New observations on martensitic and bainitic transformation in steels

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- **Abnormal relation between Ms temperature and prior austenite grain size**
- **Martensitic transformation in pillars**
- **Effect of boron on the bainitic transformation kinetics after ausforming**

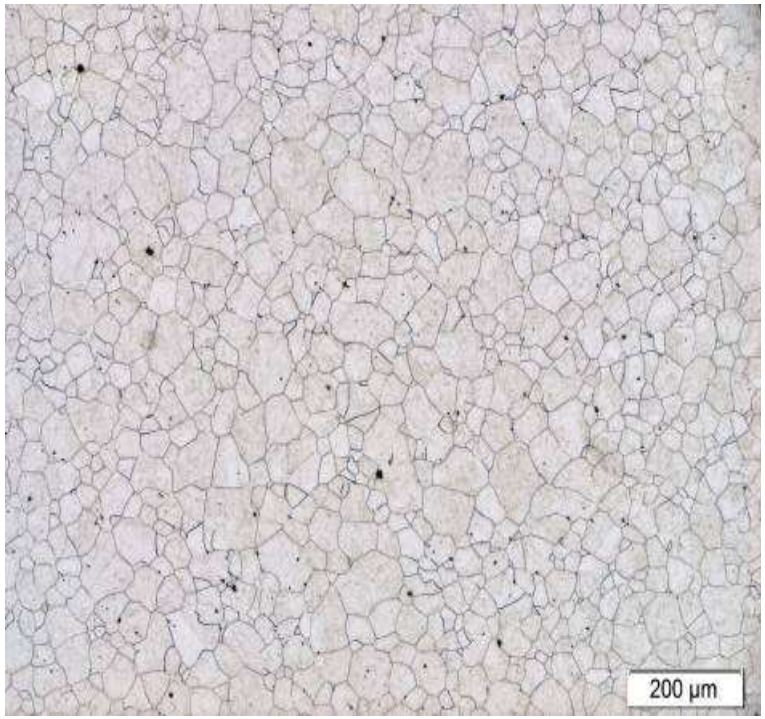
- **Abnormal relation between Ms temperature and prior austenite grain size**
- **Martensitic transformation in pillars**
- **Effect of boron on the bainitic transformation kinetics after ausforming**

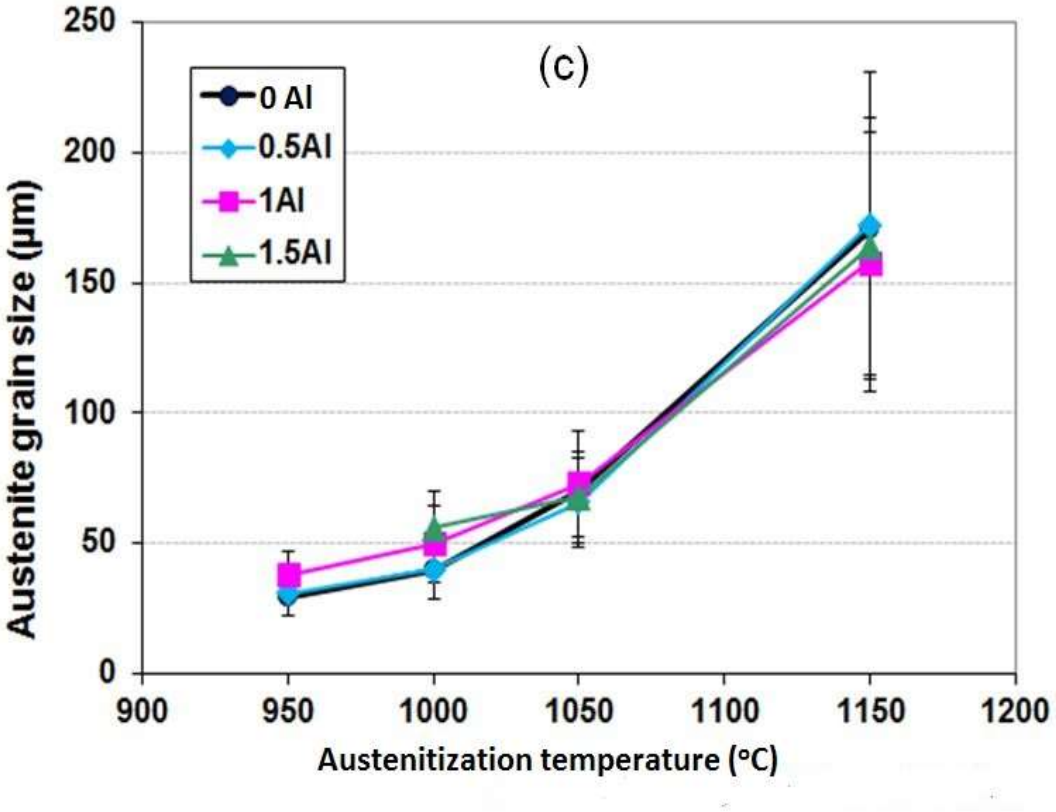
Steels

Steel	C	Mn	Si	Al
0Al	0.25	2.07	0.098	0.021
0.5Al	0.247	2.07	0.083	0.53
1Al	0.256	2.07	0.085	1.01
1.5Al	0.249	2.07	0.084	1.54

Driving force of the present study: High Al content is now being added in AHSS. We need to understand the effect of Al on Ms temperature.

Prior austenite grain szie





Higher austenisation tempeature leads to large austenite grain size.

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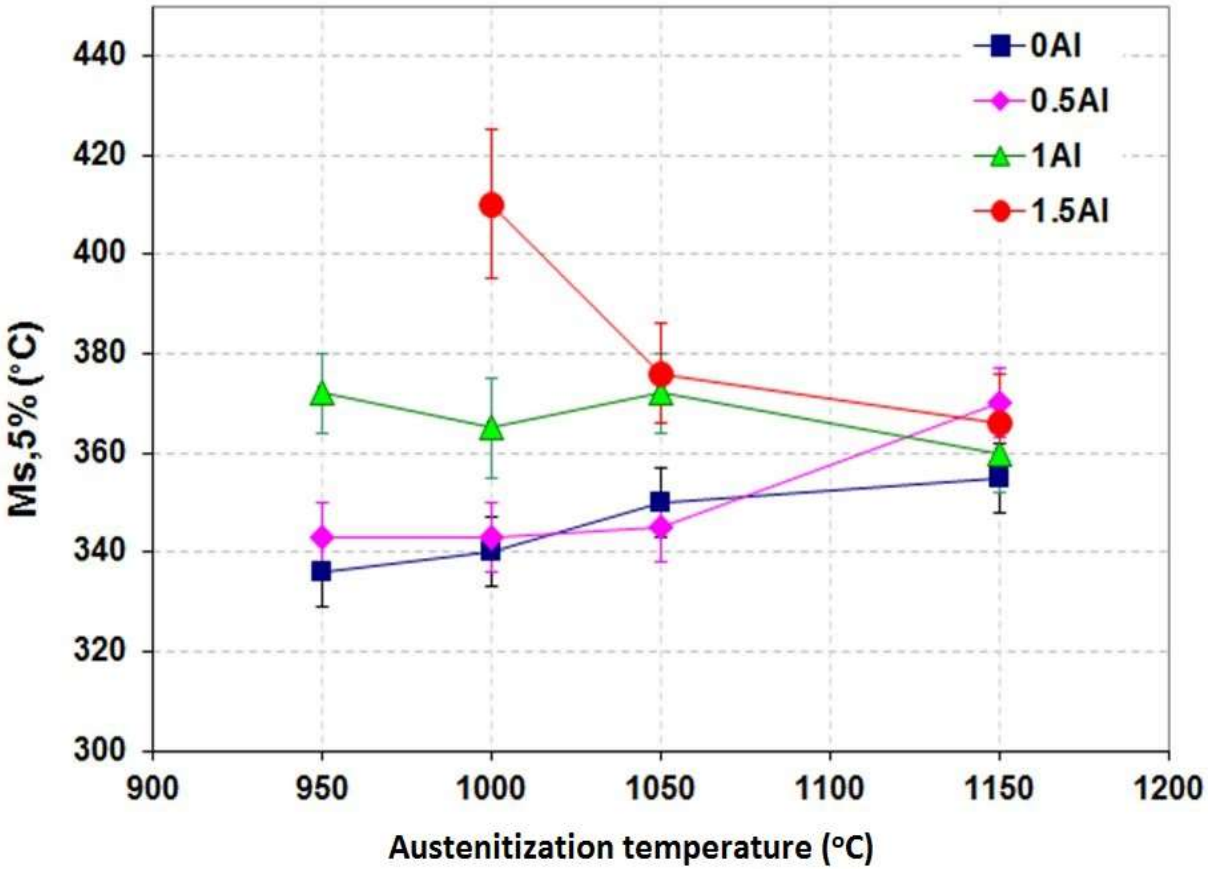
Ms temperature



