Partitioning and austenite reversion in Mn steels

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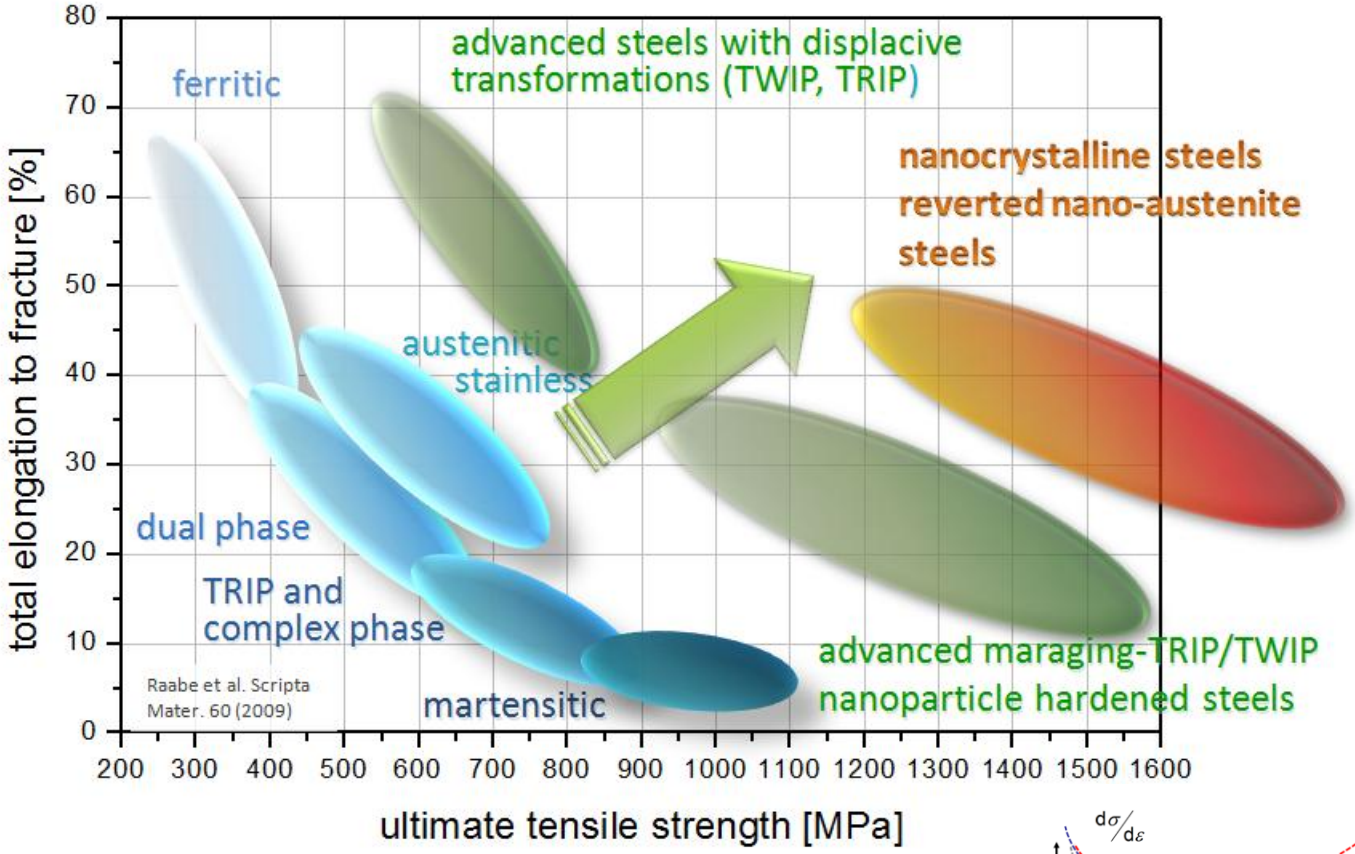
Overview

- Design of complex steels
- Nanostructuring by lattice defect decoration and selective phase transformation
- Theoretical treatment
- Summary and conclusions

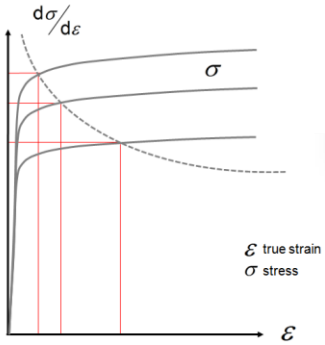
From atomistic understanding towards designing new materials



current status

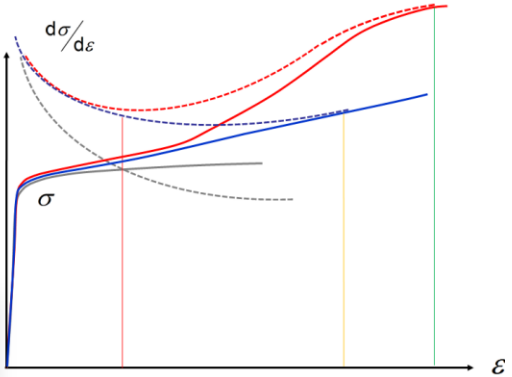
recent results

speculation



Inverse strength-ductility relation

Design strain hardening only where needed



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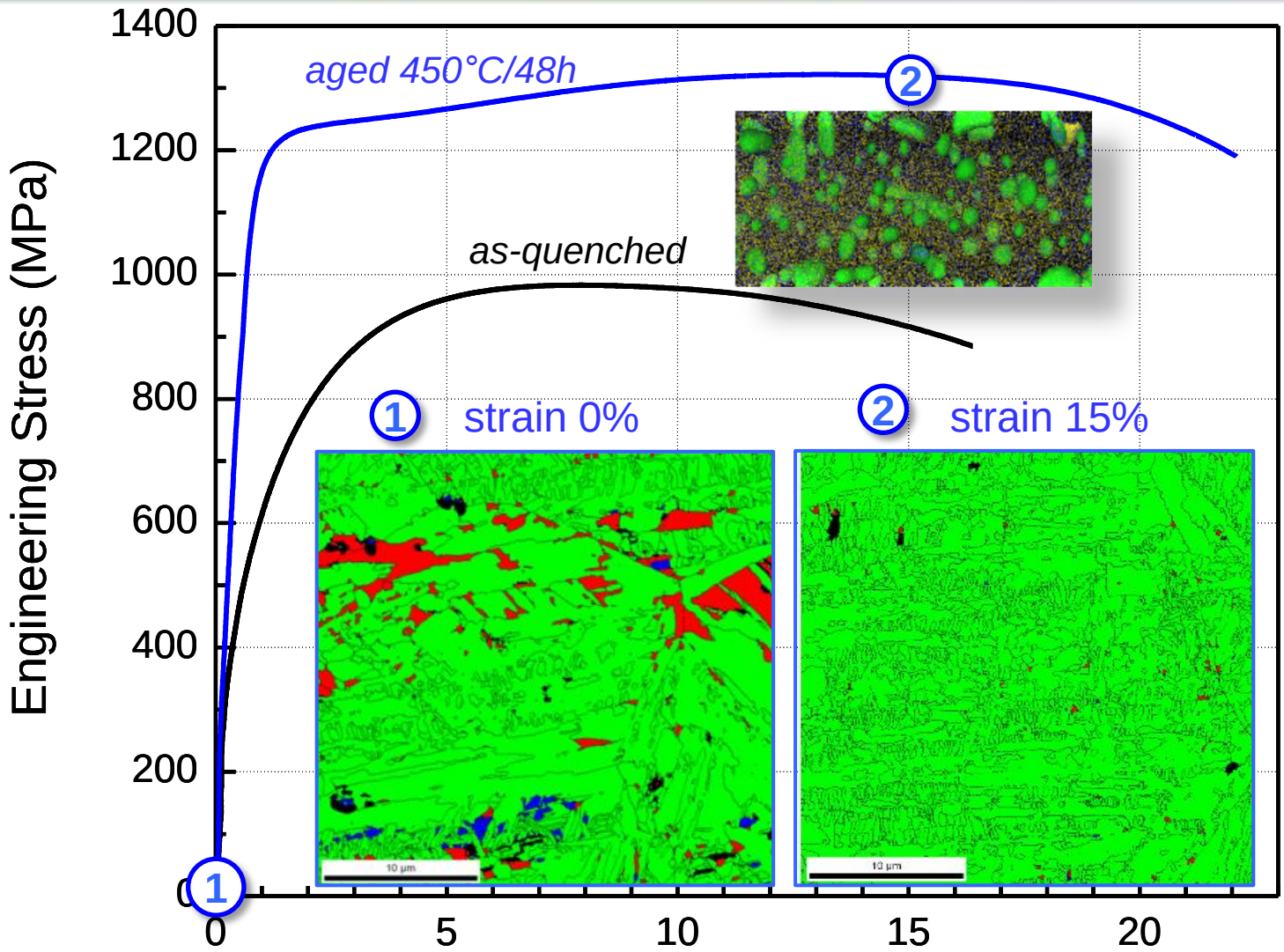
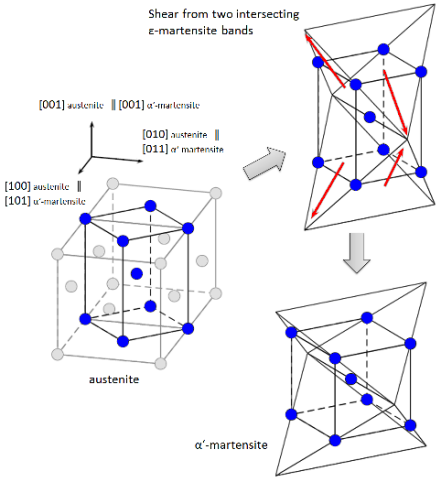
Effect of aging on ductility



