THERMO-CALC® AND DICTRA® SIMULATIONS OF THE SOLUTION HEAT TREATMENT OF SUPERDUPLEX STAINLESS STEELS

RODRIGO MAGNABOSCO
M. T. M. Fiorante

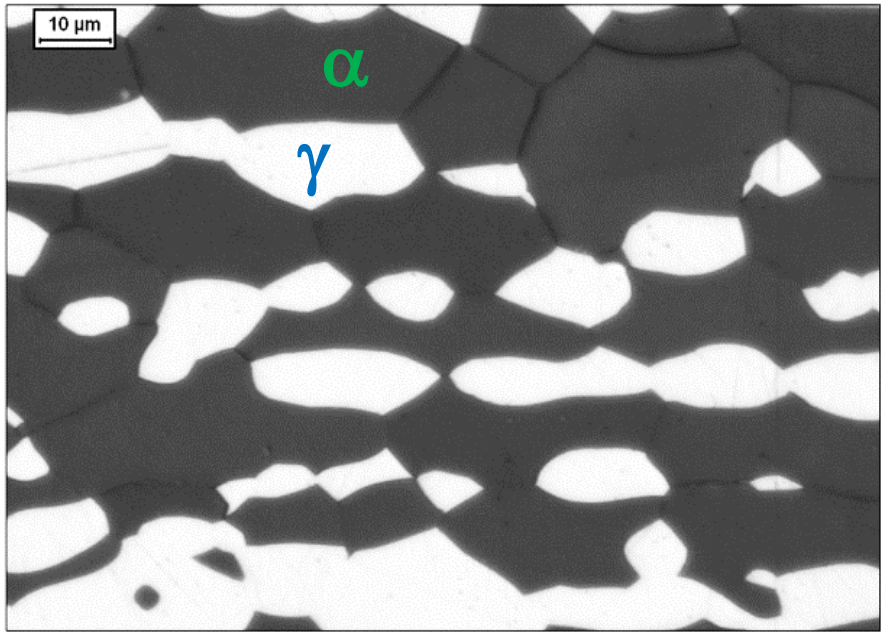
Introduction

Duplex Stainless Steels (DSS)

Approximately equal amounts of ferrite (α, BCC) and austenite (γ, FCC)

Corrosion resistance, mechanical strength, toughness

Properties are determined by the correct balance of α and γ



D. C. dos Santos, R. Magnabosco, C. Moura-Neto, Influence of sigma phase formation on pitting corrosion of an aged UNS S31803 duplex stainless steel. Corrosion, v. 69, p. 900-911, 2013.

Introduction

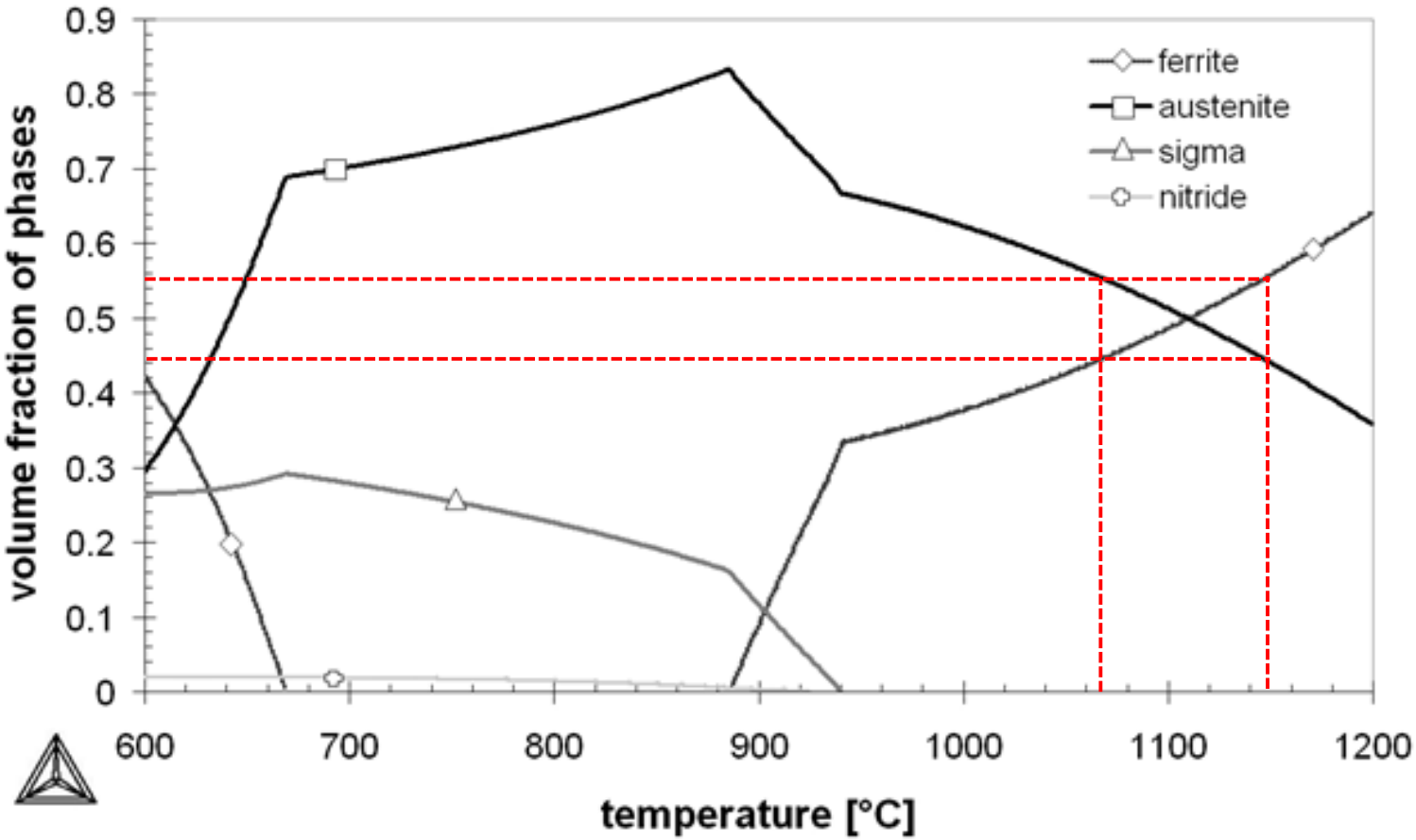
Balance between ferrite and austenite depends of:

✓ Chemical composition

✓ Solution heat treatment

ferrite (α, BCC) between 45 and 55%v is acceptable

typical solution treatment temperature lies between 1050 and 1150 °C



R. Magnabosco. Kinetics of sigma phase formation in a Duplex Stainless Steel. Materials Research, v. 12, p. 321-327, 2009.

