A Low Density Steel for Bearings

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RAL

Backgrounds and Motivations

Steels for bearings:

- Rolling contact fatigue properties
- Wear resistance

↑

Hardness ← Large carbon content

- Interstitial solid solution hardening for martensite
- Dispersion hardening by carbide precipitation

Backgrounds and Motivations

Large carbon content:

- Depressing M_s temperature
- Increasing retained austenite fraction
- Affecting the dimensional stability
- Deteriorating hardness due to soft austenite

52100 bearing steel

- Fe-1 C-0.4Mn-0.2Si-1.5Cr in wt% (C $\leq$1.1wt%)
- Survived for hundred years

Backgrounds and Motivations

New possibility for improving performance?

- Higher hardness
- Lower density

Aluminium adding in 52100 bearing steel

- Fe-*1.2~1.5* C-0.4Mn-1.5Cr-*4~8*Al in wt%

Backgrounds and Motivations

Aluminium adding in 52100 bearing steel

- Fe-*1.2~1.5* C-0.4Mn-1.5Cr-*4~8*Al in wt%

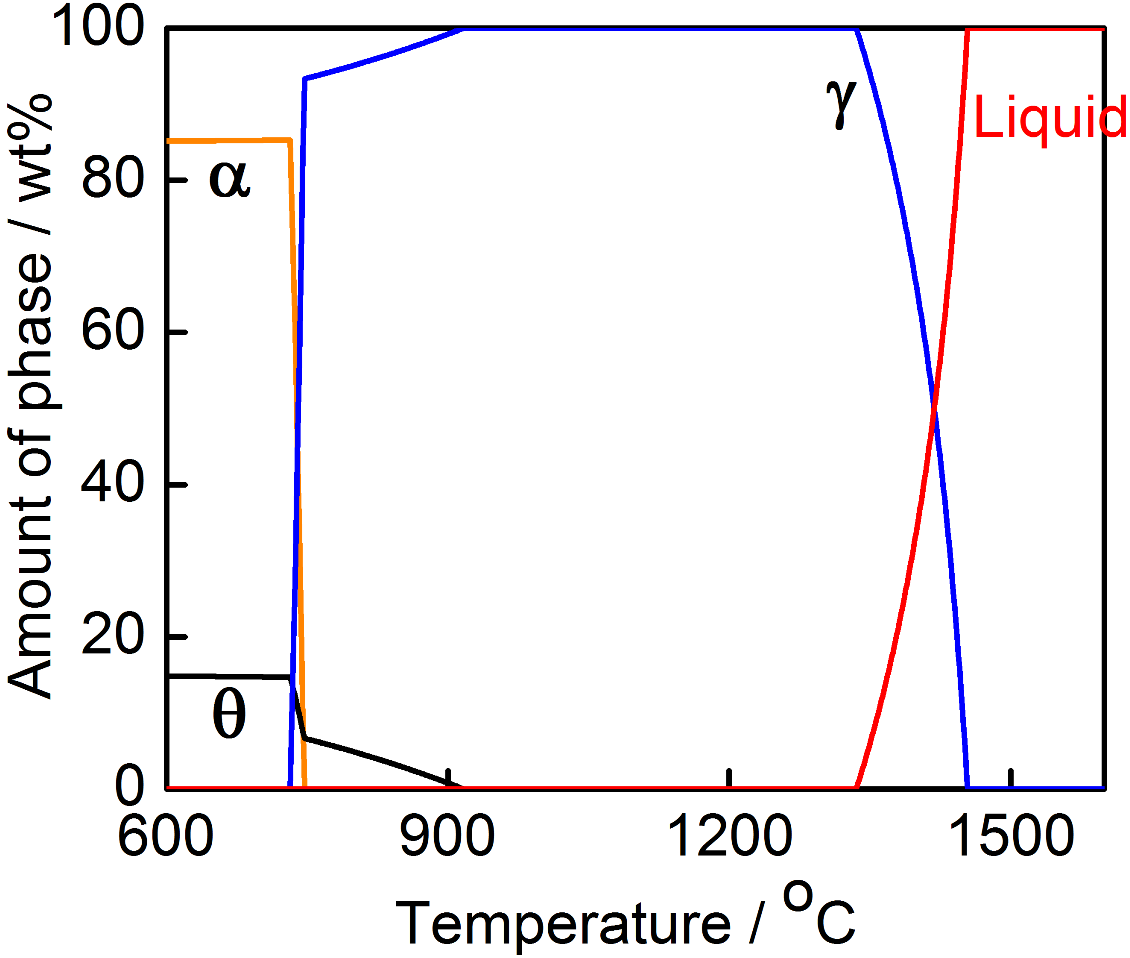
Aluminium addition → carbon addition

- Al increasing M_s temperature
- Al suppressing retained austenite fraction
- Al enhancing eutectoid carbon content
- Al lowering density of steels
- Al improving toughness by encouraging transit carbide precipitation