Precipitation hardening

increase of austenite fraction during aging



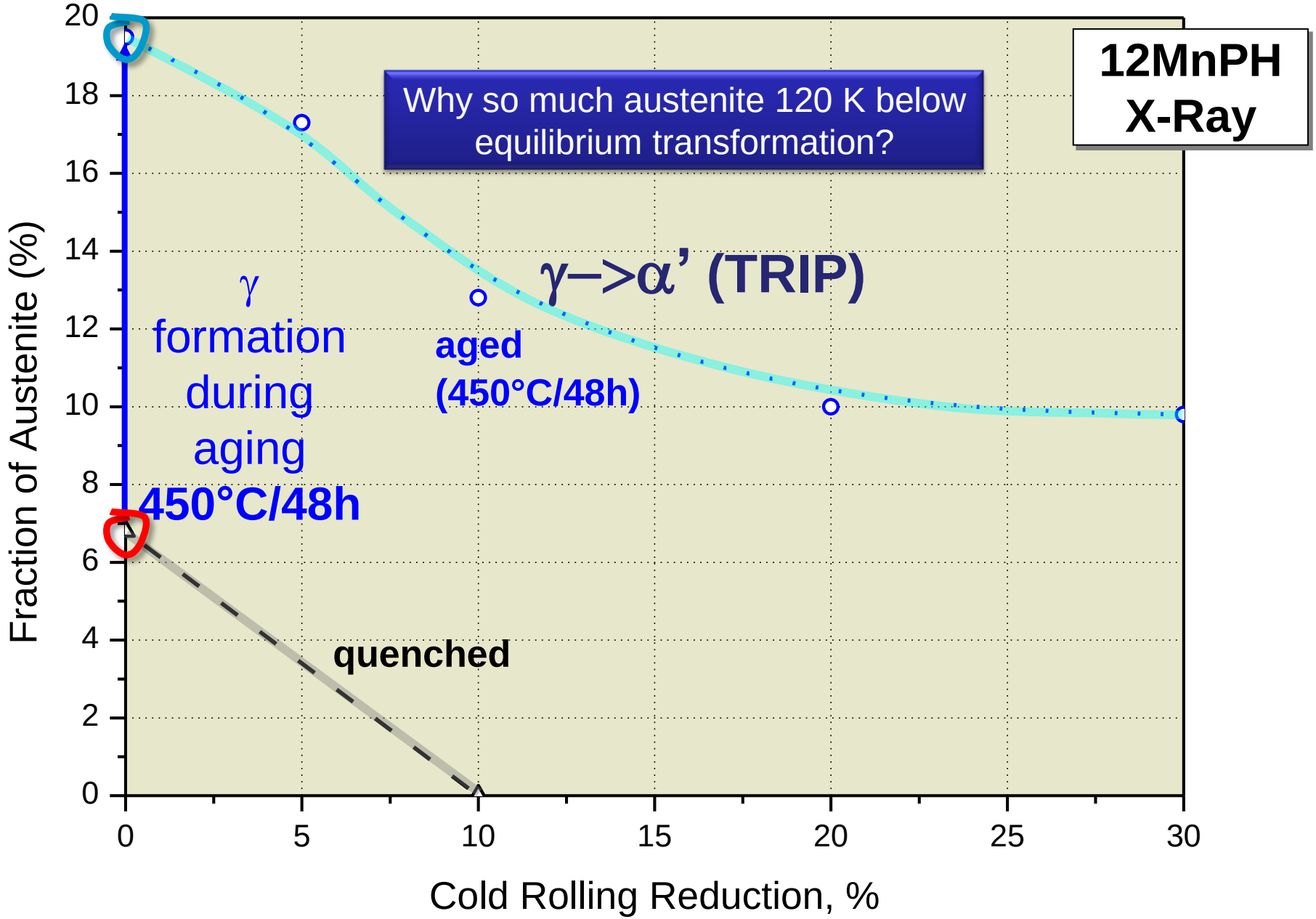
α-Fe (Martensite)

γ-Fe (Austenite), vol. fraction 15-20%

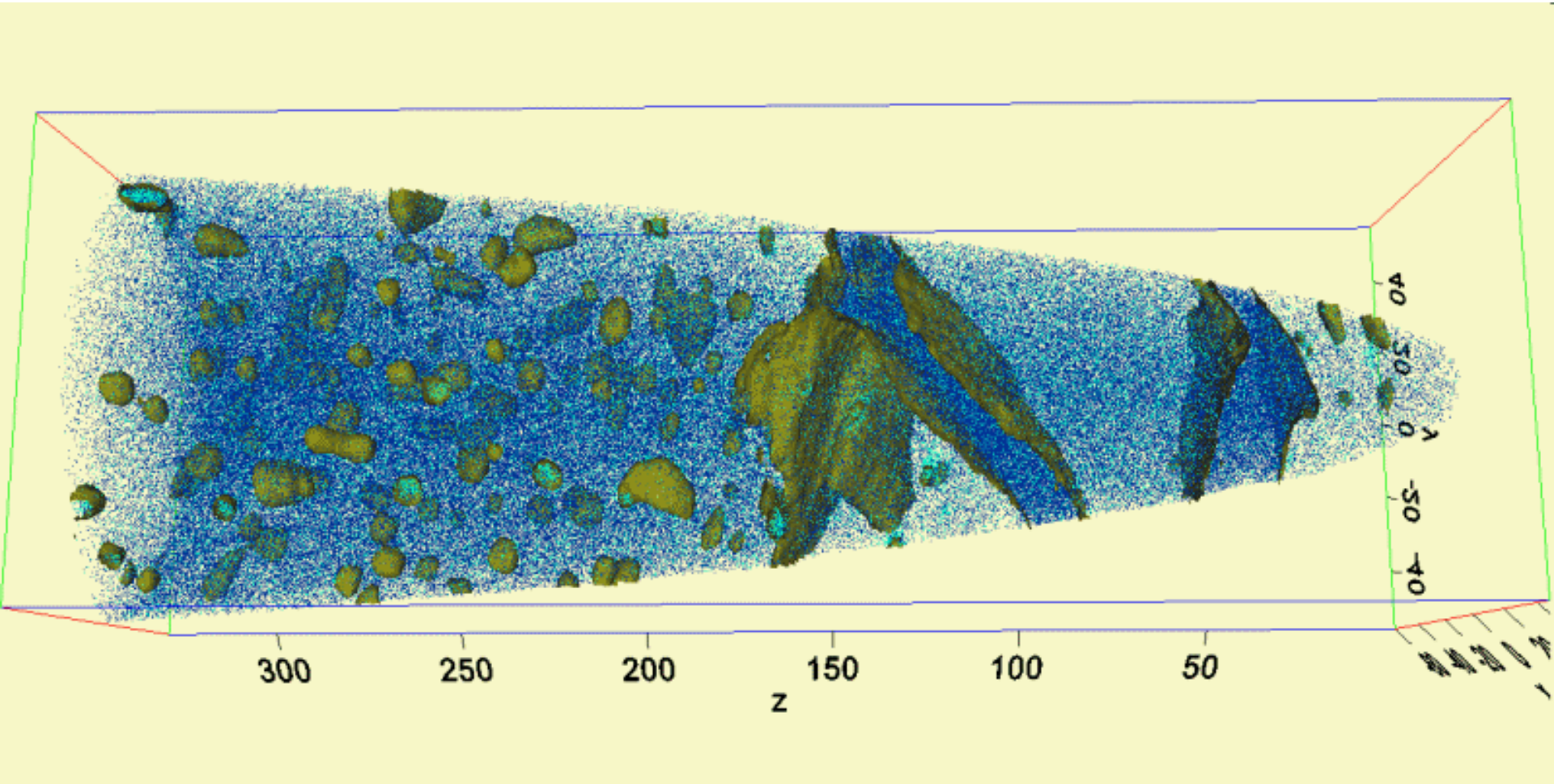
C	Ni	Mo	Ti	Al	Mn	Fe
0.01	2.0	1.0	1.0	0.15	12	bal.

D. Raabe et al. Scripta Materialia 60 (2009) 1141

Effect of cold rolling after aging



APT results: Atomic map (12%Mn, aged 450°C/48h)



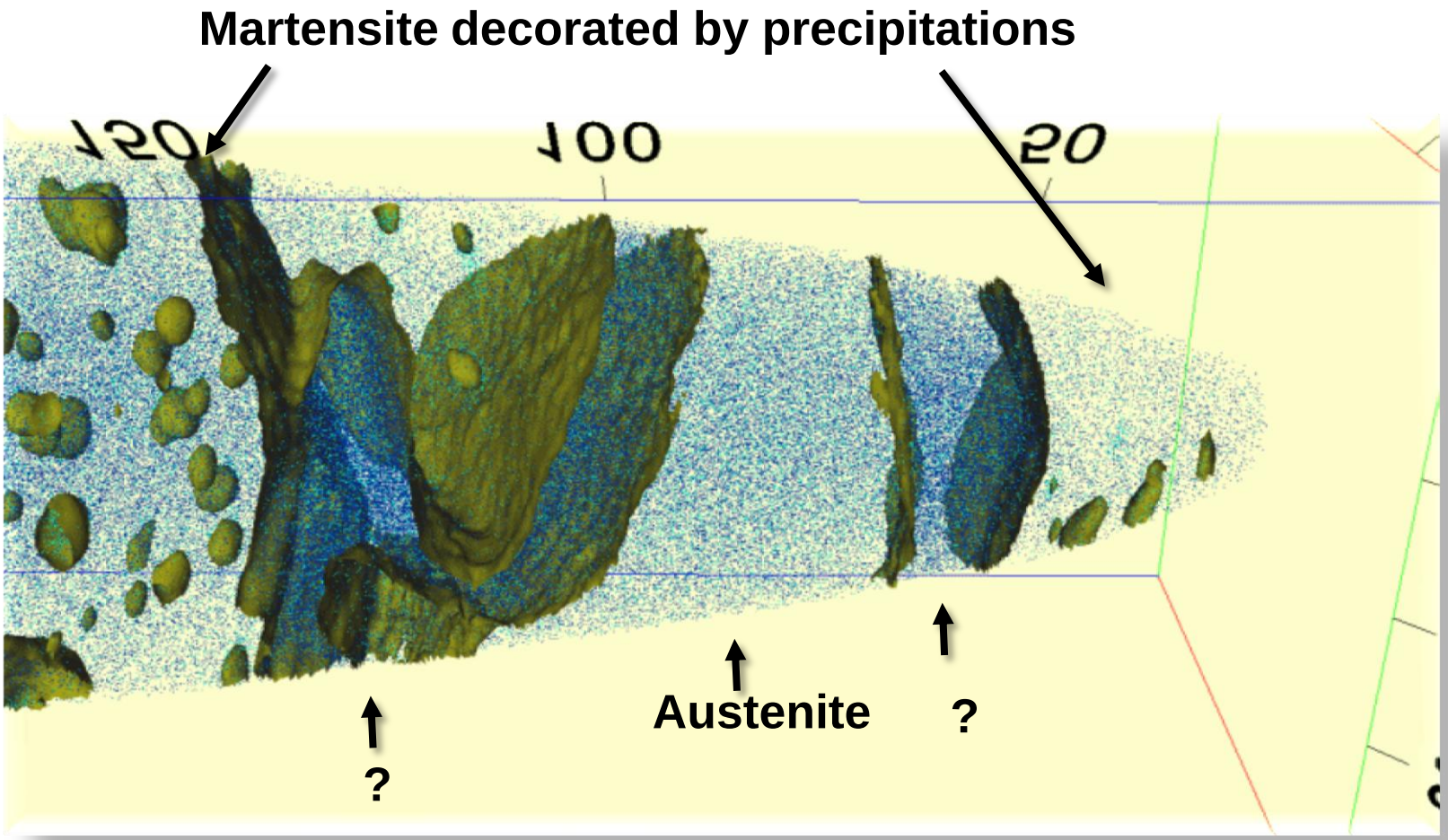
Mn atoms
Ni atoms
Mn iso-concentration: 18 at.%

C	Ni	Mo	Ti	Al	Mn	Fe
0.01	2.0	1.0	1.0	0.15	12	bal.

