In-situ observation of the growth of massive ferrite in very low carbon Fe-Mn and Ni alloys

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Back ground and contents

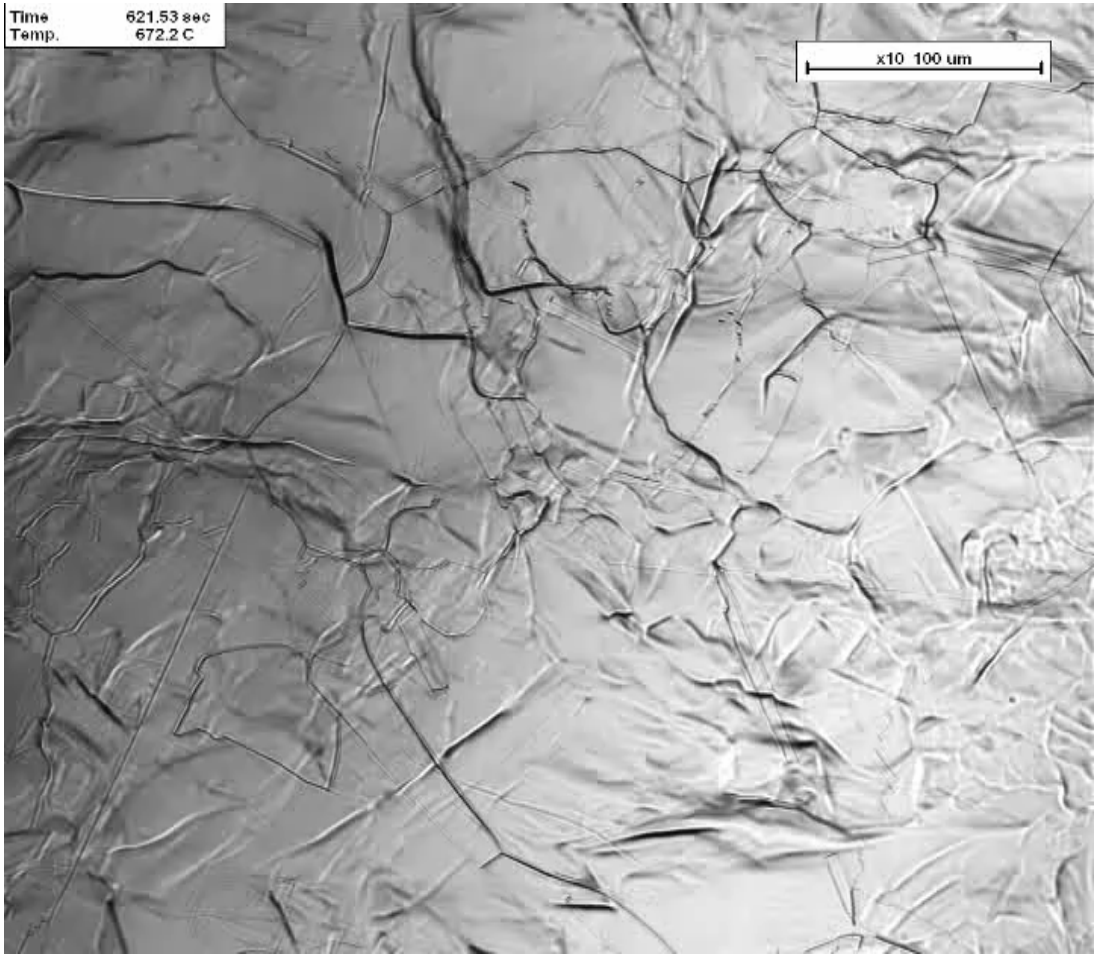
- Often neglected in the calculation of growth rate
- In very low carbon steel it could affect ferrite growth to a larger extent because the growth rate is fast.
- Ferrite growth during continuous cooling was in-situ observed in very low carbon (0.007~0.009 wt%C) Fe-(2 or 5) Mn and Ni alloys under confocal scanning laser microscope (CSLM).
- Ferrite growth rates were measured and α/γ boundary mobility was estimated.

Alloy composition (wt%) and heat treatment

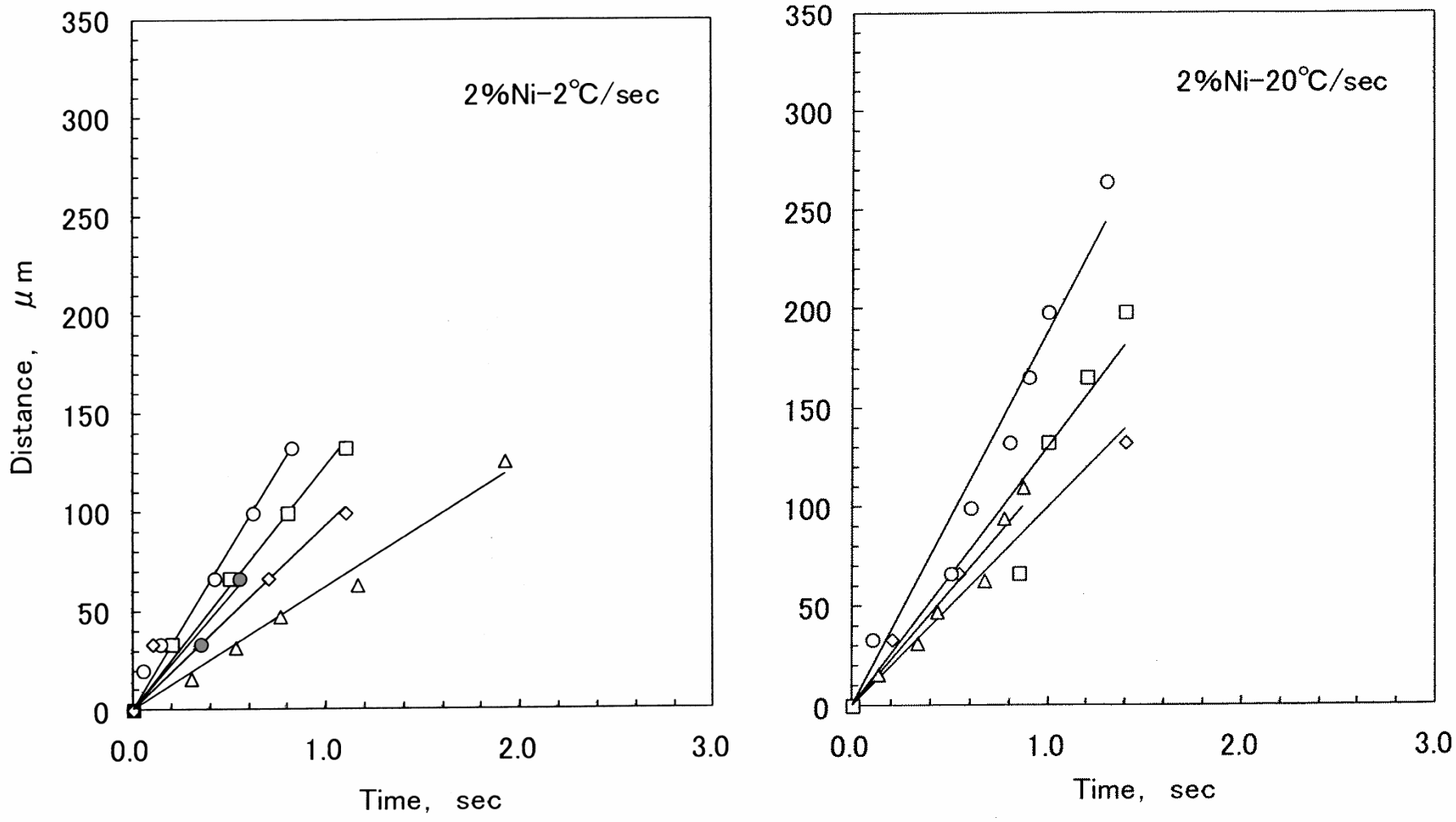
Alloy	C	Si	Mn	Ni	P	S
2N	0.008	0.01	0.01	2.0	0.002	0.0003
5N	0.007	0.01	0.01	5.1	0.002	0.0003
2M	0.009	0.01	2.0	0.01	0.002	0.0008
5M	0.007	0.01	4.9	0.01	0.002	0.0016

