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Preliminary analysis at the nanoscale of the austenite/ferrite interface during ferrite transformation

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- **Aim of the study**
- **Choice of the system**
- **Experimental analysis**
- **Modelling vs experiments**
- **Conclusion**



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Fe-C-Mn

Different Growth Modes

[Coates, Metallurgical Transactions 3 (1972) 1203]

1 Orthoequilibrium

- ▶ Either controlled by carbon diffusion with no manganese partition
⇒ fast kinetics (Local Equilibrium with Non Partition)
- ▶ Either controlled by manganese diffusion
⇒ slow kinetics (Local Equilibrium with Partition)

2 Paraequilibrium

- ▶ Constrained equilibrium in carbon only
⇒ fast kinetics

→ Transition from one mode to another one is possible

Aim of the study

Classically : which thermokinetics condition gives the better description for the growth of ferrite



- It is possible to measure the composition at the nanometer scale?
- To determine the Mn and C profile through the α/γ during ferrite formation
 - which tie-line governs the interface velocity (LENP, Para, Para to LENP ?)
 - is there a Mn spike at the α/γ interface ?
- To compare the experimental results with those one predicted by the various model



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Choice of the system

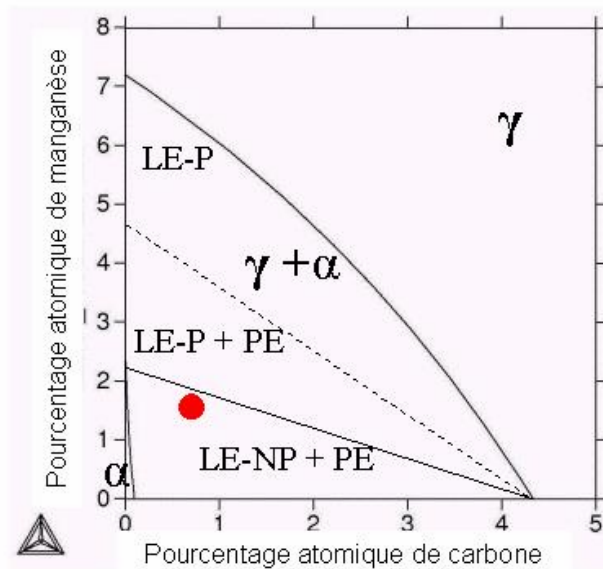


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■ Necessity to design a model alloy Fe-C-Mn :

→ A temperature and a composition where the transition from PE to LENP may occur

→ A temperature and a composition where the volume fraction of ferrite at the LENP and PE is very large to be discriminating



■ Fe-0.18wt%C-1.8wt%Mn

■ T=700°C

■ Volume fraction of ferrite

→ LENP = 25 %

→ PE = 72%



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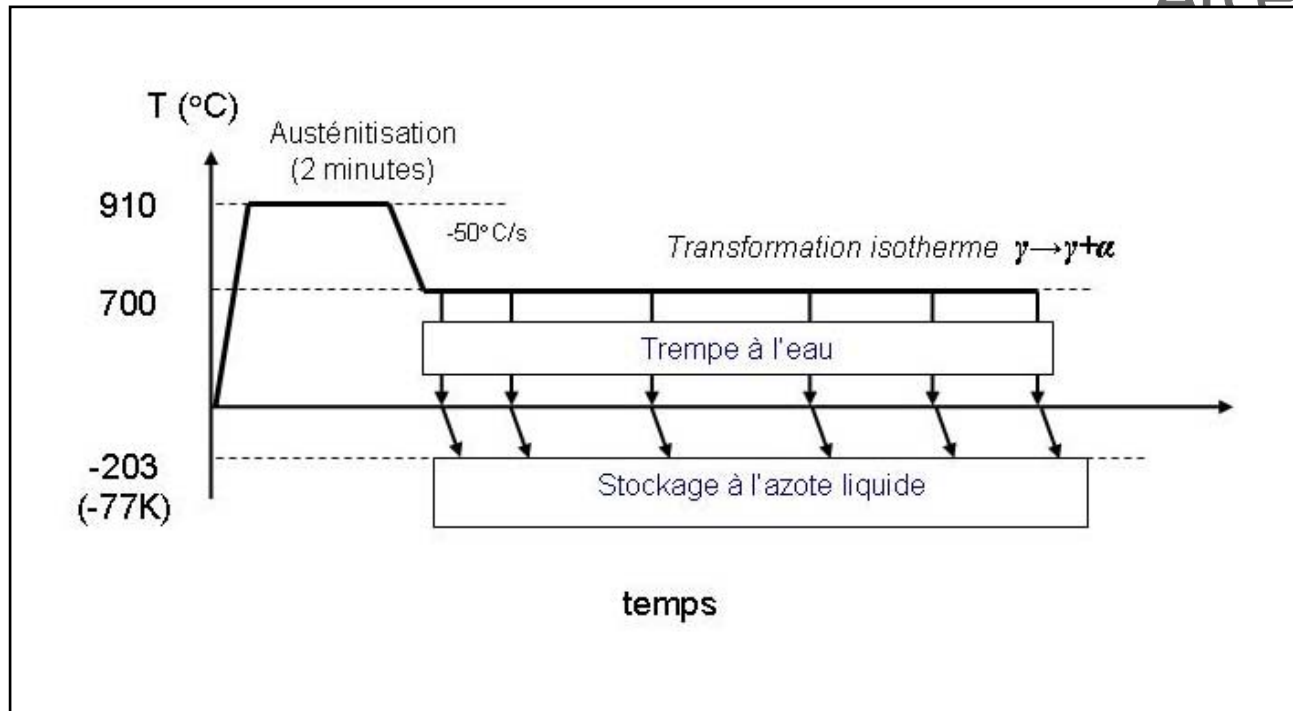
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Experimental analysis

