The critical limit of the massive transformation in Fe-Mn and Fe-Ni

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Acknowledgements
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Partionless transformations

- Massive transformation
- Martensitic transformation - Diffusionless

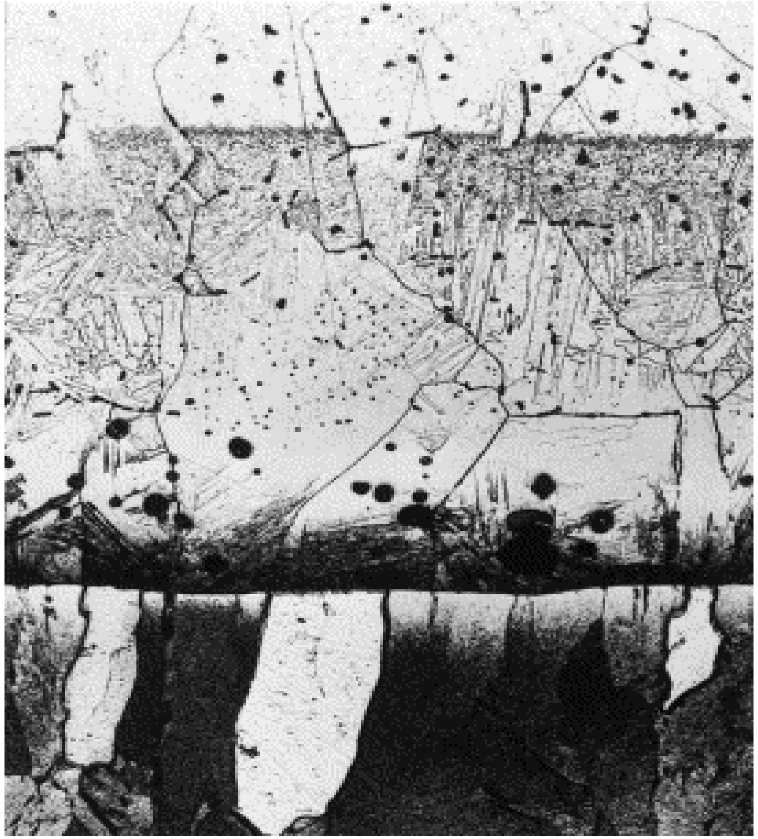
Background

Can the massive transformation take place in the two-phase field below the T_0 temperature or can it only take place in the one-phase region?

Experimental work

- Diffusion couple of Fe and Fe - 32 mass% Ni alloy annealed 400h at 1500K
- Diffusion couple of Fe and Fe - 15 mass% Mn alloy annealed 646h at 1463K
- Isothermal heat treatment
- Microstructure studied by LOM and FEG-SEM
- Measurements of the composition gradients with EPMA and ASEM