70 million ions
Laser mode
(0.4nJ, 54K)

Dmitrieva et al. Acta Mater 59 (2011)

APT results: Atomic map (12MnPH aged 450°C/48h)



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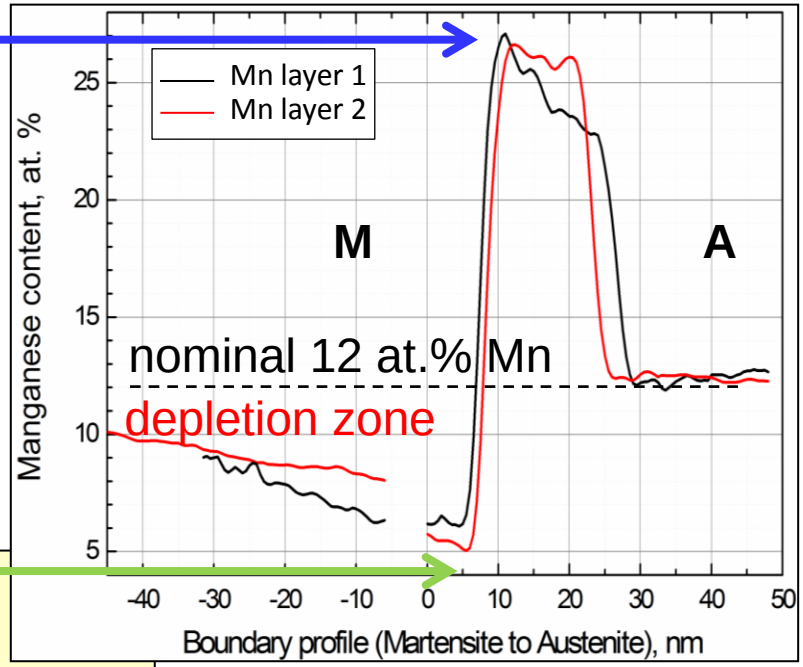
Aging-induced austenite reversion

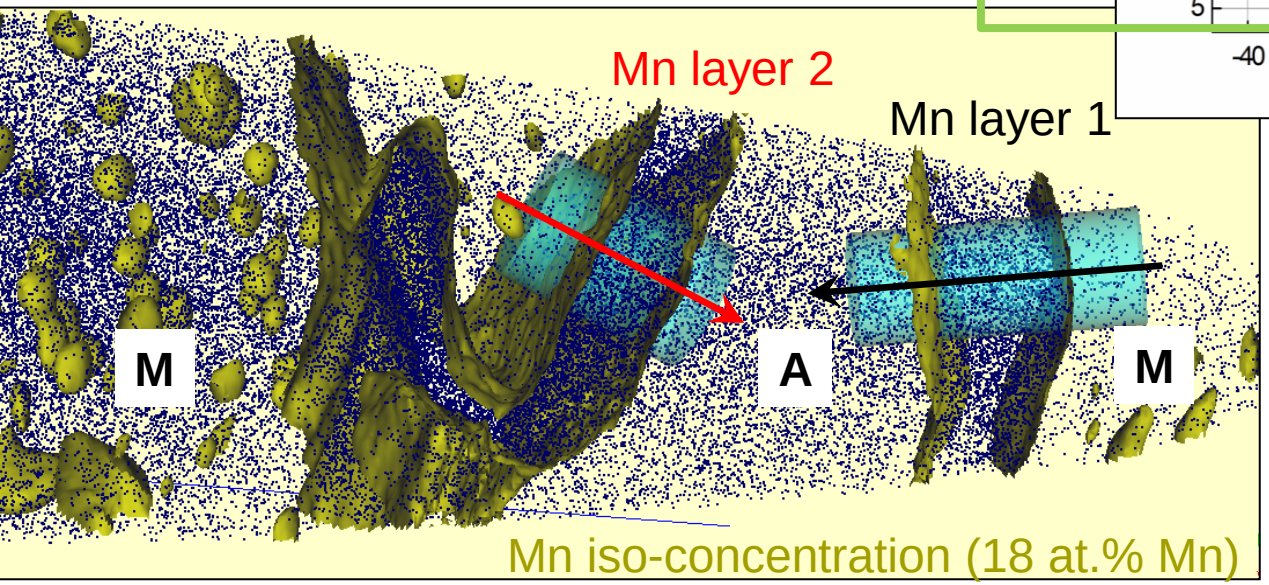
Thermo-Calc ⇒

equilibrium Mn-conc.:

27 at. % Mn in austenite (A)

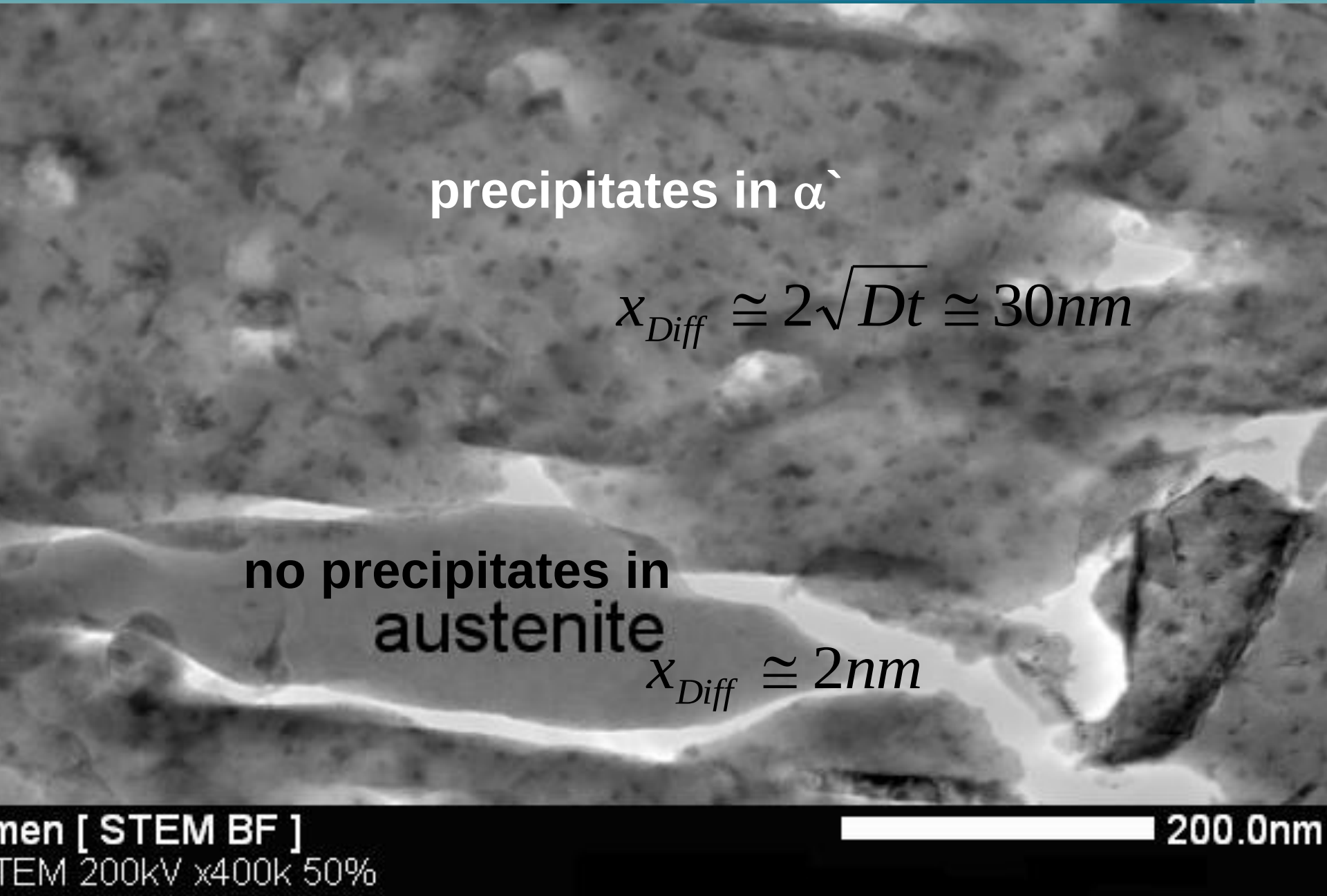
3 at. % Mn in ferrite (martensite) (M)





Dmitrieva et al. Acta Mater 59 (2011)

12MnPH after aging (48h 450°C)