- Vacuum induction melting, 25 kg ingot
- Hot-rolling at 1250°C into a plate of 15 mm thickness
- Homogenization, vacuum-sealed and annealed at 1250°C for 48 hr

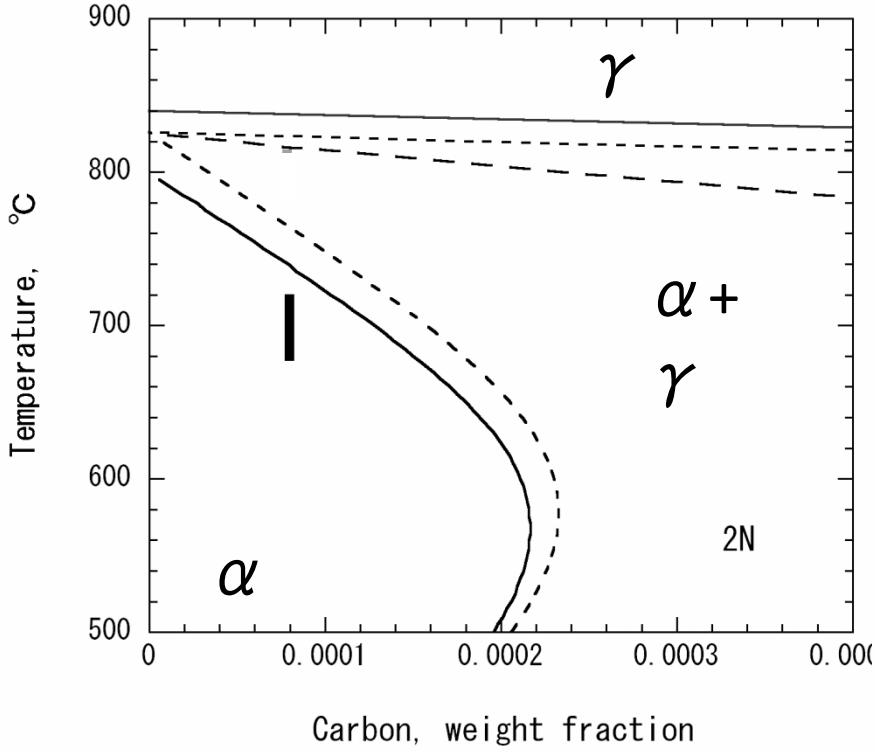
5N cooled at 2°C/s

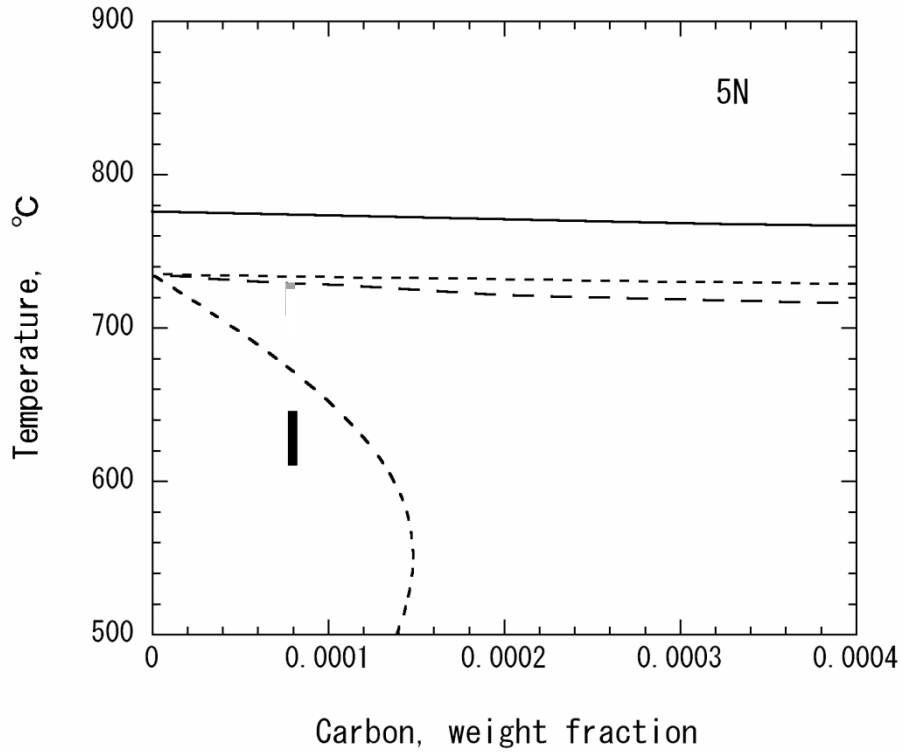


Displacement vs time plot — Alloy 2N

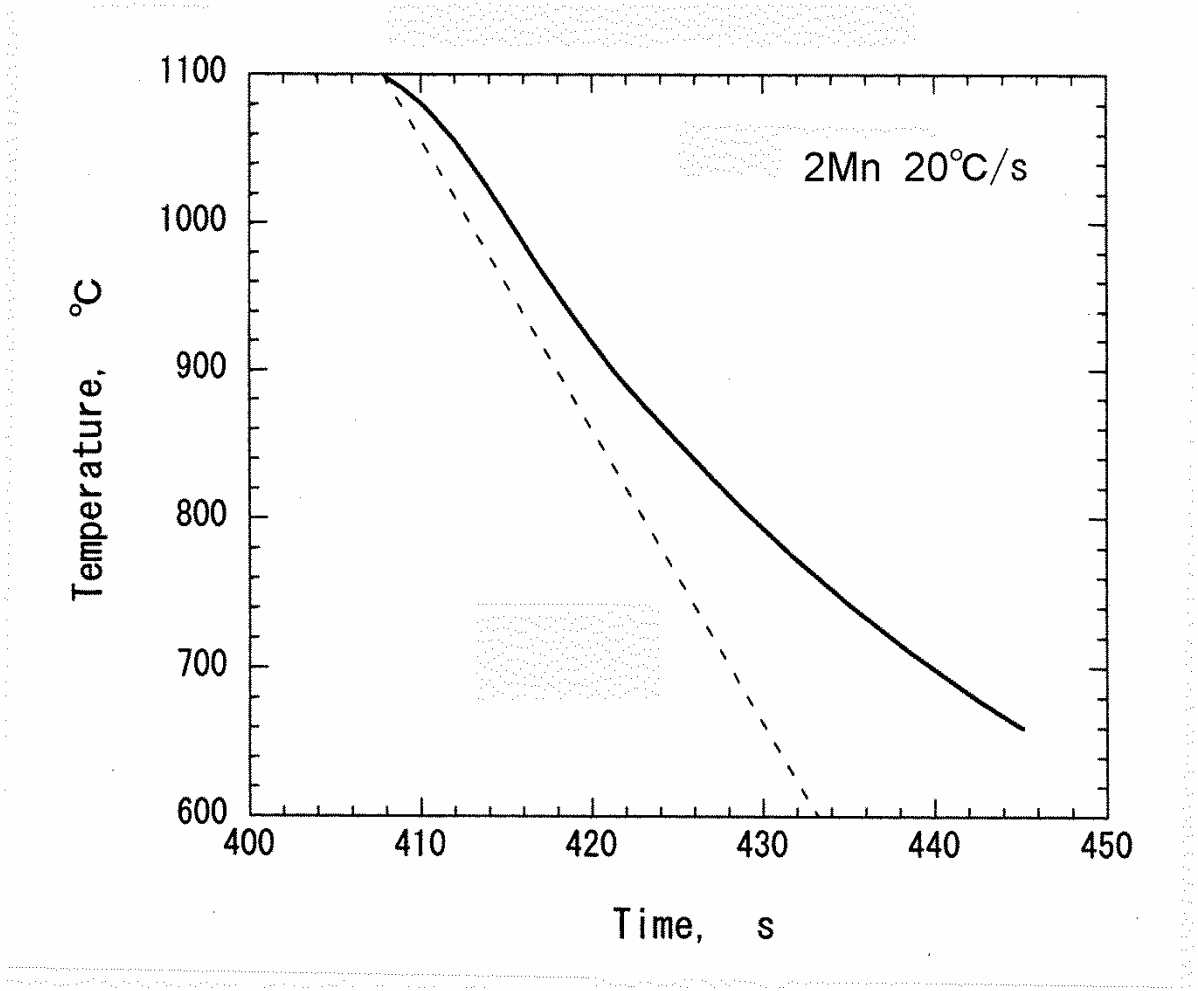


Observed transformation temperatures — 2N, 5N