■ Fe-0.18 wt%C-1.8 wt%Mn



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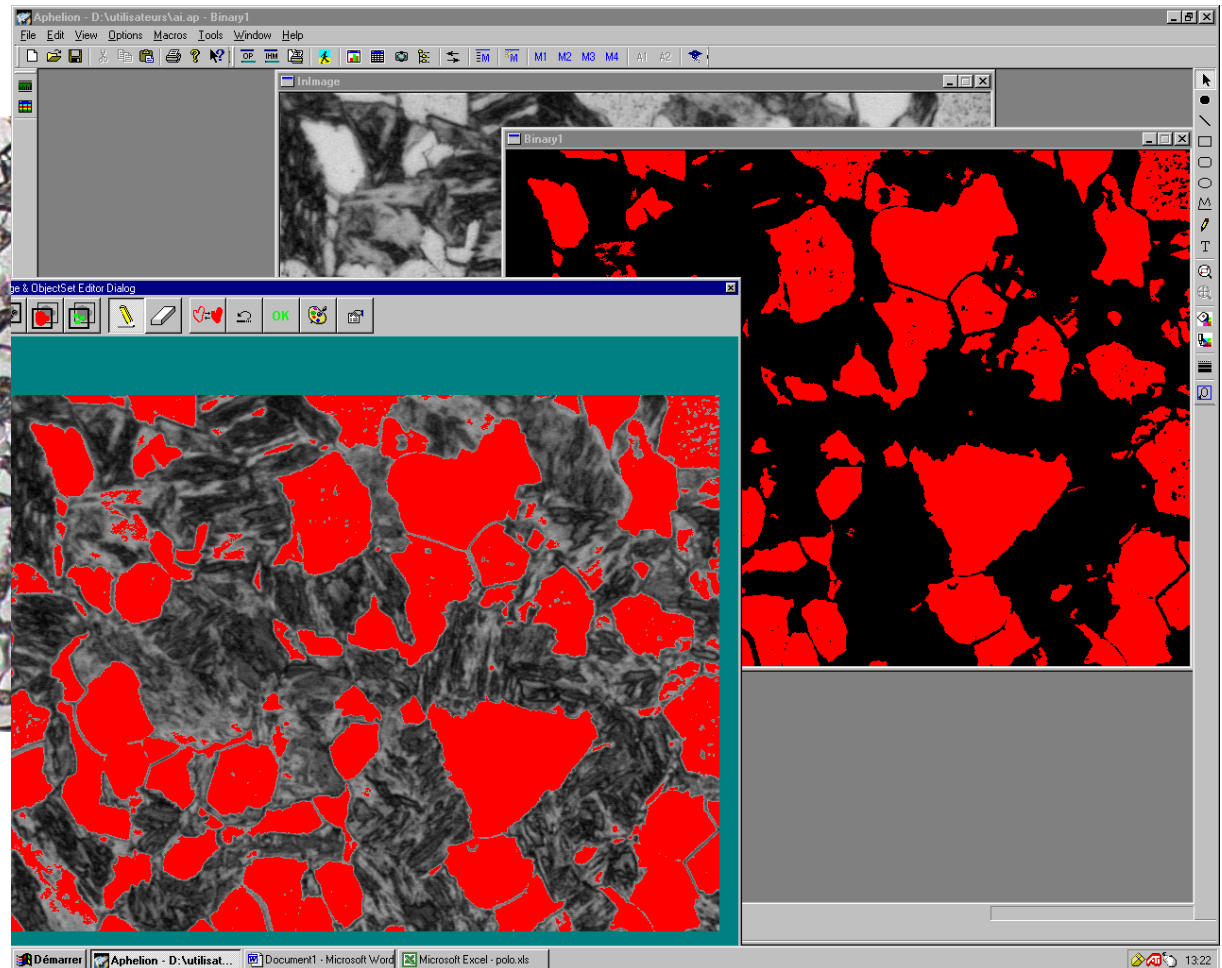
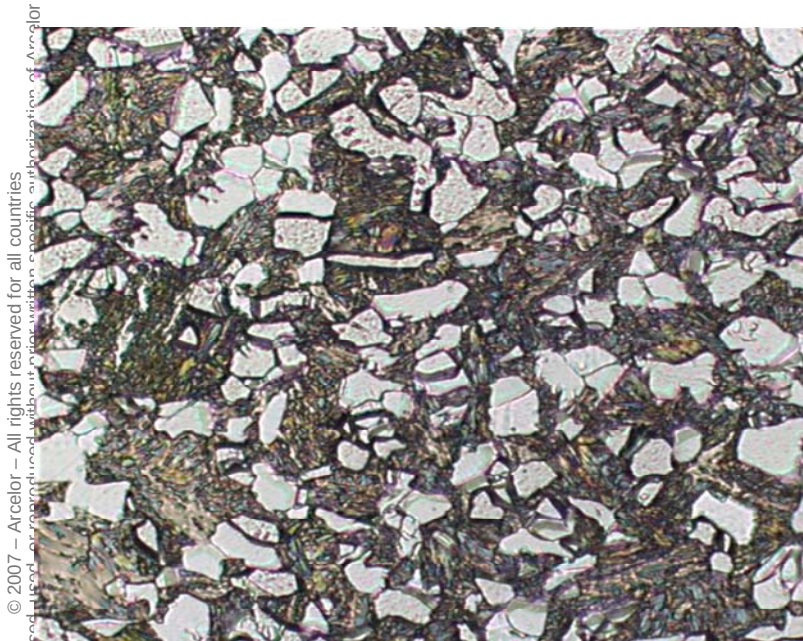
- Growth of ferrite at 700°C
- Water quench at different time
- Stocking at nitrogen liquid

