Carbon enrichment in austenite during ferrite and bainite transformations in Fe-Mn-C based alloys

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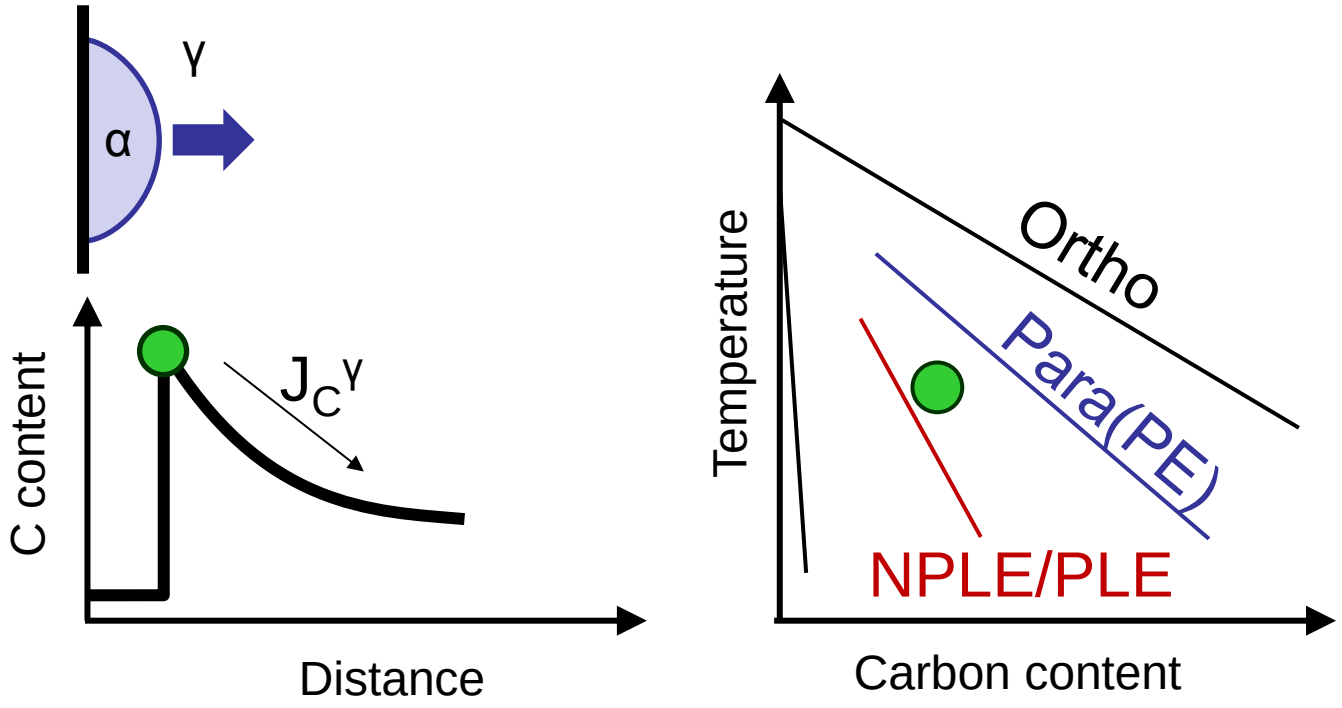
C enrichment in austenite (γ) during transformation



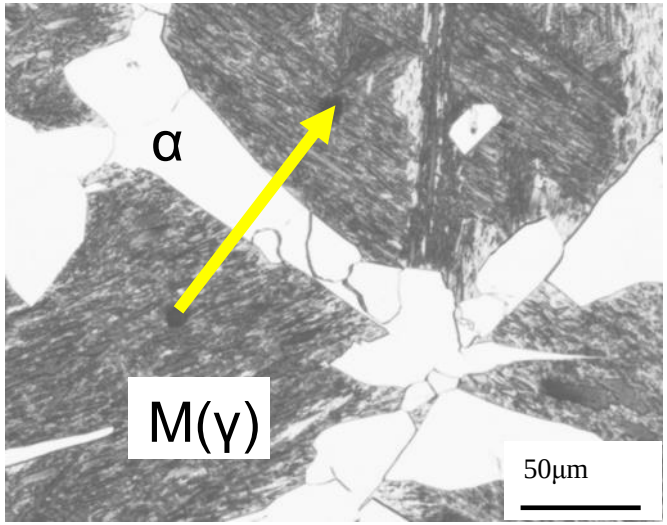
Carbon enrichment in γ at the interface

- dominates α growth rate.
- represents non-equilibrium state of migrating interface.
- influences austenite stability (TRIP effect).

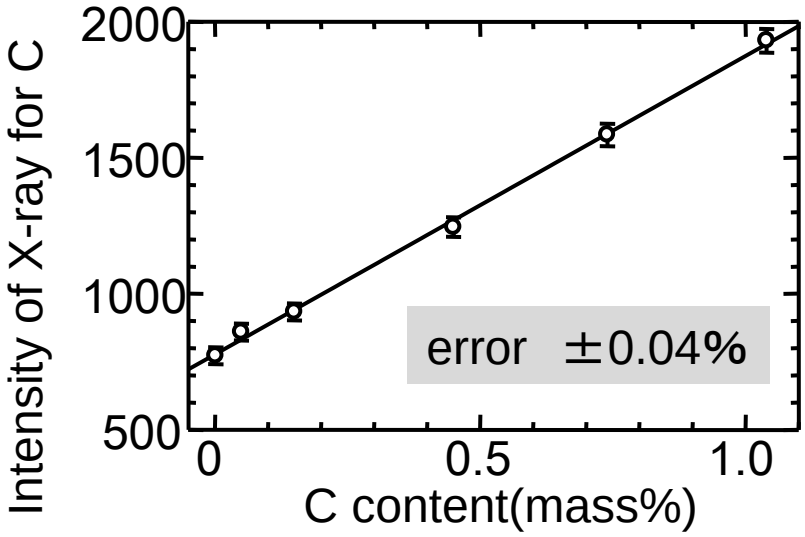
Direct measurement of C content by FE-EPMA