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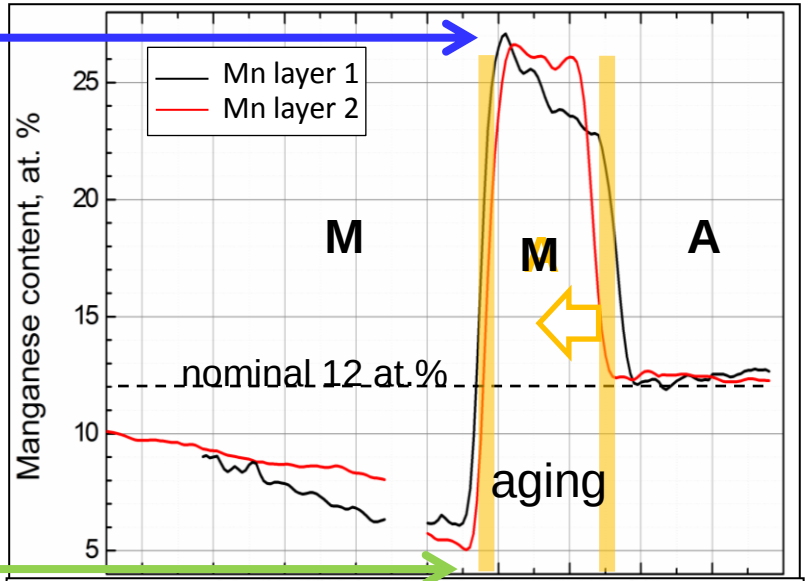
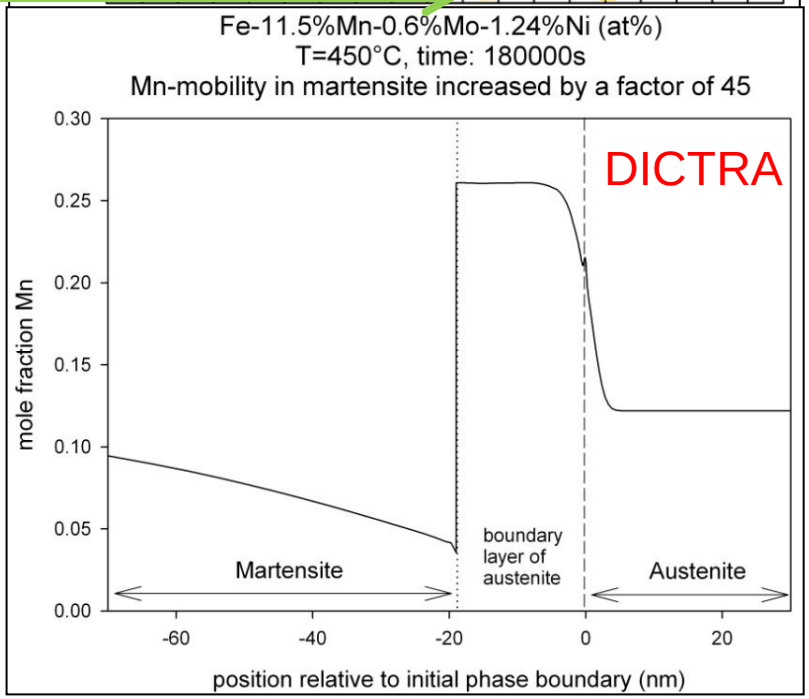
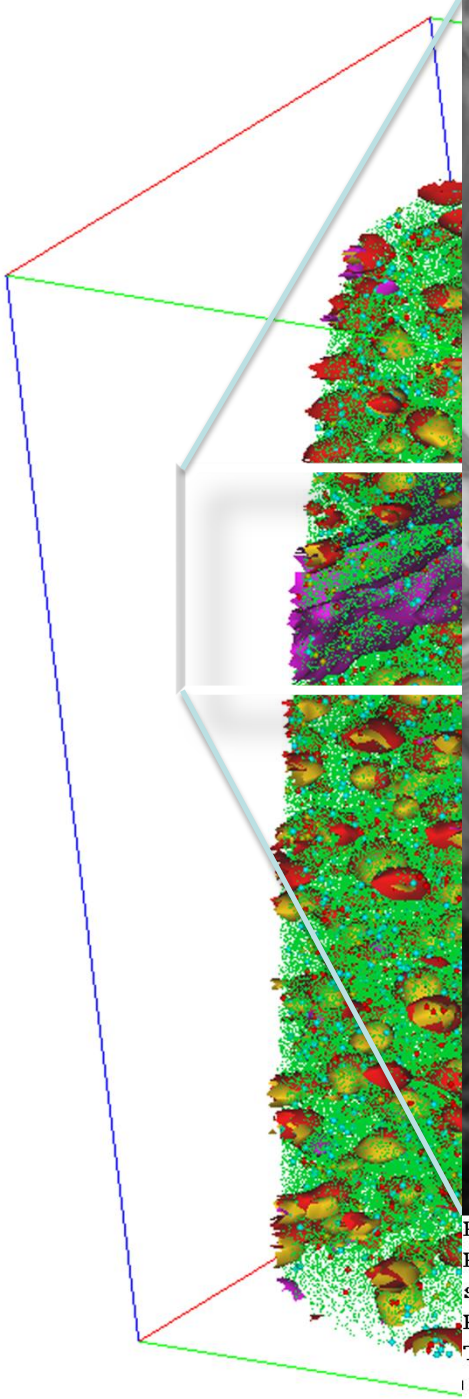
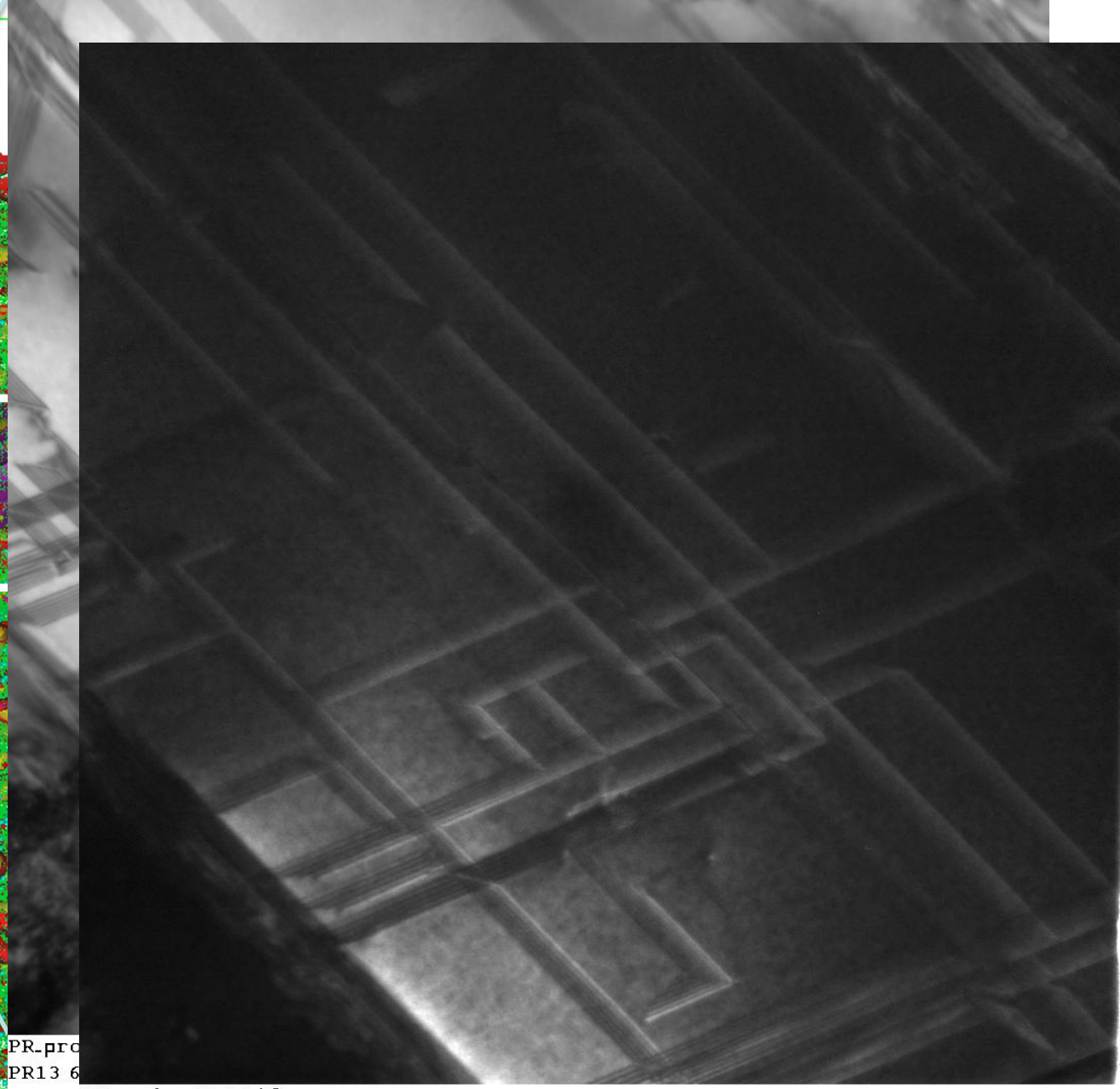




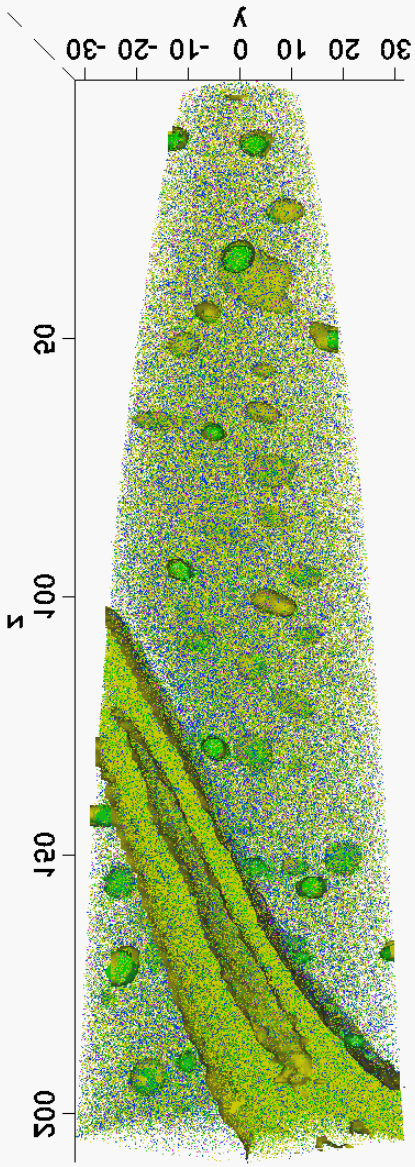
Excellent agreement between experiment & simulation !