Introduction

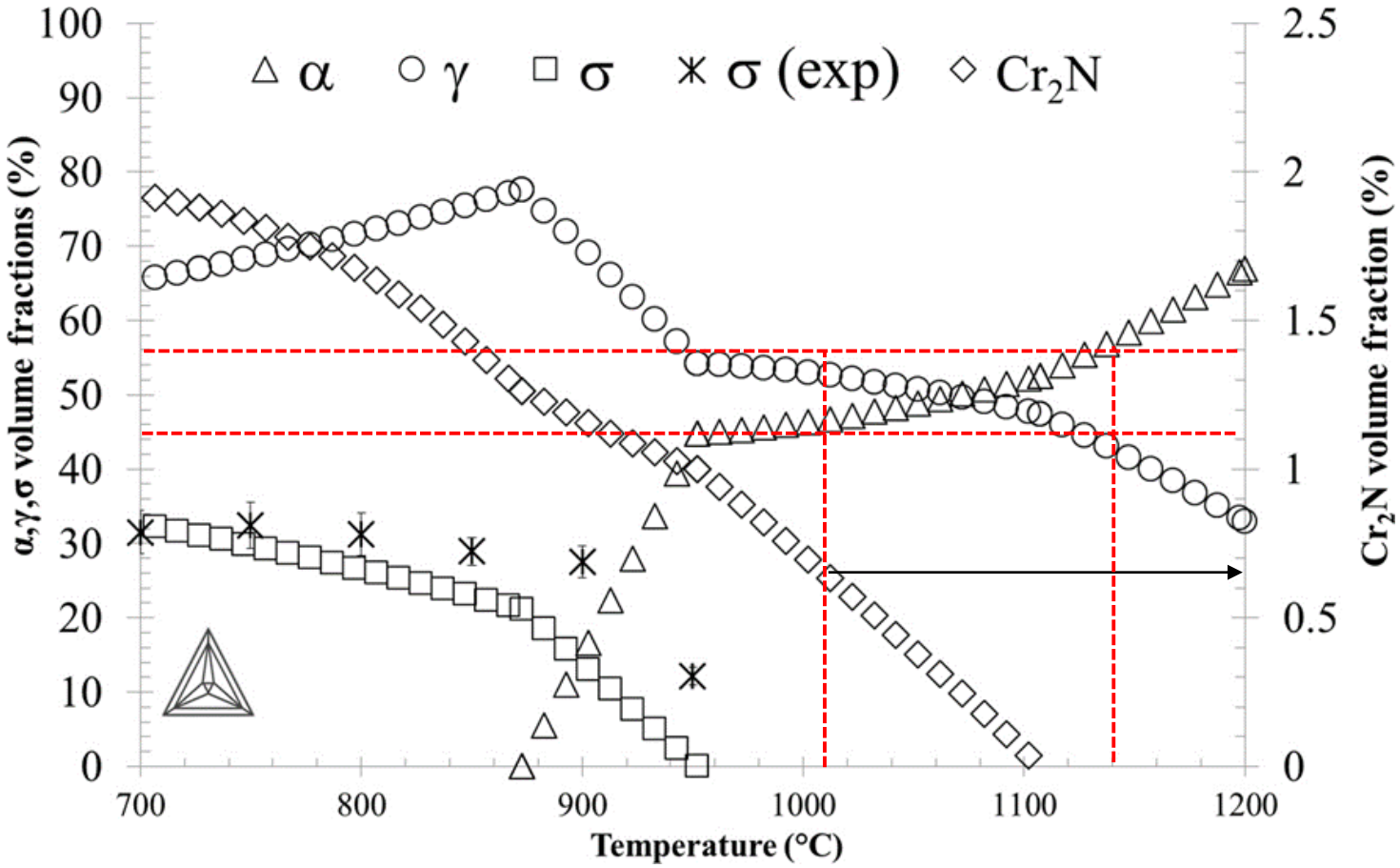
Balance between ferrite and austenite depends of:

✓ Chemical composition

✓ Solution heat treatment

small amounts of Cr_2N can be formed depending on chemical composition

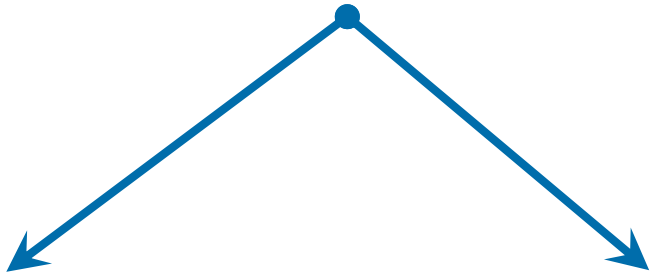
Thermodynamic simulations only predicts the equilibrium phase content: what about kinects?



D.C. dos Santos, R. Magnabosco. Kinetic Study to Predict Sigma Phase Formation in Duplex Stainless Steels. Metall. Mat. Trans. A (2016) 47: 1554.