Cooling curve



Cooled at 2 °C/s , the temperature of the specimen followed closely . However, the cooling rate was slower (~10°C/s) when cooled at 20°C/s.

Simulation of boundary displacement

$$\ell = \int_0^t v dt = \int_0^t M \frac{\Delta G}{V_m} dt = \int_{T_2}^{T_1} M \frac{\Delta G}{V_m} \frac{dT}{L}$$

M: three equations

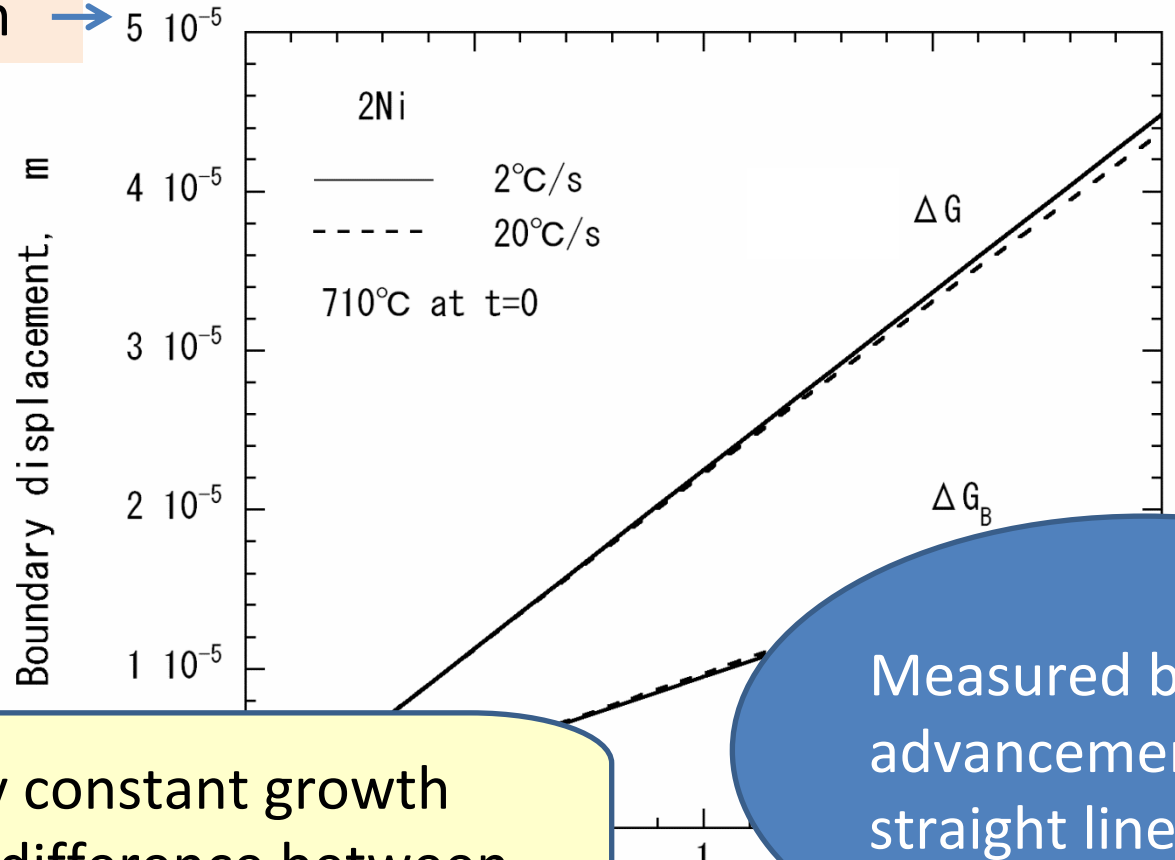
△G: a) Undercooling from T_0 (Case I)