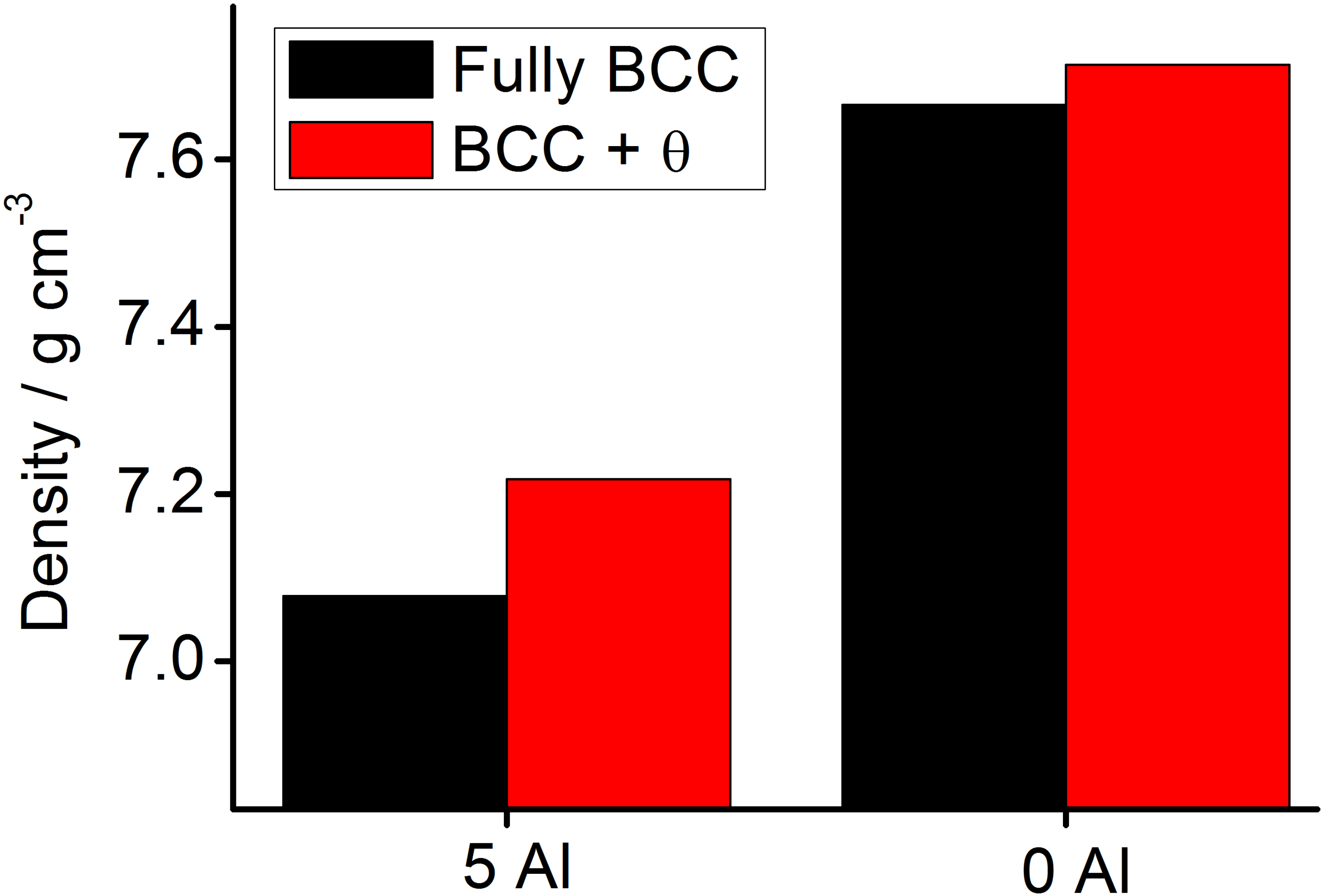
Alloy design

in wt.%

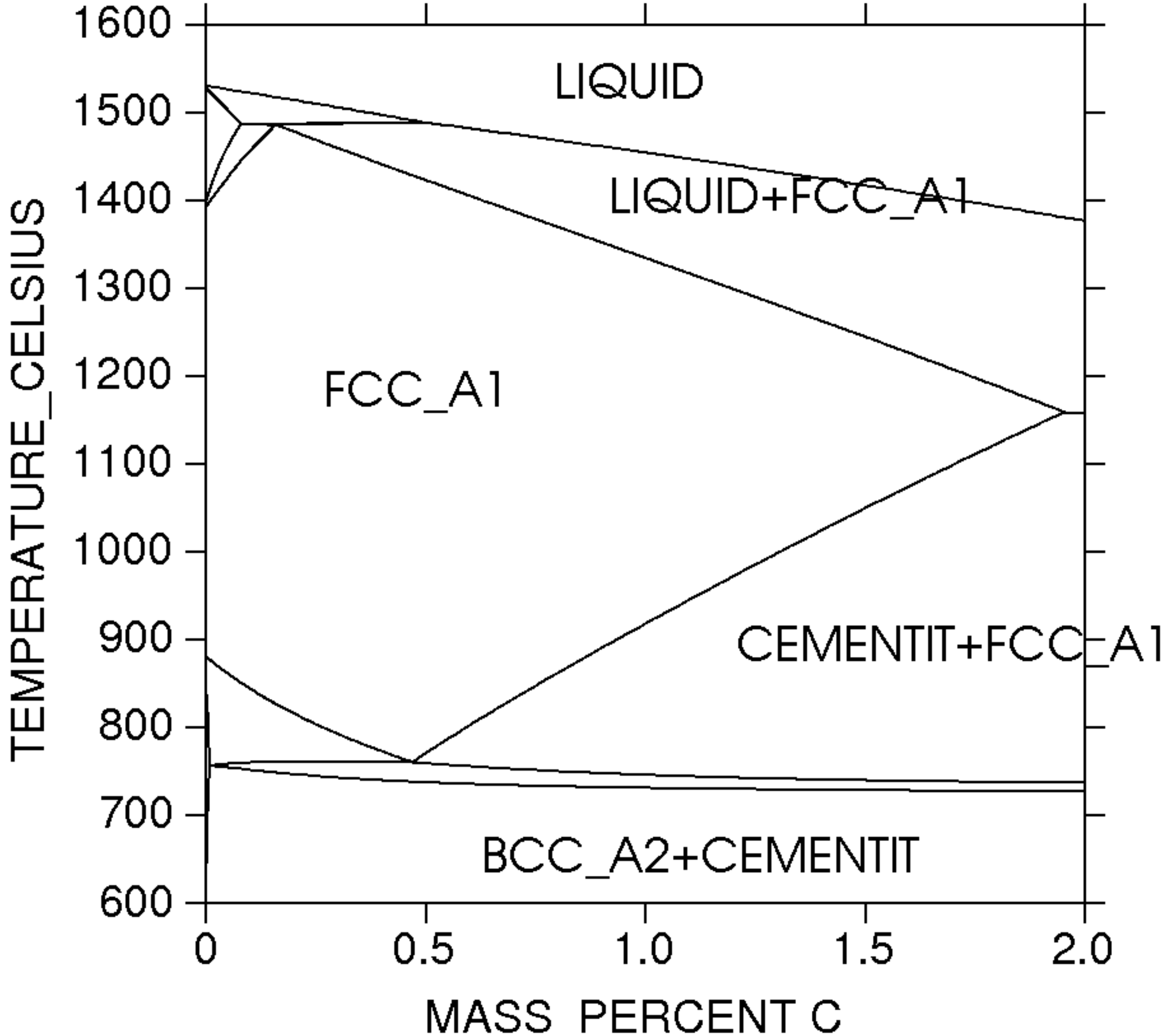
C	Mn	Si	Al	Mo	Cr	Ni	Cu
1.2	0.35	0.25	5	0.1	1.55	0.2	0.15