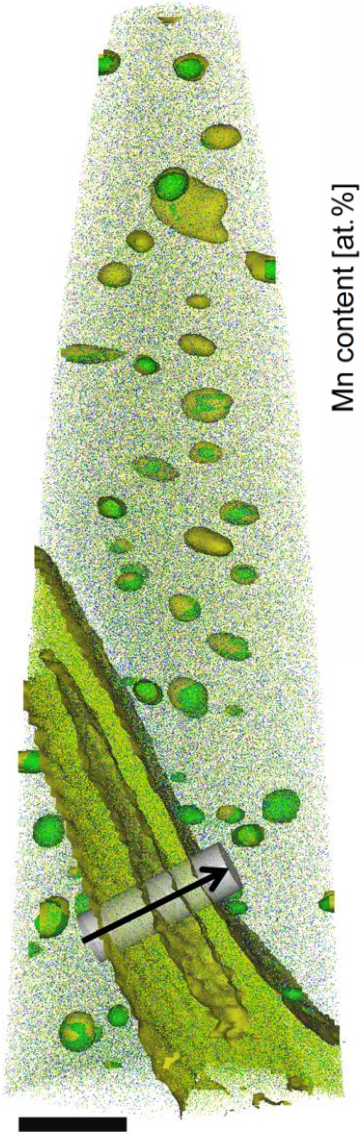
Raabe, Ponge, Dmitrieva, Sander: Adv. Eng. Mat. 11 (2009) 547



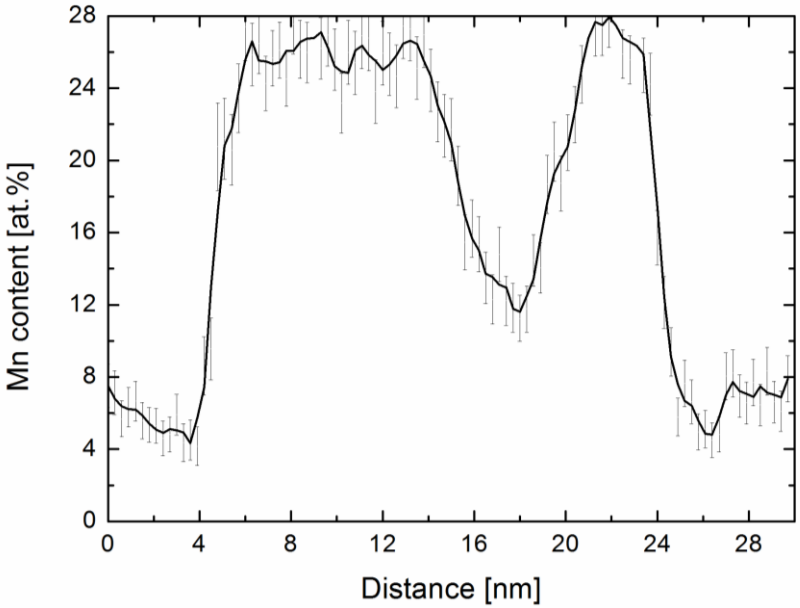

PR-pro
PR13 6
stack
Print
TEM Mo
PR-proben004.tif
PR13 65h@450 C
stacking faults DF
Print Mag: 49500x @ 100 mm
TEM Mode: Imaging
100 nm
HV=200,0kV
Direct Mag: 44000x
X:-107.882 Y: 194.593

Growth of retained austenite 450°C/48h. 12MnPH





Mn profile

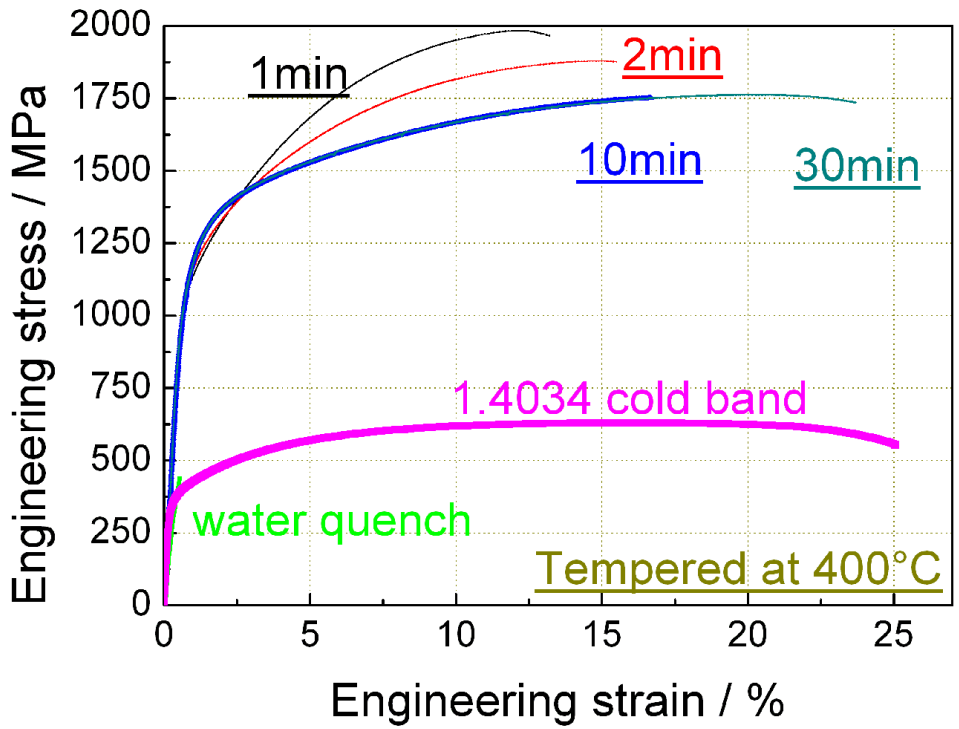


- Mn atoms
- Ni atoms
- Al atoms
- Ti atoms
- Mo atoms
- Fe atoms
- 10at.% Ni iso-conc. surface
- 22at.% Mn iso-conc. surface

C	Ni	Mo	Ti	Al	Mn	Fe
0.01	2.0	1.0	1.0	0.15	12	bal.

Martensite relaxation & aging & nanoscale austenite reversion

650 MPa to 2 GPa

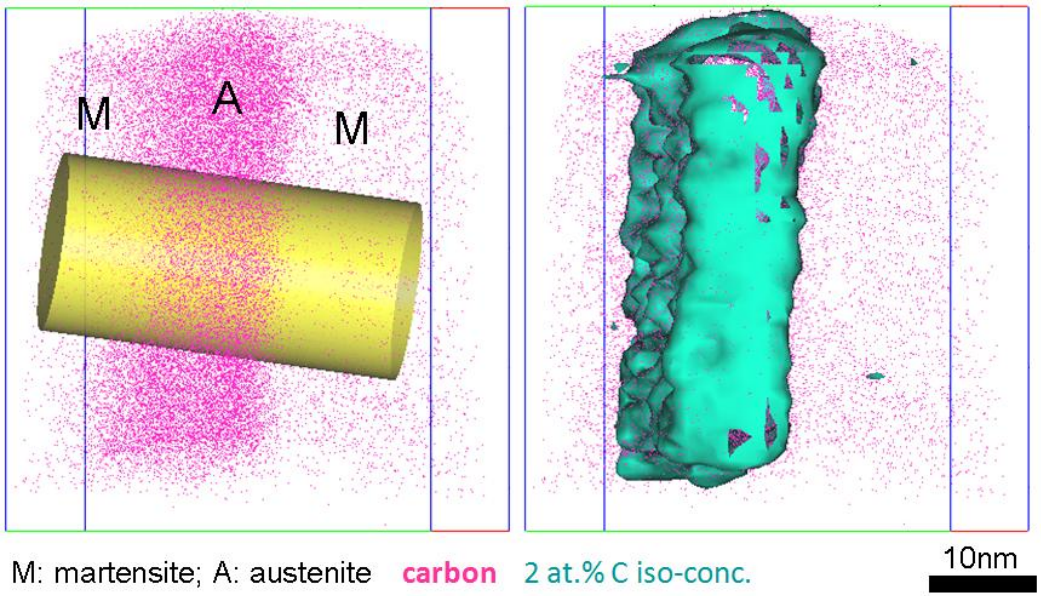


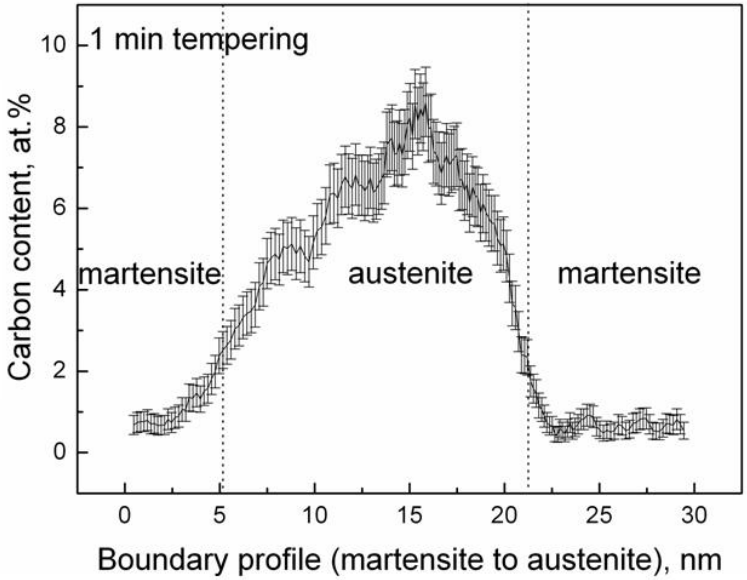
400°C aging: Ms-relaxation + prec. (aging) + austenite reversion

Fe-13.6Cr-0.44C (wt.%)