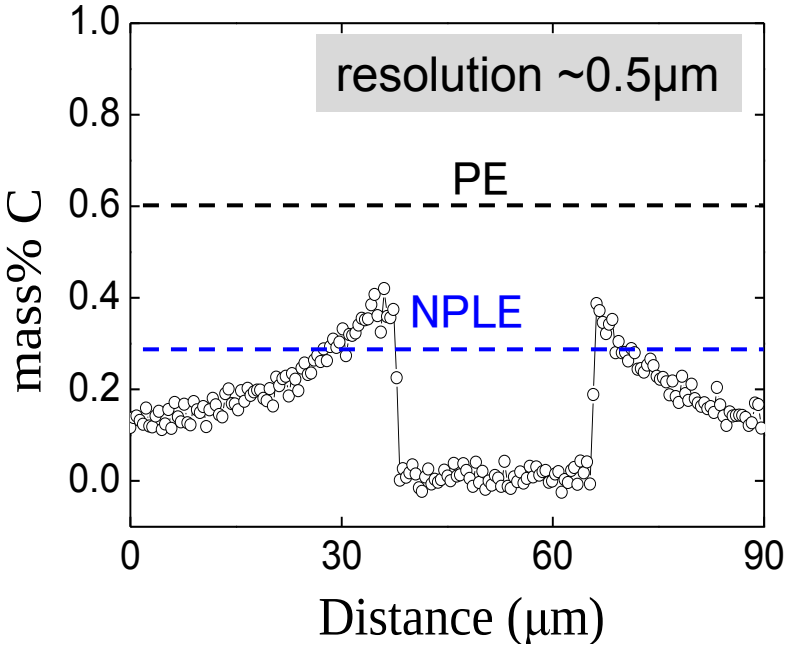
Field Emission
Electron Probe MicroAnalizer

JXA-8530F



Calibration curve from std specimens

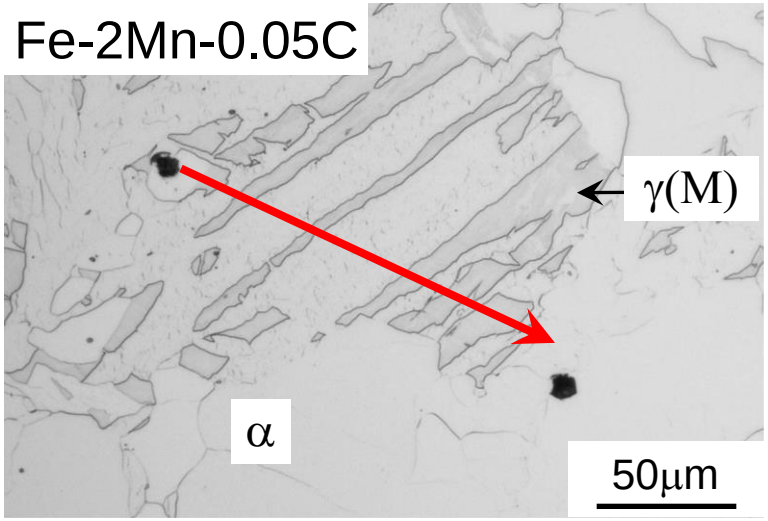




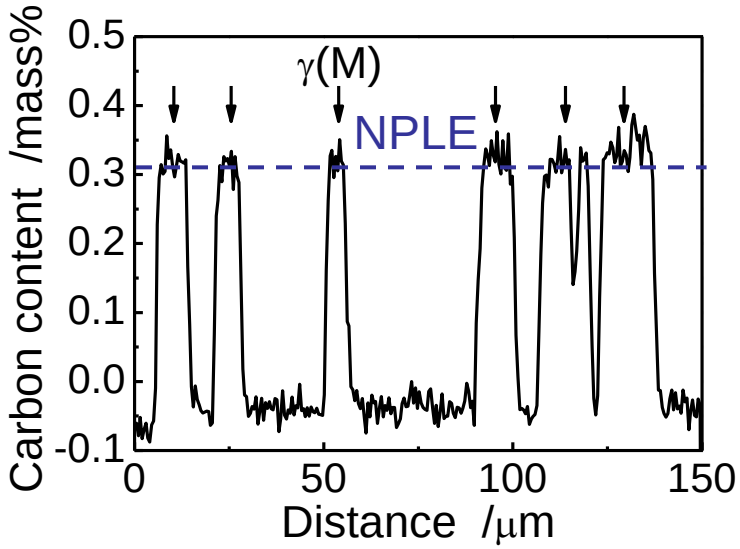
C content in γ in Fe-2Mn-(0.05, 0.14)C alloys [1]