Objectives

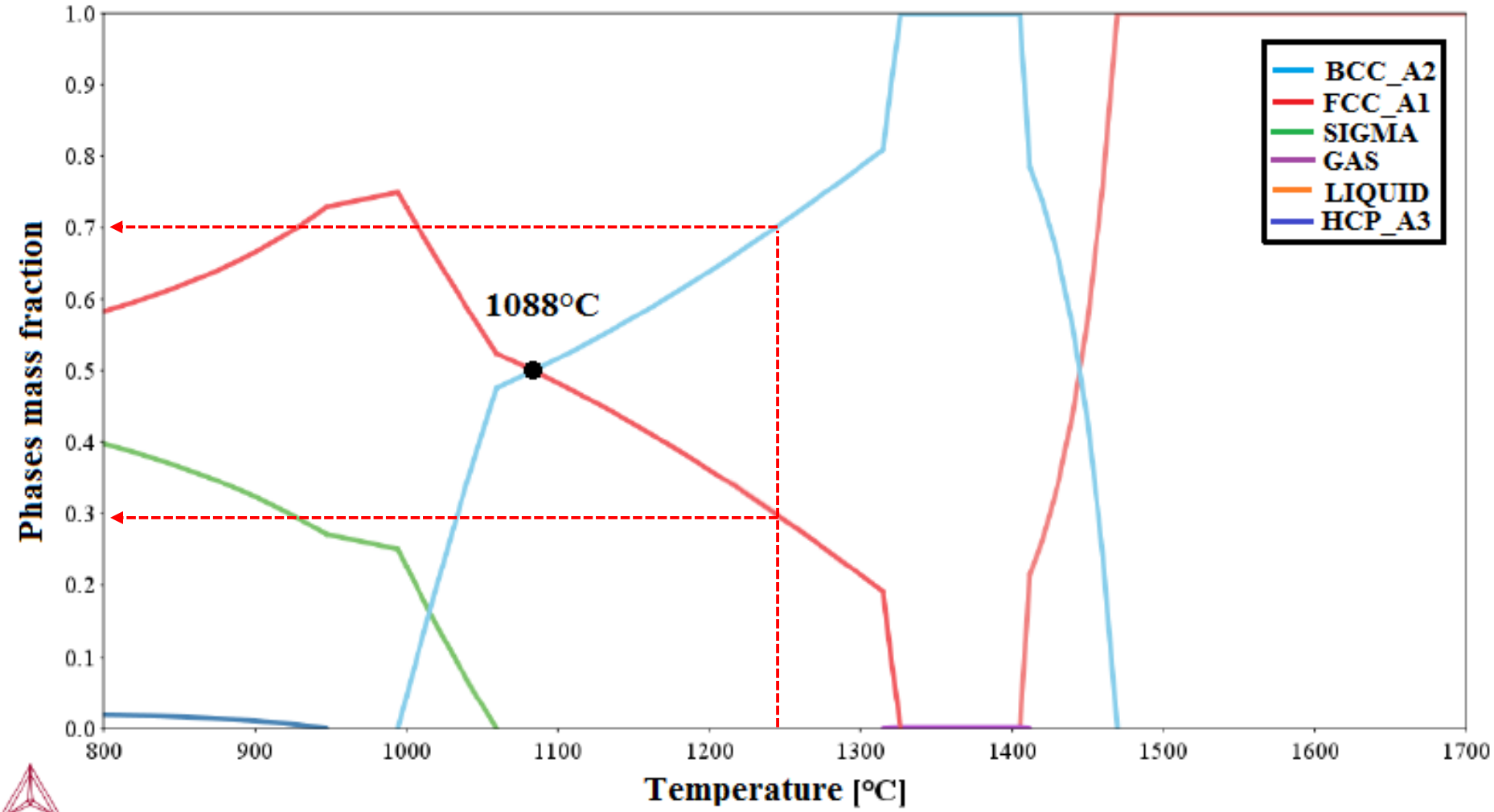
Computational simulations of the equilibrium and phase transformation kinetics of a superduplex stainless steel UNS S32750 in two different heat treatment cycles:



Isothermal at 1250 °C (a possible hot work temperature)

Isothermal for generation of duplex structure after a 1250 °C temperature hold

Computational modelling



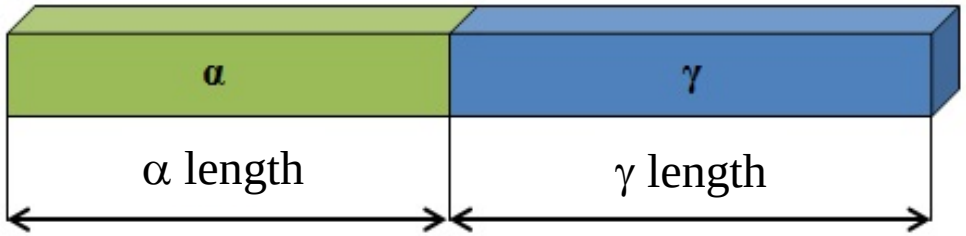
TCFE8

Only using
Fe, Cr, Ni, Mo, N

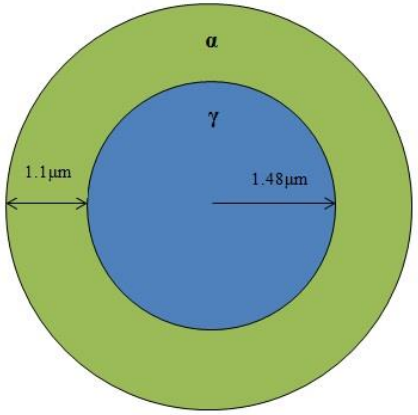
Cr	Ni	Mo	N	Mn	W	C	Fe
25.17	6.88	3.61	0.25	0.60	0.69	0.01	balance

Computational modelling

Simulation time	Temperature	Geometric model	α length	γ length
3 h	1250 °C	Planar	10 μm	10 μm
16 h	1250 °C	Spherical	1.3 μm (thickness)	5 μm (radius)