0Al. 0.5 Al: normal, higher temperature (large austeintie grain size)-> higher Ms

1Al, 1.5Al, **abnormal,** higher temperature (large austeintie grain size)-> lower Ms

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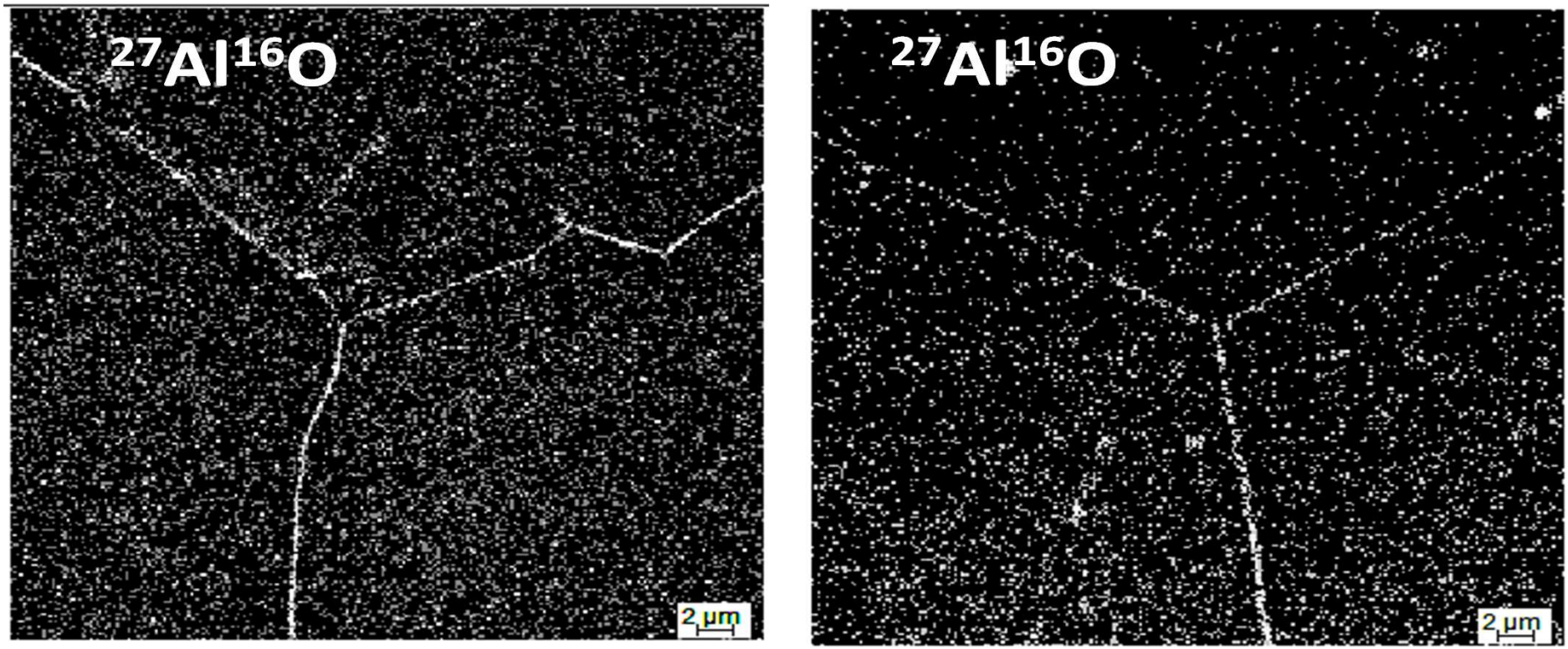
Al segregation at prior austenite grain bournady