923K 7.2ks

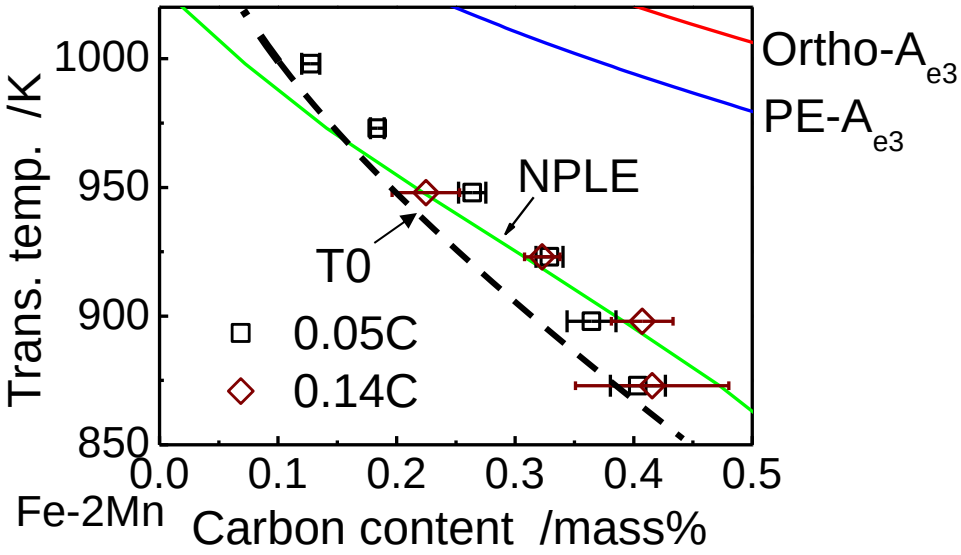
Fe-2Mn-0.05C



%C for PE = 0.96%



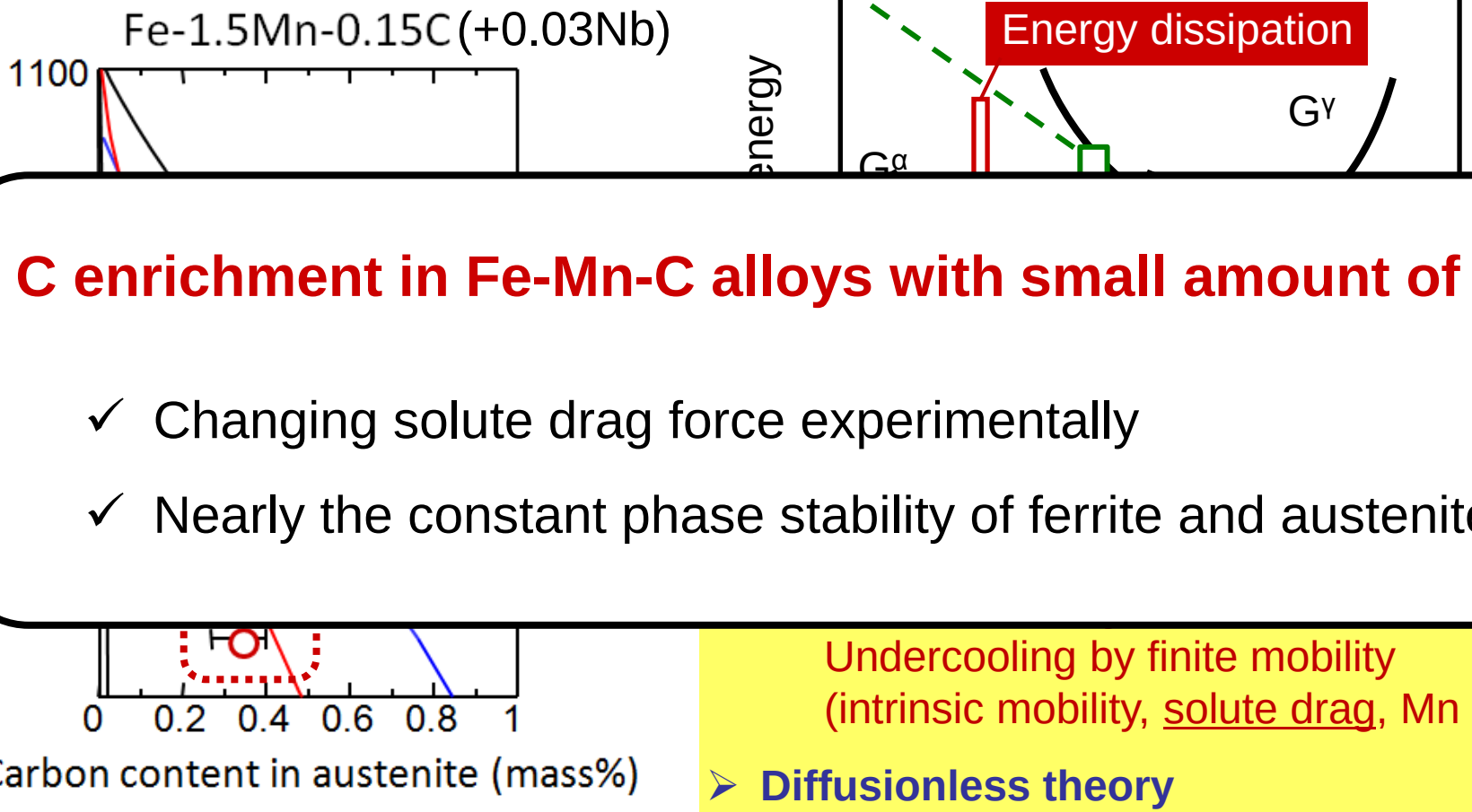
C content in γ in the steady stage



C content in γ agrees with NPLE model or T0 composition.

[1] Z.-Q. Liu, G. Miyamoto, Z.-G. Yang, T. Furuhara, MMTA, 44A(2013), 5456

Deviation of C content from equilibrium



C enrichment in Fe-Mn-C alloys with small amount of Mo

- ✓ Changing solute drag force experimentally
- ✓ Nearly the constant phase stability of ferrite and austenite

Undercooling by finite mobility
(intrinsic mobility, solute drag, Mn spike)

➢ **Diffusionless theory**
Undercooling by strain energy

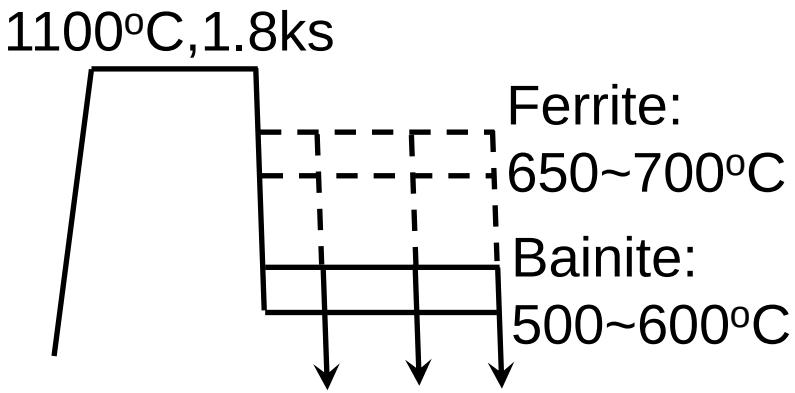
Experimental procedure

➢ **Alloys** (mass%)