MOBFE3

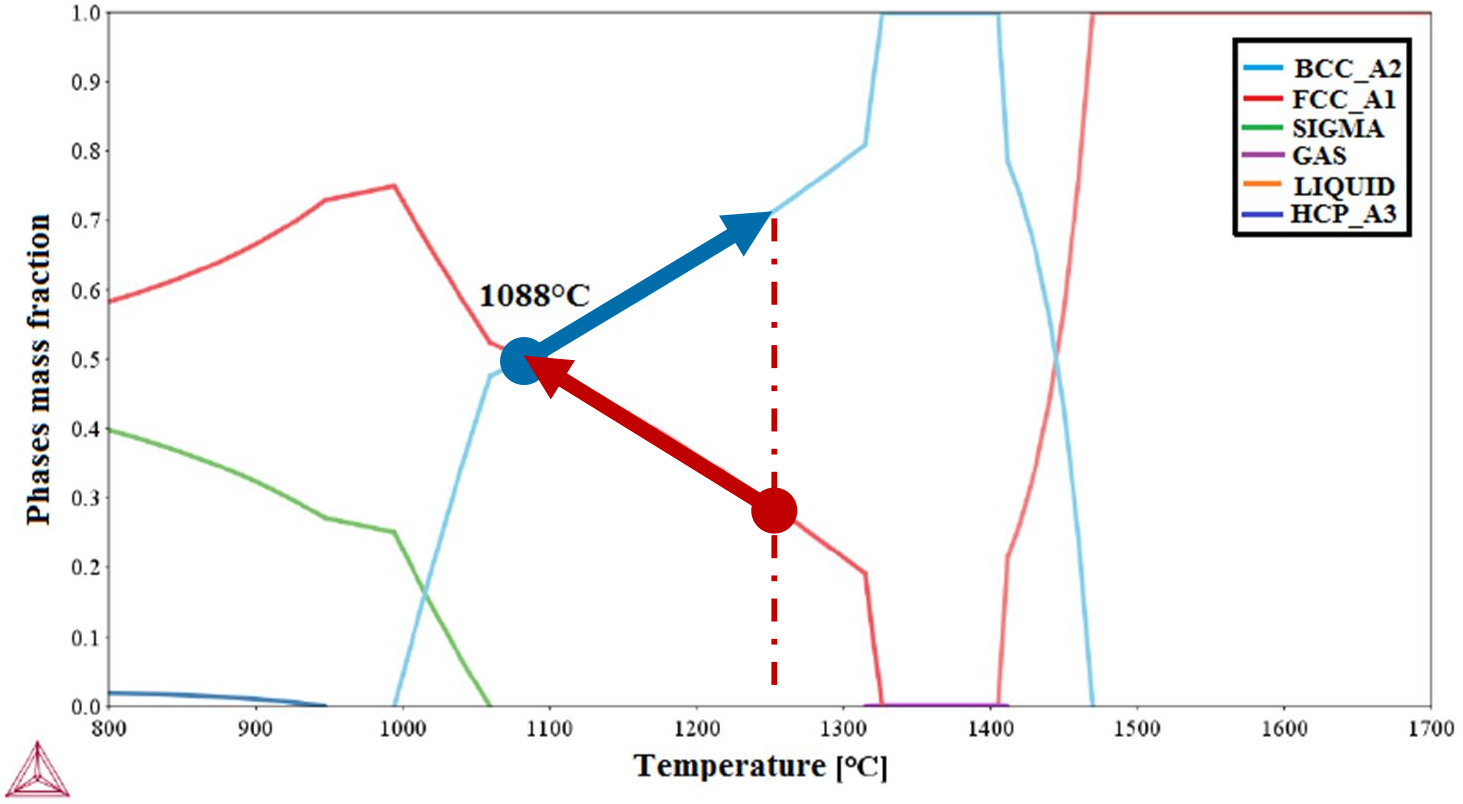


Simulation time	Temperature	Geometric model	α length	γ length
1000 h	1088 °C	Planar	67 μm	28 μm
20 h	1088 °C	Spherical	6.9 μm	14 μm

only using Fe, Cr, Ni, Mo, N

Experimental procedure

Initial condition	Temperature	Holding time
As received	1250 °C	1 min, 2 min, 40 min, 3 h
3 h @ 1250°C, water quenched	1088 °C	2 min, 30 min, 3 h, 12 h, 36 h



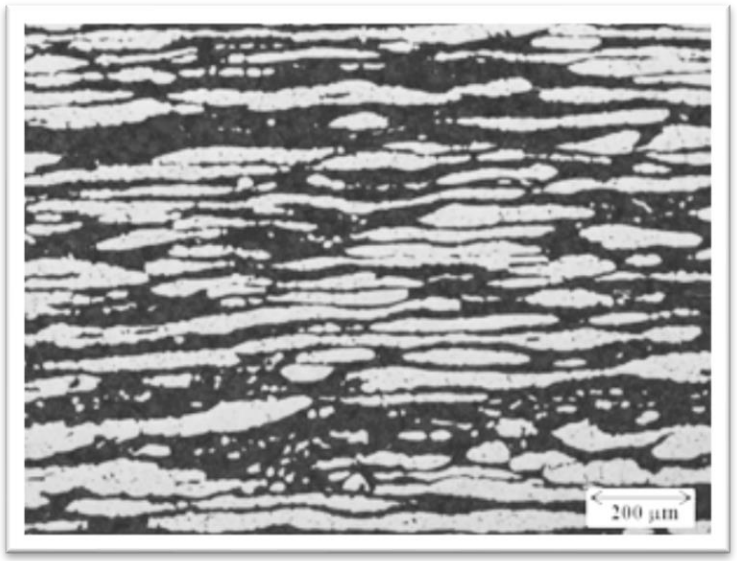
Experimental procedure

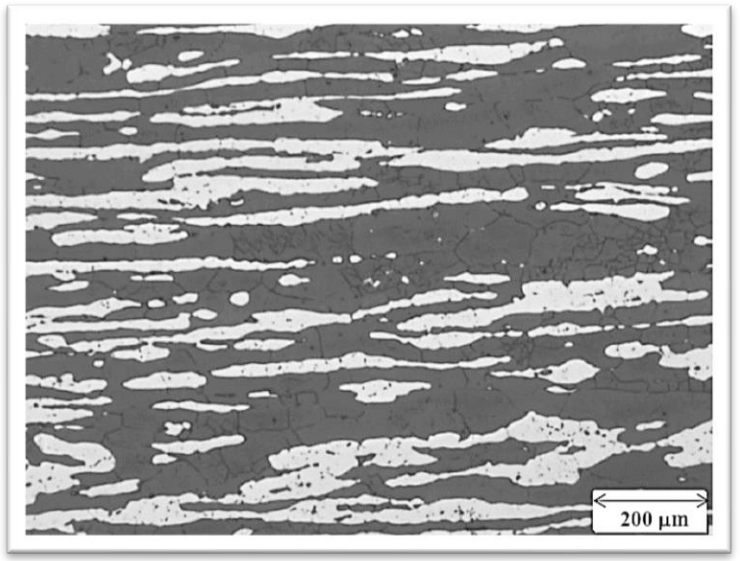
Initial condition	Temperature	Holding time
As received	1250 °C	1 min, 2 min, 40 min, 3 h
3 h @ 1250°C, water quenched	1088 °C	2 min, 30 min, 3 h, 12 h, 36 h