1000°C

1150°C

NanoSIMS 1.5Al

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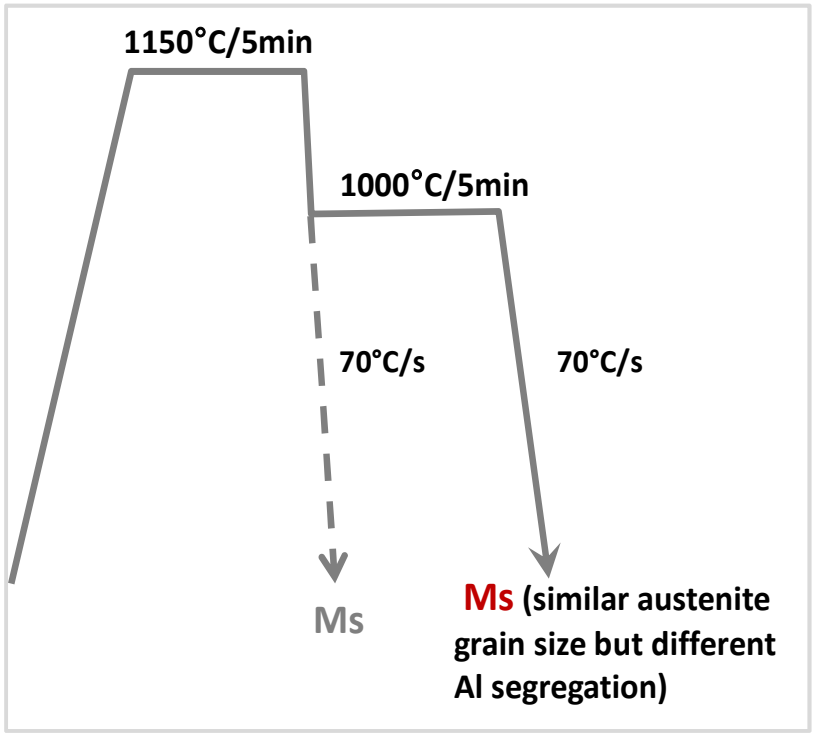
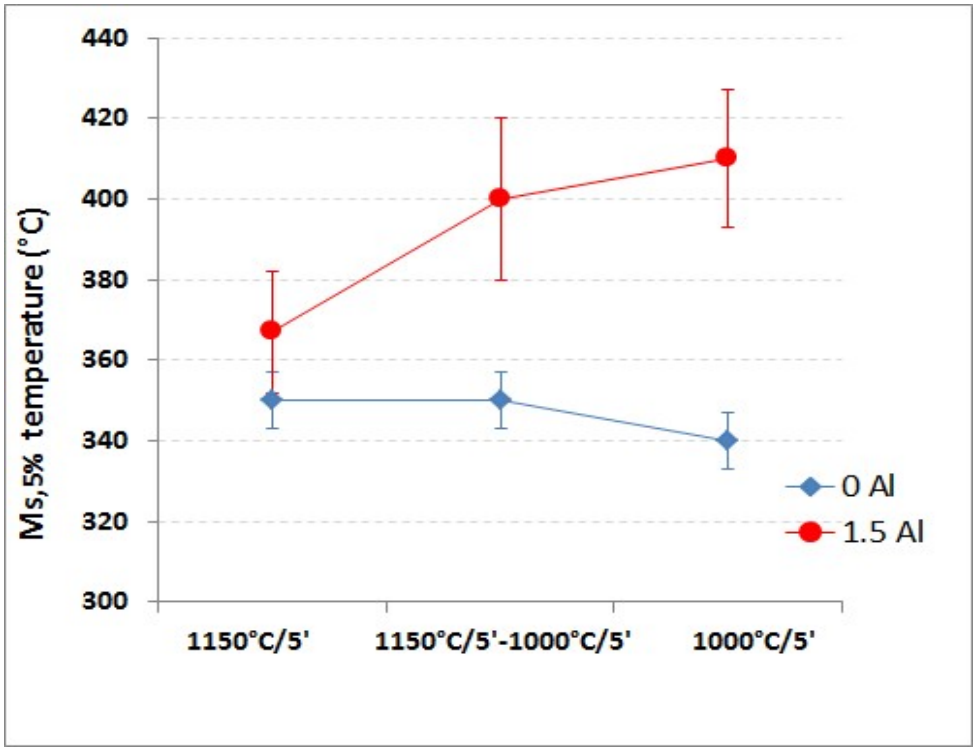
Similar Grain size, but different Al content





Al segregation at grain boundary is more important.

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Summary of topic 1

- Ms temperature increases with the decrease of PAGS in steels with Al content higher than 1wt.%.
- This relationship is in contrast to what has been reported earlier in the literature.
- It is revealed that the Al segregation at prior austenite grain boundaries may be the origin of this abnormal phenomenon.
- **Both PAGS and segregation of alloying elements** should be taken into account when predicting the Ms temperature.

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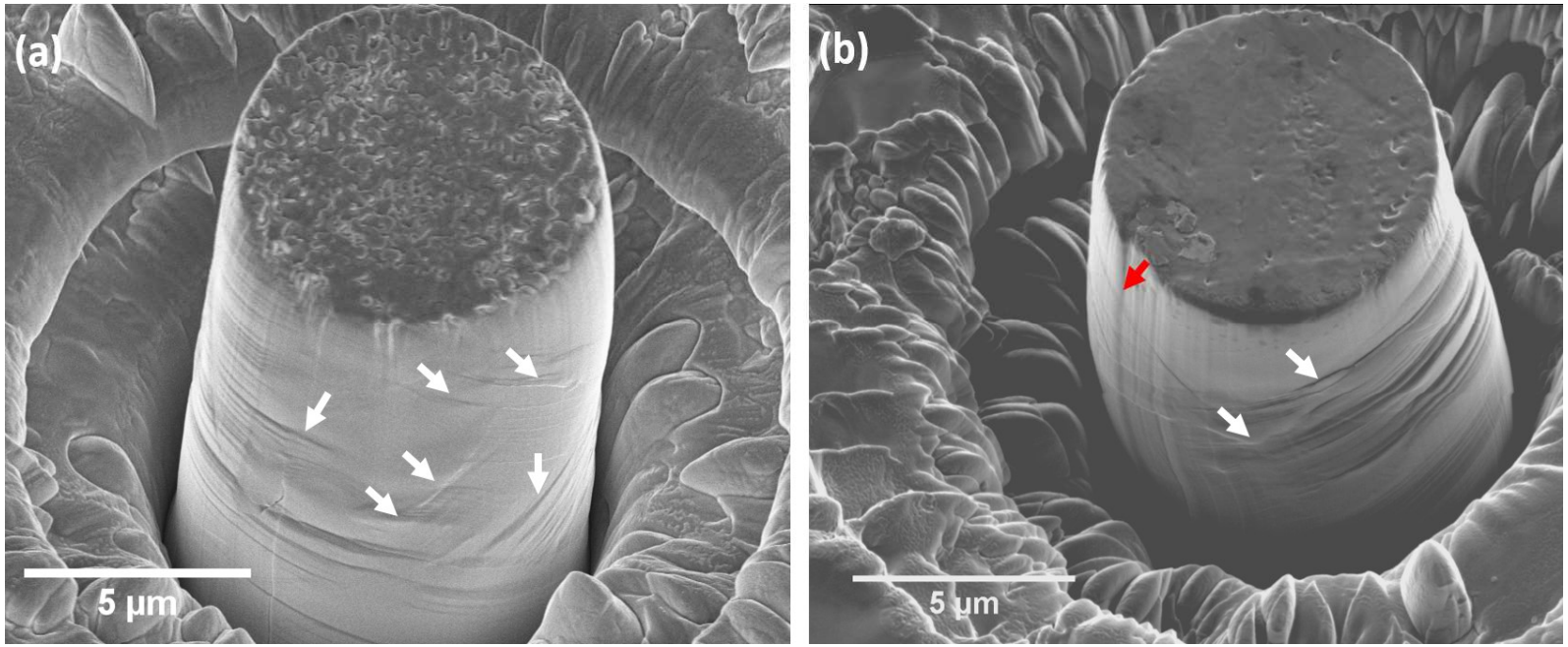
- Abnormal relation between Ms temperature and prior austenite grain size

- **Martensitic transformation in pillars**

- Effect of boron on the bainitic transformation kinetics after ausforming

Effect of orientation of martensitic transfomraiton

Fe-9Mn-0.6C



(a) [1 0 0] pillar ;