Base alloy : Fe-0.1C-1.5Mn

Mo-added : Base +(0.03, 0.3, 0.5, 1.0)Mo

➢ **Heat treatment**

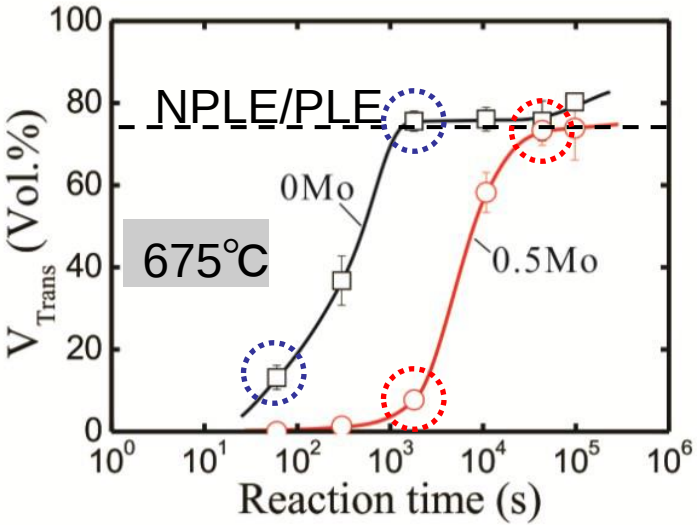


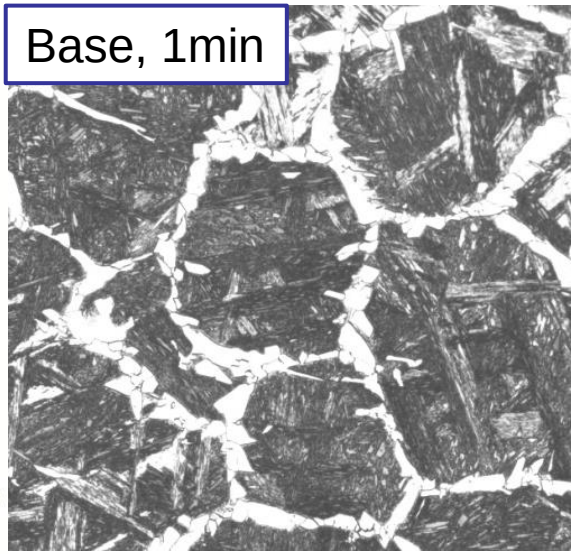
➢ **Characterization**

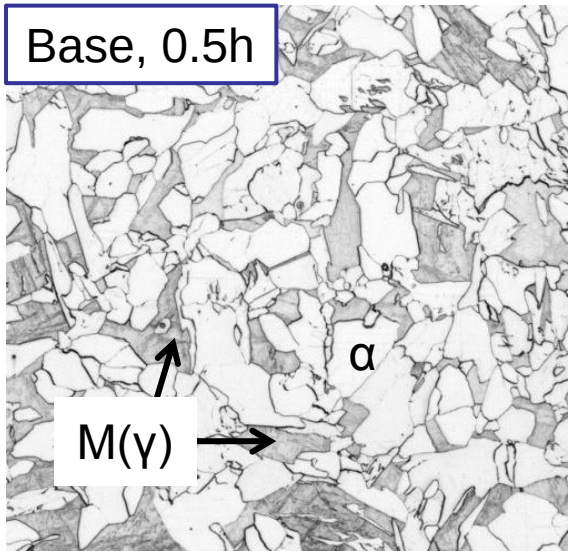
1. Optical Microscopy (OM)
2. Point Counting
3. FE-EPMA