- Water quenching after all isothermal heat treatments
- Optical Microscopy (OM) after modified Beraha etching
  - Quantitative analysis of ferrite, 20 random fields at 100x magnification
- Optical Microscopy (OM) after oxalic acid electrolytic etching (6 Vdc, 30 s)
  - Linear intercept mean grain size measurements of the two initial conditions
  - Data used for estimation of the α and γ lengths in DICTRA models

Results and Discussion

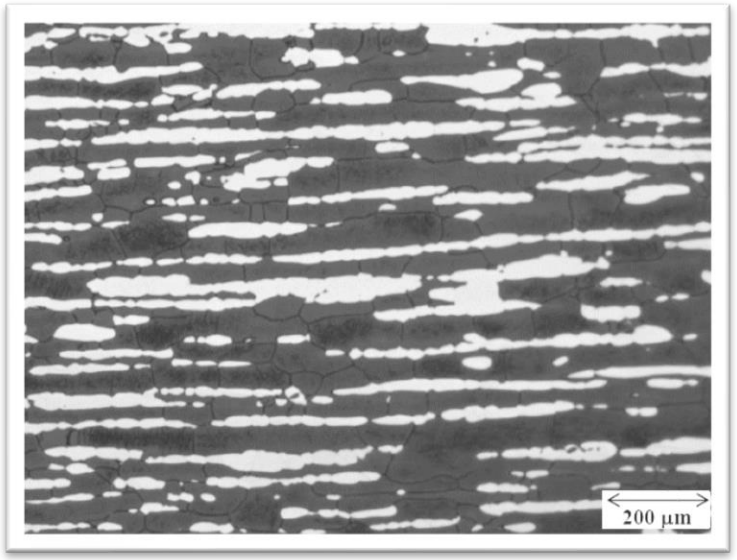
1 min
@ 1250 °C
Beraha

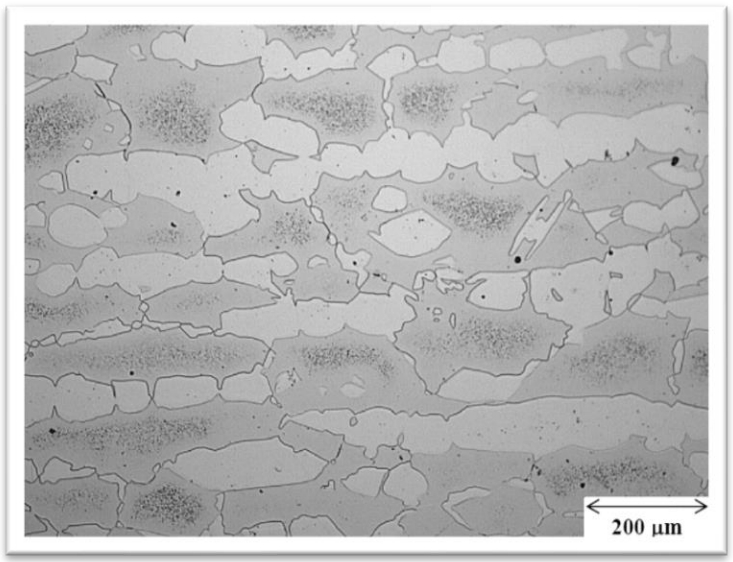