Experimental analysis

Image analysis



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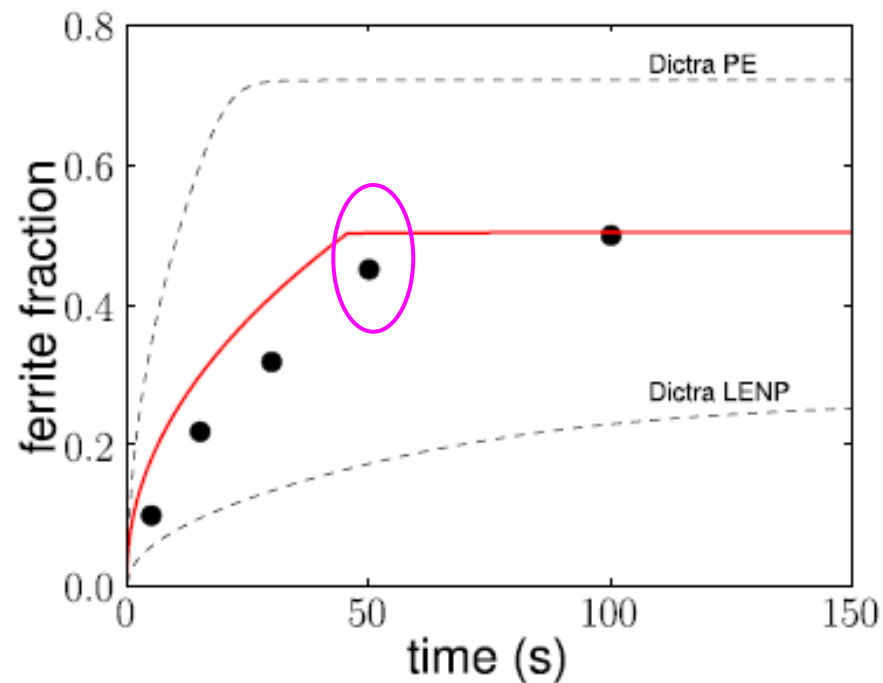
- Volume fraction
- Ferrite grain size