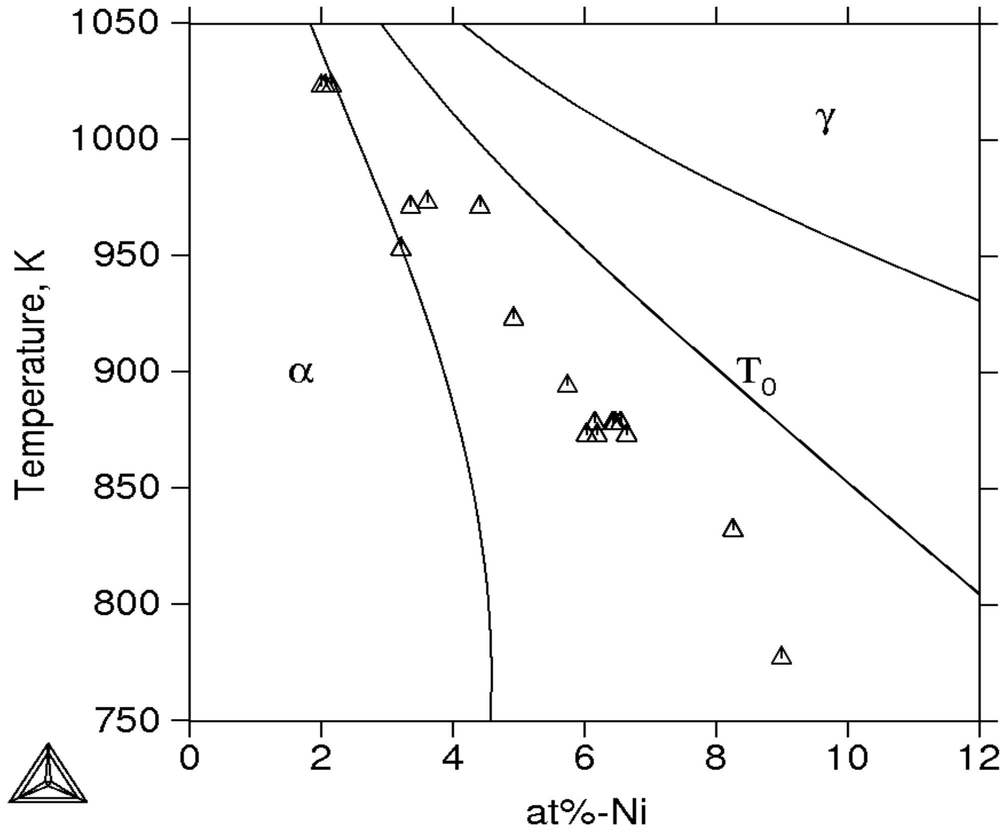
Massive transformation in Fe-Ni



2h at 973K

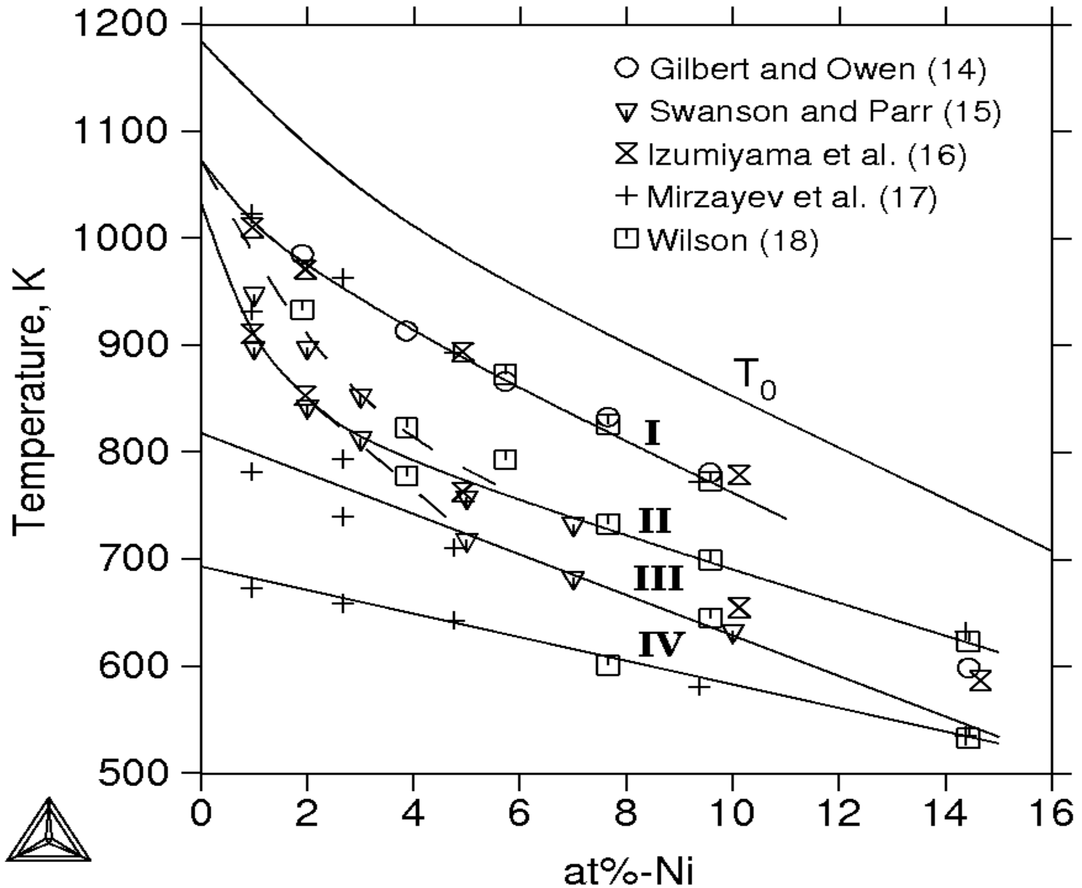
Borgenstam and Hillert, 2000

Limit of the massive growth of ferrite in Fe-Ni



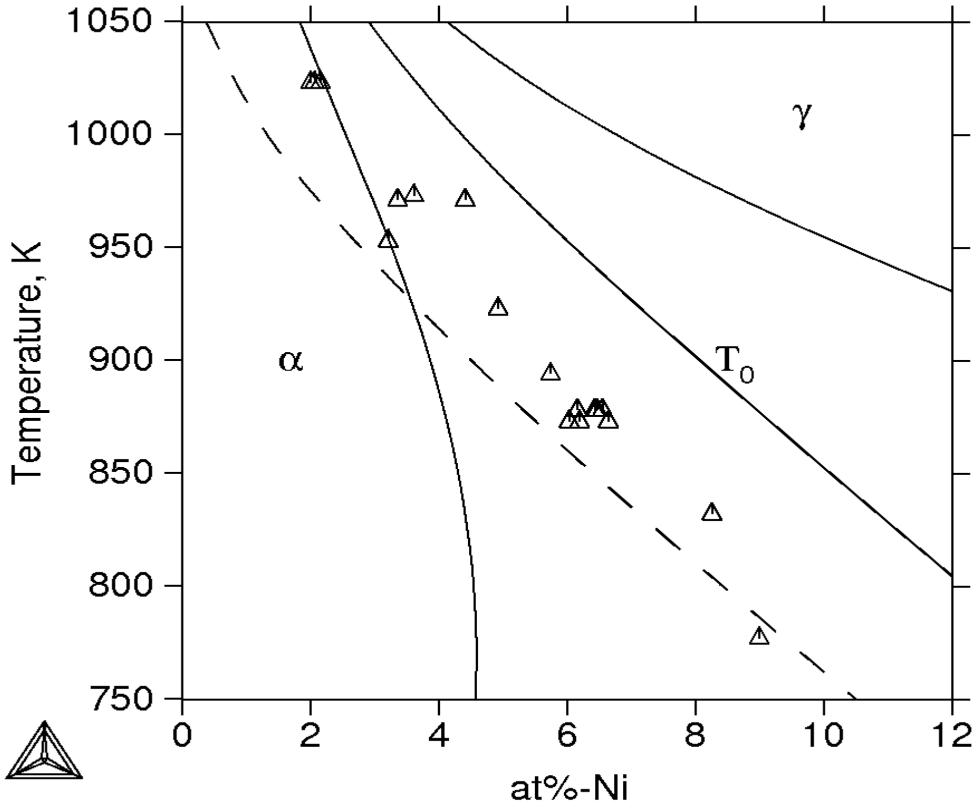
Borgenstam and Hillert, 2000

Plateau temperatures for various partitionless transformations in Fe-Ni

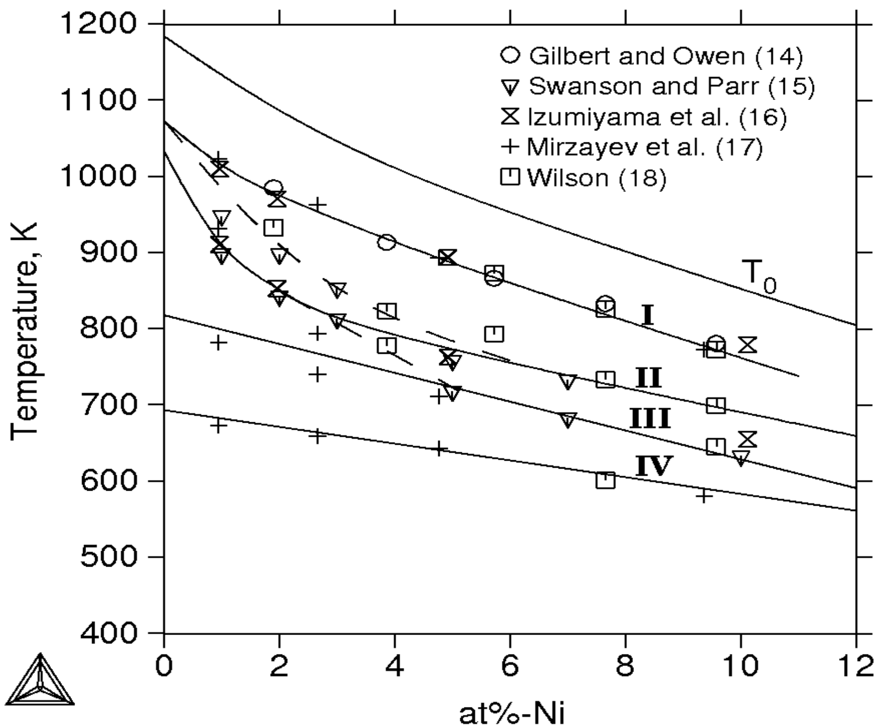


Borgenstam and Hillert, 1997

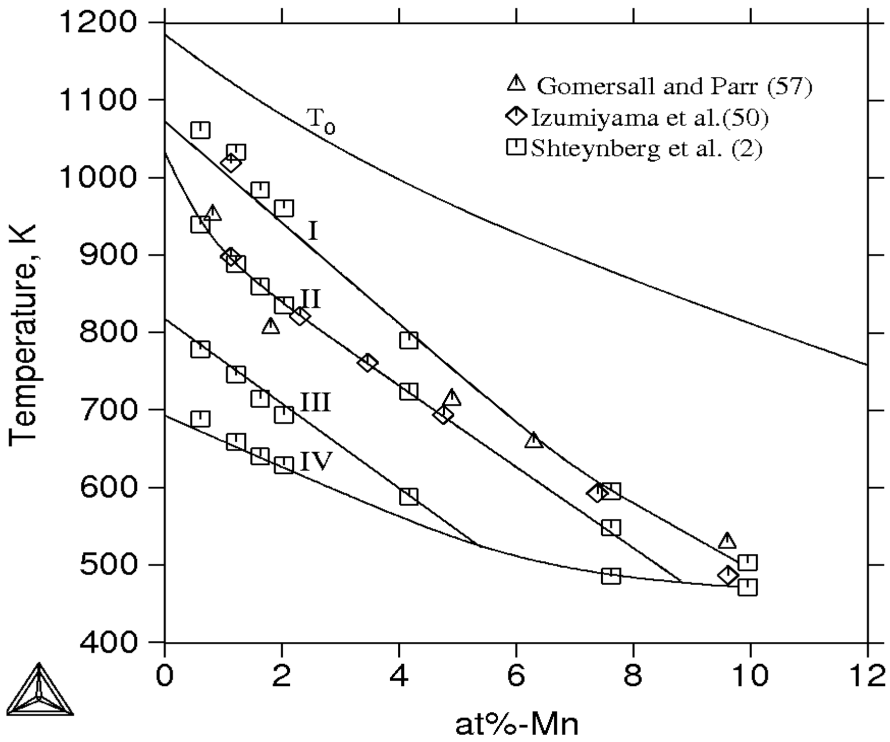
Limit of the massive growth of ferrite in Fe-Ni compared with the plateau temperature for equiaxed ferrite