2 min
@ 1250 °C
Beraha

40 min
@ 1250 °C
Beraha

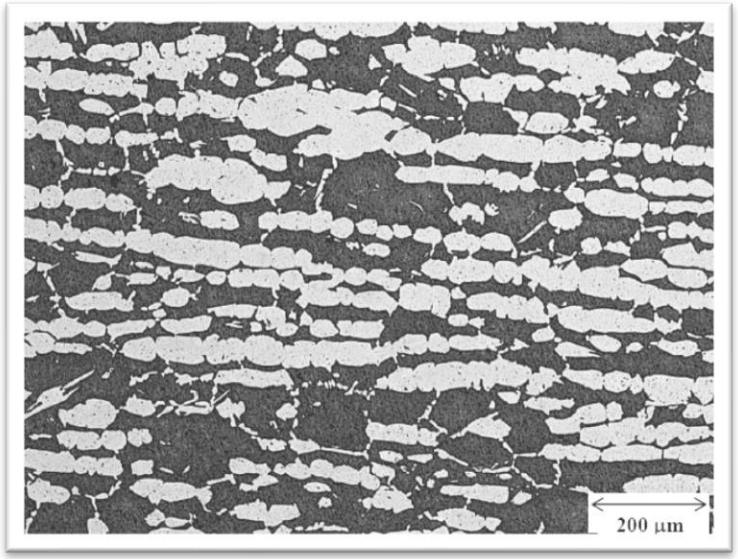


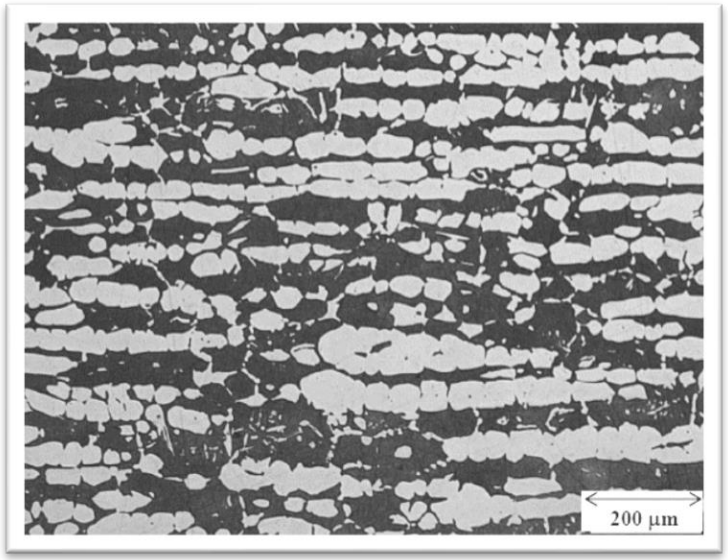


3 h
@ 1250 °C
oxalic

Results and Discussion

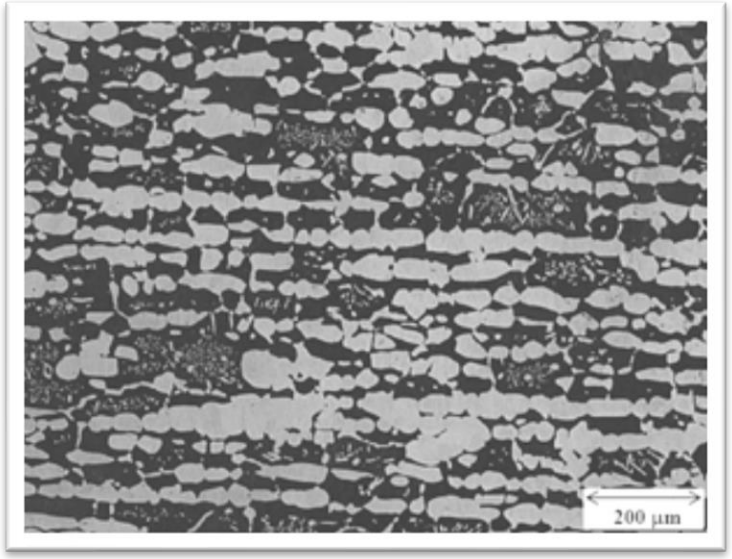
2 min
@ 1088 °C
Beraha

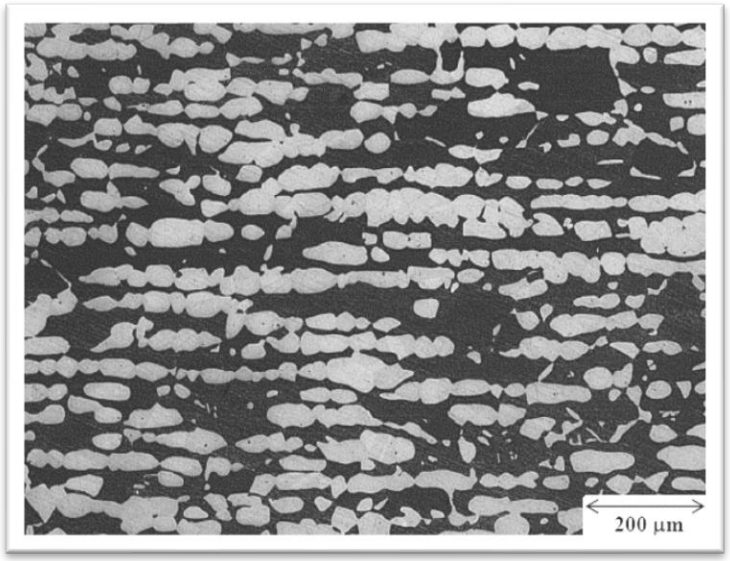




30 min
@ 1088 °C
Beraha

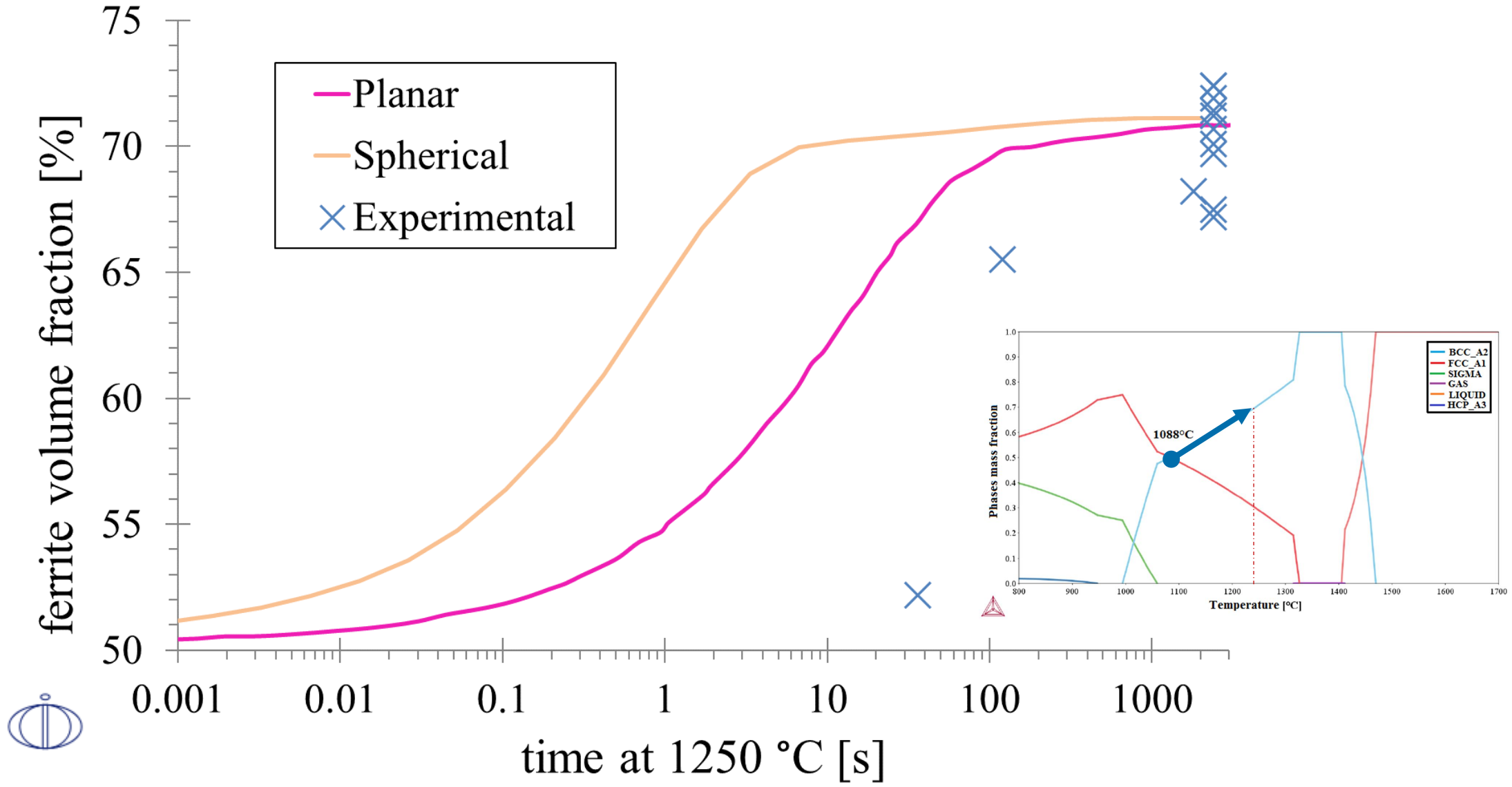
3 h
@ 1088 °C
Beraha



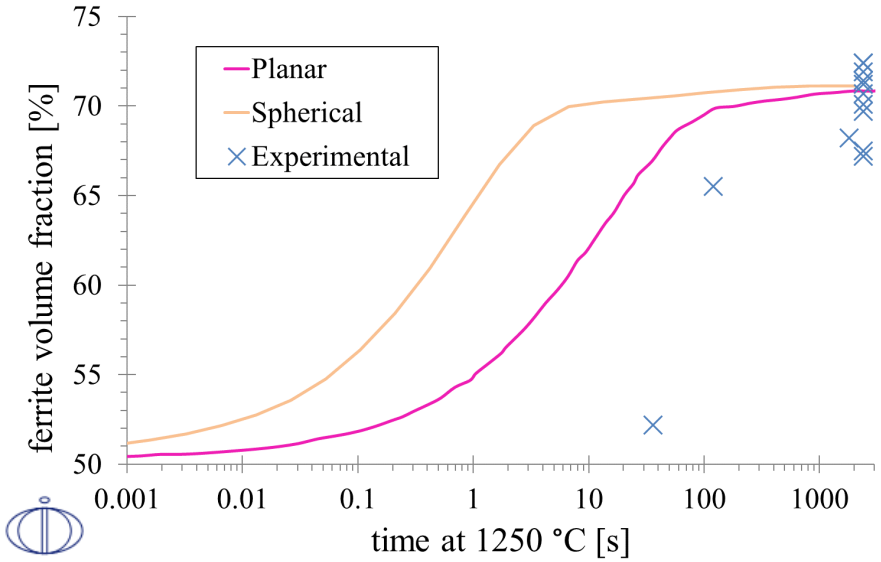


36 h
@ 1088 °C
Beraha

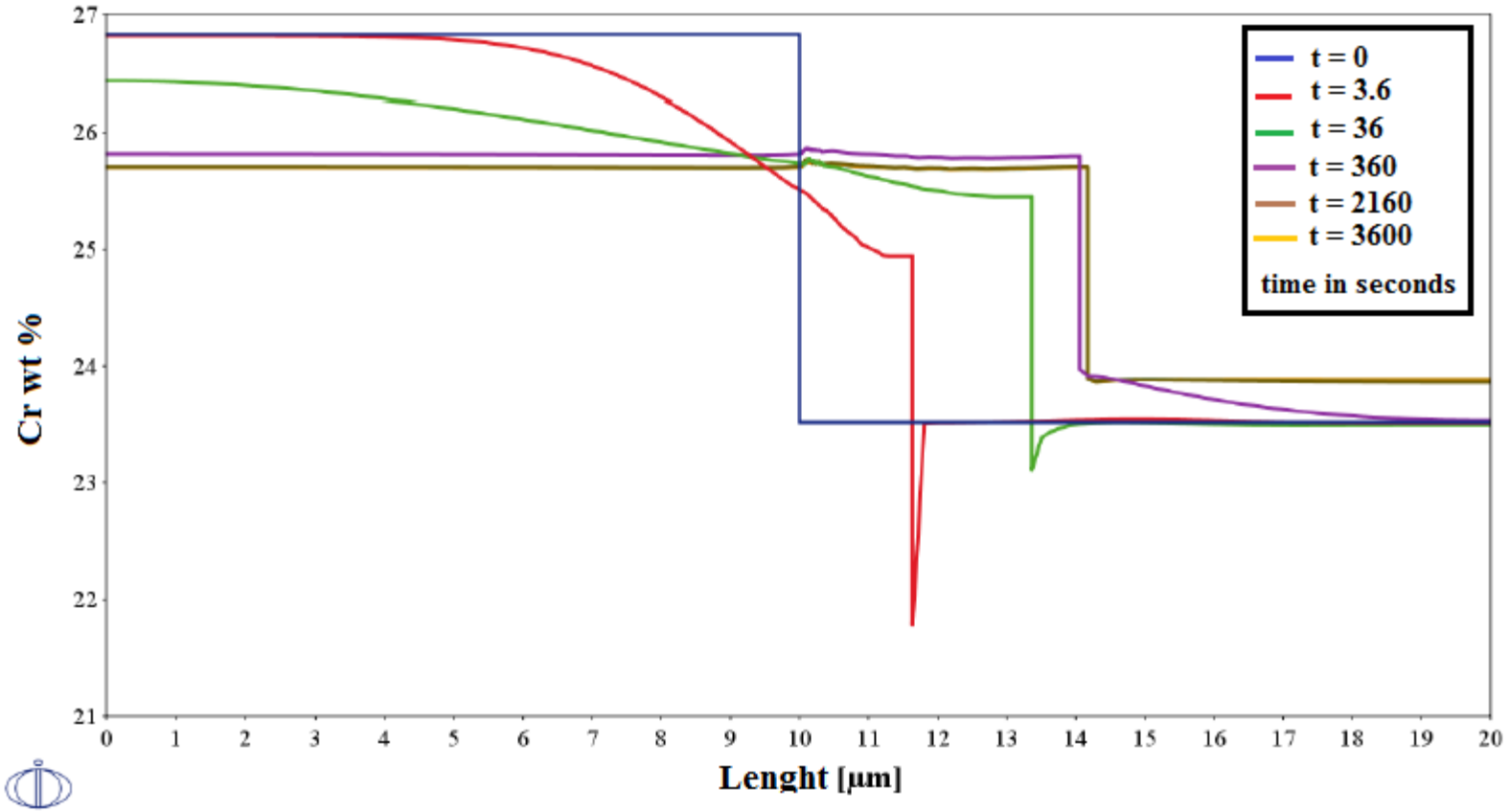
Results and Discussion