Martensite relaxation & aging & nanoscale austenite reversion

at 5.45 at.% C, austenite forms at 400°C





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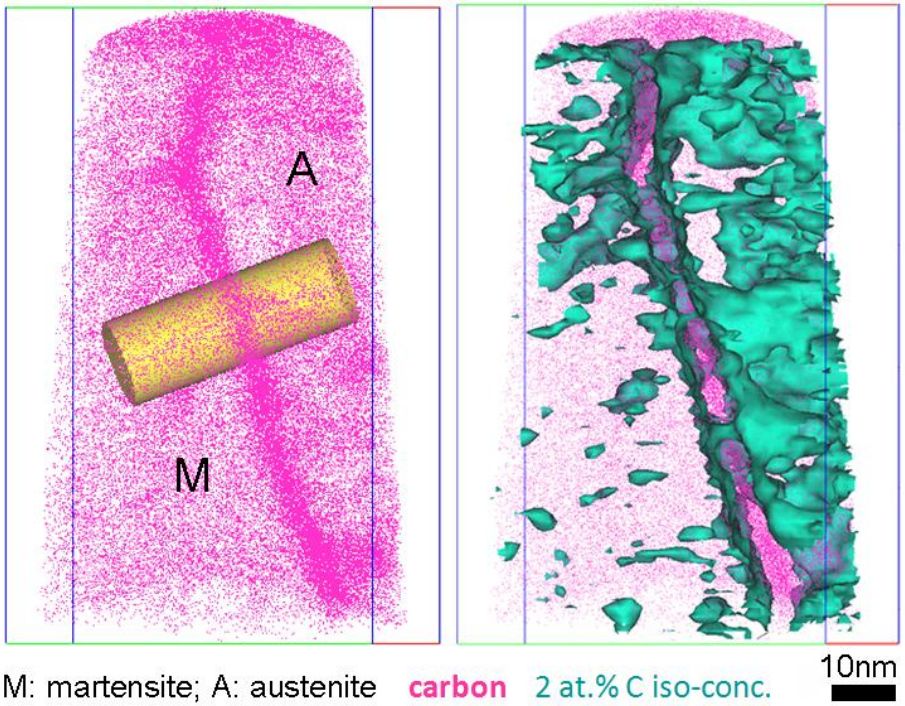
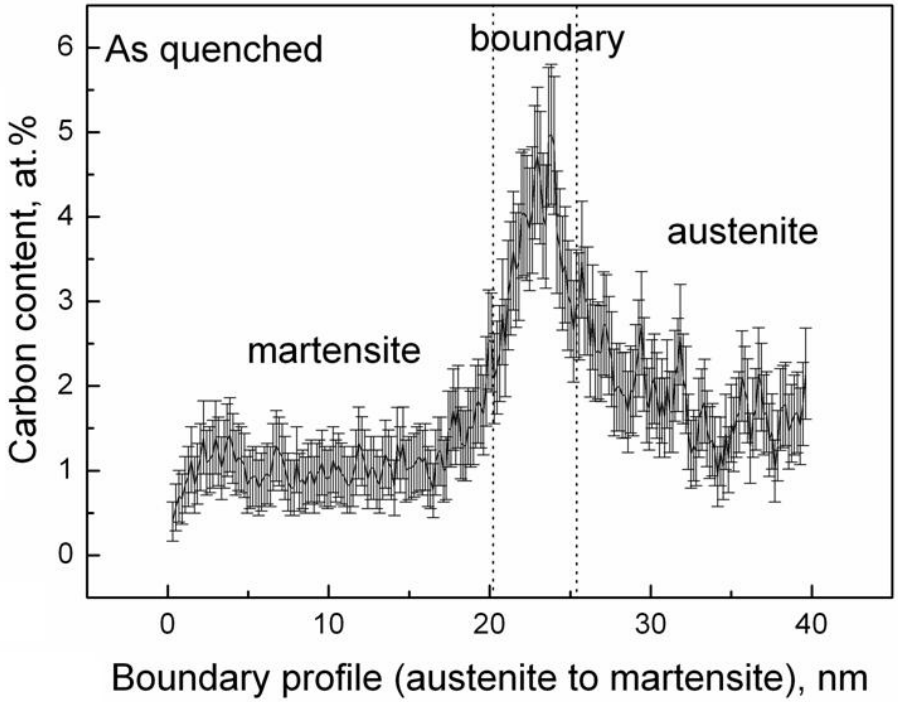
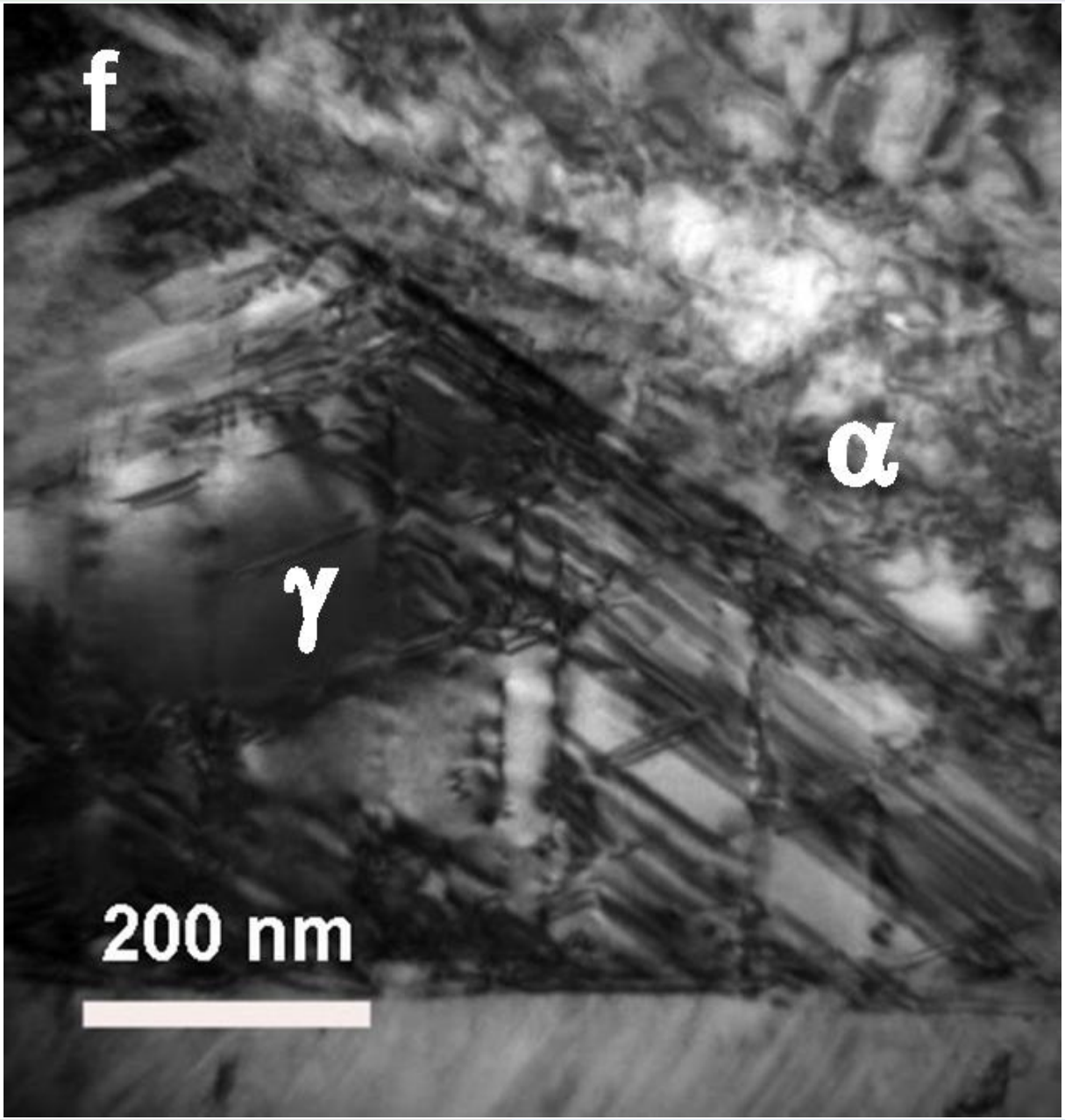