Experimental analysis



Kinetics of ferrite formation ArcelorMittal

- γ grain size = $20\ \mu\text{m}$
- $T = 700^\circ\text{C}$



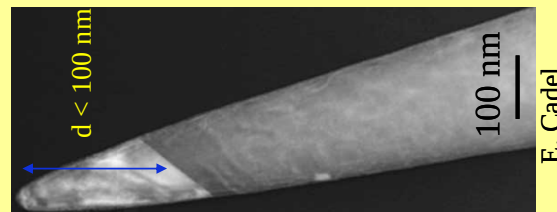
Experimental analysis

By 3D atom probe



■ The investigation of interfaces by 3D atom probe is a tedious process :

→ the interface must be positioned at less than 200 nm of the apex of the tip



- specimen preparation can be done by two methods
- the pulse back polishing combined with TEM
 - the dual focussed ion beam

(the both methods have been checked....)

→ Once an interphase is positioned at less than 200 nm of the tip apex, the Specimen is introduced in a vacuum chamber and polarized

→ Unfortunately, the high electric field applied leads to the failure of the specimen
In more than 95 % of the cases

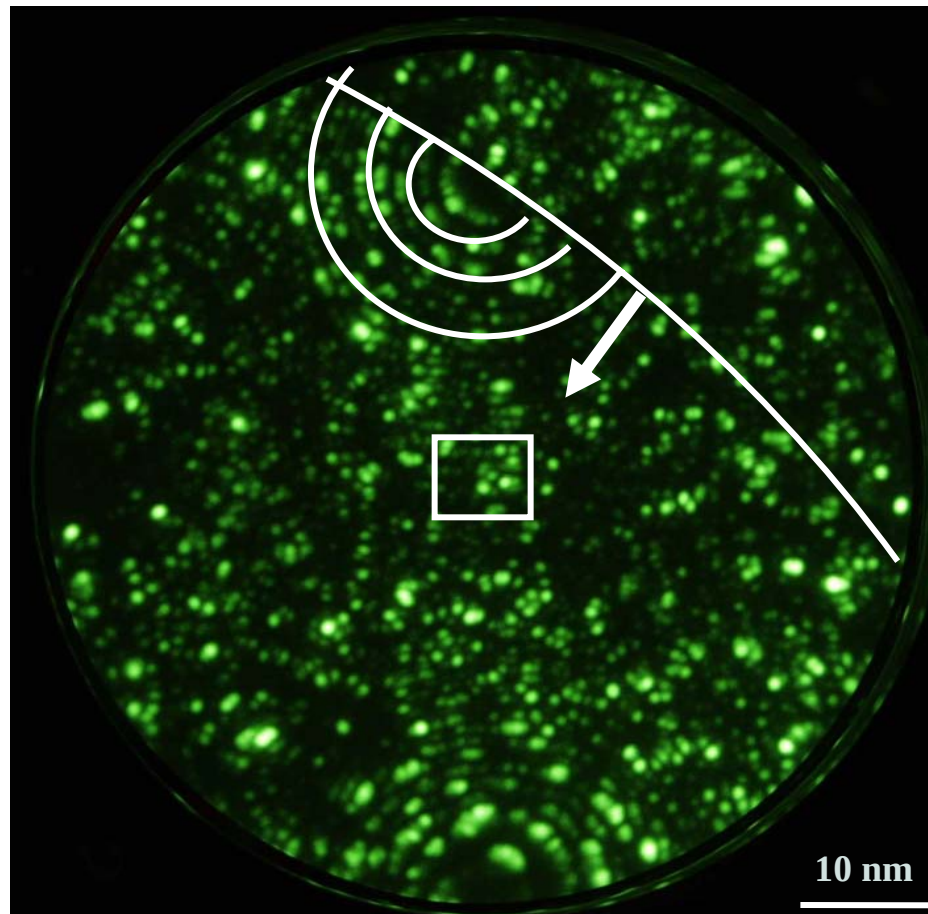
Experimental analysis

By 3D atom probe : treatment time = 50s



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- A specimen has been successfully analysed
- It was first investigated by field ion microscopy (FIM).
 - the circles define some cristallographic directions
 - The failure of the circles indicates a cristallographic change