(b) [1 1 0] pillar

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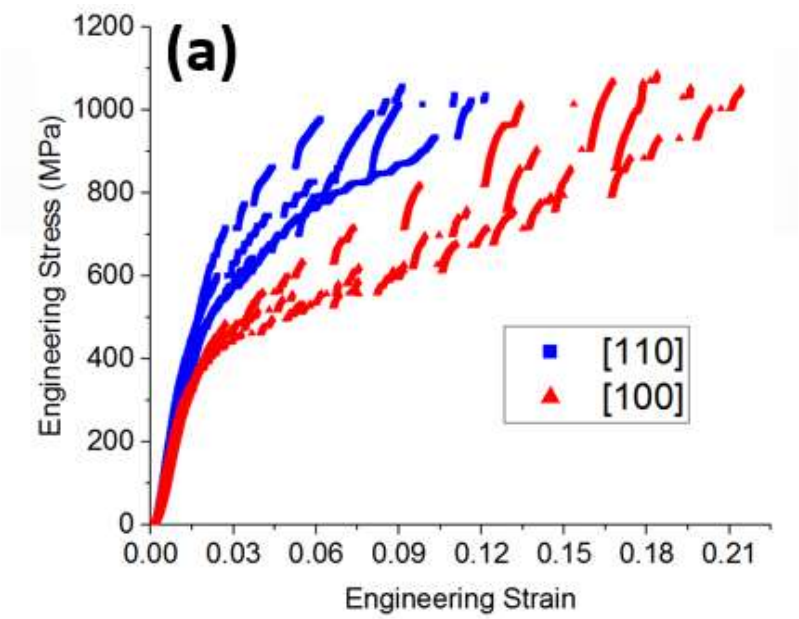
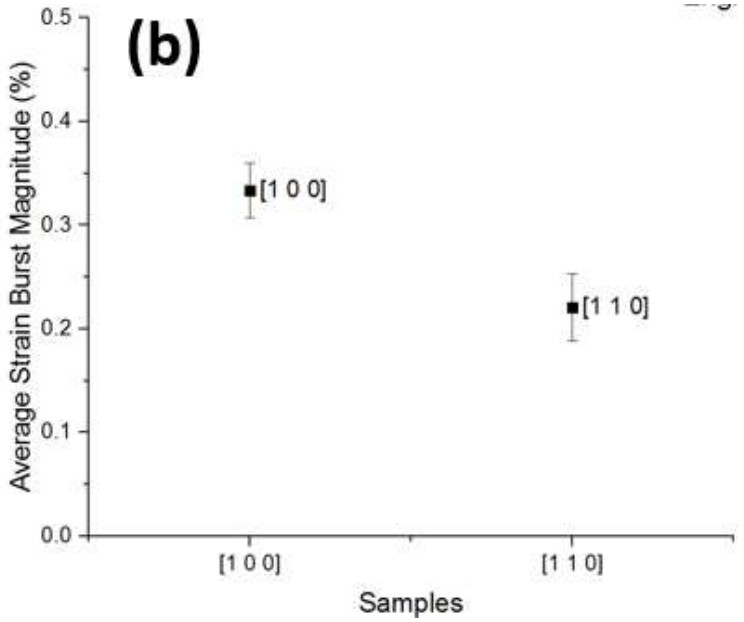
Strain burst





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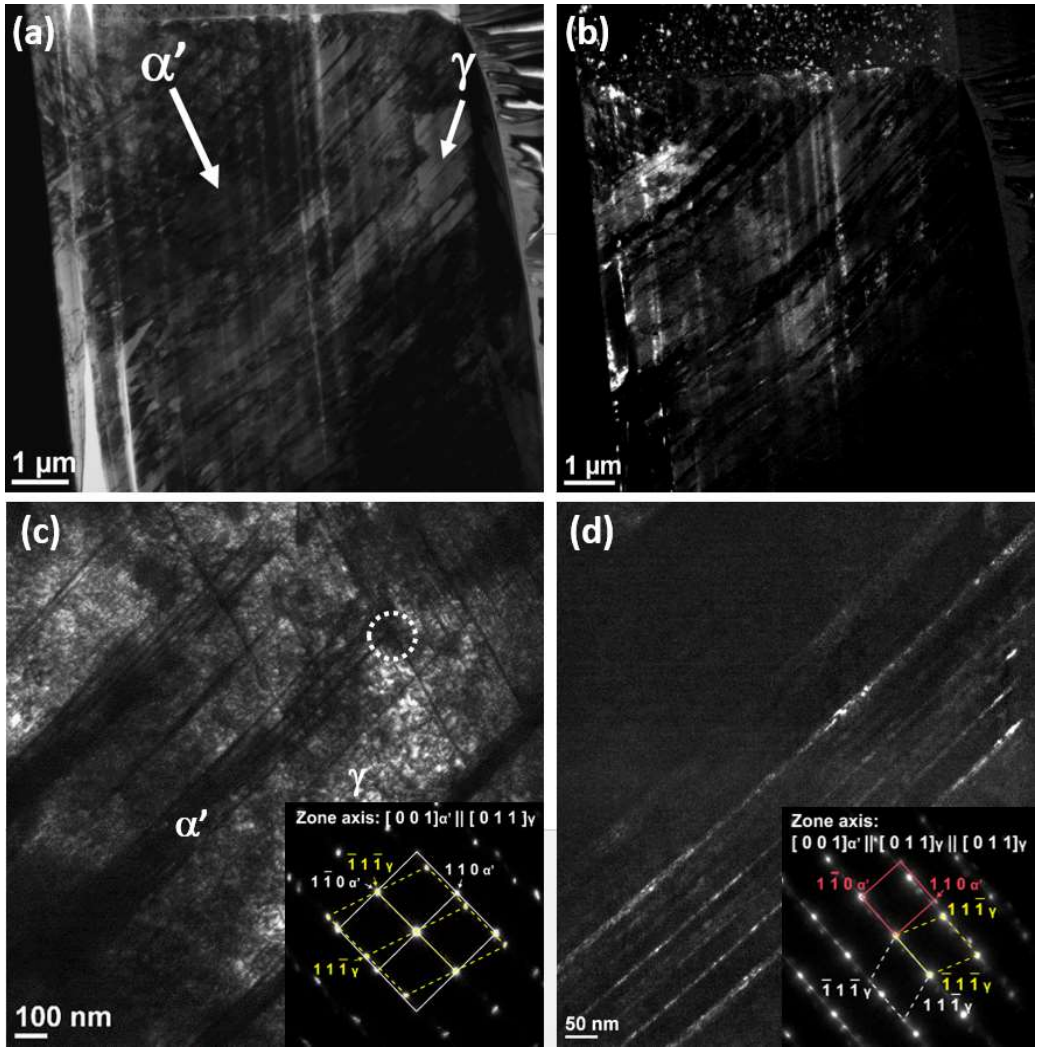
Schmid factors

	Full Dislocation			Partial Dislocation			
				Leading Partial		Trailing Partial	
	Slip Plane	Slip Direction	Schmid Factor	Slip Direction	Schmid Factor	Slip Direction	Schmid Factor
[1 0 0]	(111)	$<\bar{1}01>$	0.44	$<11\bar{2}>$	0.5	$<\bar{2}11>$	0.26
	$(1\bar{1}1)$	<101>	0.44	$<\bar{1}1\bar{2}>$	0.47	<211>	0.30
[1 1 0]	(111)	$<\bar{1}01>$	0.44	$<11\bar{2}>$	0.30	$<\bar{2}11>$	0.45
	$(\bar{1}11)$	<101>	0.46	$<\bar{1}1\bar{2}>$	0.31	<211>	0.48