Microstructure development

400° C
1min



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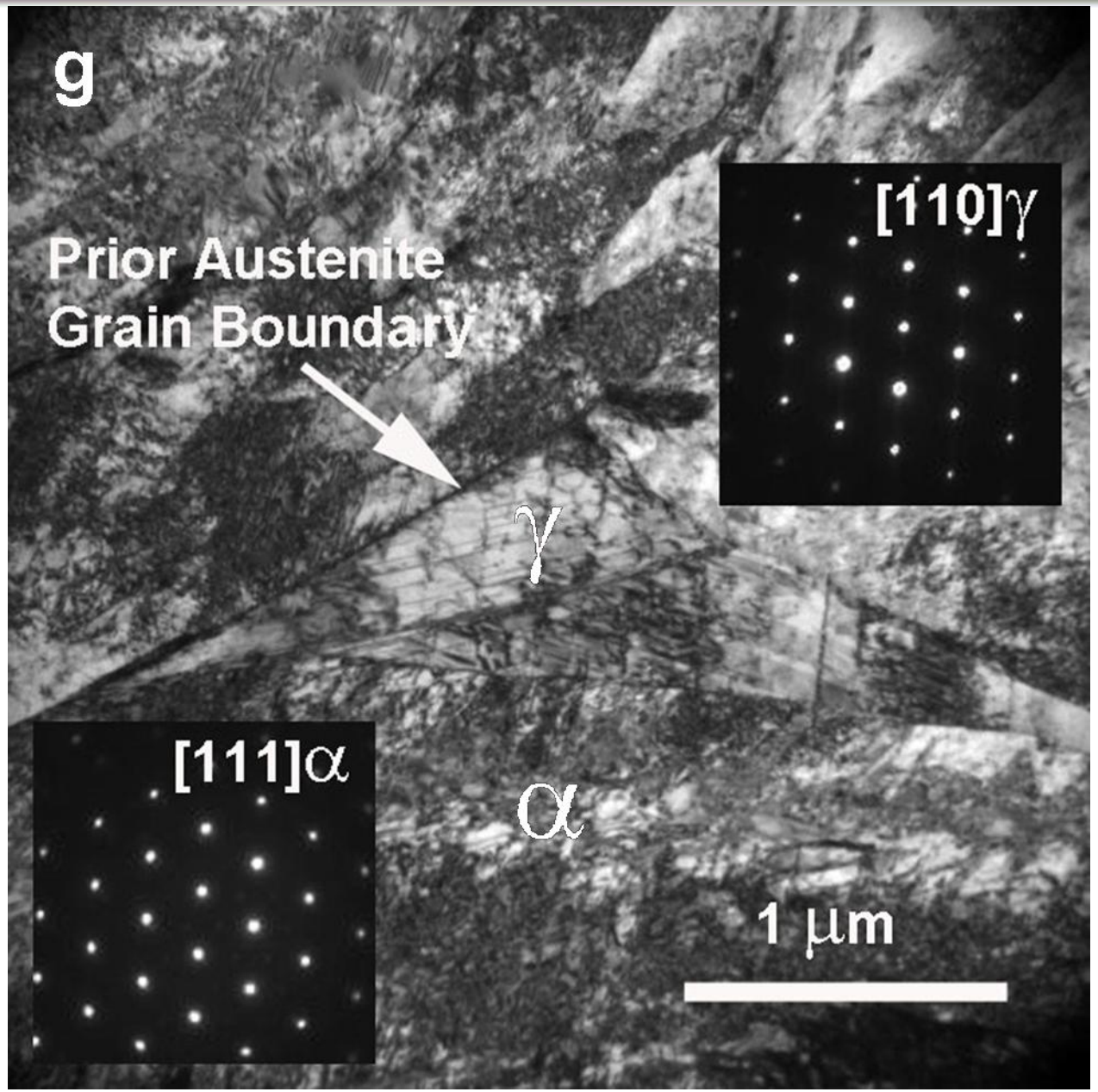
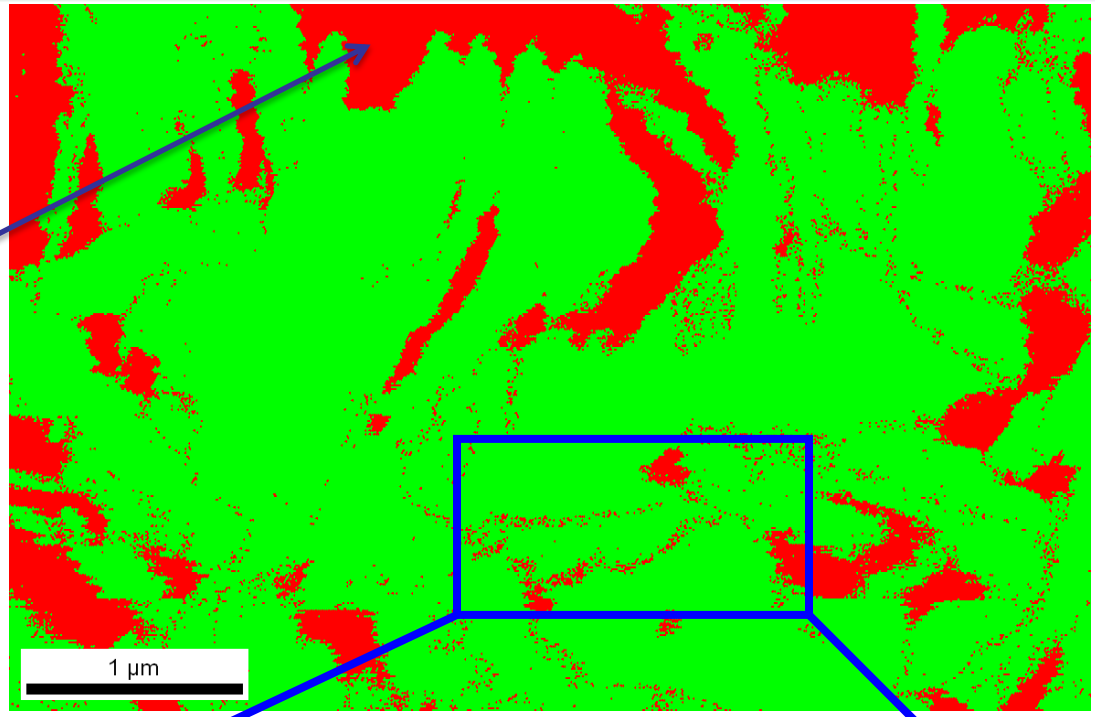


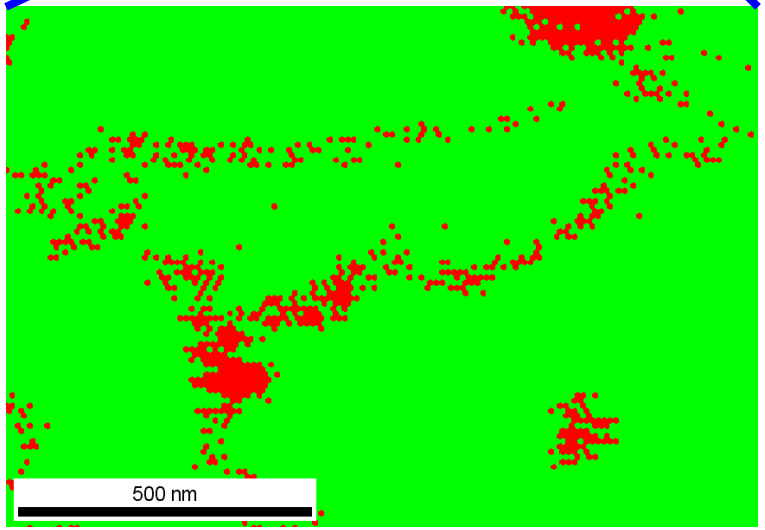
Self-repair steels

Retained austenite



Phase
Iron - Gamma
Iron - Alpha

Reversed austenite



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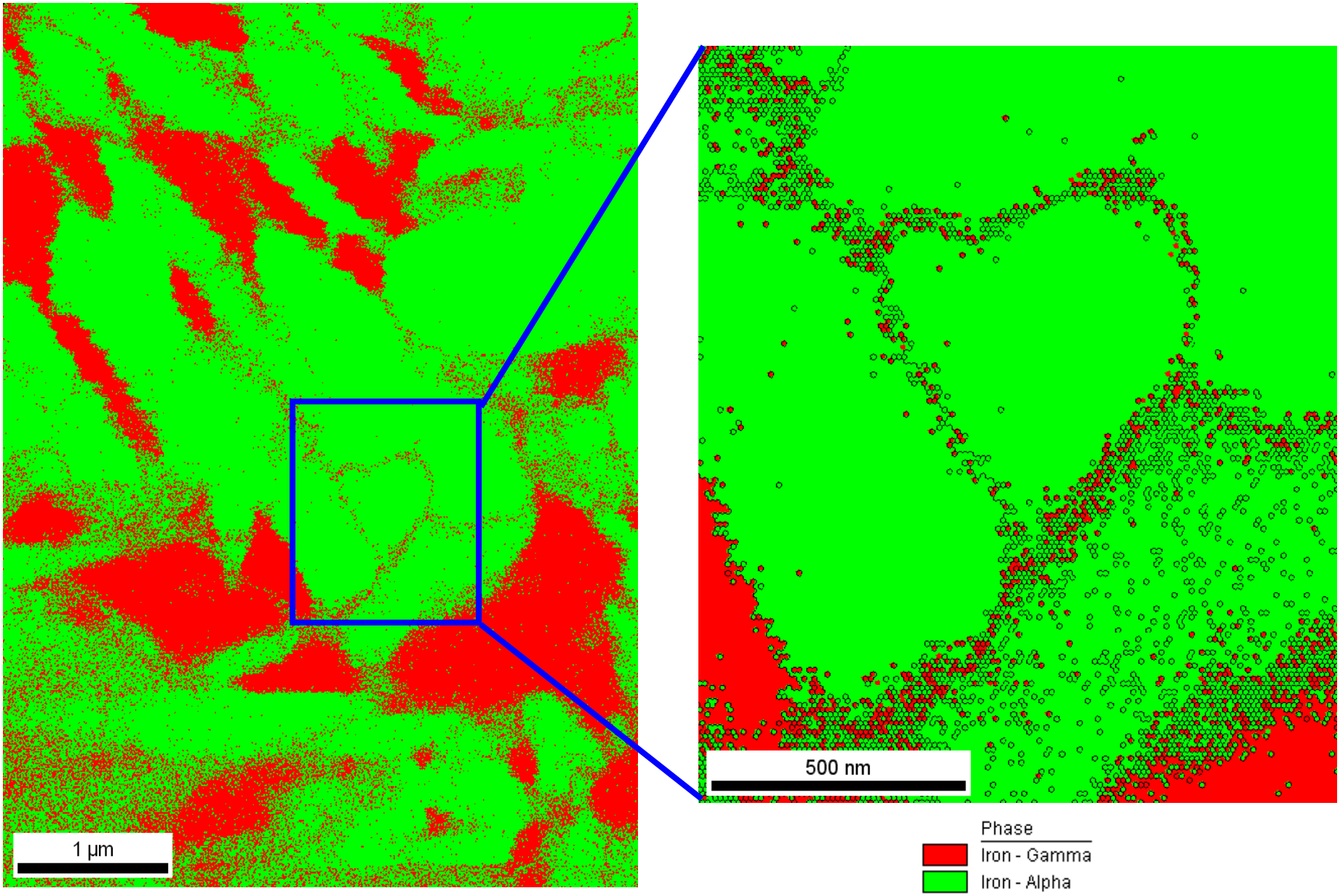