Al lowering density for 8.3% in full BCC



Fe−1.2C−0.35Mn−0.25Si−0.1Mo−1.55Cr−0.2Ni−0.15Cu −*5Al* in wt.%



Fe−1.2C−0.35Mn−0.25Si−0.1Mo−1.55Cr−0.2Ni−0.15Cu
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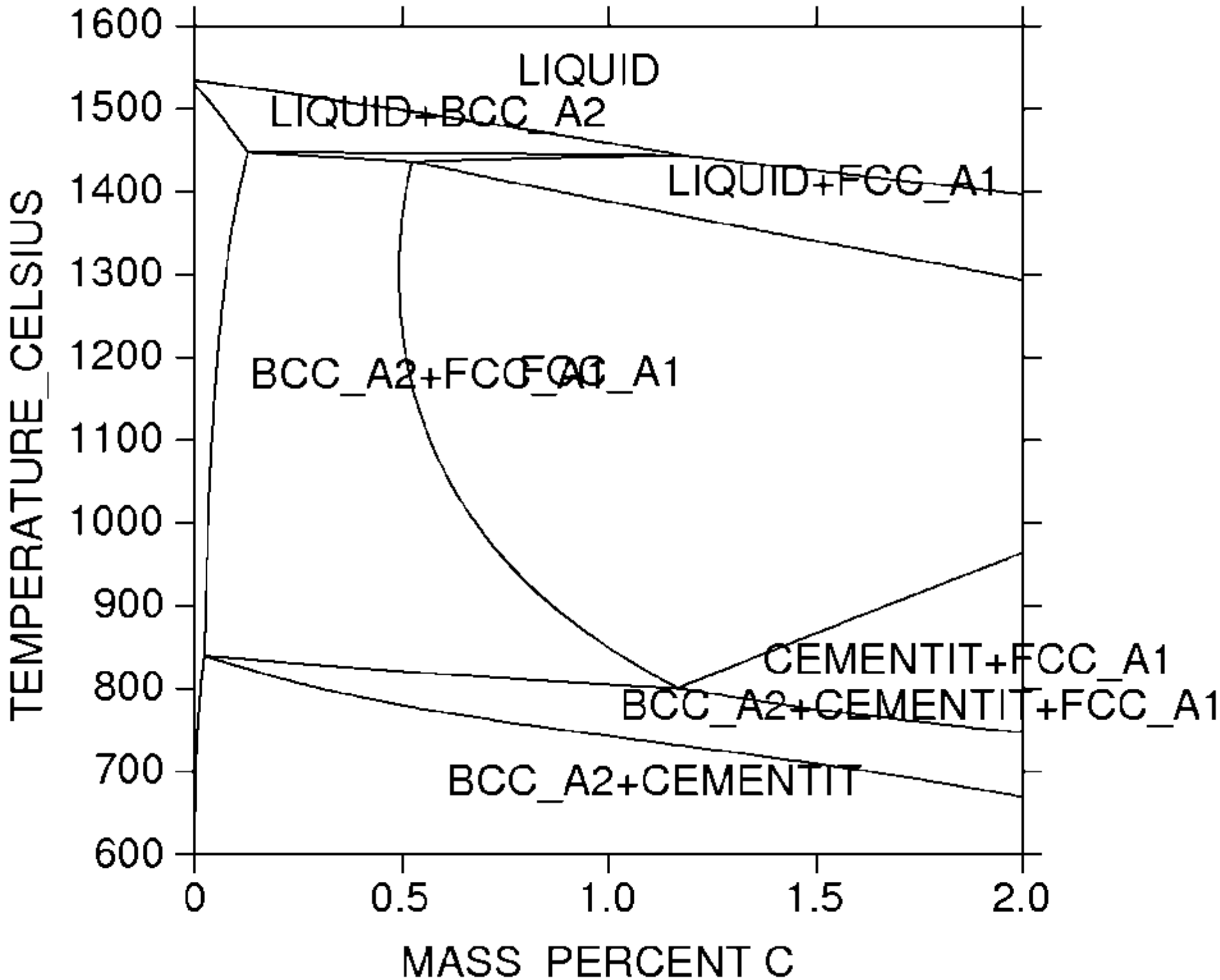
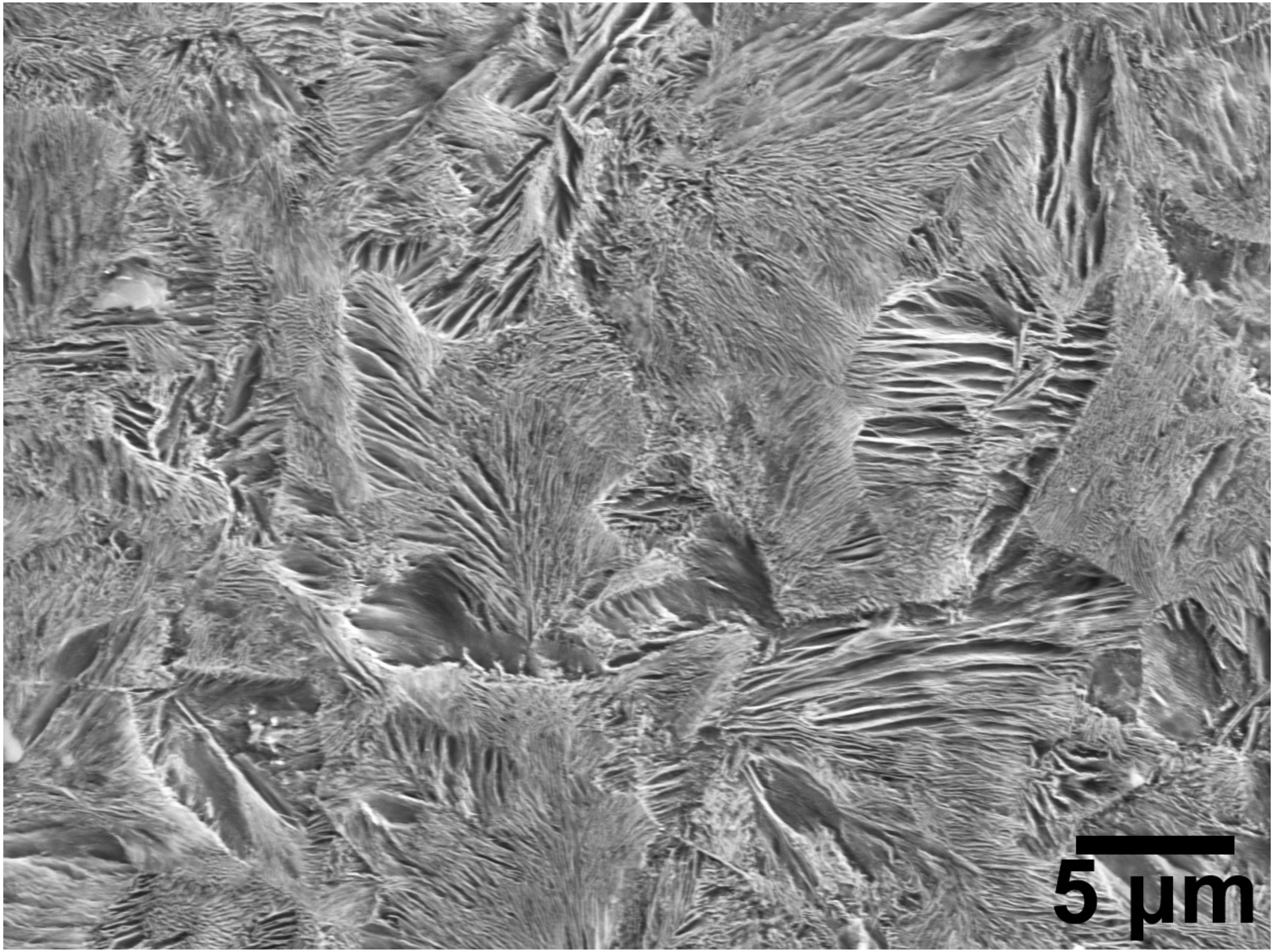
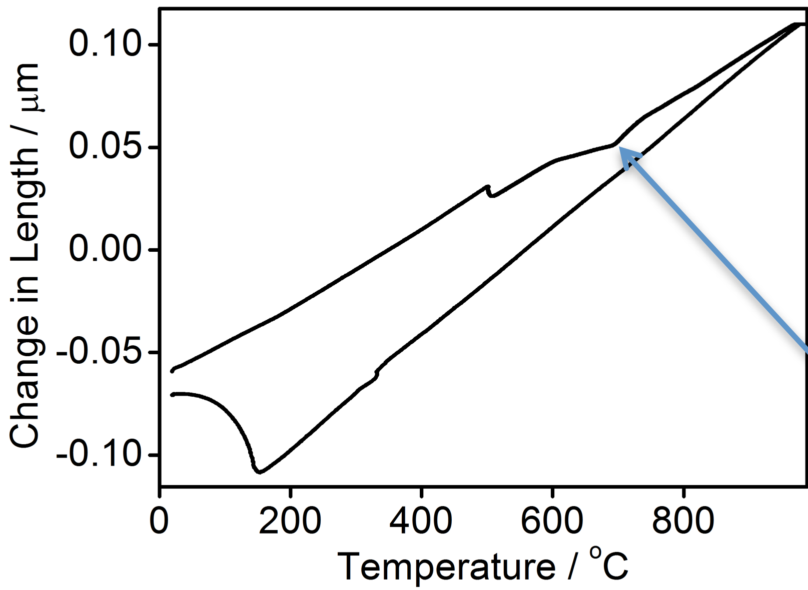