Arcelor Research S.A./ BIMIO E. Cadel

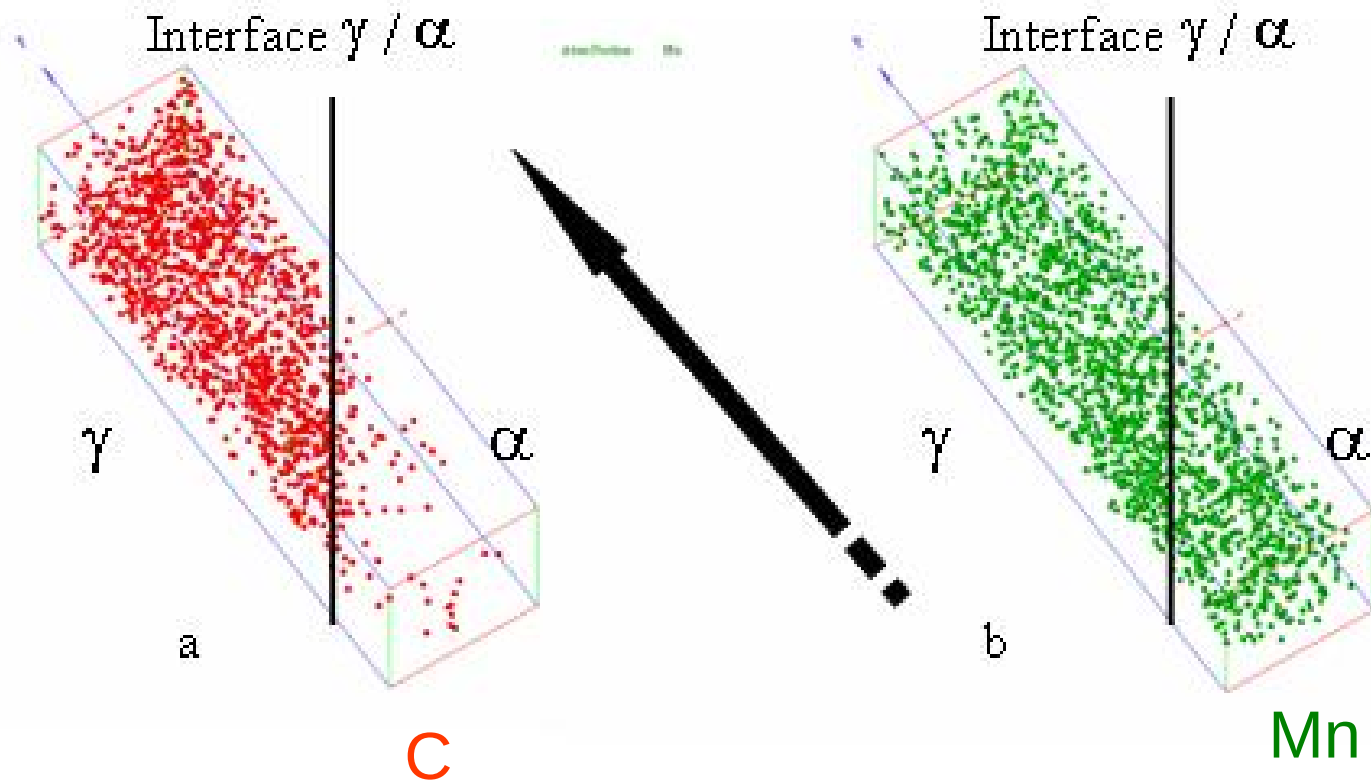
7.41 kV / Ne 3.2 10⁻⁵ Torr / 80K

Experimental analysis

By 3D atom probe : treatment time = 50s



Reconstruction of an γ/α interface analysed by Energy Compensated Optical Tomographic Atome Probe