b) Carbon spike in front of the interface (Case II)

$$\Delta G = \Delta G_B + \Delta G_D$$

Boundary advancement calculated in 2N using mobility by Wits et al

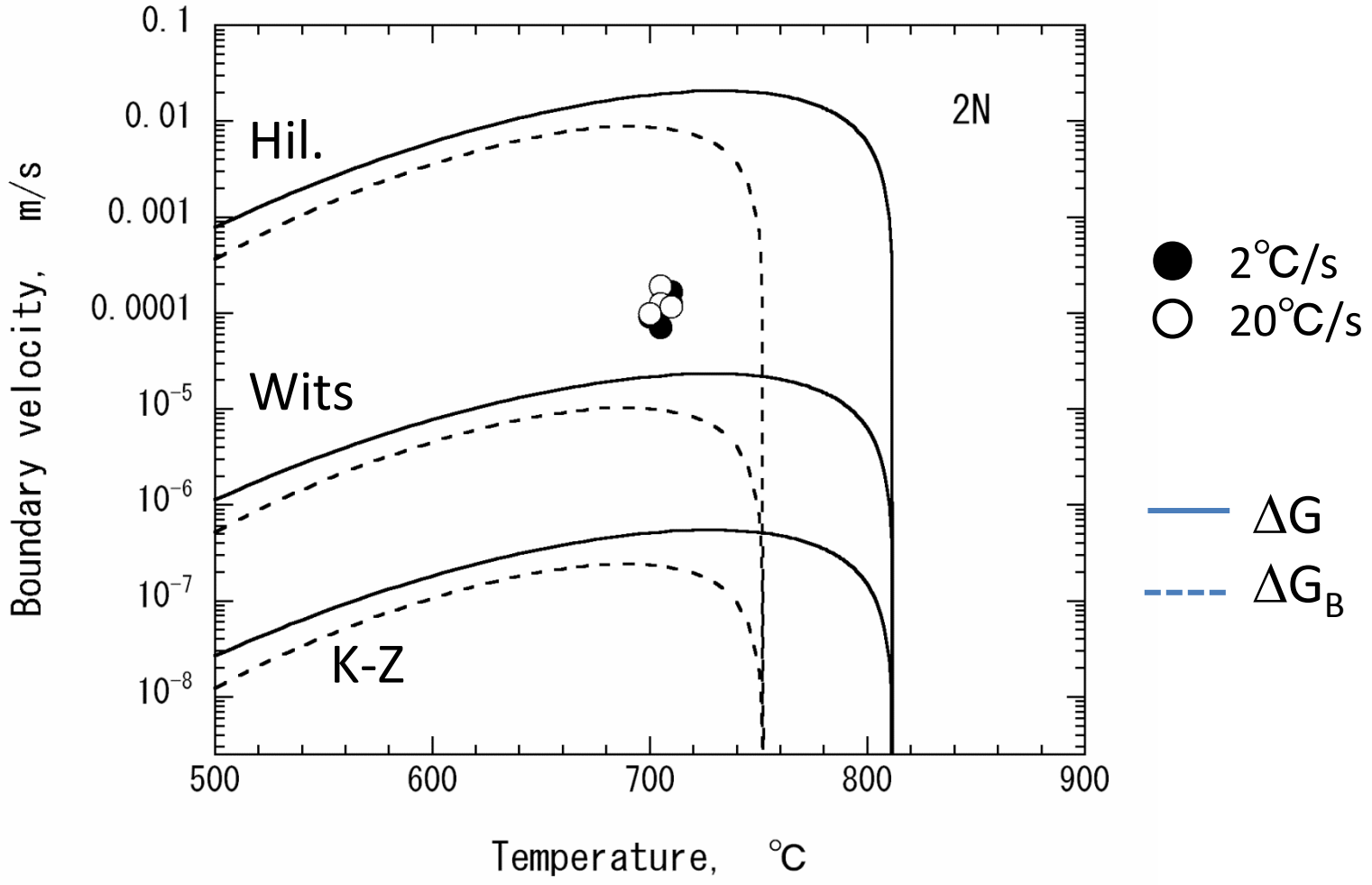
50 μm →



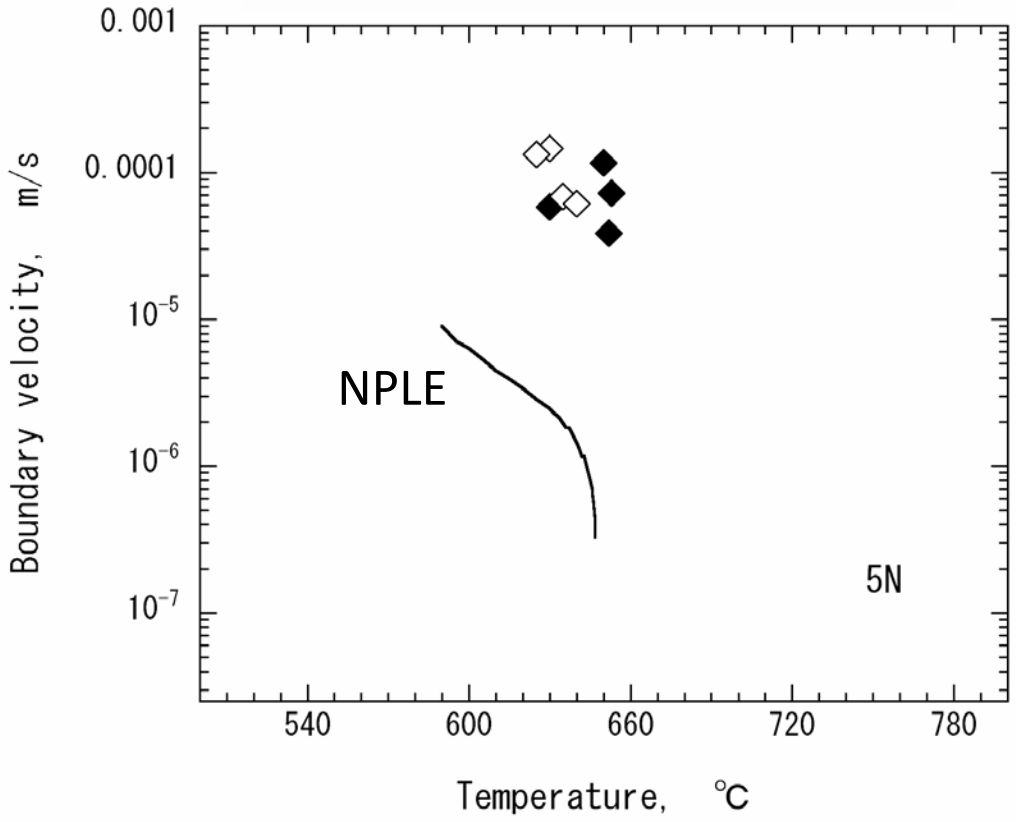
- Nearly constant growth
- Little difference between slow and fast cooling