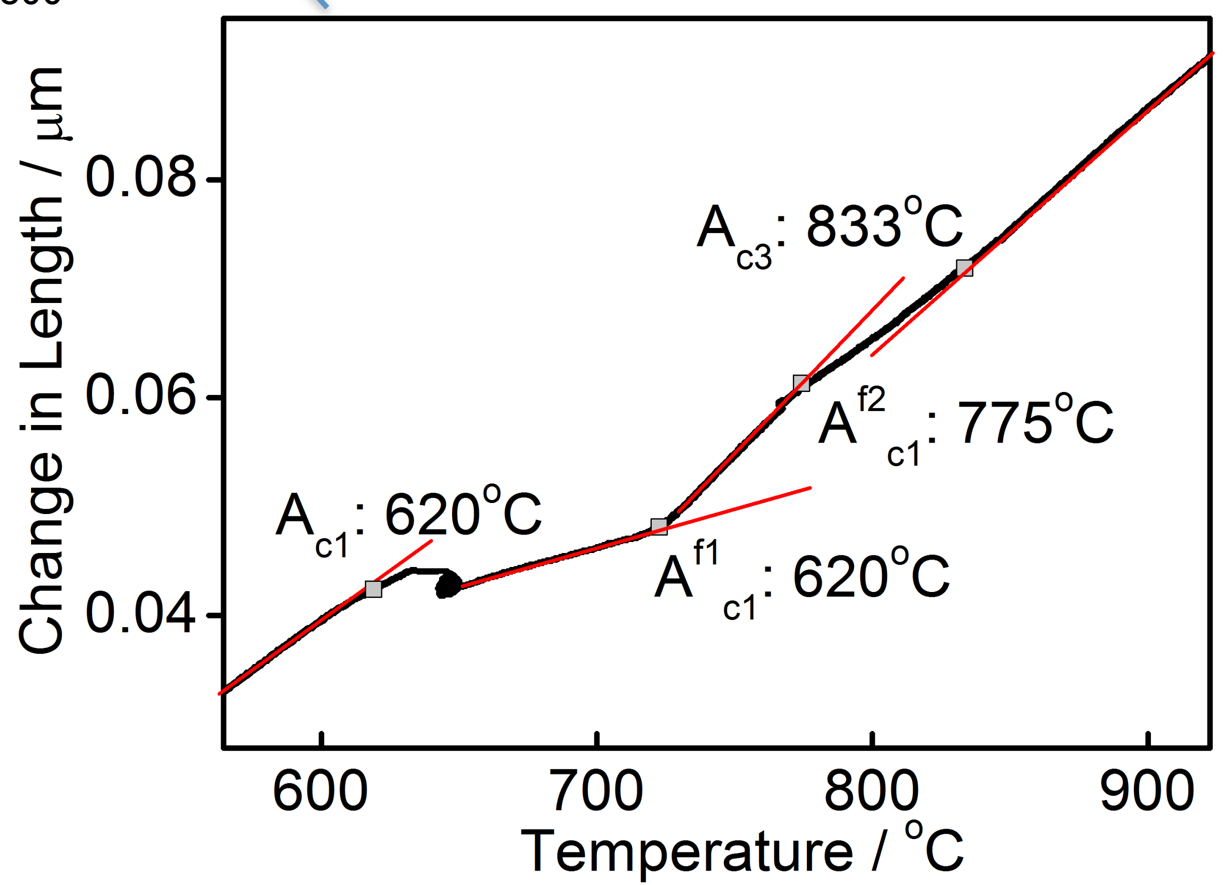
Moving eutectoid carbon from ~0.5 to ~ 1.2 wt%