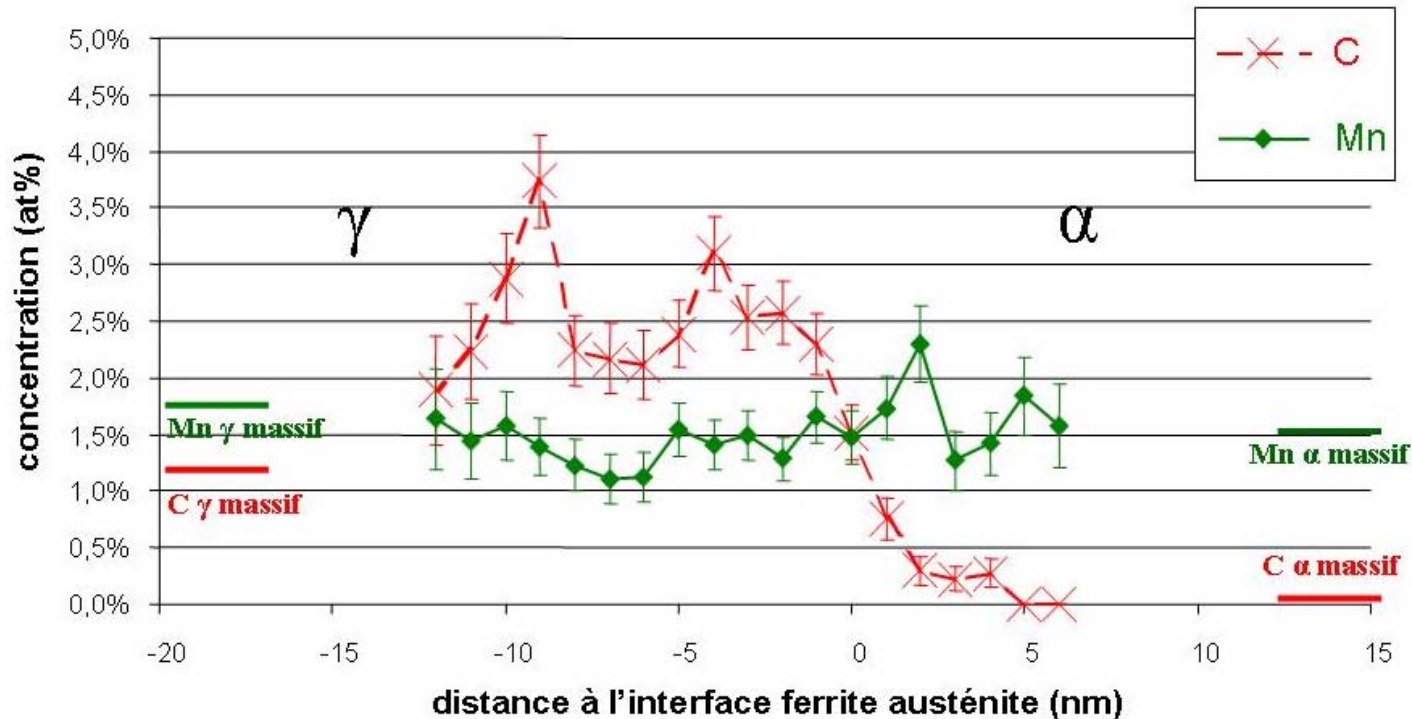


Experimental analysis

By 3D atom probe : treatment time = 50s



C and Mn profile across the α/γ interface rcelorMittal



- The concentration profile confirms the presence of two phases with different C composition
- The carbon profile is diffuse ▶
- No clear evidence of Mn spike ▶

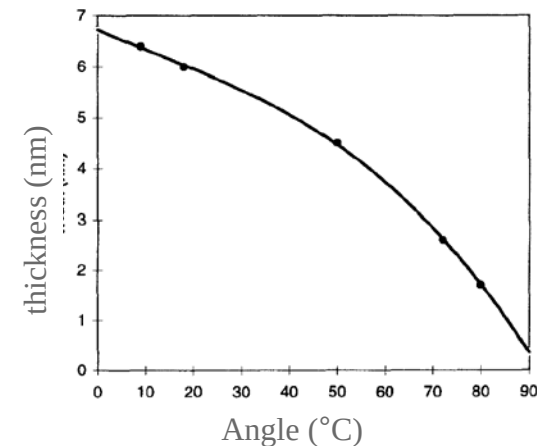
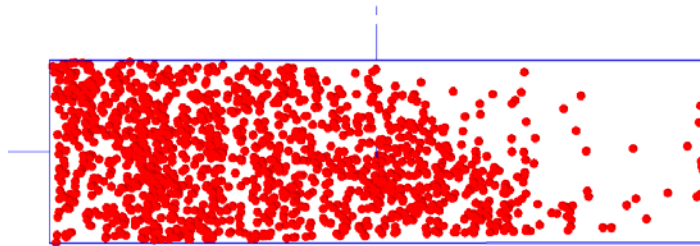
Experimental analysis

■ The carbon concentration profile is diffuse



→ It may be suspected that the interface is not perfectly planar over the intercepted surface,

→ It would be related to the tilt angle between the interface and the analyzed surface. Indeed, in this configuration the overall spatial resolution is deteriorated, leading to an artificial spread of interface width.