Comparison between plateau temperatures in Fe-Mn and Fe-Ni



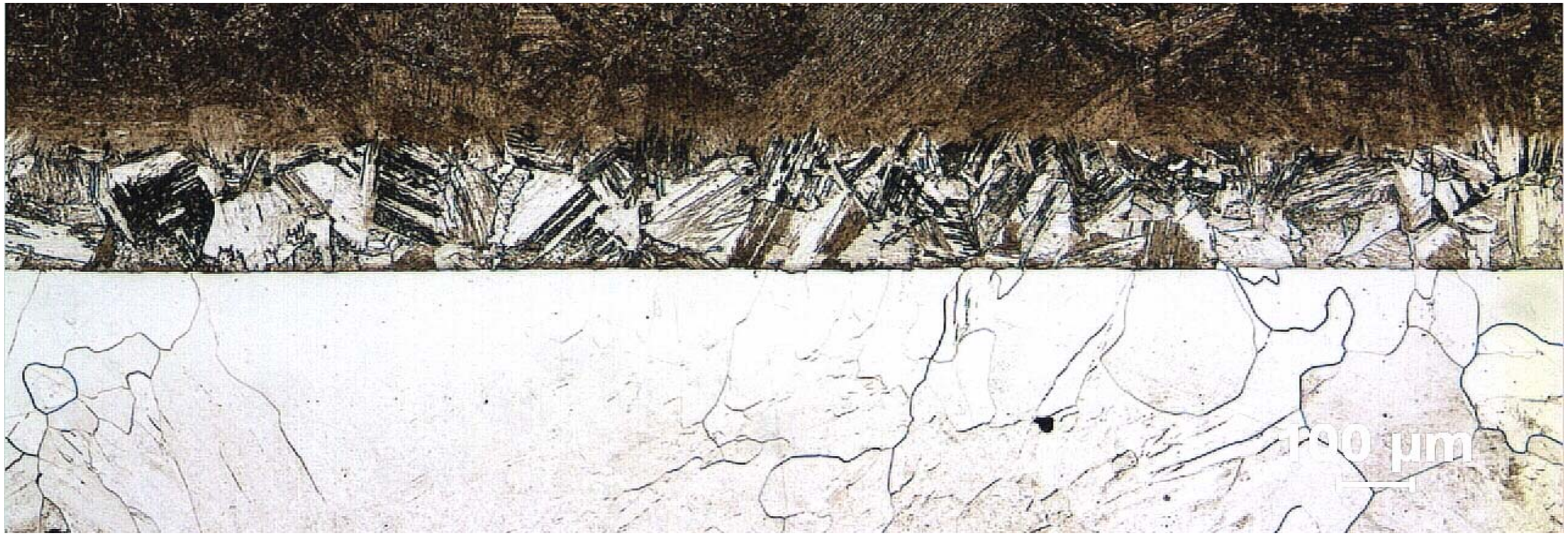
Fe-Ni



Fe-Mn

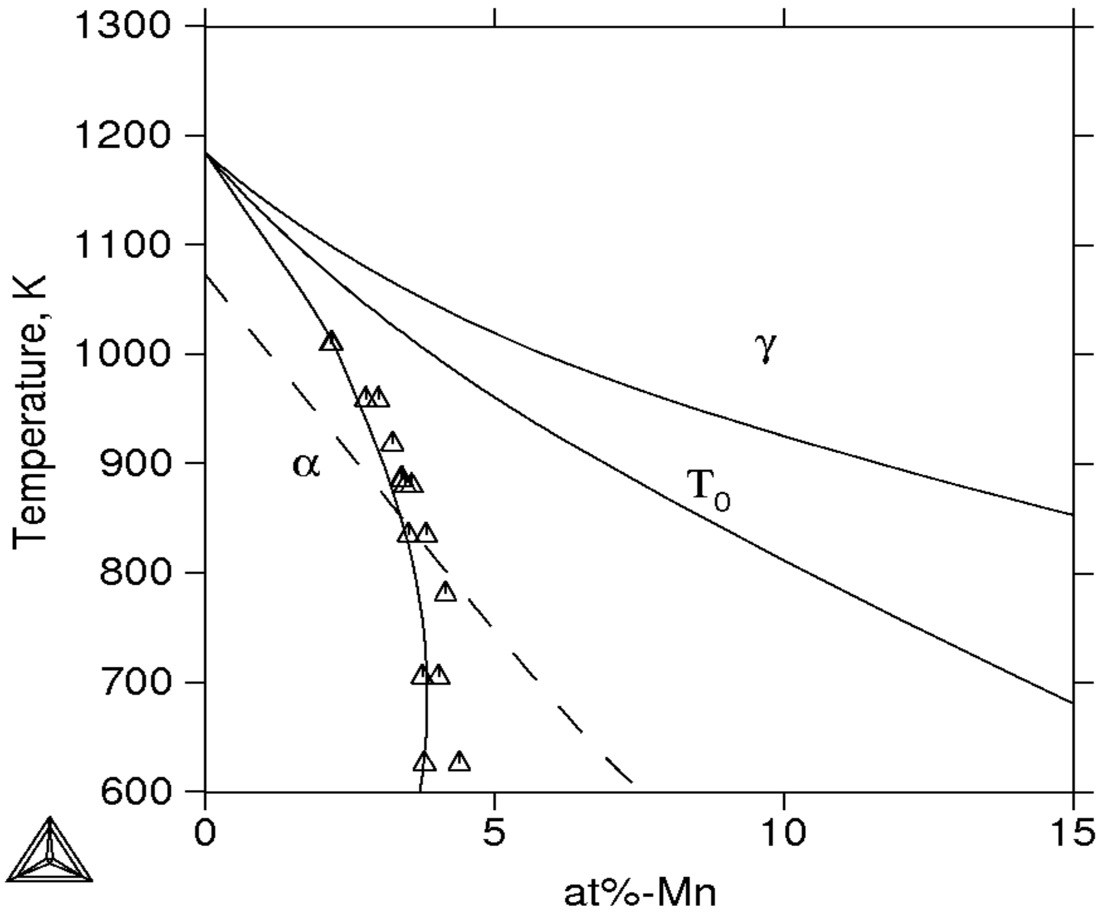
Borgenstam and Hillert, 1997

Massive transformation in Fe-Mn



2 min 977 K

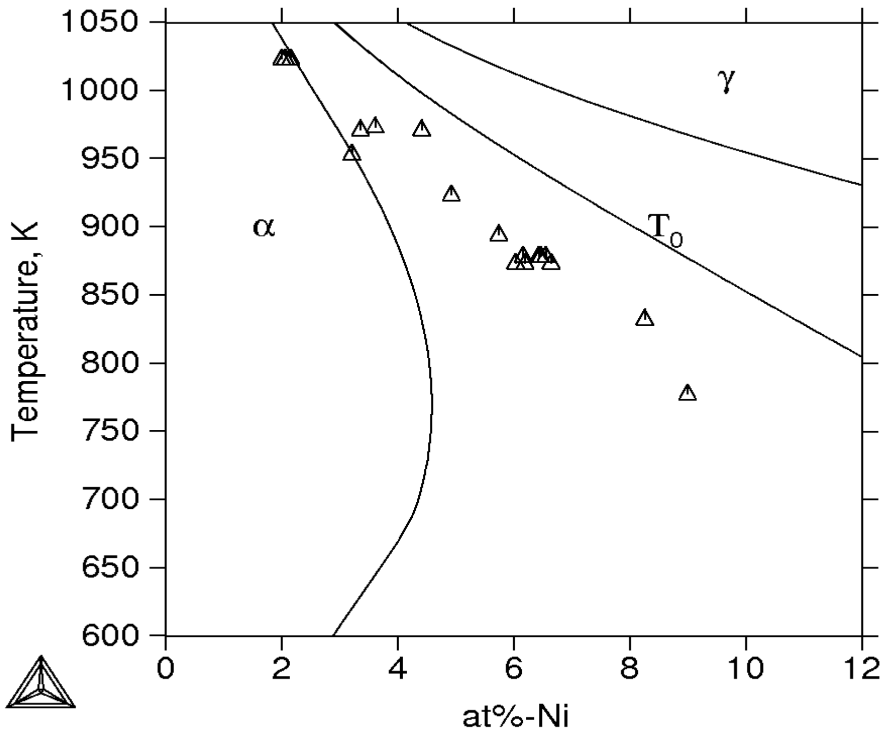
Limit of the massive growth of ferrite in Fe-Mn compared with the plateau temperature for equiaxed ferrite