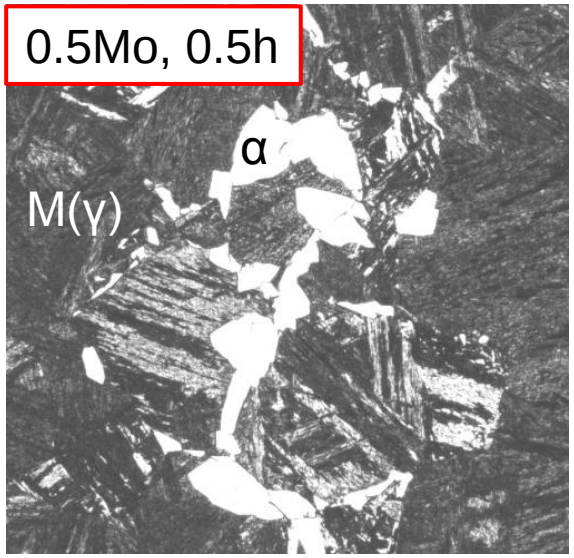
Mo effects on ferrite transformation

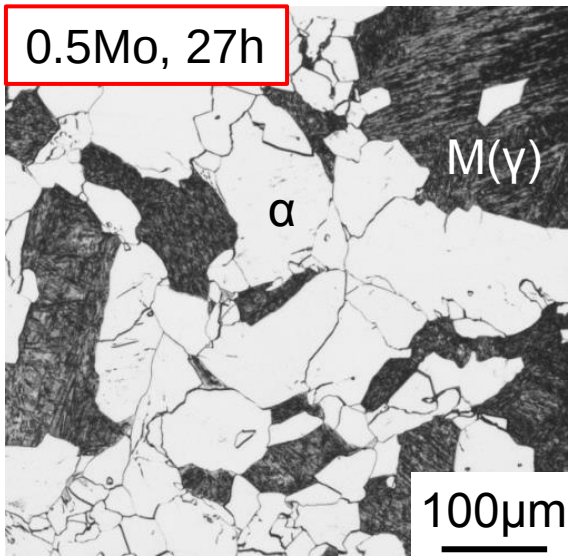
Transformation at 675°C









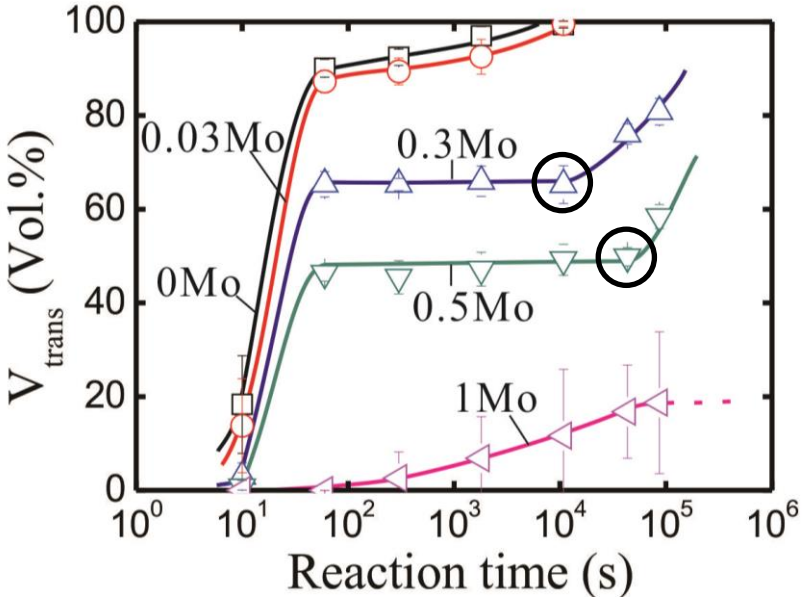


Mo addition results in

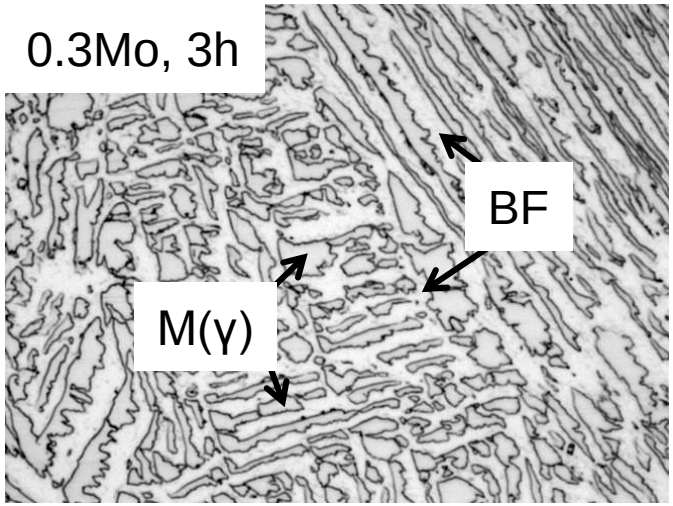
- Retardation of kinetics
- No influence on volume fraction in the steady stage