Hot rolled: full pearlite

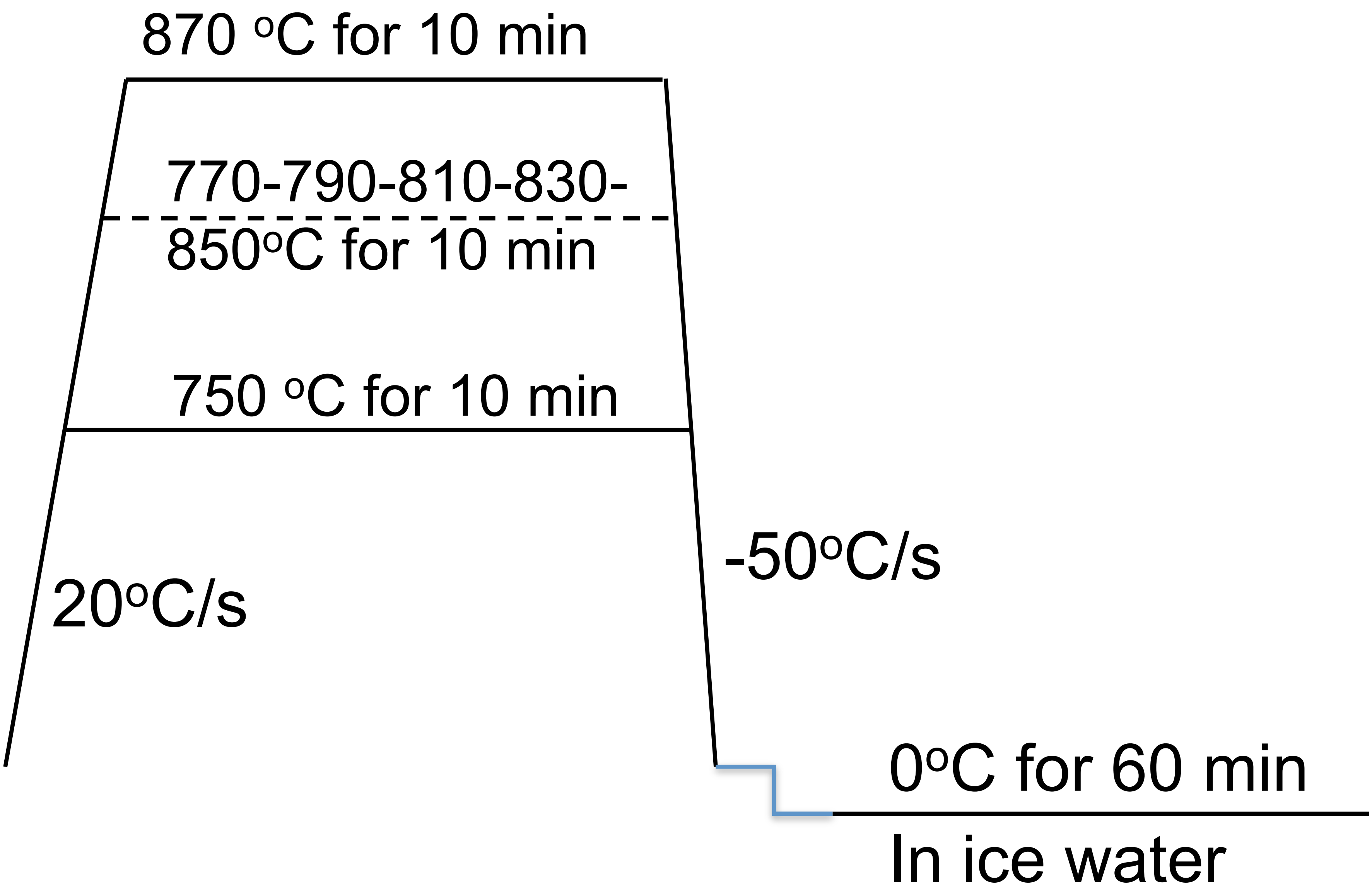


A_{c1}-A_{c3} Measured by Dilatometer

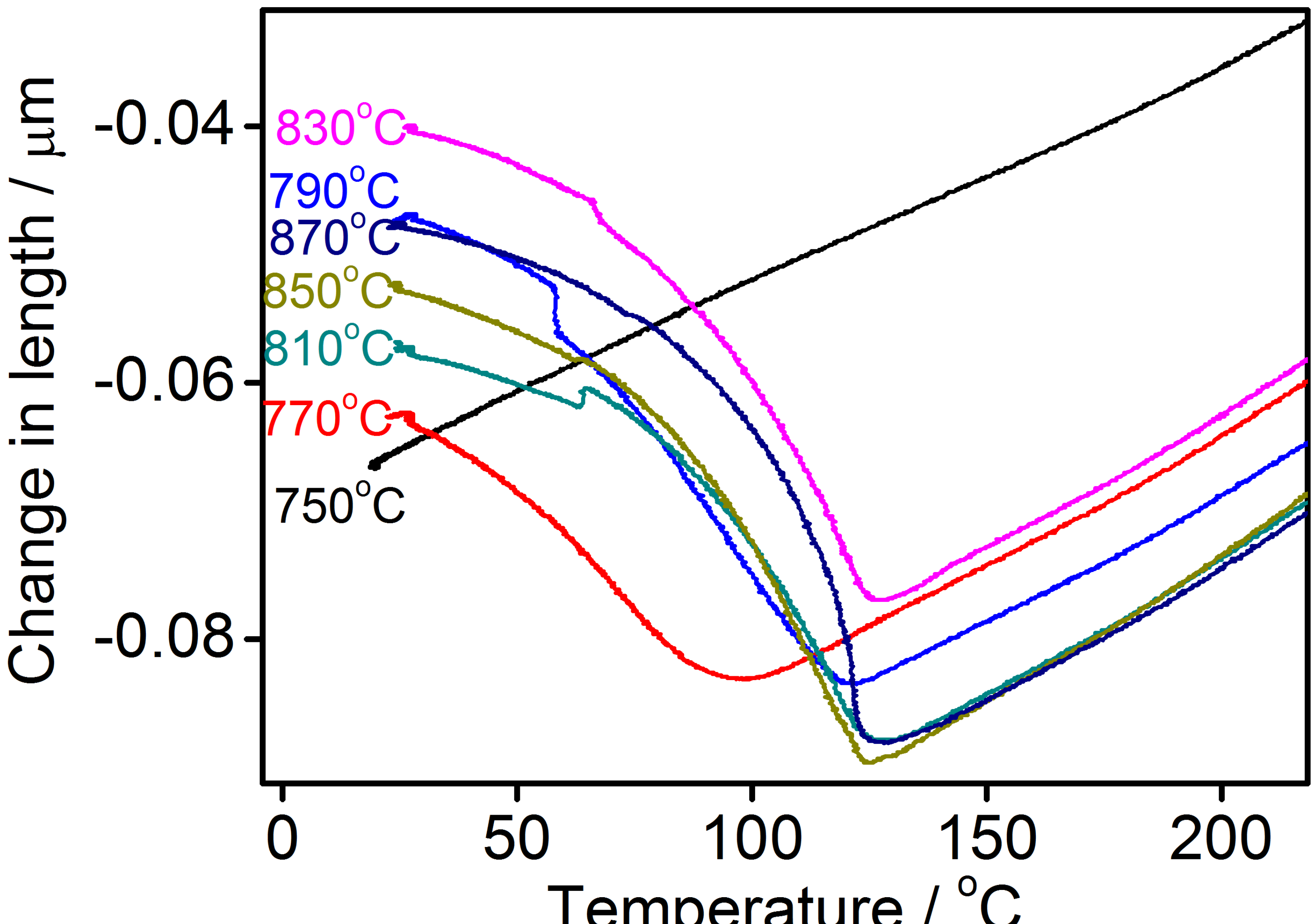


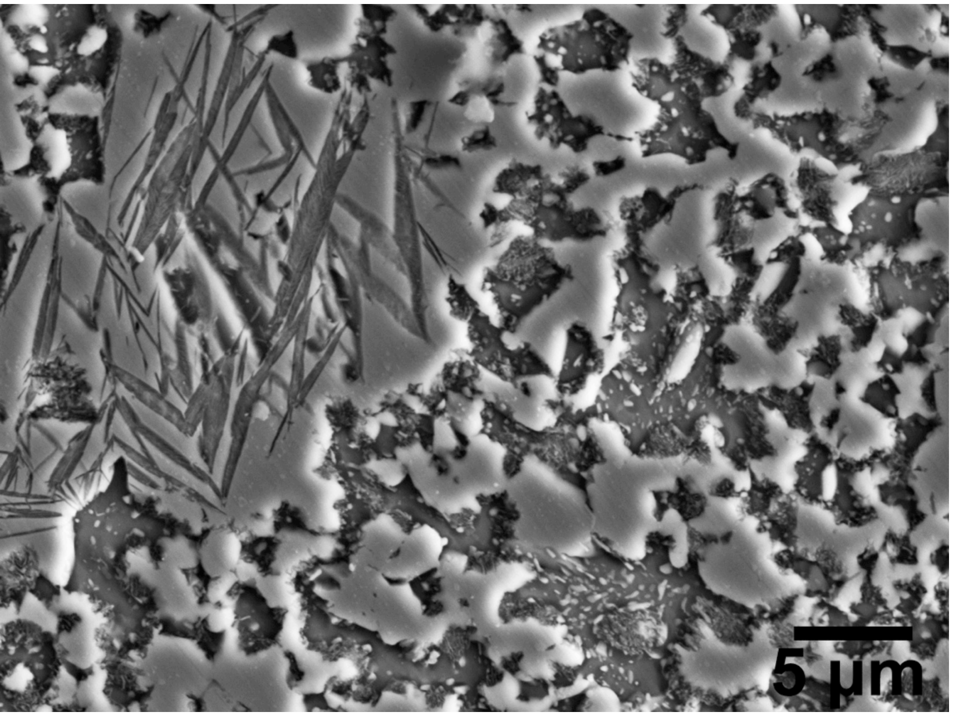