Measured boundary advancements fit a straight line

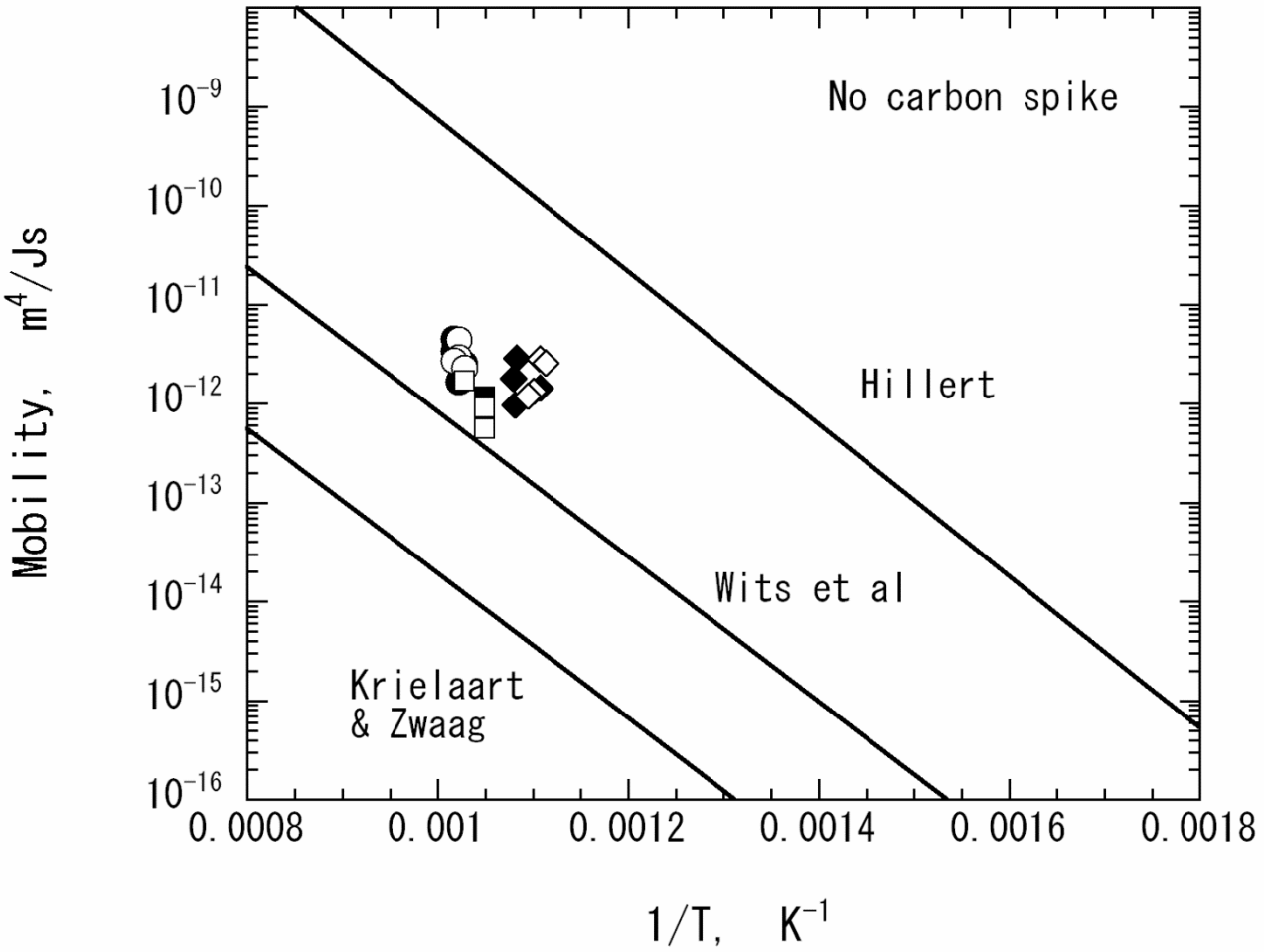
Comparison of growth rate — Alloy 2N



Comparison with NPLE growth rate at 1 s (= α /2) ── 5N



Mobility calculated from growth rate using ΔG (case I)



Lengthening of ferrite plate in a low carbon high-strength steel

Fe	C	Mn	Si	Ni	Cr	Mo	Nb	Ti
Bal.	0.056	1.62	0.23	0.235	0.21	0.23	0.057	0.013
B	P	S	N					
0.0015	<0.015	<0.005	<0.0045					

Heated to 1400°C at 5°C/s, held for 5-30s and cooled at 5°C/s

The growth of ferrite was observed in-situ under CSLM.