[100]: full slip

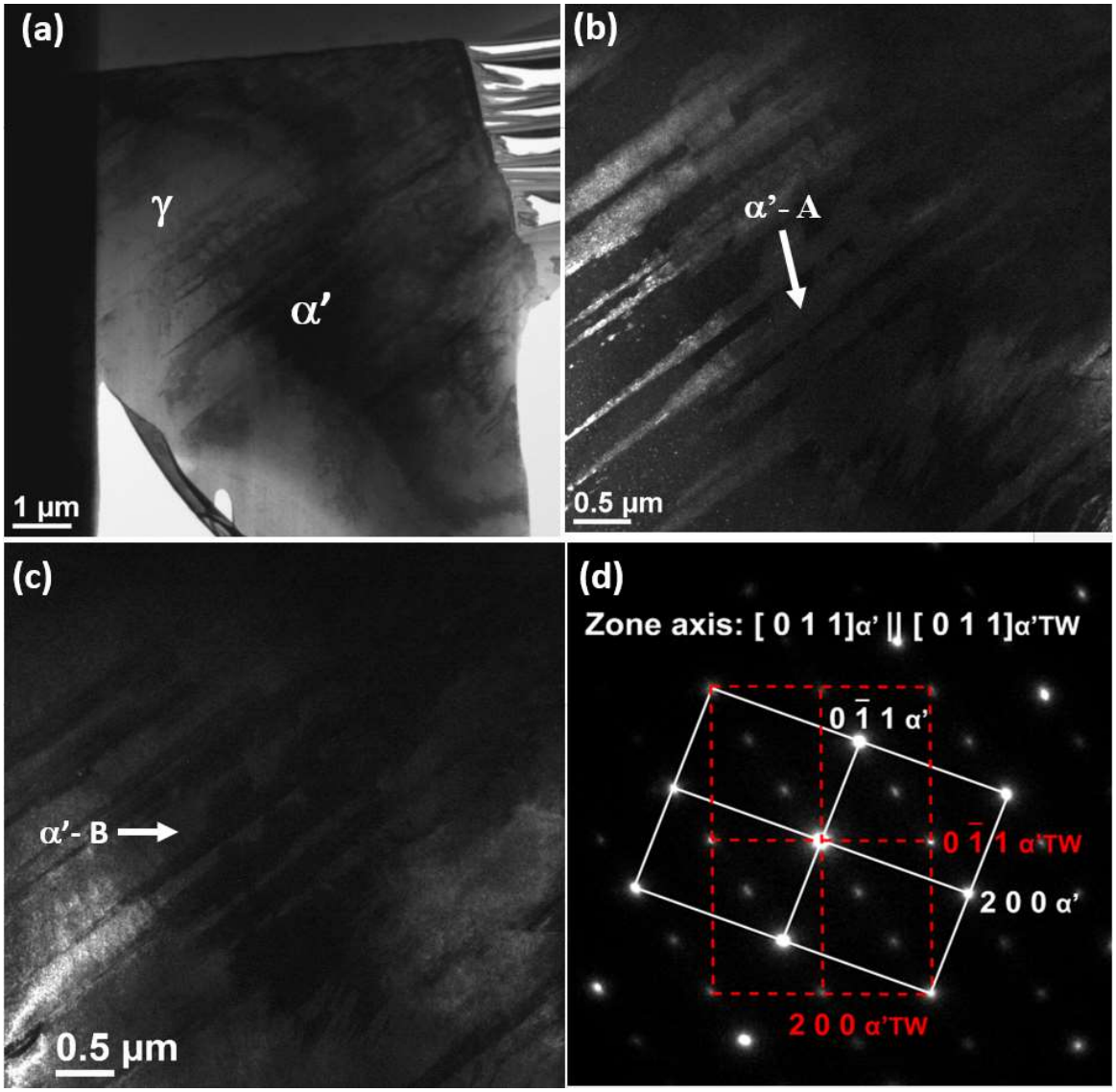
[110]: partial slip

[100] pillar



[1 0 0] pillar (a) Bright field image (b) Dark field image of martensite formed in the pillar (top part); (c) Dark field image showing abundance intersecting bands; the selected diffraction patent on the white circle shows martensite nuclei at the intersection of slip bands (d) Dark field image showing some bands are twins.

[110]



[1 1 0] pillar (a) Bright field image; (b) Dark field image showing one of the twinned martensite variant (α'-A); (c) Dark field image showing the other twinned martensite variant (α'-B); (d) Diffraction pattern showing the two twinned martensite variants in (b) and (c).

Summary of topic 2

- large strain bursts in austenitic micropillars can be induced by martensitic transformations.
- The magnitude of the strain bursts is directly correlated to the fraction of martensite formed during compression.
- The fraction of transformed martensite is influenced by the orientation of the pillar.
- Pillars with [1 0 0] orientation where partial dislocation slip is favourable have a higher fraction of transformed martensite than the pillars with [1 1 0] orientation where partial dislocation slip is not preferred.
- Morphology of martensite is affected by orientaton.

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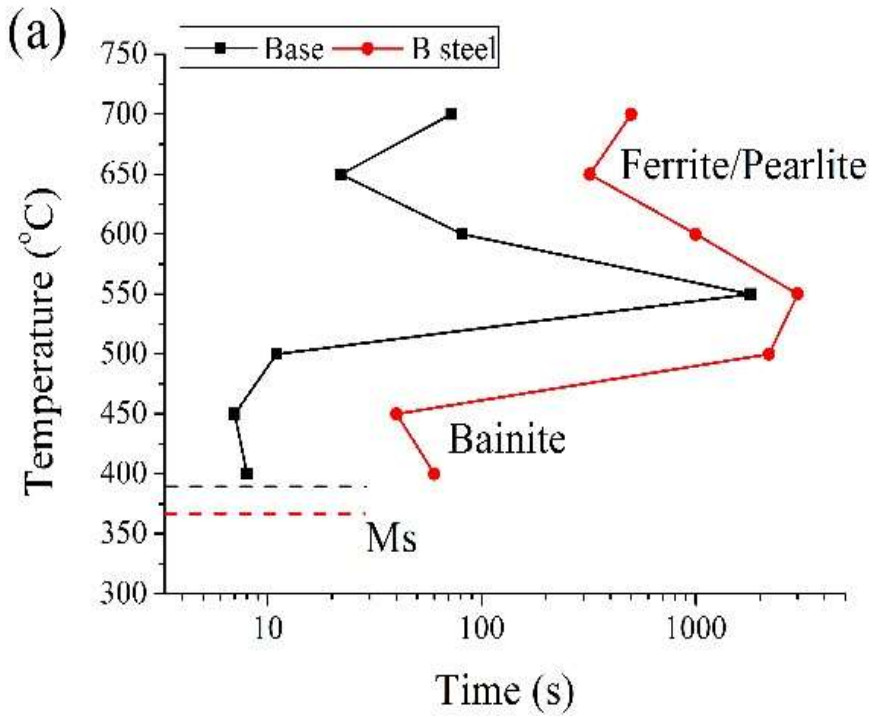
Materials