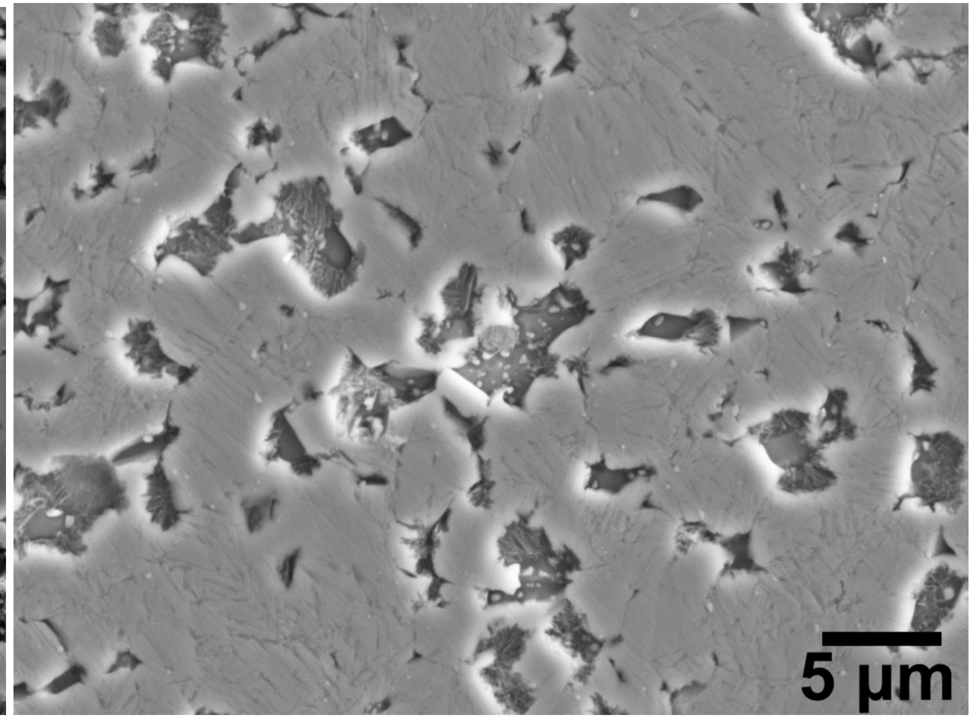
Heat treatment by dilatometer



M_s temperature measurement







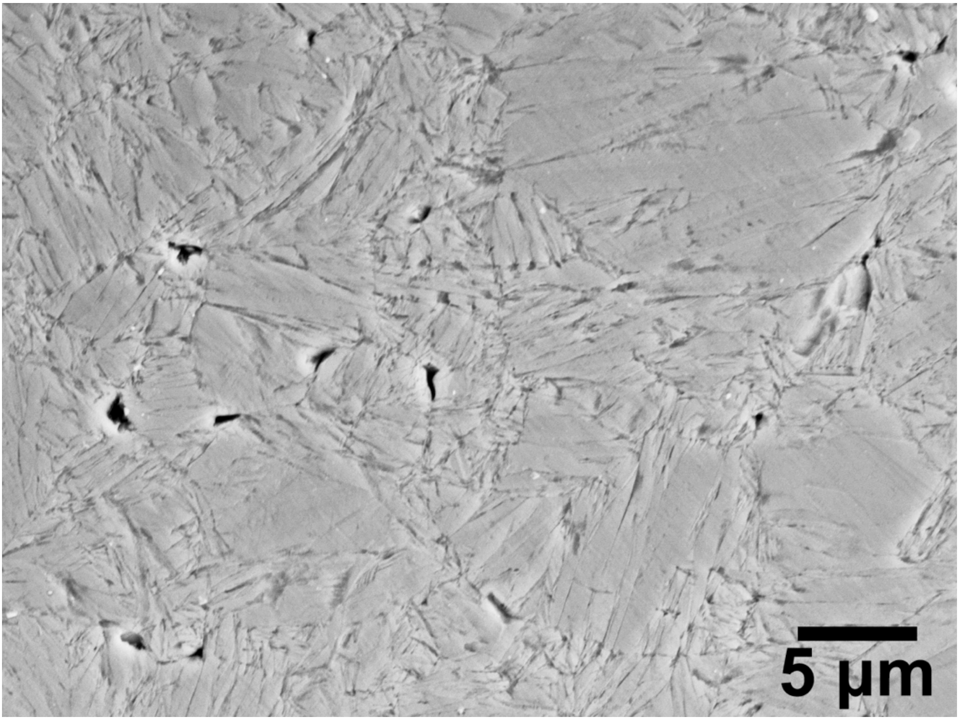
750 °C: few martensite
(θ+α) + γ