Letellier and al

The experimental results can not be ruled out that a C composition gradient exists at the α/γ interface



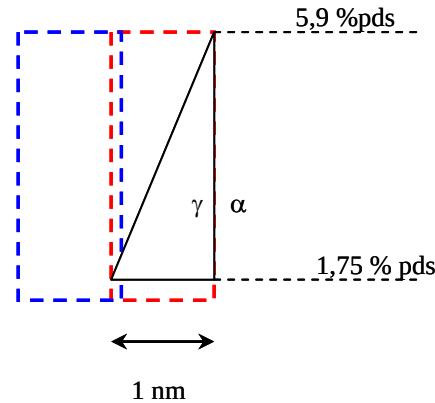
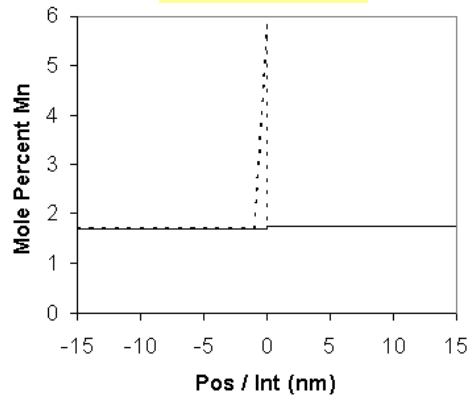
Experimental analysis

■ On the presence of the spike ?

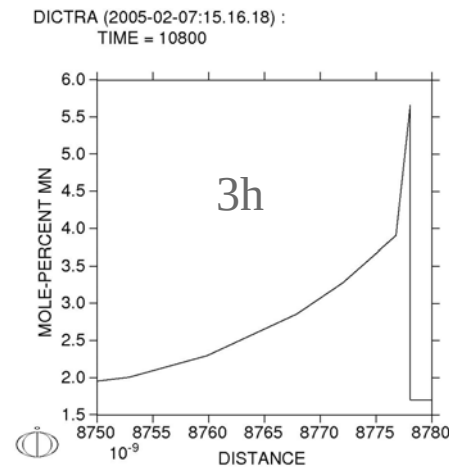


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t=50s
T=700°C



- High probability to measure a composition very close to the bulk
- Due to the accuracy of the device it is difficult to detect the presence of the Mn spike
- A higher treatment time is needed (3 h)



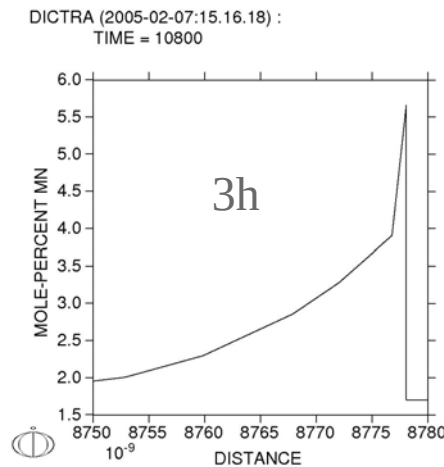


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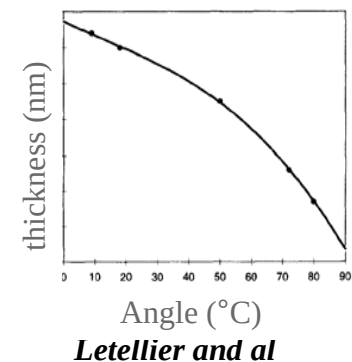
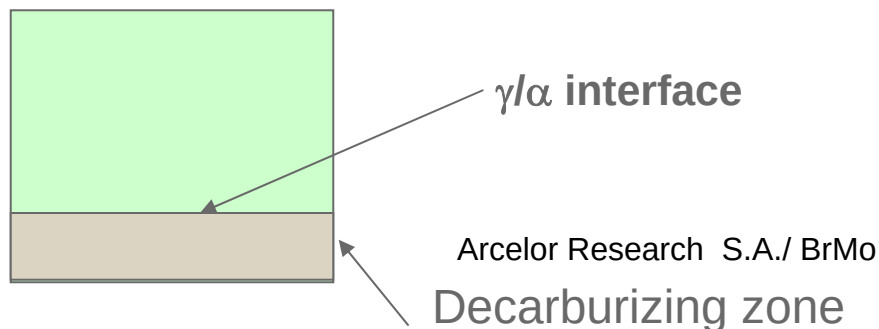
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Conclusion

- The analysis of the α/γ interface at the nanoscale is possible by 3D atom probe
↗
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- *It is a tedious process since the failure of the specimen in 95 % of the cases*
- Unfortunately, the Mn distribution (spike ?) can not be detected for the selected time.