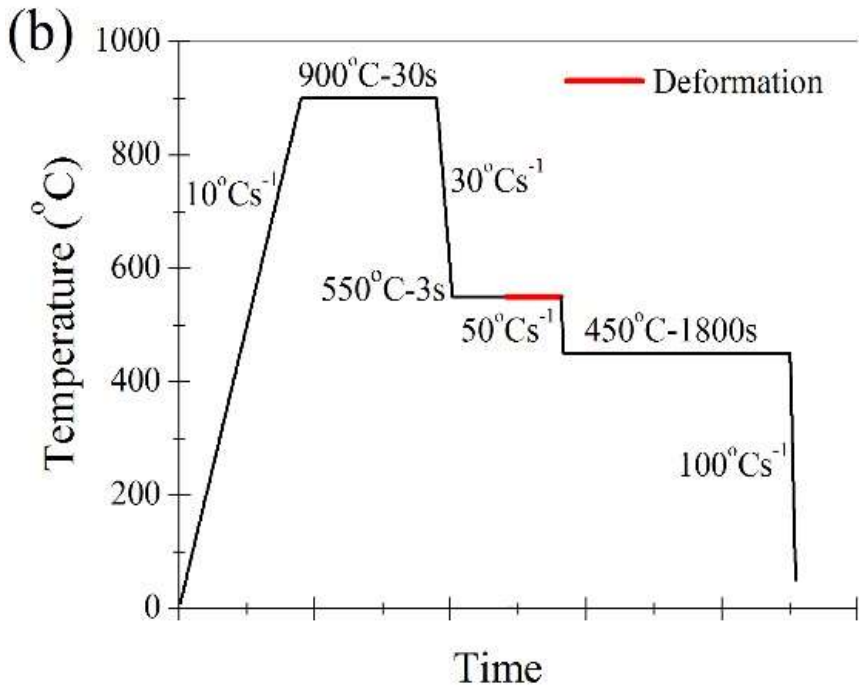
	C	Mn	Cr	Ti	B
Base	0.2	1.6	2	0.001	**0.0002**
B steel	0.2	1.6	2	0.023	**0.0041**

	Ac_1	Ac_3	Ms	Grain size
Base	762 °C	795 °C	391 °C	12 ±2mm
B steel	765 °C	805 °C	367 °C	11 ±3mm

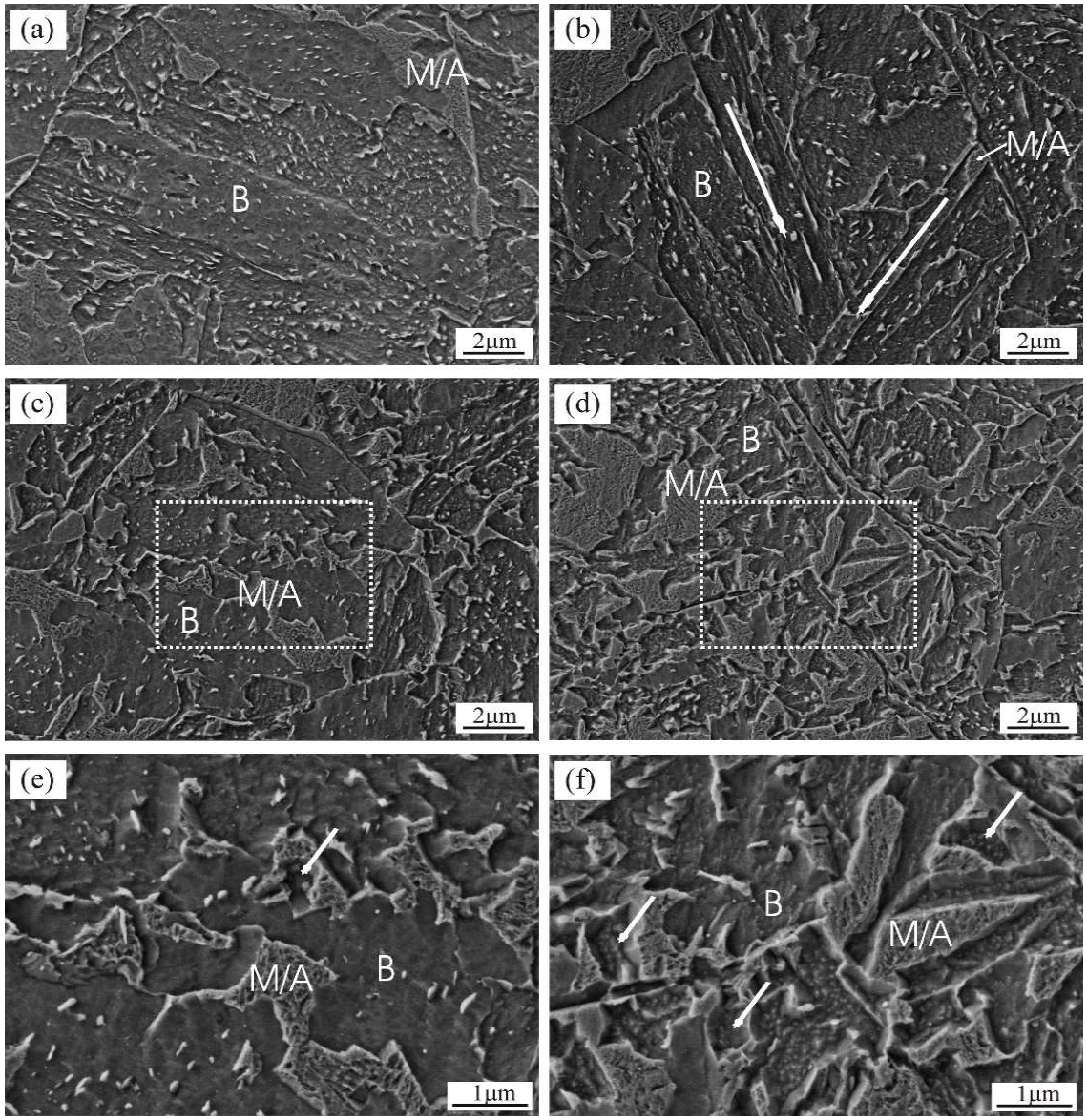
B.B. He, W. Xu, **M.X. Huang***,, *Journal of Materials Science & Technology*, accepted (2017)

Ausforming


(a)
Base
B steel
Ferrite/Pearlite
Bainite
Ms
Temperature (°C)
Time (s)
750
700
650
600
550
500
450
400
350
300
10
100
1000