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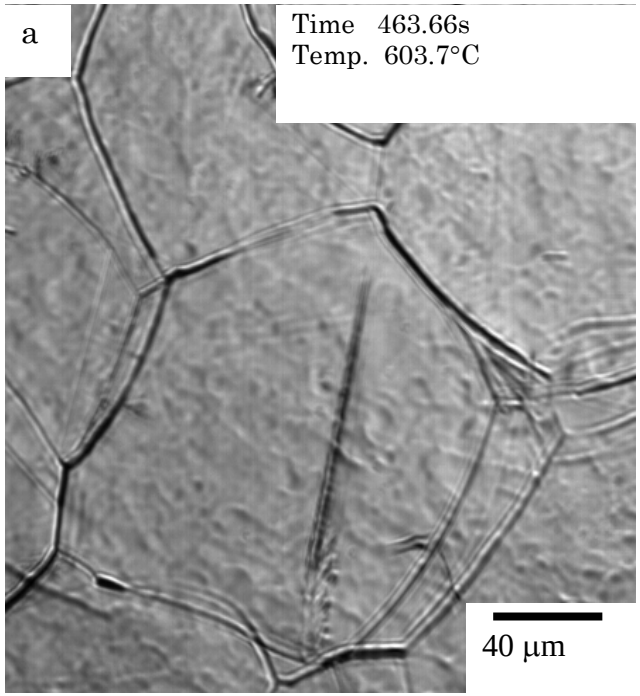
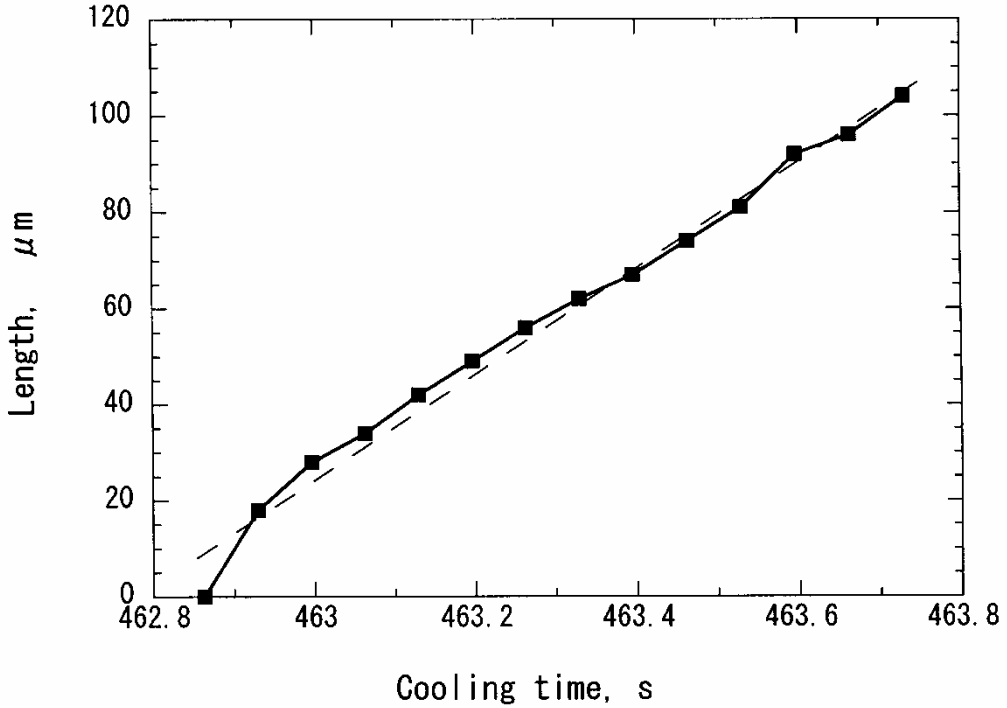
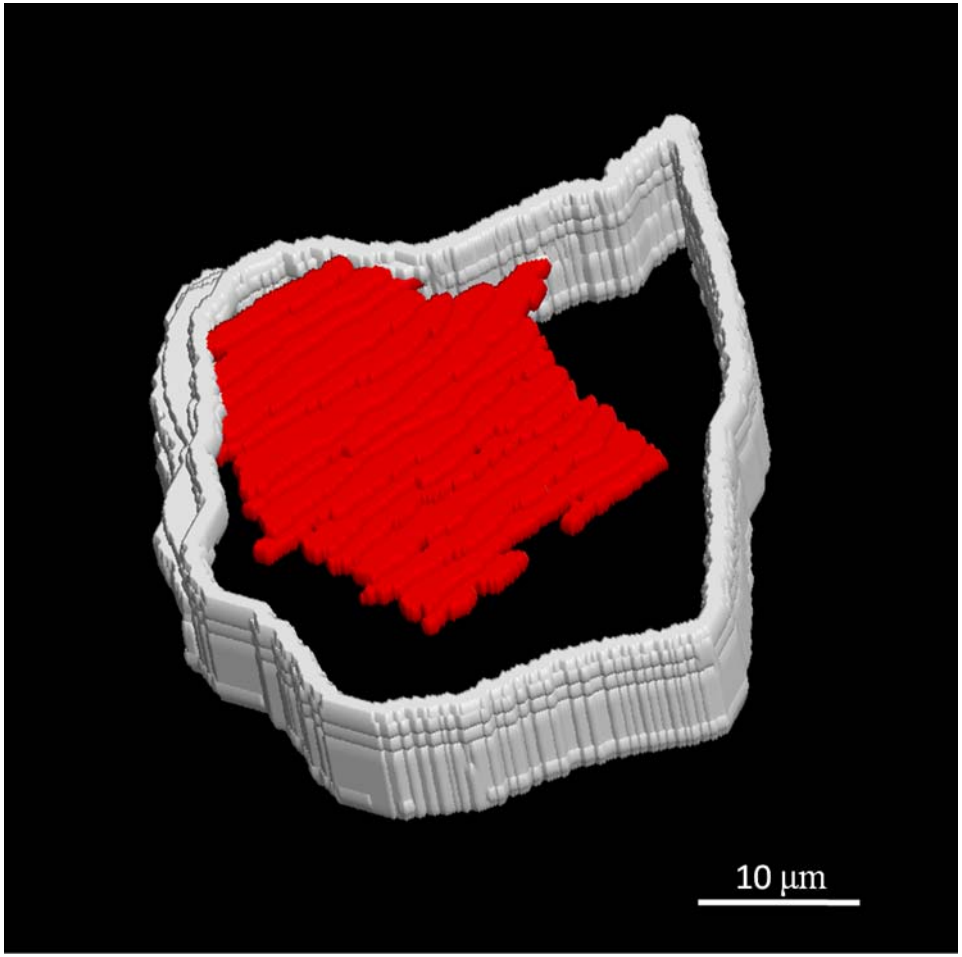
Lengthening of ferrite plate in a low carbon high-strength steel