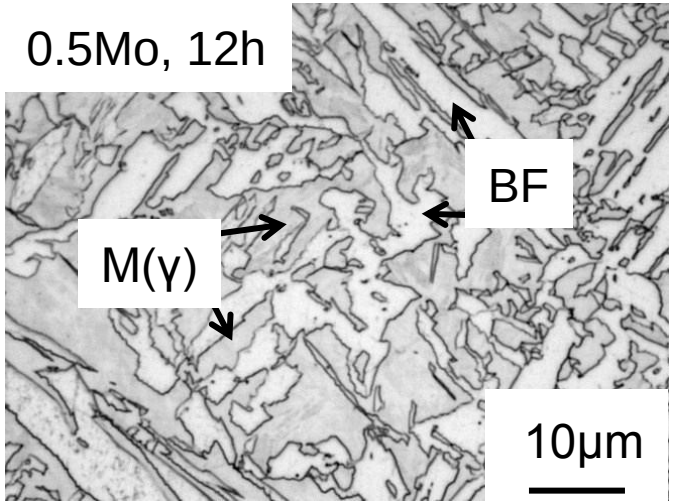
Effects of Mo on bainite transformation

Transformation at 575°C

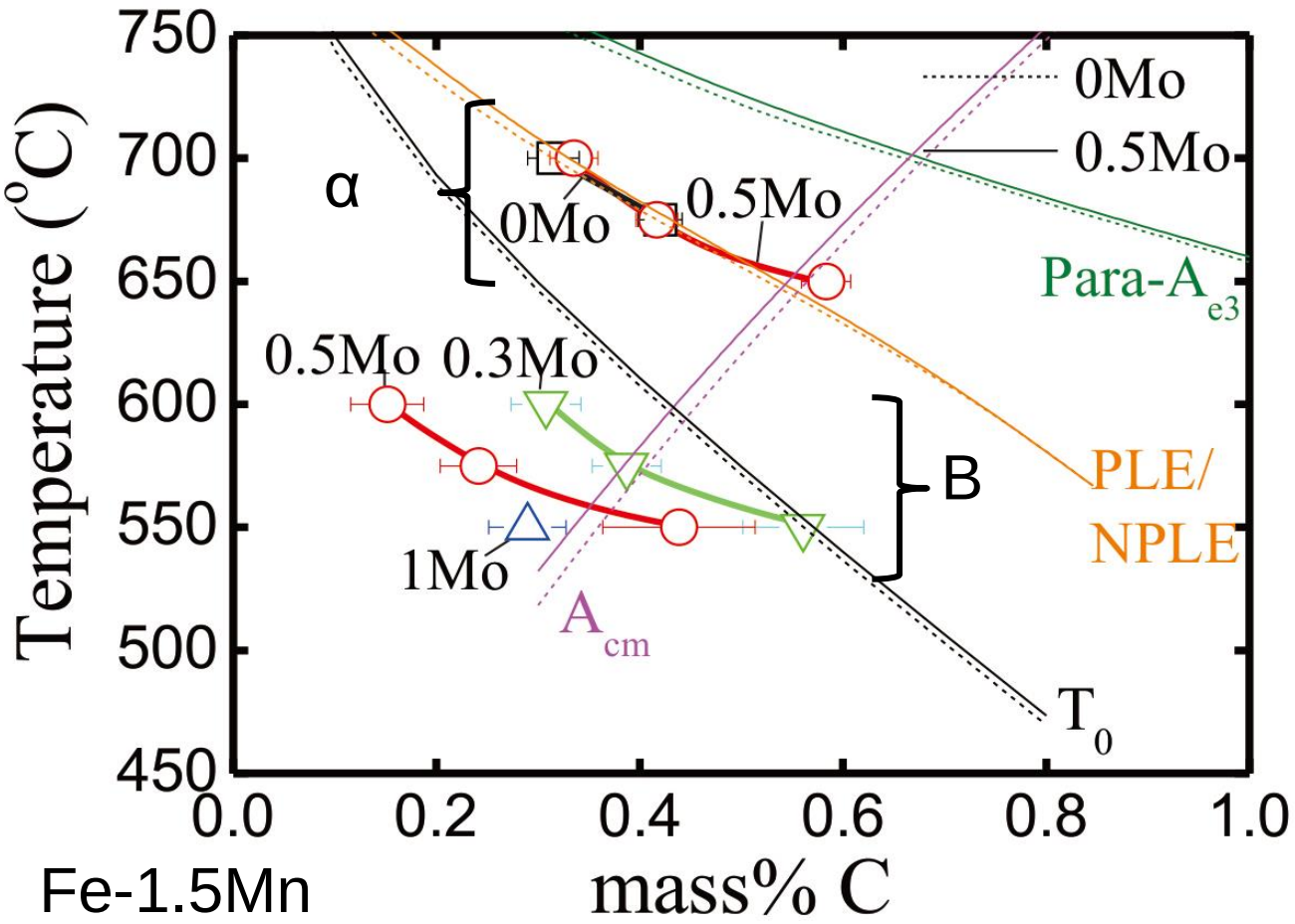


- Delaying kinetics
- Reducing volume fraction in the steady stage





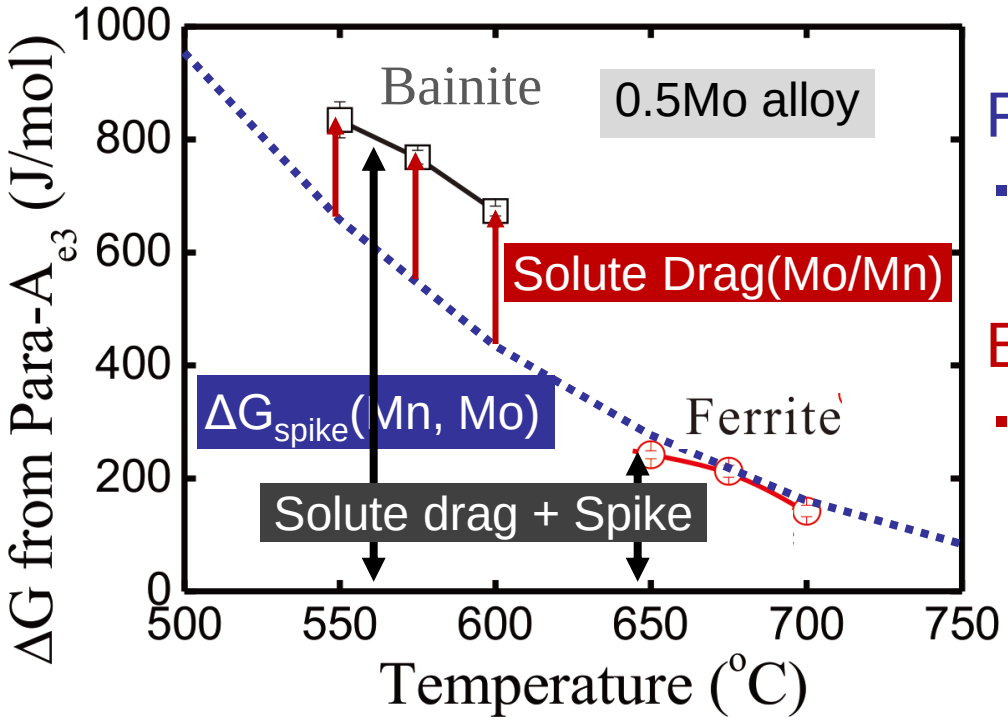
C enrichment in γ at the steady stage or stasis



Ferrite : good agreement with NPLE model regardless of Mo.
Bainite : lower than T0 composition and decreased by Mo.