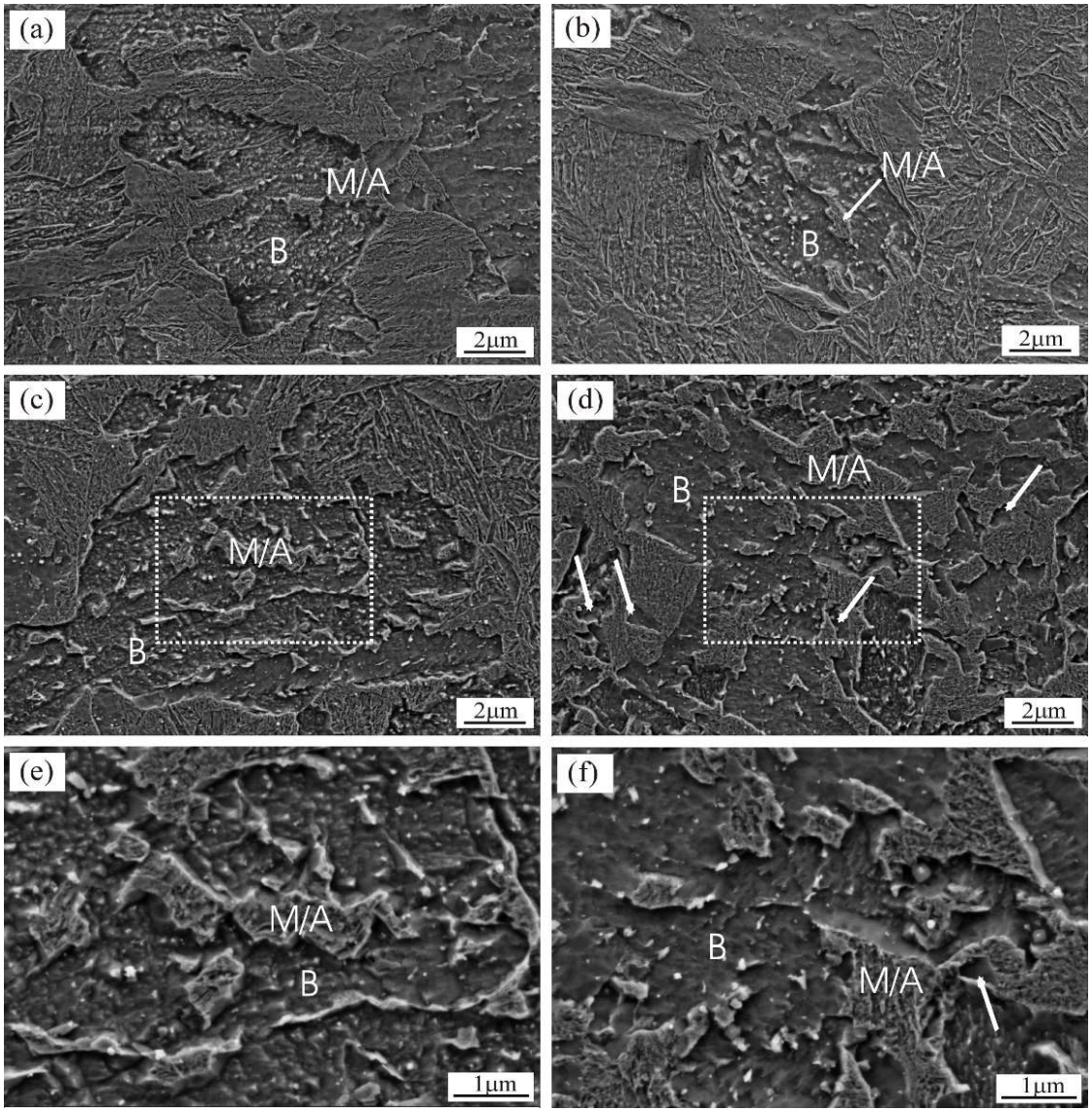

(b)
Deformation
900°C-30s
10°Cs⁻¹
30°Cs⁻¹
550°C-3s
50°Cs⁻¹
450°C-1800s
100°Cs⁻¹
Temperature (°C)
Time
1000
800
600
400
200
0

Effect of ausfomring



Base steel. (a) 0%; (b) 2%; (c) 10%; (d) 25%;

Effect of ausfomring



B steel. (a) 0%; (b) 2%; (c) 10%; (d) 25%;

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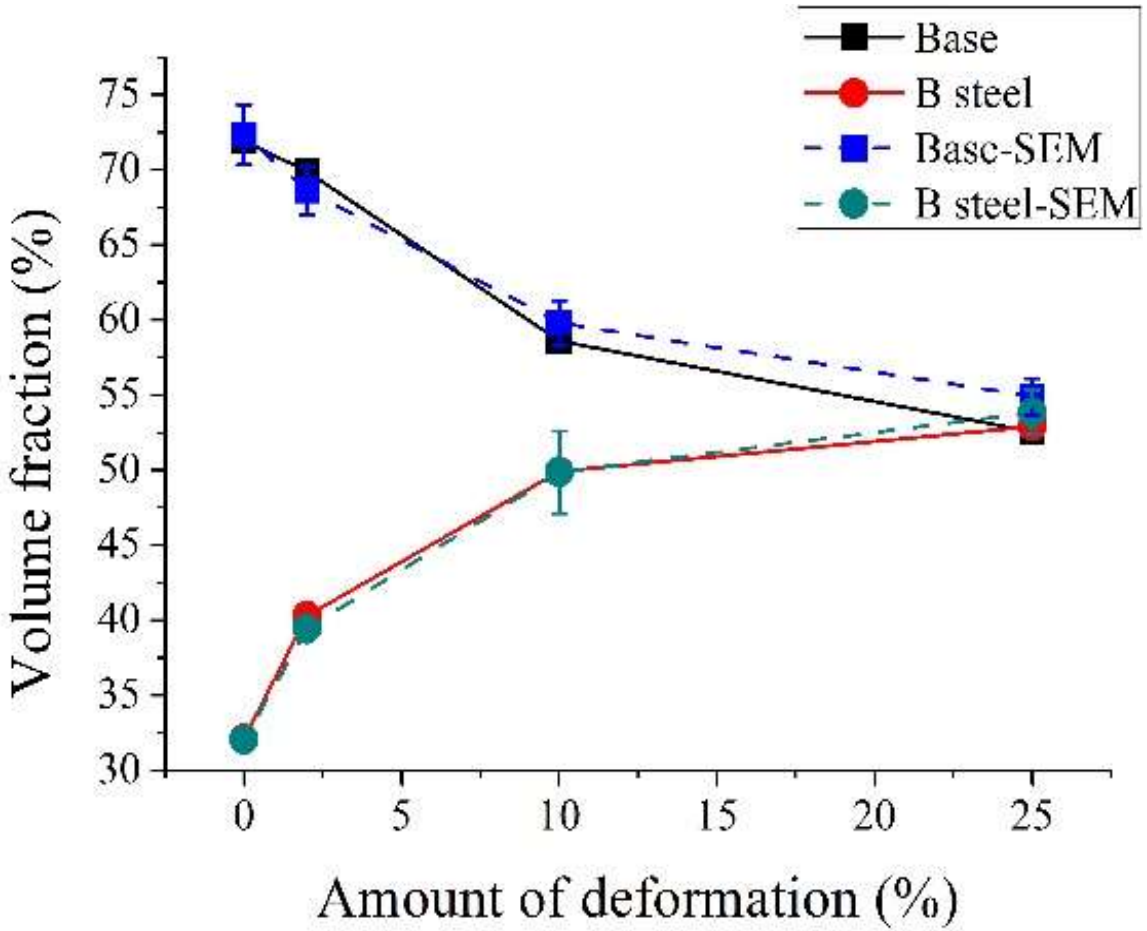
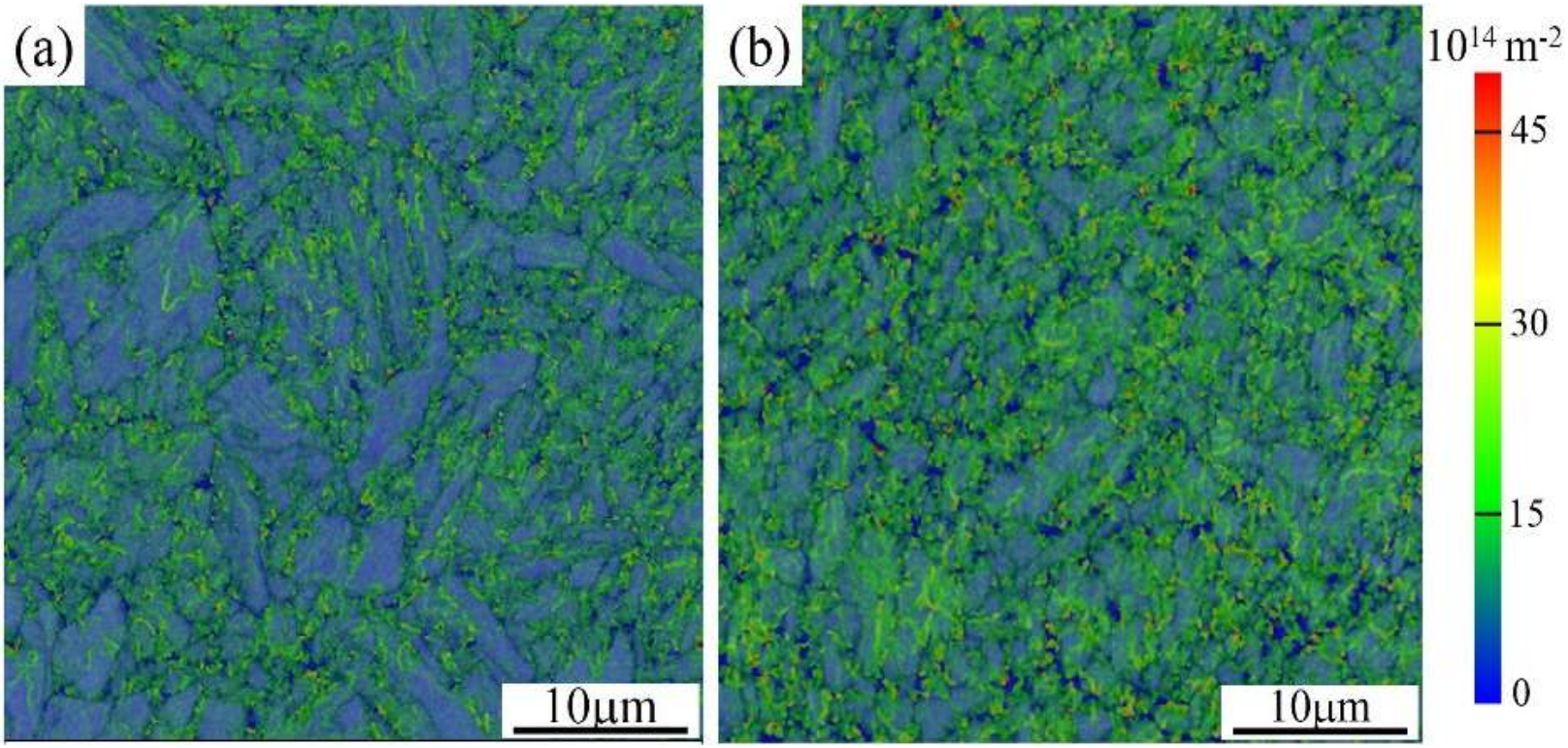
Effect of ausforming on bainite fraction