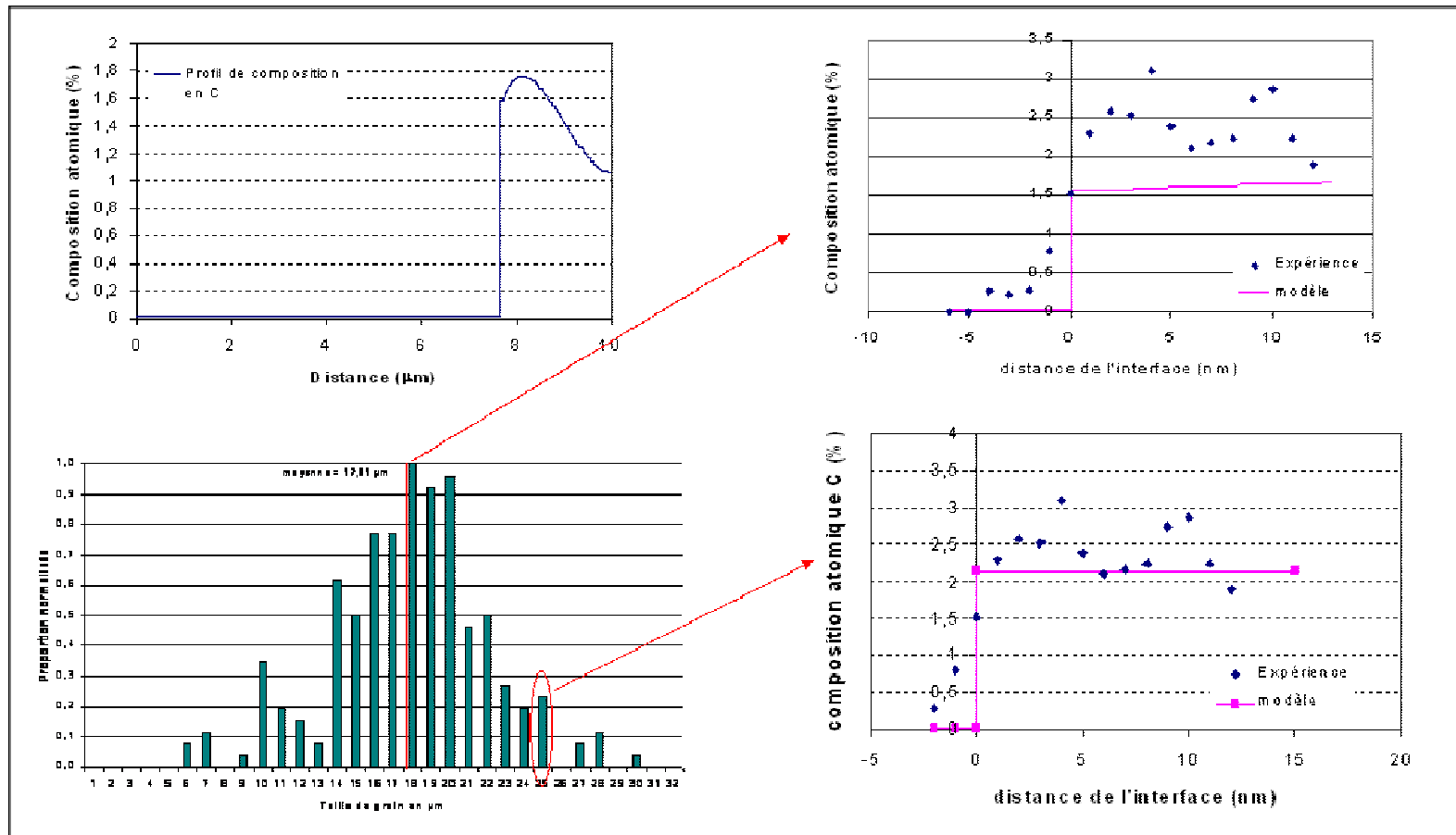
- To analyse correctly the C profile through the interface : need to couple the decarburization experiments and 3D atom probe



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- Difficult to analyse the C profile since we do not know exactly in which austenite grain size the interface comes from

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THANK YOU FOR ANNIKA and KTH

Modelling vs Experimental