Discussion ~ Examination by diffusional theory

Undercooling from PE at steady state/stasis

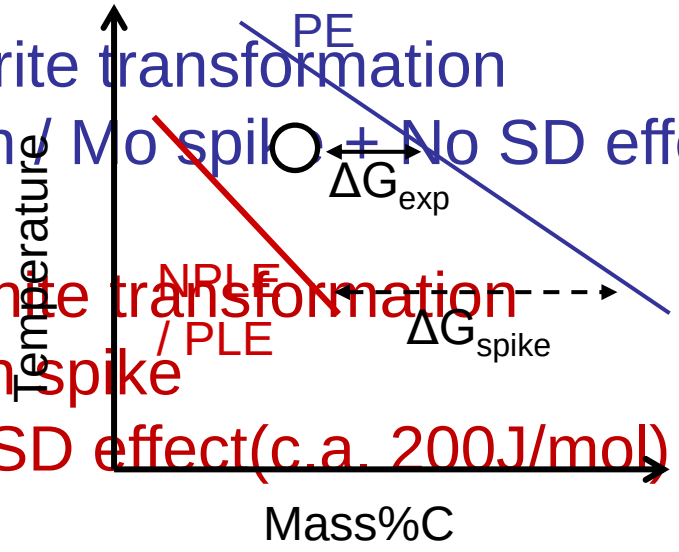


Ferrite transformation

- Mn/ Mo spike + No SD effect

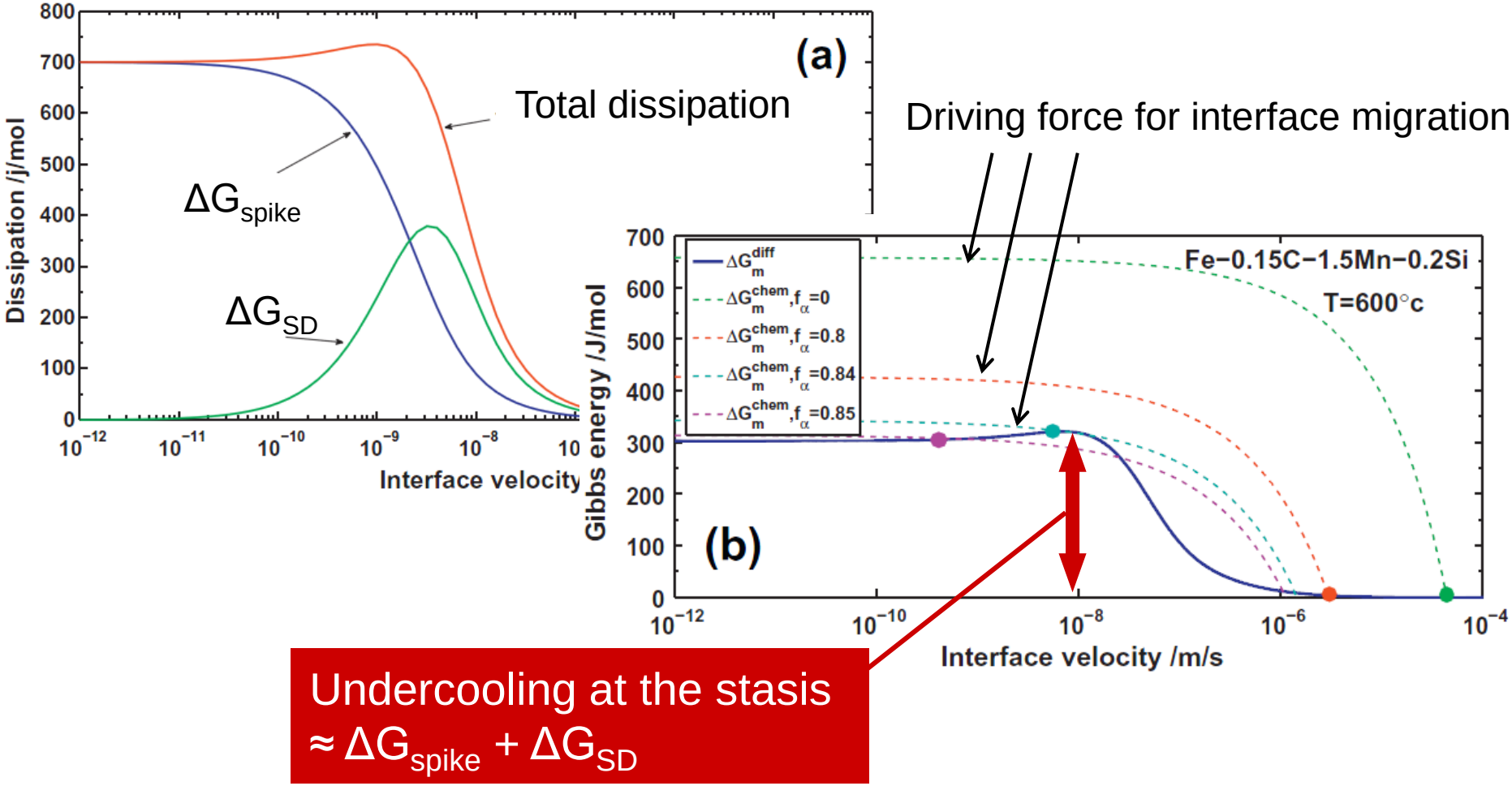
Bainite transformation

- Mn spike
  + SD effect(c.a. 200J/mol)



Gibbs energy balance(GEB) model by Hao Chen [1]