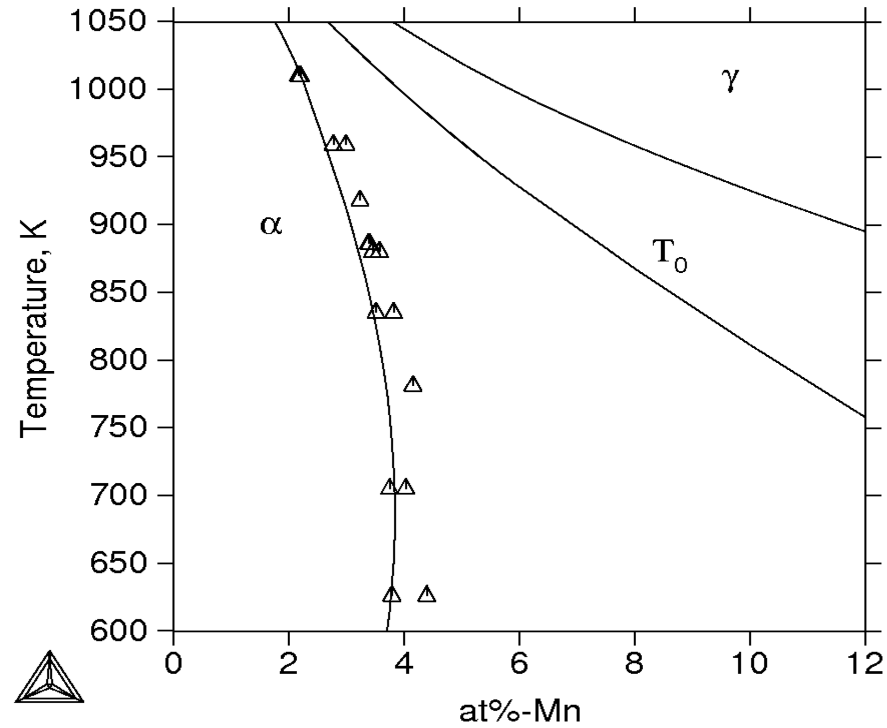


Three matters regarding the massive transformation are of current interest.

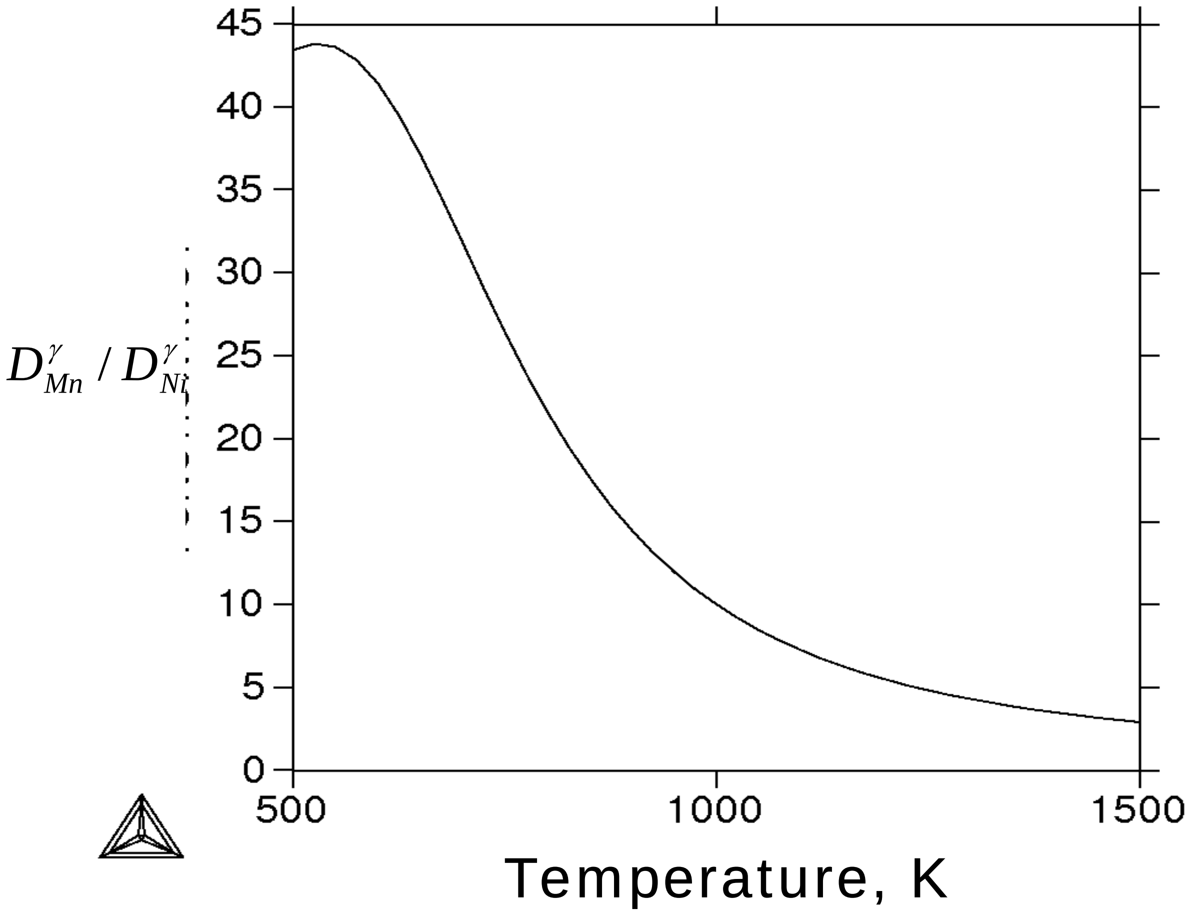
- What are the conditions at the migrating phase interface?
- Is there an orientation relationship between the new phase and the matrix grain into which it is growing?
- Is it justified to regard a partitionless transformation as massive whether the interface is smooth or more jagged or even acicular?

- What are the conditions at the migrating phase interface?
- Is it close to local equilibrium or close to the case where the different atoms behave as if they belong to the same element?





Ratio between diffusivity of Mn in Fe and Ni in Fe in FCC as function of temperature



Trans-interface diffusivity in the Fe-Ni system

- Model by Larssons et al, 2007, for simulating diffusional phase transformations without prescribing local equilibrium at the migrating interface was modified by Larsson and Borgenstam, 2007
- First term: Mass transfer by individual jumps of atoms
- Second term: Mass tansfer by a cooperative mechanism

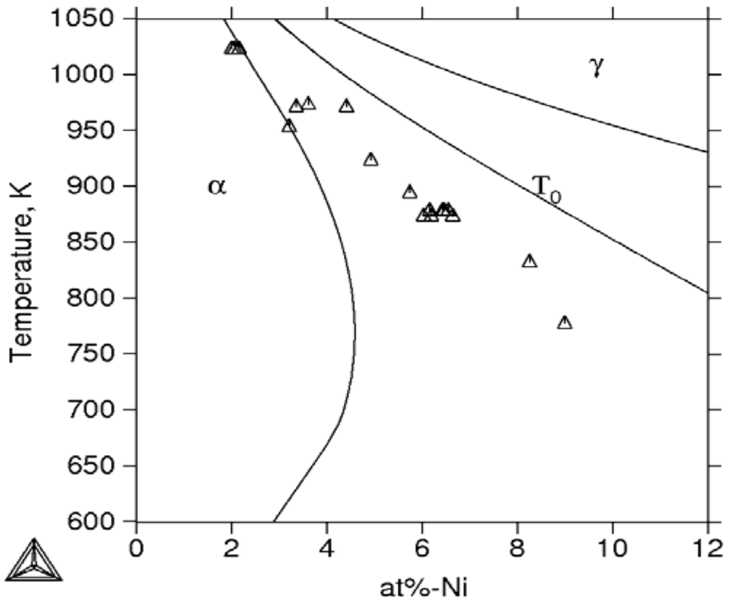
$$J_k = -\frac{RT}{V_m}\sqrt{x_k^a x_k^b}\left\{ \begin{array}{l} \dfrac{M_k}{\Delta z} 2\sinh\left(\dfrac{\mu_k^b - \mu_k^a}{2RT}\right) + \\ M^{\text{int}} \times \left[\exp\left(\dfrac{\sum x_j^b\left(\mu_j^b - \mu_j^a\right)}{RT}\right) - \exp\left(\dfrac{\sum x_j^a\left(\mu_j^a - \mu_j^b\right)}{RT}\right) \right] \end{array} \right\}$$

The ratio between the phase interface mobility, M^{int},and the mobilty of components across the interface, M_k, has been estimated by fitting to the experimental data on the critical limit for massive growth in Fe-Ni

$$\rho = (M_k / \delta) / M^{\text{int}}$$

where the interfacial thickness δ=1 nm

$$M^{\text{int}} = 0.058 \exp(-140000 / RT)$$



Results Fe-Ni

The observed critical limits are approximately
x_{Ni}=0.080, 0.034 at T=823, 973

ρ	T(K)						
	823				973		
0.15					M	D	
0.10	D					M	D
0.05	M	D					M
0.01			M	D			
$x_{Ni}^{\gamma 0} \rightarrow$	0.075	0.080	0.090	0.095	0.034	0.035	0.036