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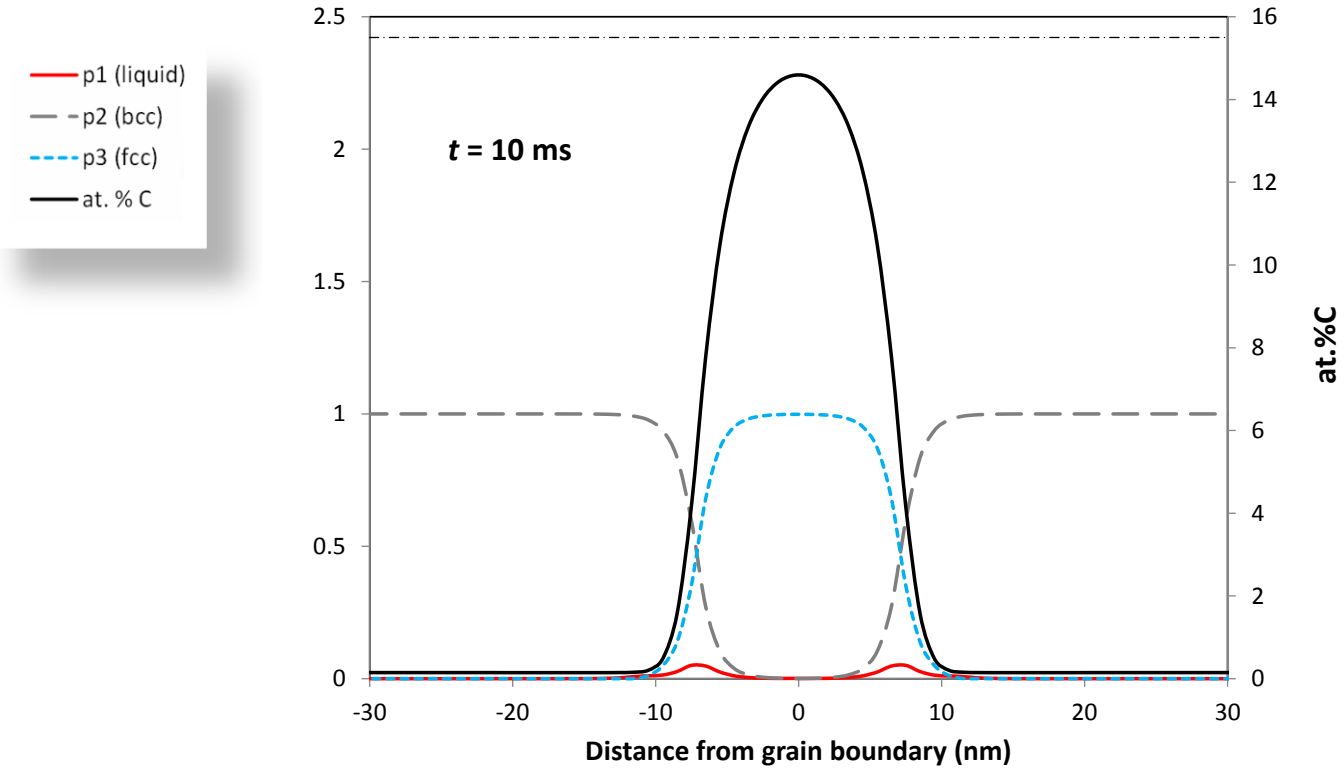
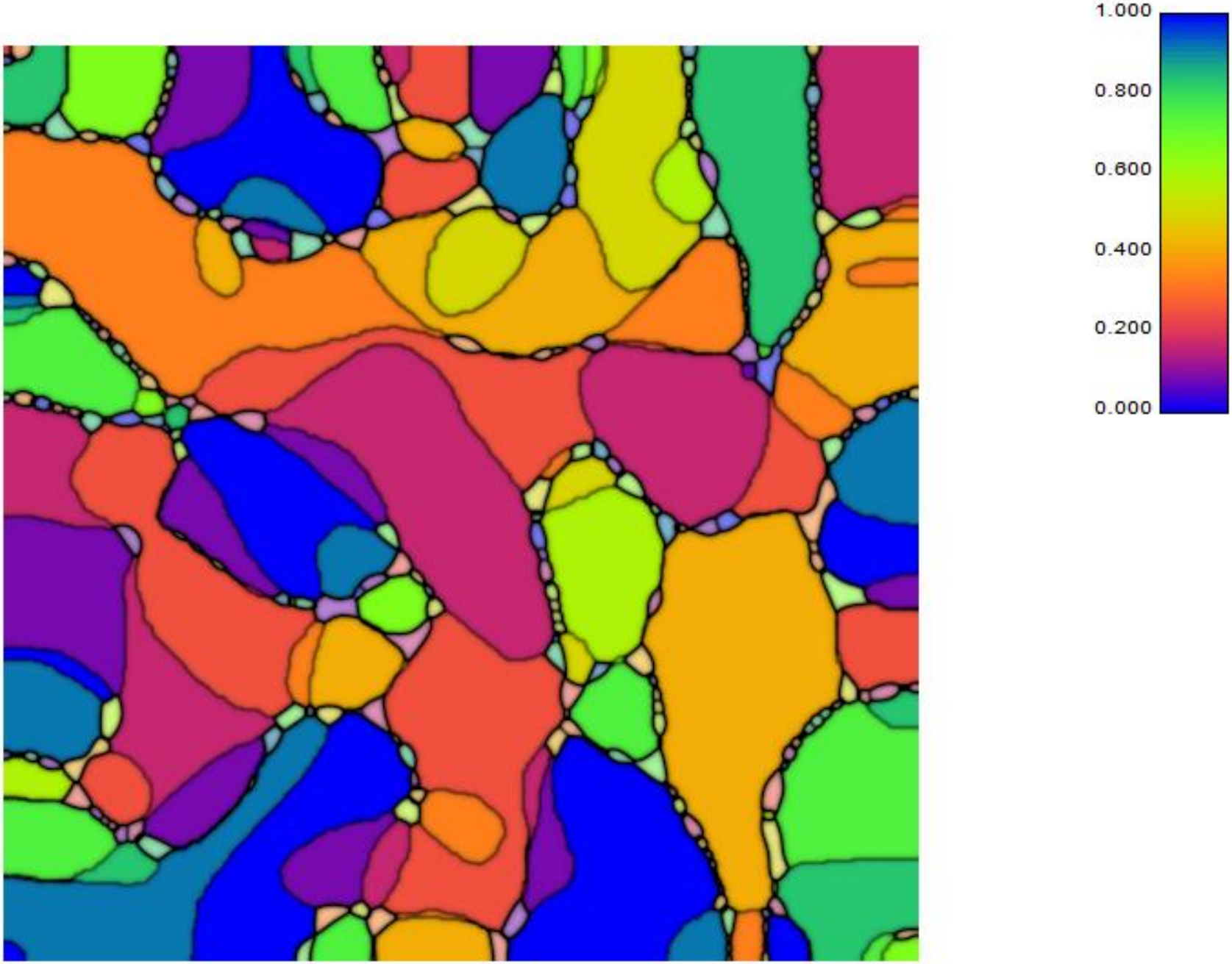
Raabe: Adv. Mater. 14 (2002)

Nanoscale austenite reversion in Fe-C system

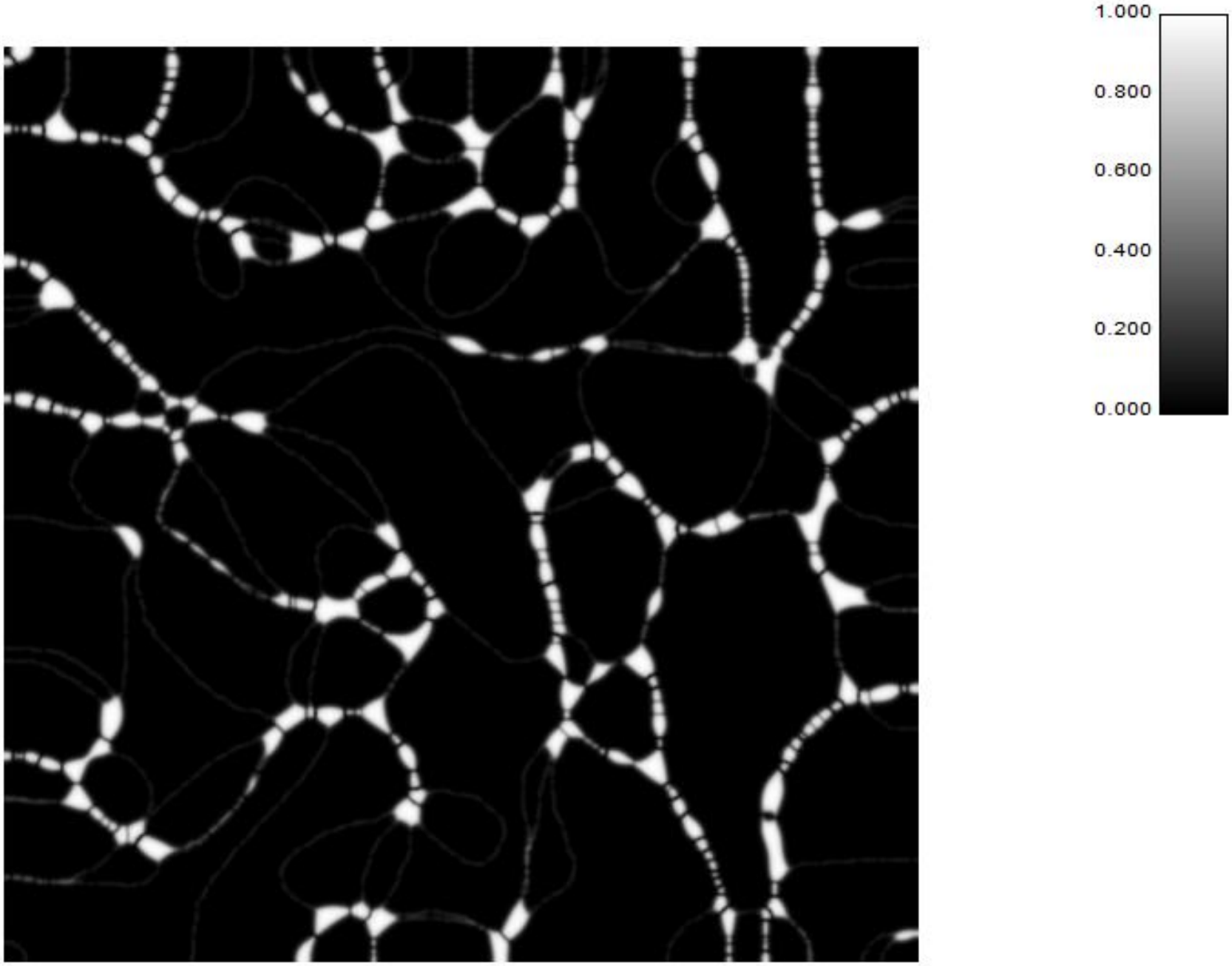


Equilibrium carbon concentration in austenite

Phase / Orientation



LRO / p3



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