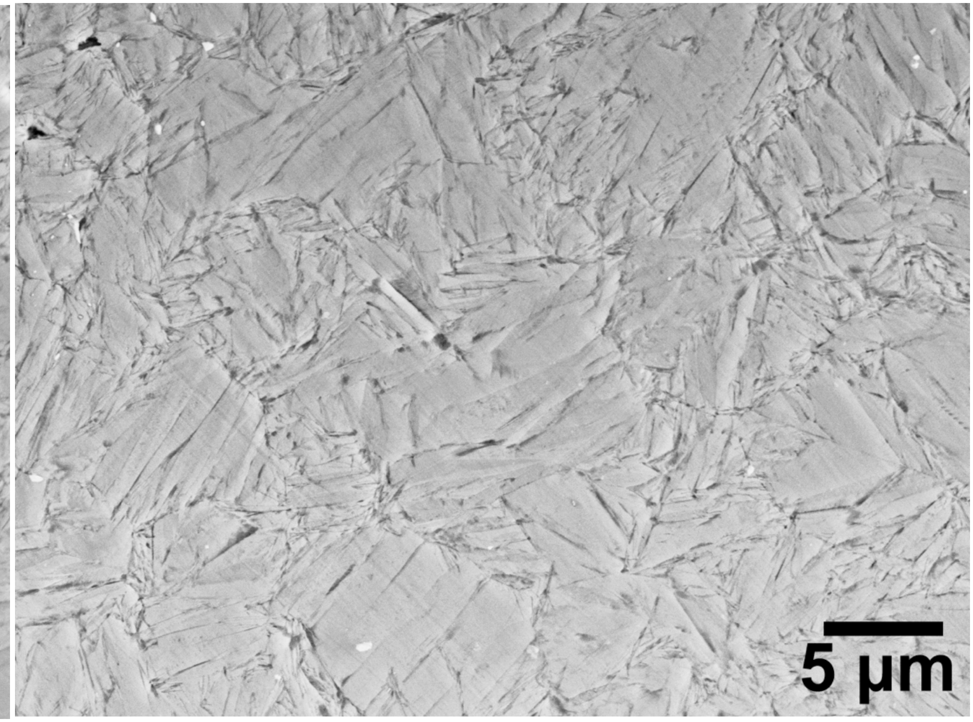
HV20: 387±7

770 °C: M_s at 103 °C
(θ+α) + (γ+ α')

HV20: 606±11

α' transformed: 67.8%





790 °C: M_s at 122 °C
α + (γ+ α')

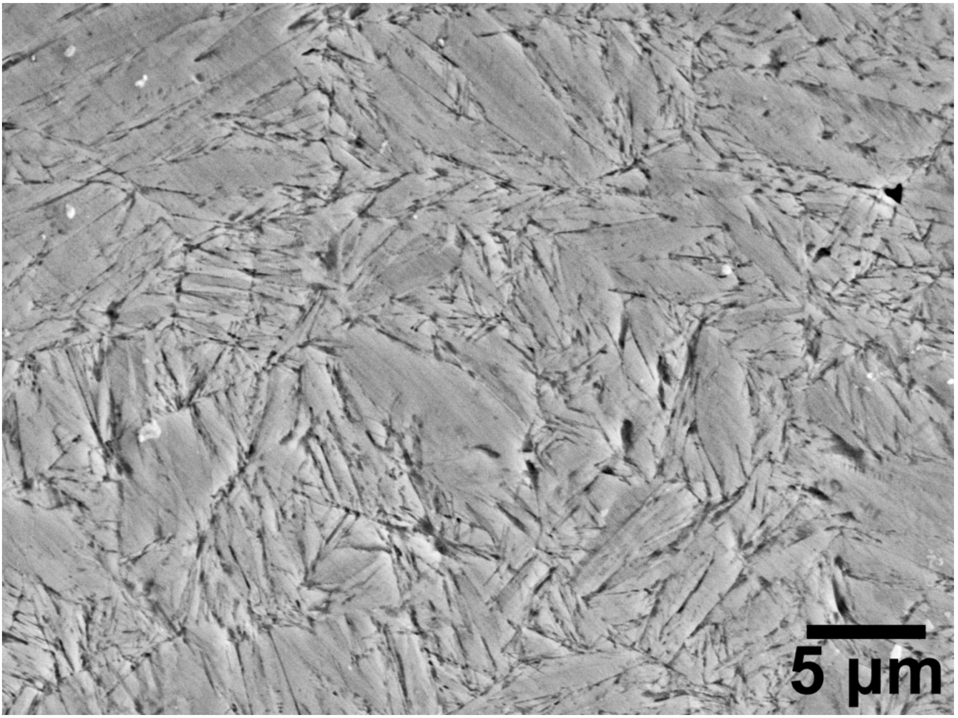