Larsson and Borgenstam, 2007

Results Fe-Mn

The observed critical limits are approximately
x_{Ni}=0.040, 0.037, 0.029 at T=705, 835, 959

ρ	T(K)		
	705	835	959
20	D		
10	M		
5		D	
2		M	
0.5			D
0.1			M
$x_{Mn}^{\gamma 0} \rightarrow$	0.040	0.037	0.029

Larsson and Borgenstam

Comparison of Fe-Ni and Fe-Mn

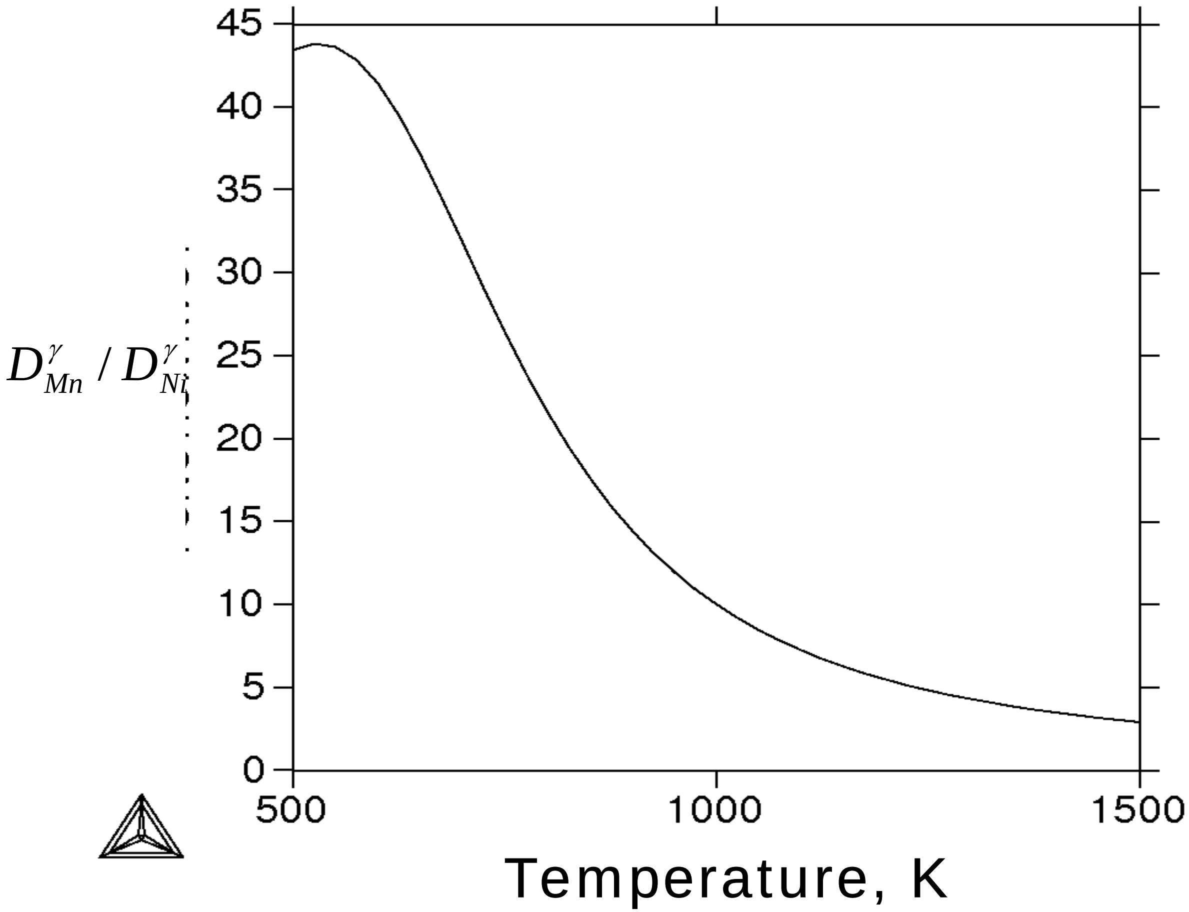
- The phase interface mobility, M^{int}, and interfacial thickness, δ, is assumed to be the same in the two cases.

$$\rho = (M_k / \delta) / M^{\text{int}}$$

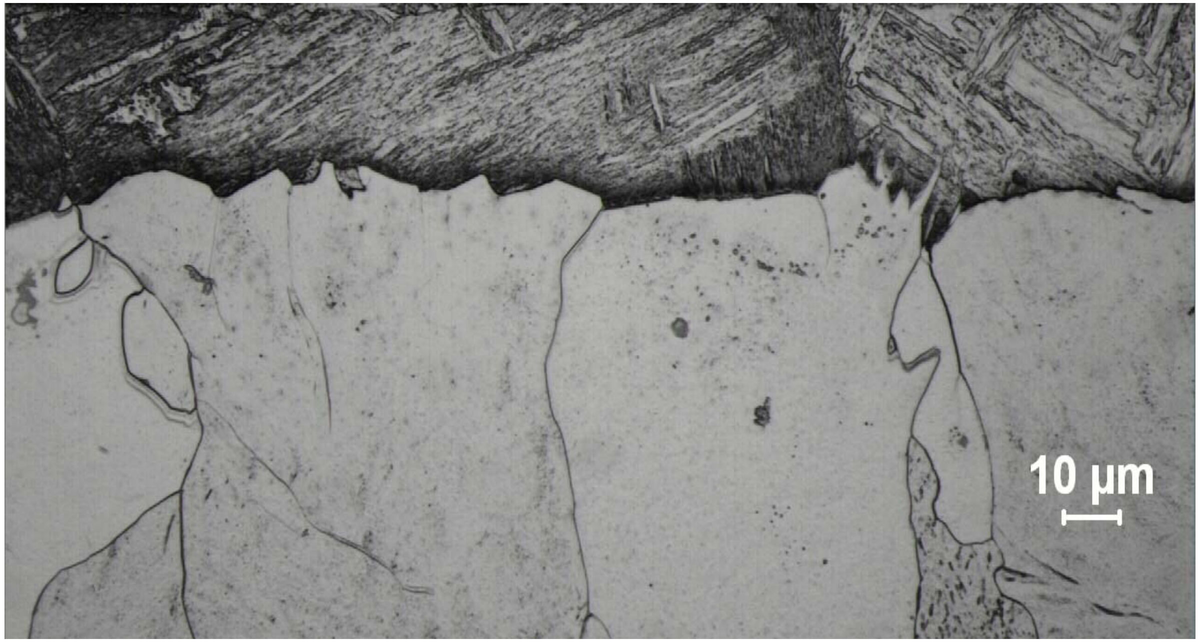
	T(K)	ρ
Fe-Ni	823	0.05
	973	0.15
Fe-Mn	835	2-5
	959	0.10-0.50

At 823-835 K ρ is 40-100x higher in Fe-Mn than in Fe-Ni and at 959-973 K 1-3x higher.

Ratio between diffusivity of Mn in Fe and Ni in Fe in FCC as function of temperature