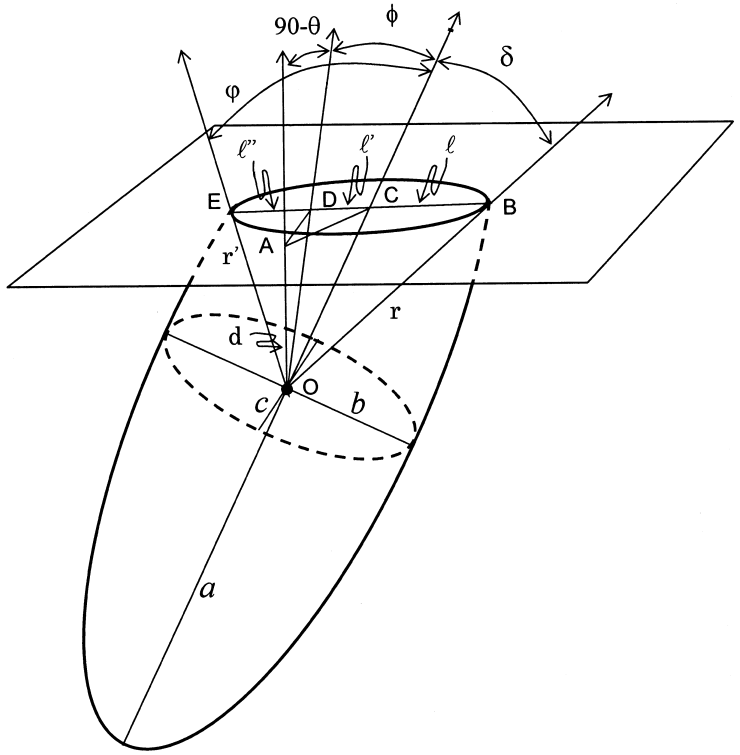


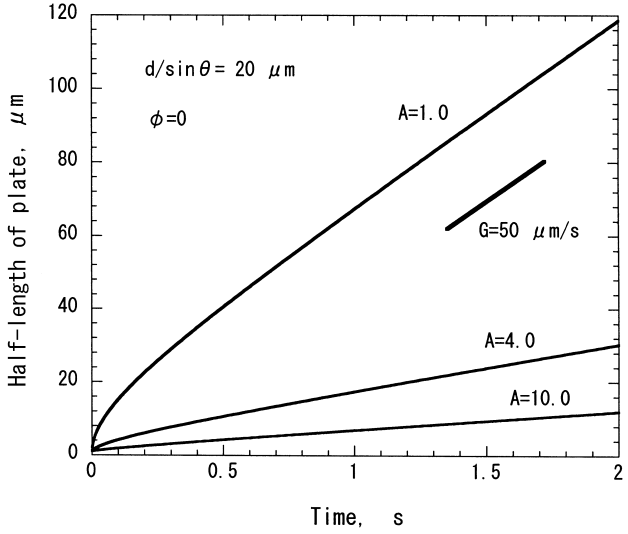


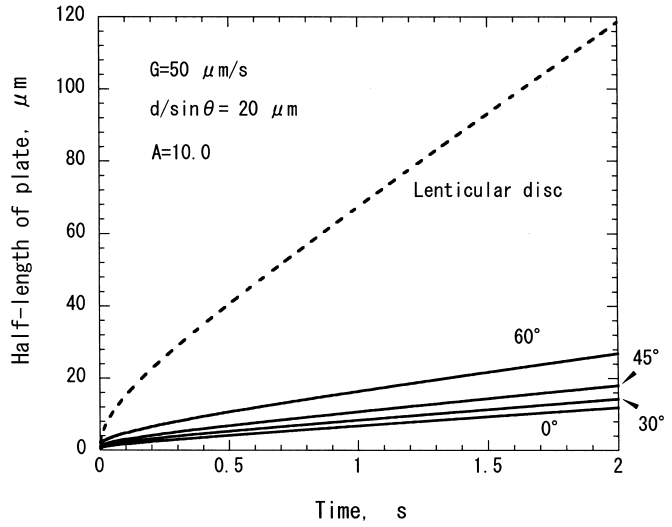
3D-morphology of ferrite plate



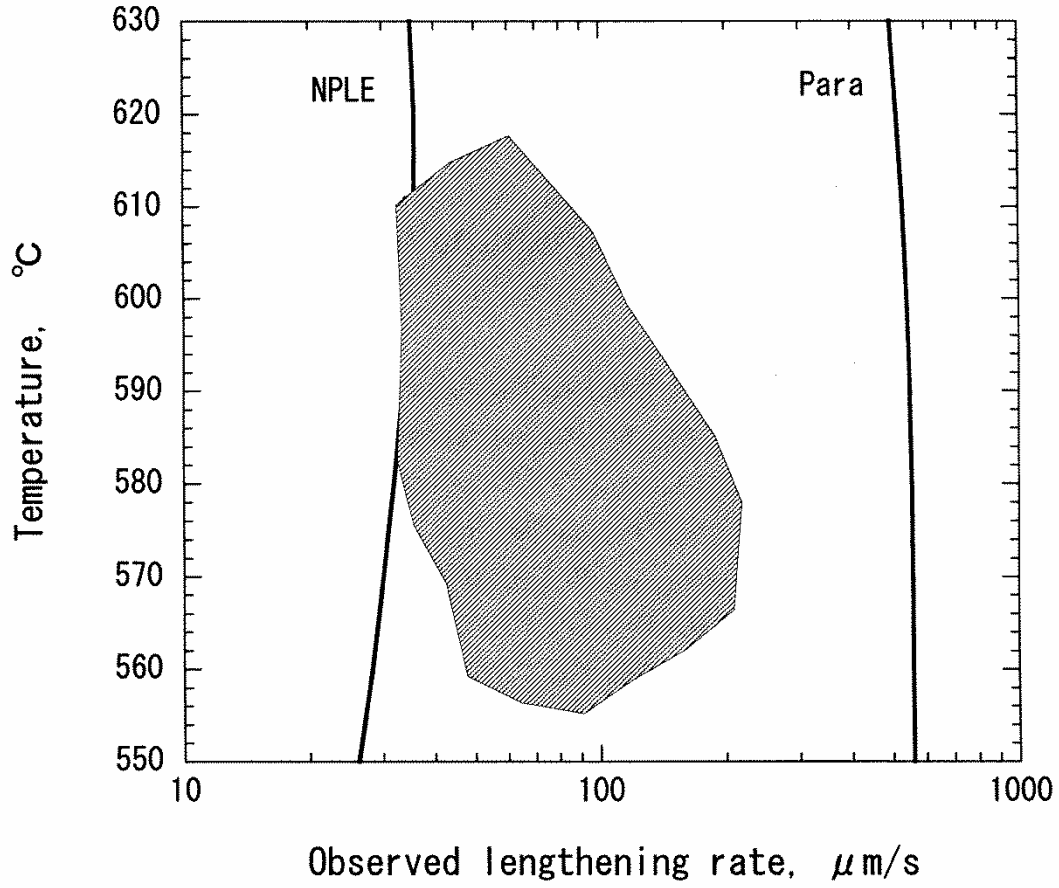
The lengthening rate varies with inclination angle and aspect ratio (=a/b) of the plate