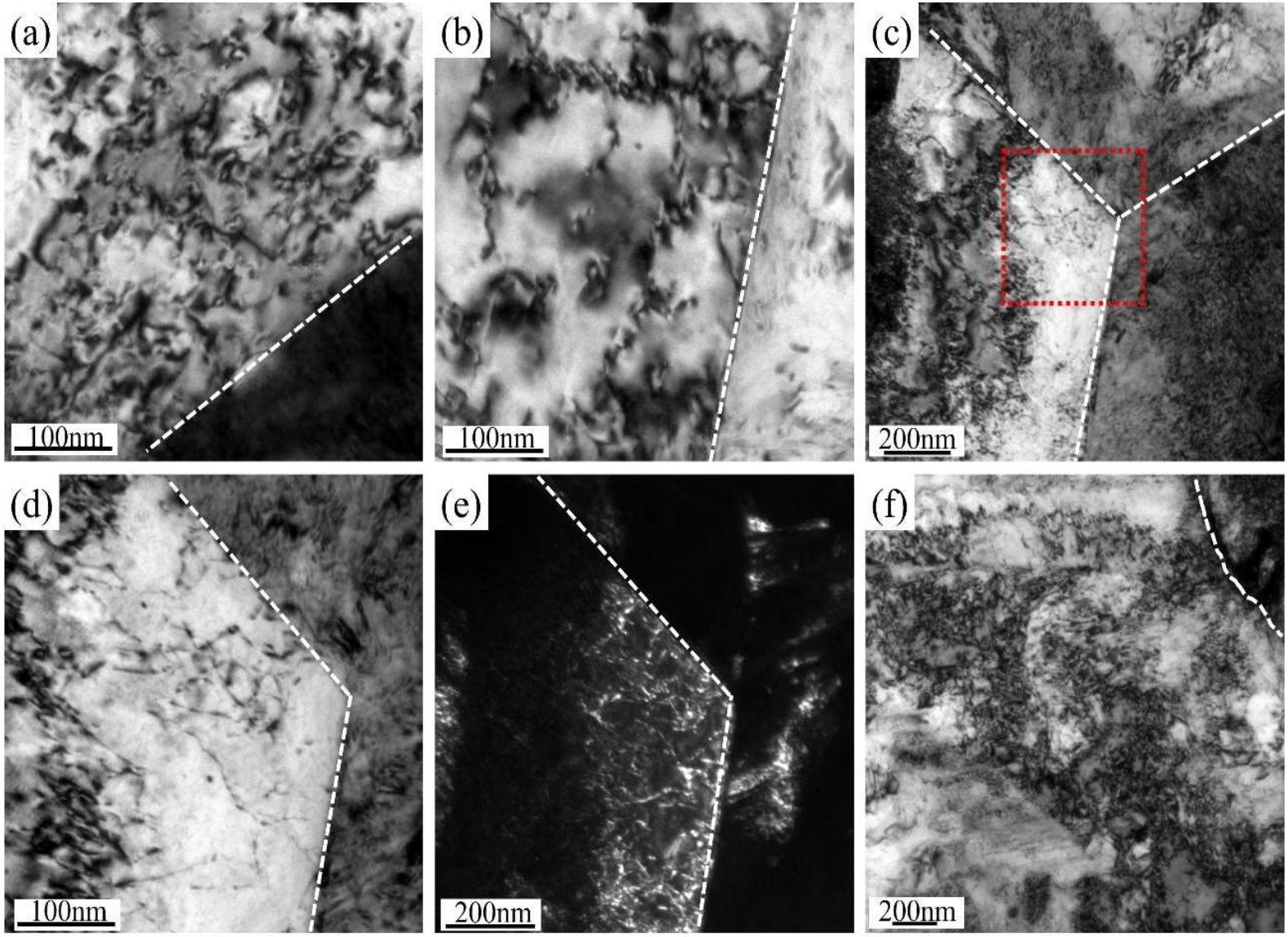
The retarded effect of B decreases with deformation.

B will segregate at dislocations instead of prior austenite grain boundaries.

GND after ausforming



GND density in the transformed product of B steel after different amount of deformation. (a) 0%; (b) 25%.


(a)
100nm
(b)
100nm
(c)
200nm
(d)
100nm
(e)
200nm
(f)
200nm

Summary of topic 3

- In 0B steel, bainite fraction reduces with the increase of ausforming strain as ausforming increases the stability of prior austenite.
- In contrast, in B steel, bainite fraction increases with increase of ausformaing strain as B segregates at dislocations instead of prior austenite grain boundaries. The effect of B on bainitic transformation is eliminated as large ausforming strain.

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Thank you!