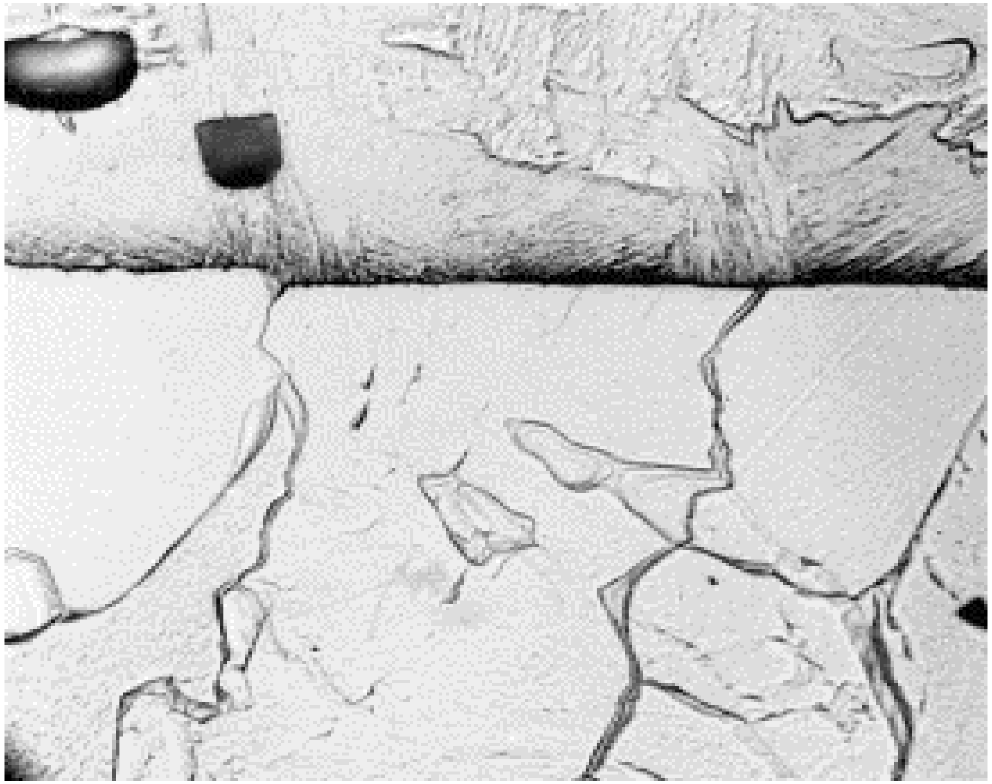
- Is there an orientation relationship between the new phase and the matrix grain into which it is growing?
- If so, what is the role of that orientation relationship during growth?



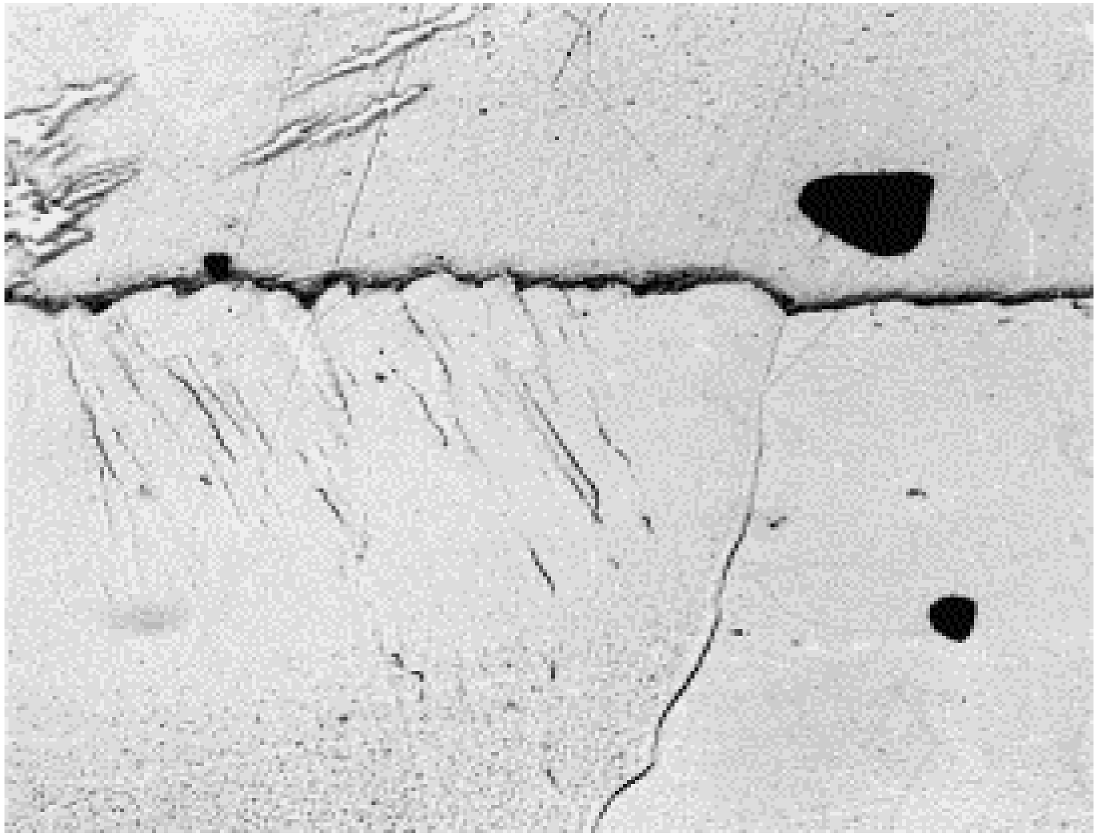
Fe-Mn, 2 min 959 K

One grain with planar phase interface and on with a more acicular phase interface

Fe-Mn, 2 min 1004 K



Fe-Ni, 2min at 923K

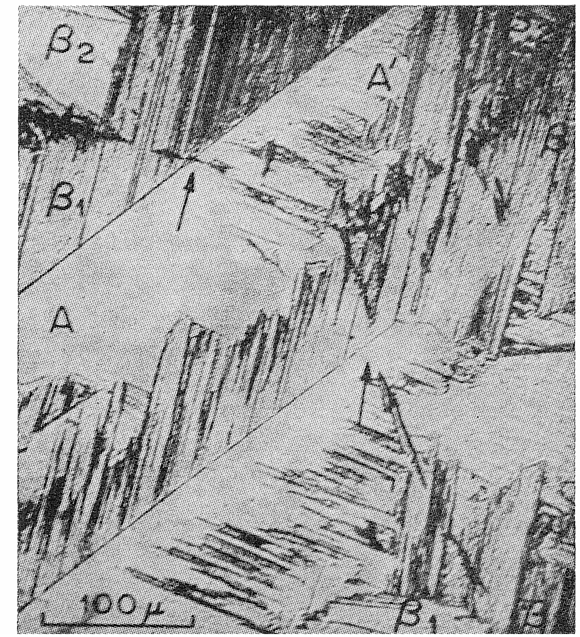


Fe-Ni, 2 min at 832 K

Is it justified to regard a partitionless transformation as massive whether the interface is smooth or more jagged or even acicular?