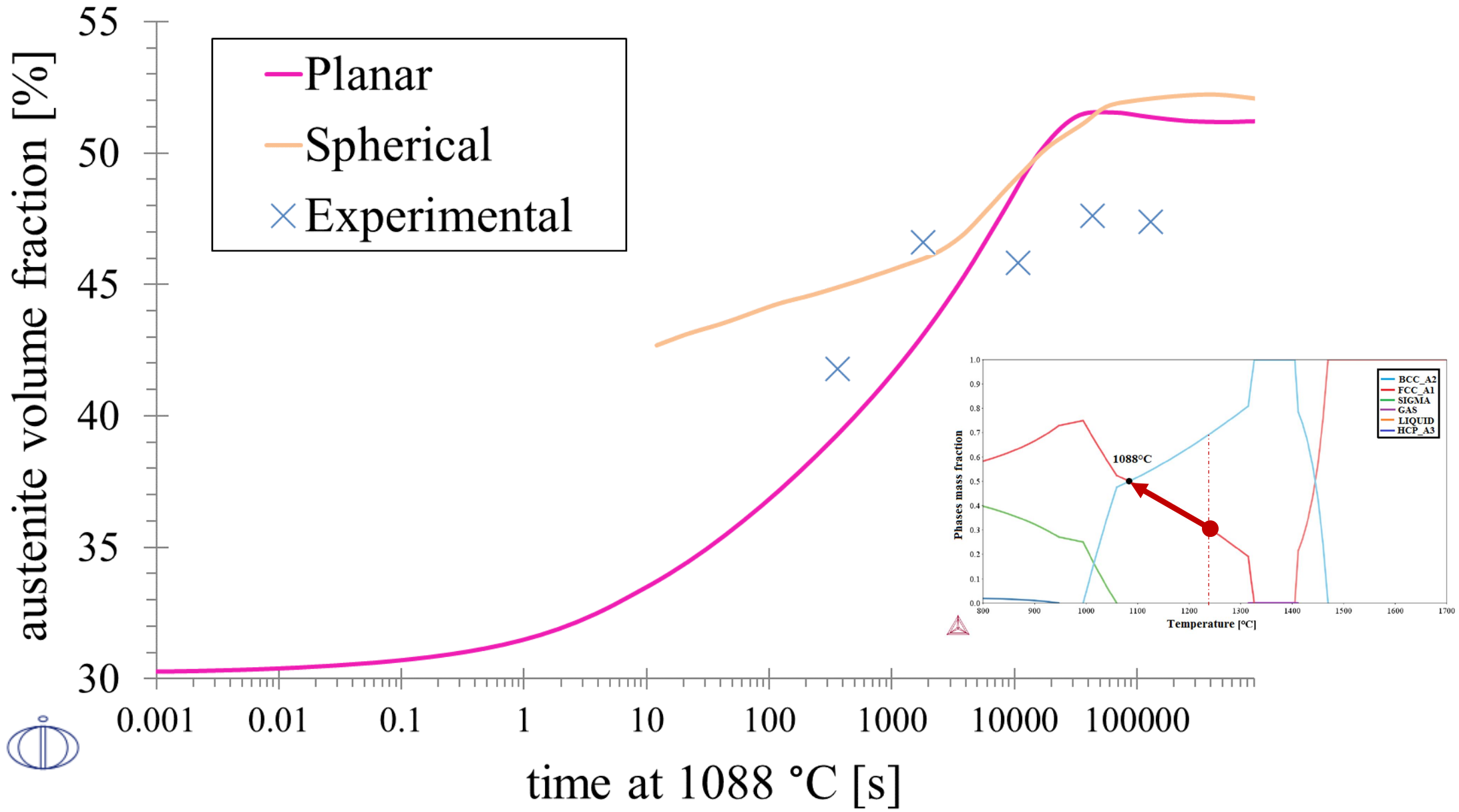
Results and Discussion



Cr and Mo gradients only vanishes after 1800 s (30 min) of heat treatment @ 1250 °C



Results and Discussion



Conclusions

Planar model used in DICTRA® simulations is the one that better assess the behaviour of volume fraction phase's changes for both heat treatments.

Conclusions

Ferrite and austenite volume fractions stabilize after 30 min of heat treatment, obtaining 71% of ferrite at 1250 °C and 51% of austenite at 1088 °C; simulations are in accordance with experimental validations.

Conclusions

Equilibrium of chemical composition, marked as the absence of compositional gradients, is established long after the achievement of the equilibrium volume fraction of phases, reached after 30 min.

The information about total attenuation of gradient profiles can only be obtained in DICTRA® simulations.

Acknowledgements

Grant 301458/2016-2

THERMO-CALC® AND DICTRA® SIMULATIONS OF THE SOLUTION HEAT TREATMENT OF SUPERDUPLEX STAINLESS STEELS

RODRIGO MAGNABOSCO

rodrmagn@fei.edu.br