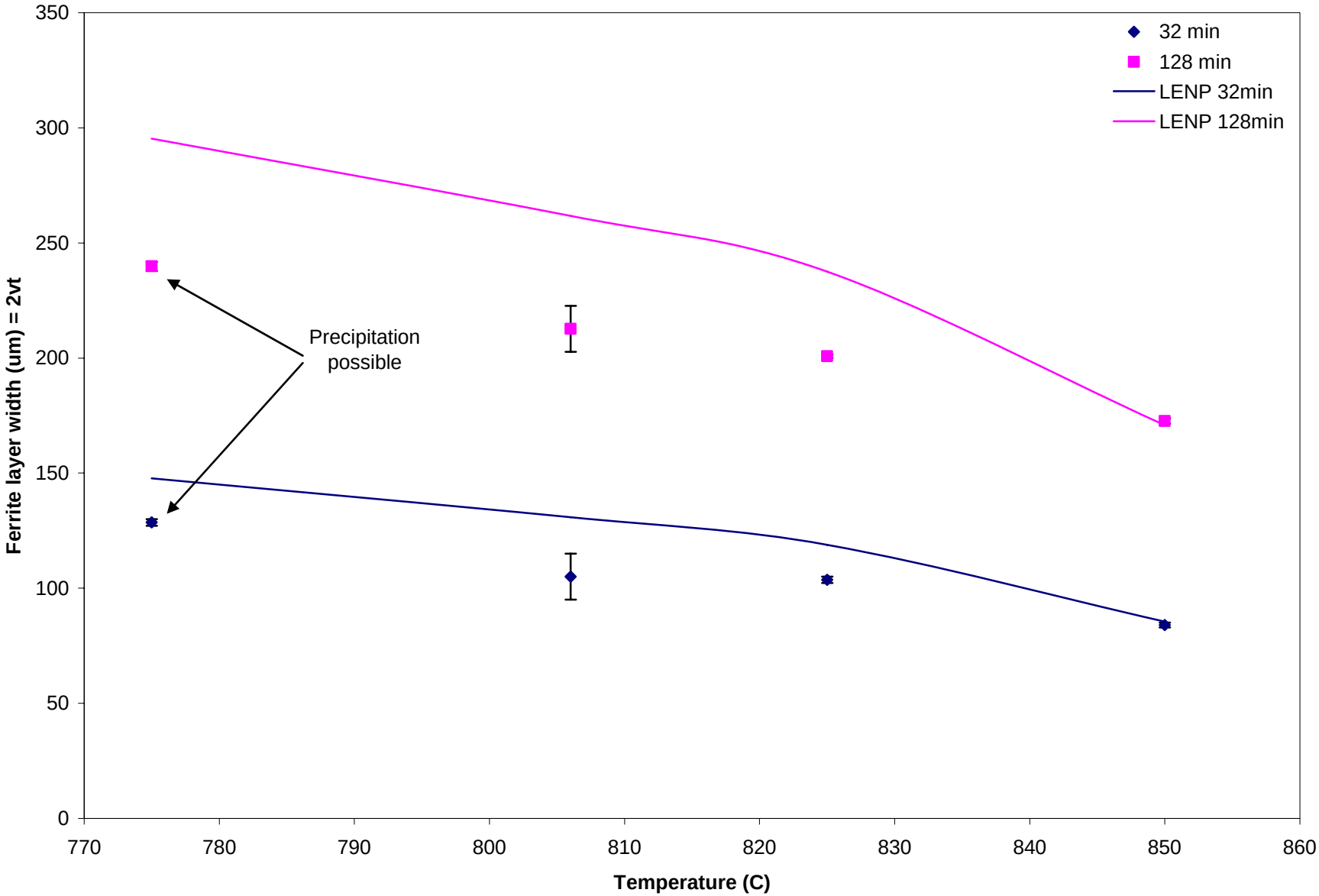
Fe-0.58Mn-0.31Si-0.61C



Fe-0.88Si-0.58C



Fe-2Cr-0.58C


32 min
128 min
LENP 32min
LENP 128min
Precipitation possible
Ferrite layer width (um) = 2vt
Temperature (C)
350
300
250
200
150
100
50
0
770
780
790
800
810
820
830
840
850
860

Fe-0.51Mo-0.54C