Fe-C

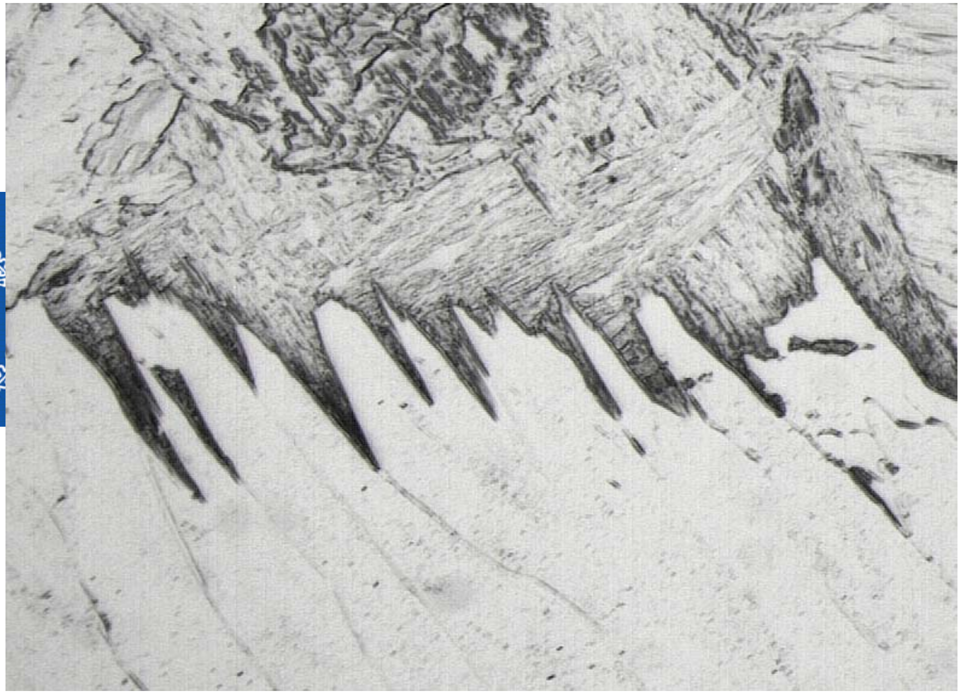
Cu-Zn



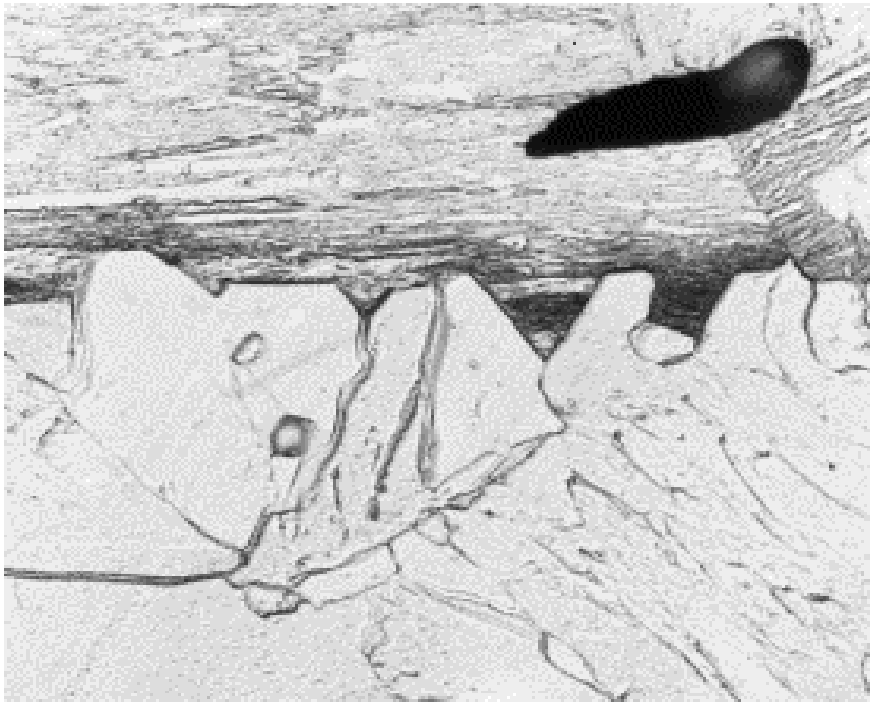
Cu-Ga

Massalski 1968

Jagged interface

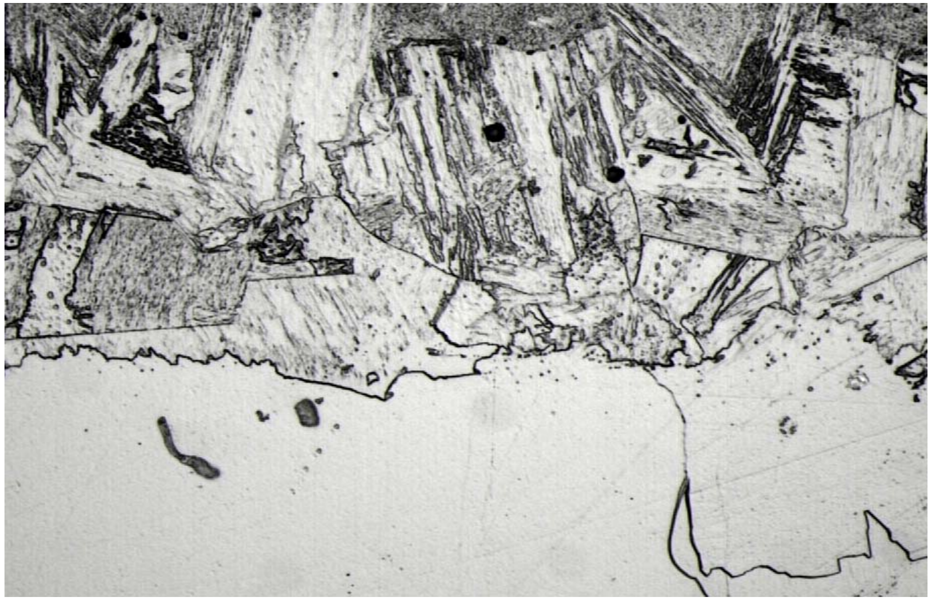


Fe-Mn, 2 min at 886 K

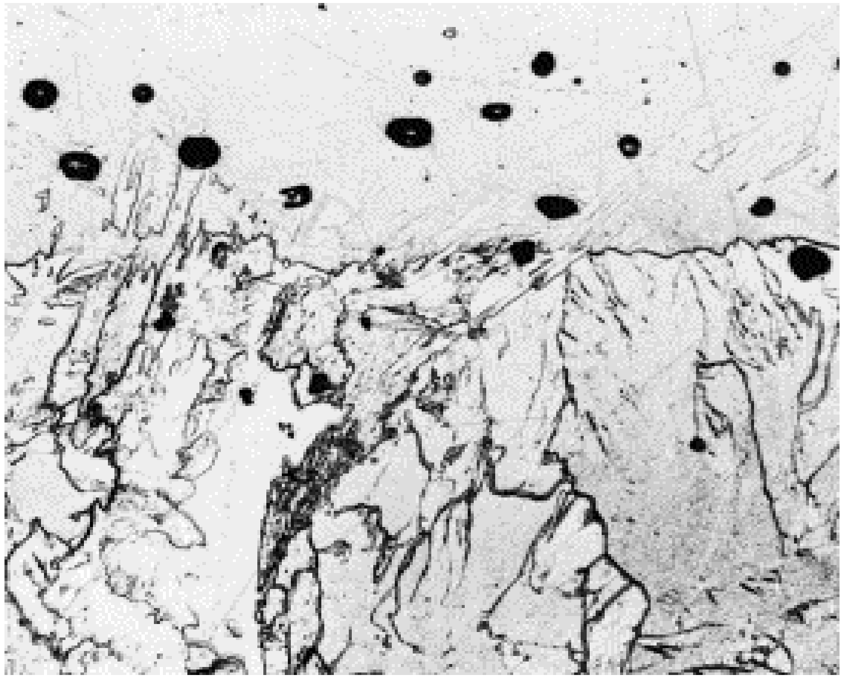


Fe-Ni, 2 min at 953 K

Partly acicular interfaces

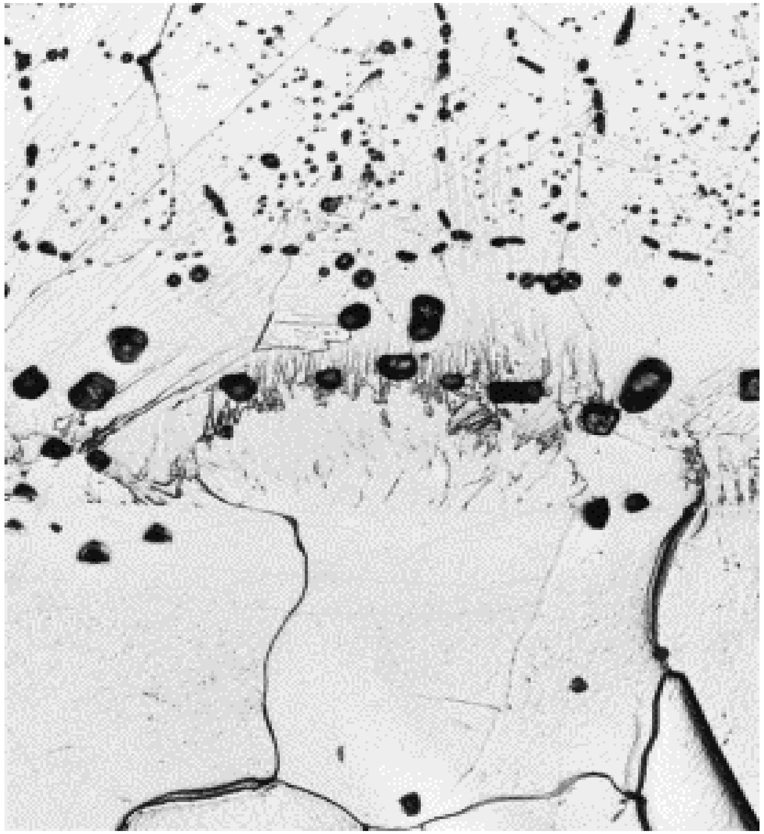


Fe-Mn, 2 min 626 K



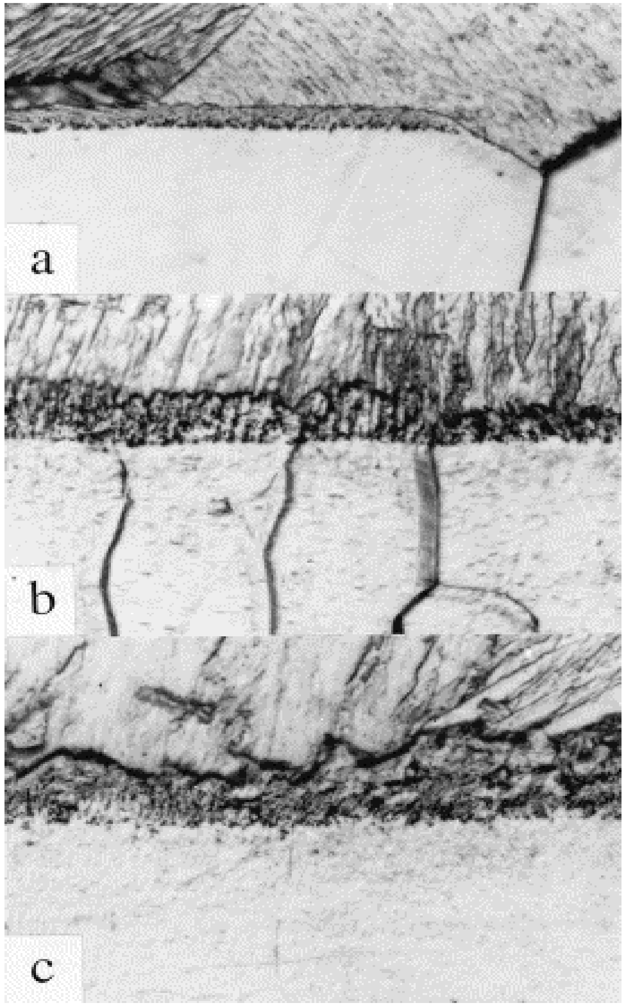
Fe-Ni, 2 min 777 K