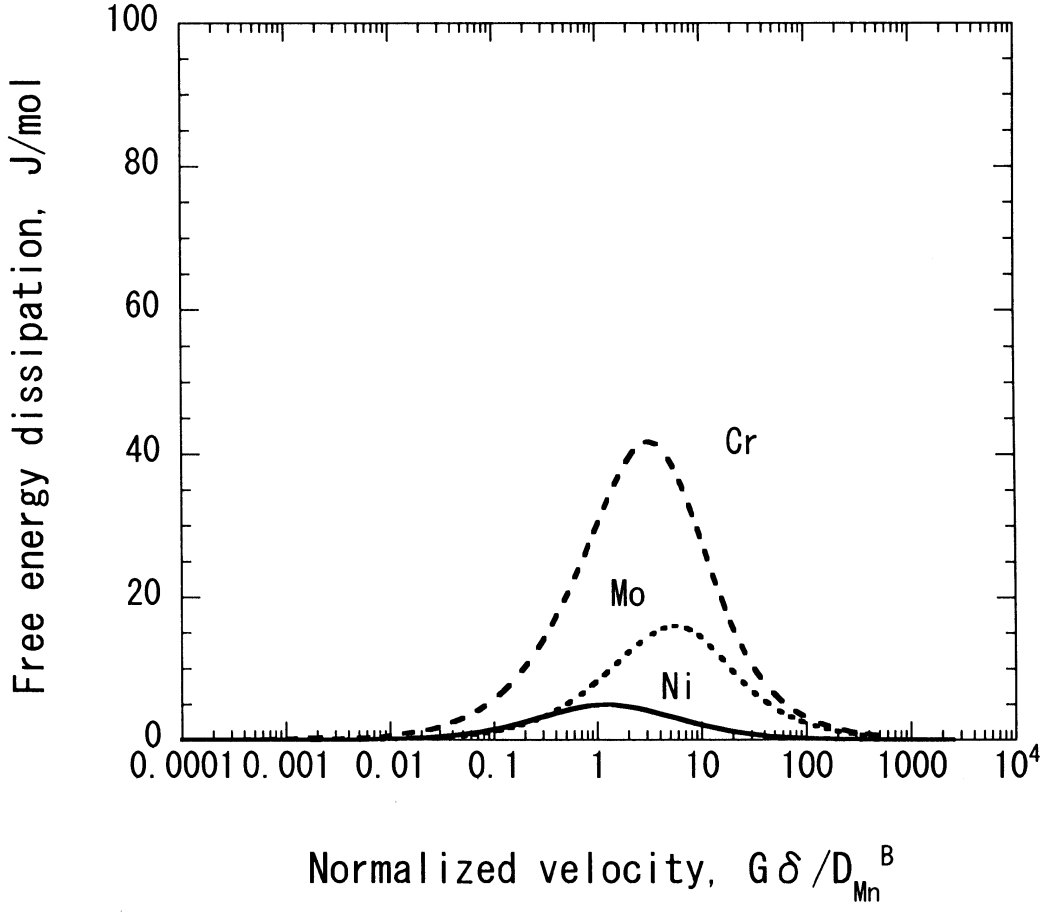


Comparison of measured lengthening rate with those calculated under NPLE and Para

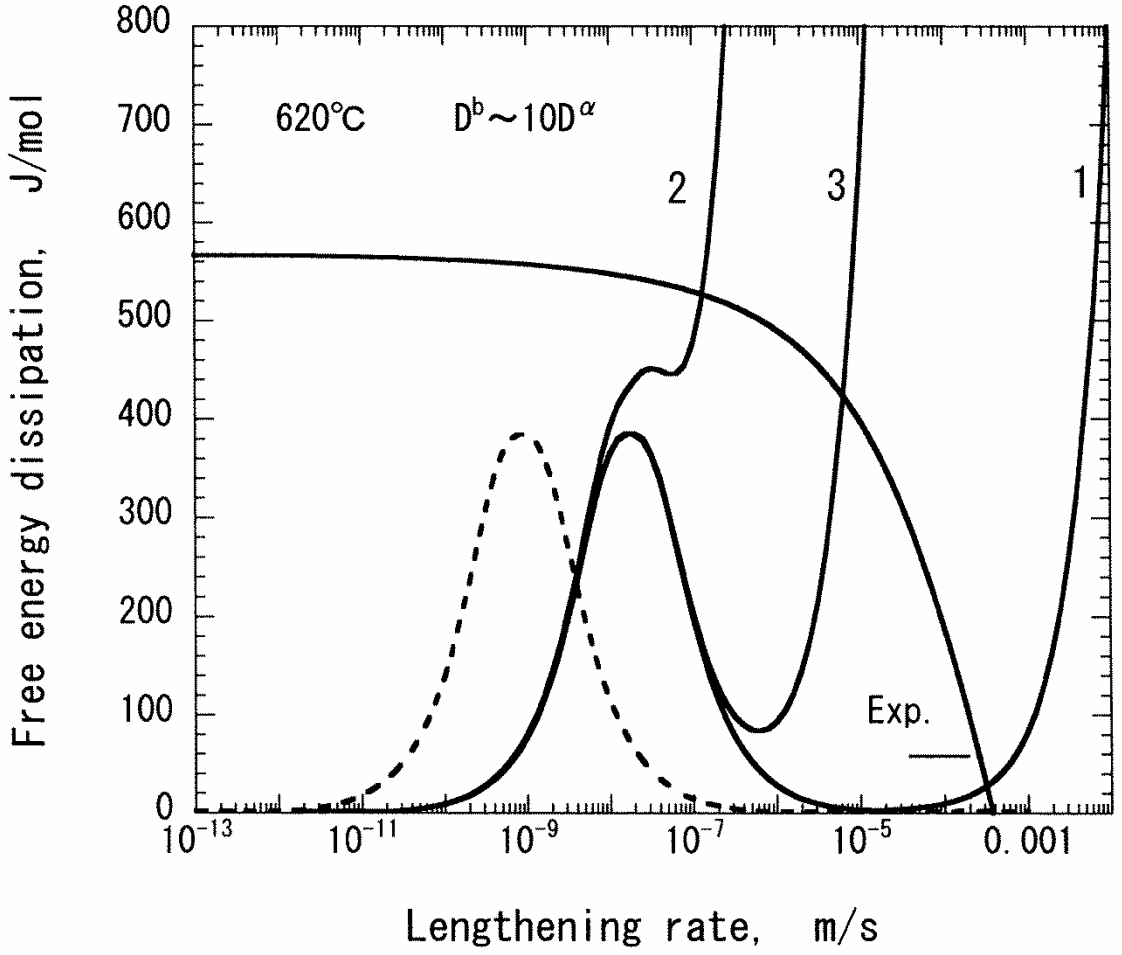


Calculation of solute drag ion multi-component Fe-C alloys

— Influence of X in an Fe-0.05C-1.6Mn-0.23Si alloy



Measured growth rates fell between mobility 1 (Hil) and 3 (Wits)



Summary

- The growth of ferrite was in-situ observed in very low carbon Fe-C-Mn and Ni alloys under CSLM.
- The growth occurred in paraequilibrium α single phase region and probably in a massive manner.
- From the boundary displacement vs time plots the mobility was evaluated to fall between those proposed by Hillert and Wits et al.
- A similar observation was made with the growth of plate in a low carbon high-strength steel.