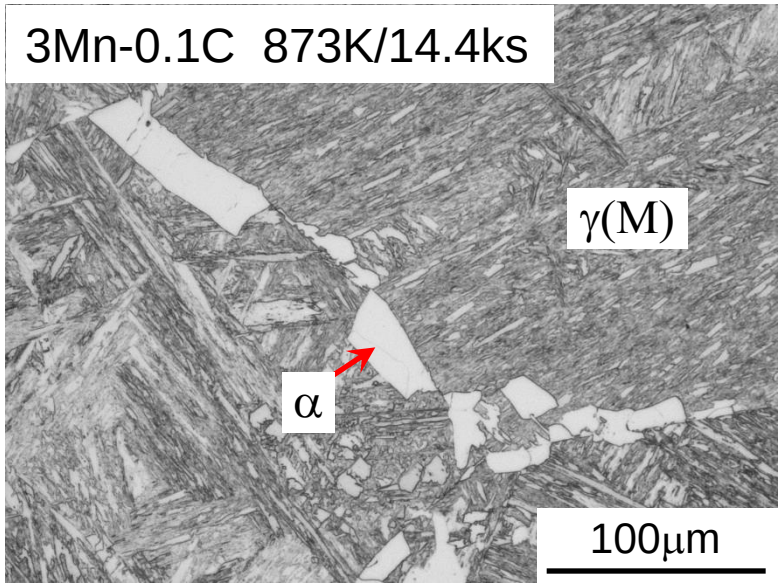
Fe-3Mn-0.1C@ 550°C

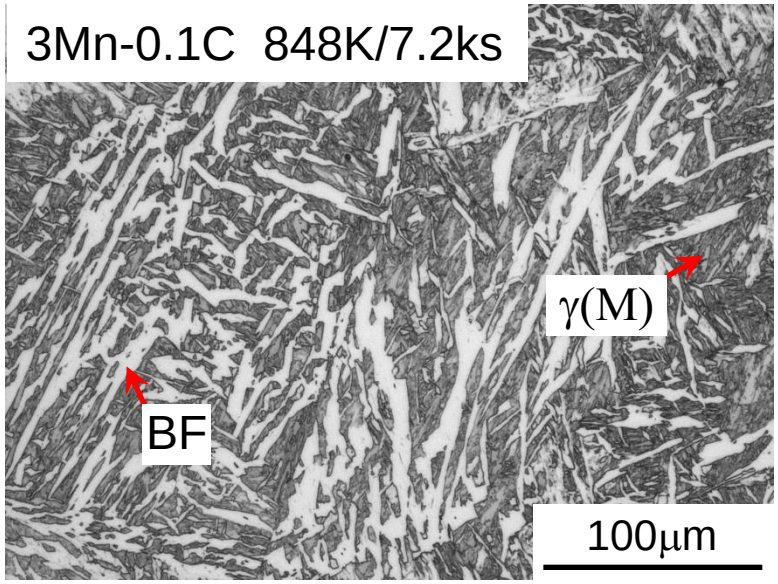


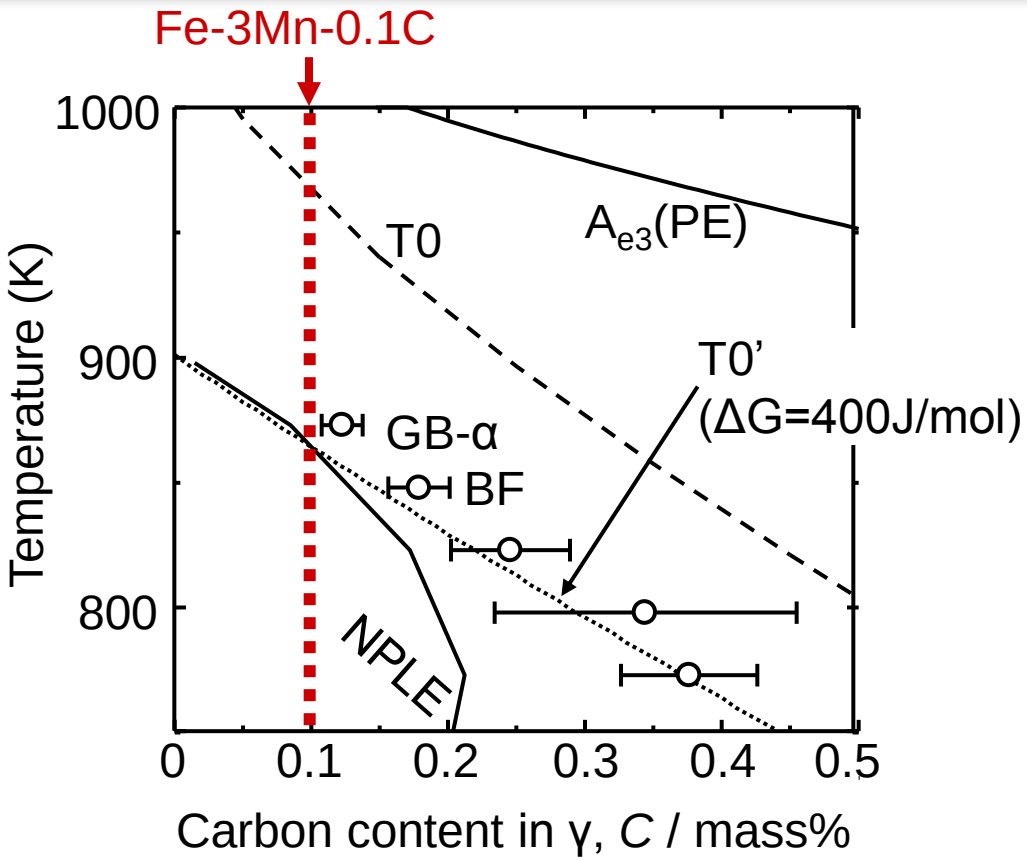
Undercooling at the stasis
≈ $\Delta G_{spike} + \Delta G_{SD}$

[1] H. Chen et al., Acta Mater., 61(2013), 5458.

C content at interface in γ in Fe-3Mn-0.1C alloy [1]





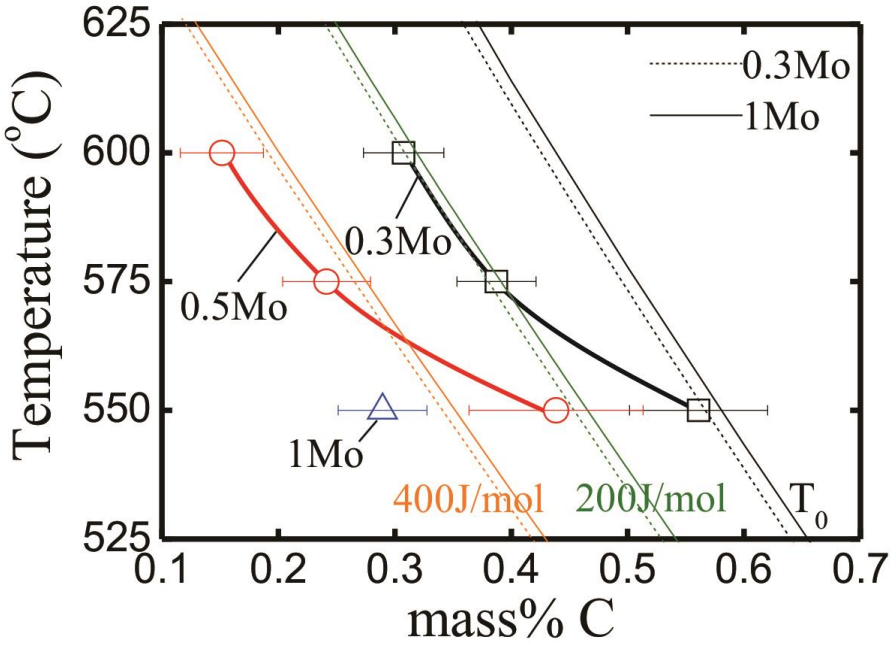


$\Delta G_{exp} < \Delta G_{spike}$ ⇒ unable to explain by Spike + SD

T0 : undercooling ~ 400 J / mol

[1] Z-Q. Liu, G. Miyamoto, Z-G. Yang, C. Zhang, T. Furuhara, Metall. Mater. Trans. A, in press

Discussion ~ Examination by T0' limit theory



Undercoolings from T_0 are 0~500J/mol which is reasonable for strain energy in displacive transformation.

However, undercoolings increase with Mo content although shear strain should not be changed by small amount of Mo.

Strength of γ may be increased by Mo due to retardation of dynamic recovery of transformation strain. But preliminary experiment shows this effect is not so large to explain increment of undercooling with Mo.

Composition and temperature dependences in undercooling should be taken into account for T0' theory.

Summary

C enrichment in γ during α and bainite transformations in Fe-Mn-C based alloys were investigated.

- C content in γ in the steady stage of α transformation is not affected by Mo addition and coincides with NPLE model.
  This result is explained by assuming energy dissipation of spike development without solute drag effect.

- In bainite transformation, C contents in γ in the stasis are decreased with increasing Mo content, which is in contradiction to conventional diffusionless theory. On the other hand, undercooling from PE corresponds well to $\Delta G_{spike} + \Delta G_{SD}$.

- In Fe-3Mn-0.1C alloy, C contents in γ agree well with T0’ model while they are higher than NPLE model, which is inconsistent with the model assuming $\Delta G_{spike} + \Delta G_{SD}$.