Acicular structure formed during quenching

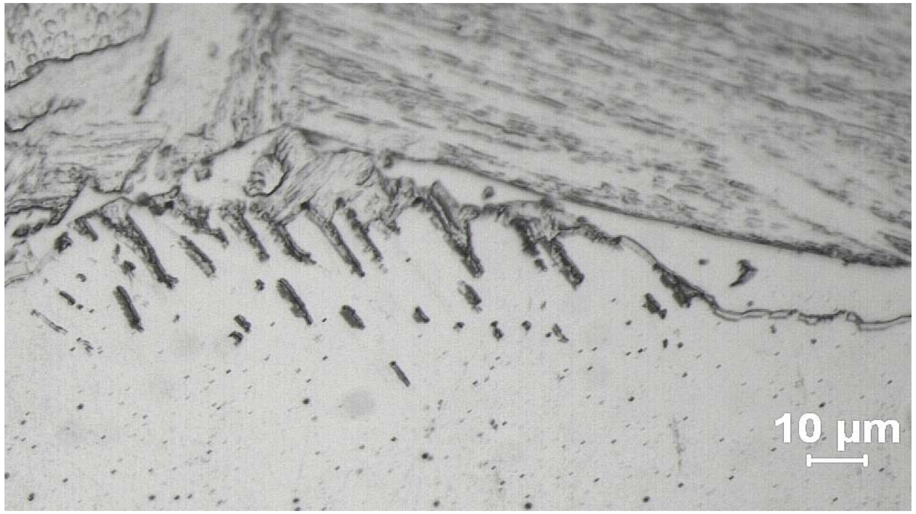


Fe-Ni, 5 sek at 1023 K

Resumed growth during quenching

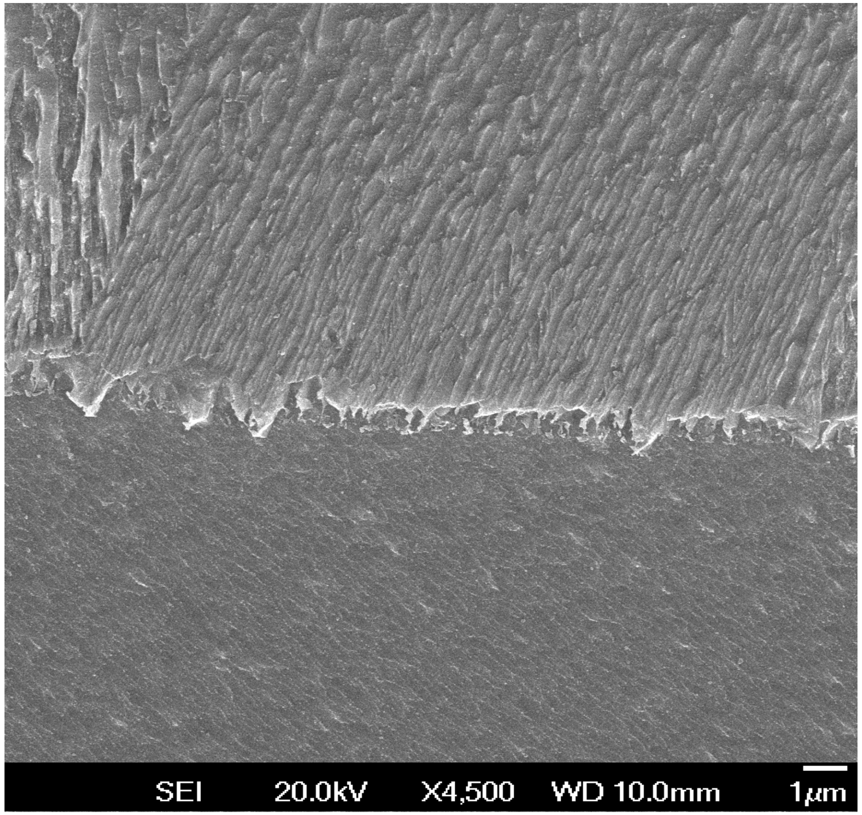


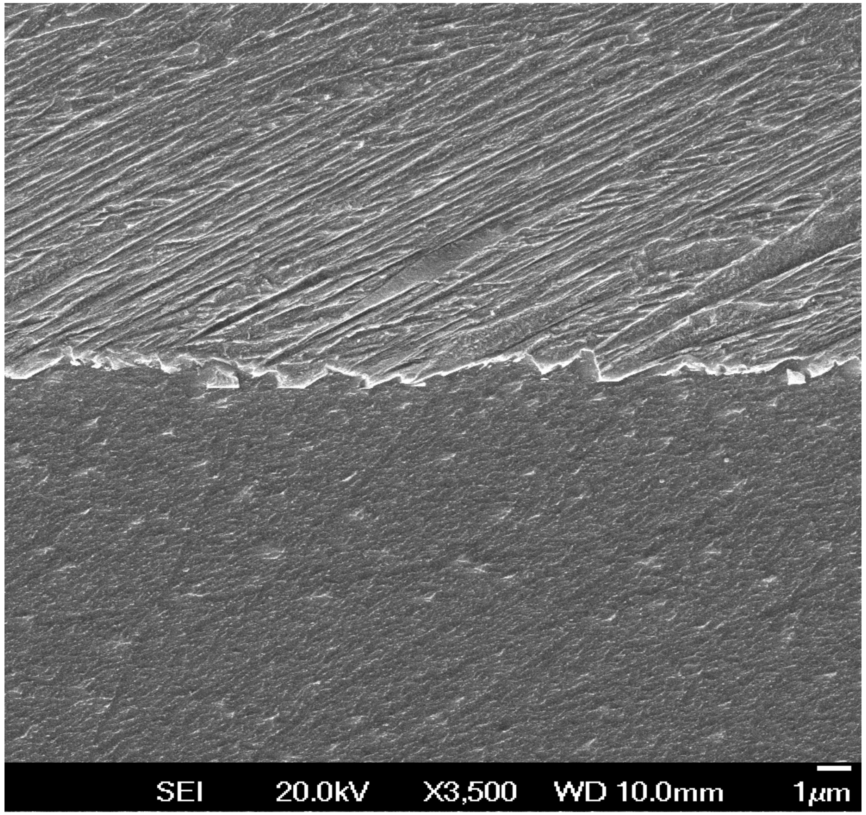
Fe-Ni, 2 min 1023 K



Fe-Mn, 7 sec 1013 K

Resumed growth during quenching





Fe-Mn, 2 min 977 K

Summary

- What are the conditions at the migrating phase interface?
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