HV20: 779±5

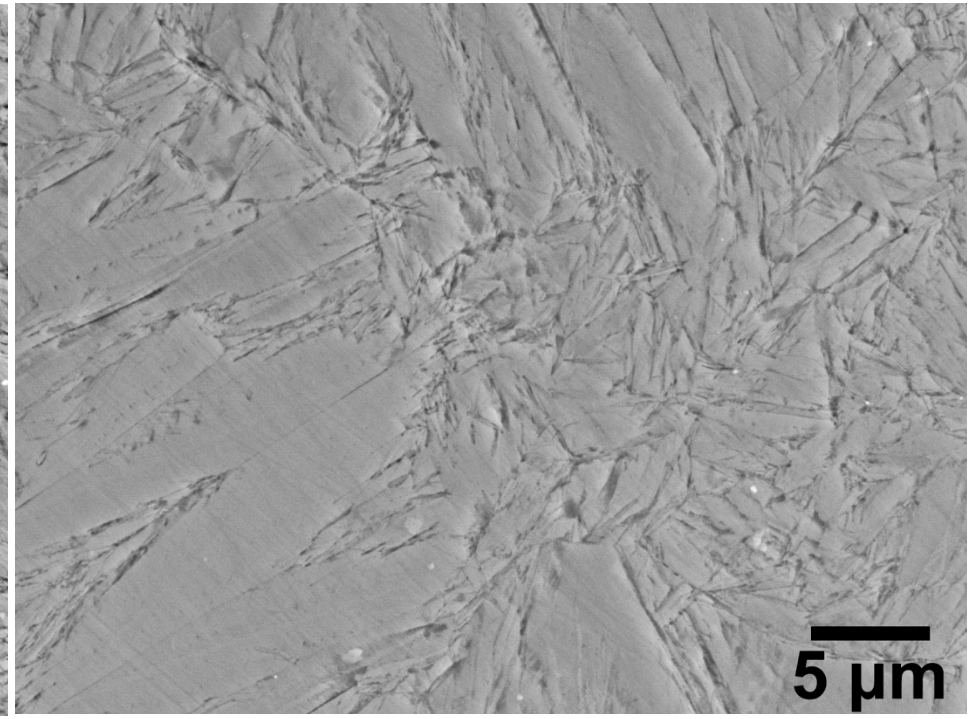
α' transformed: 73.9%

810 °C: M_s at 128 °C
γ+ α'

HV20: 765±5

α' transformed: 75.5%





830 ^oC: M_s at 130 ^oC
γ+ α'

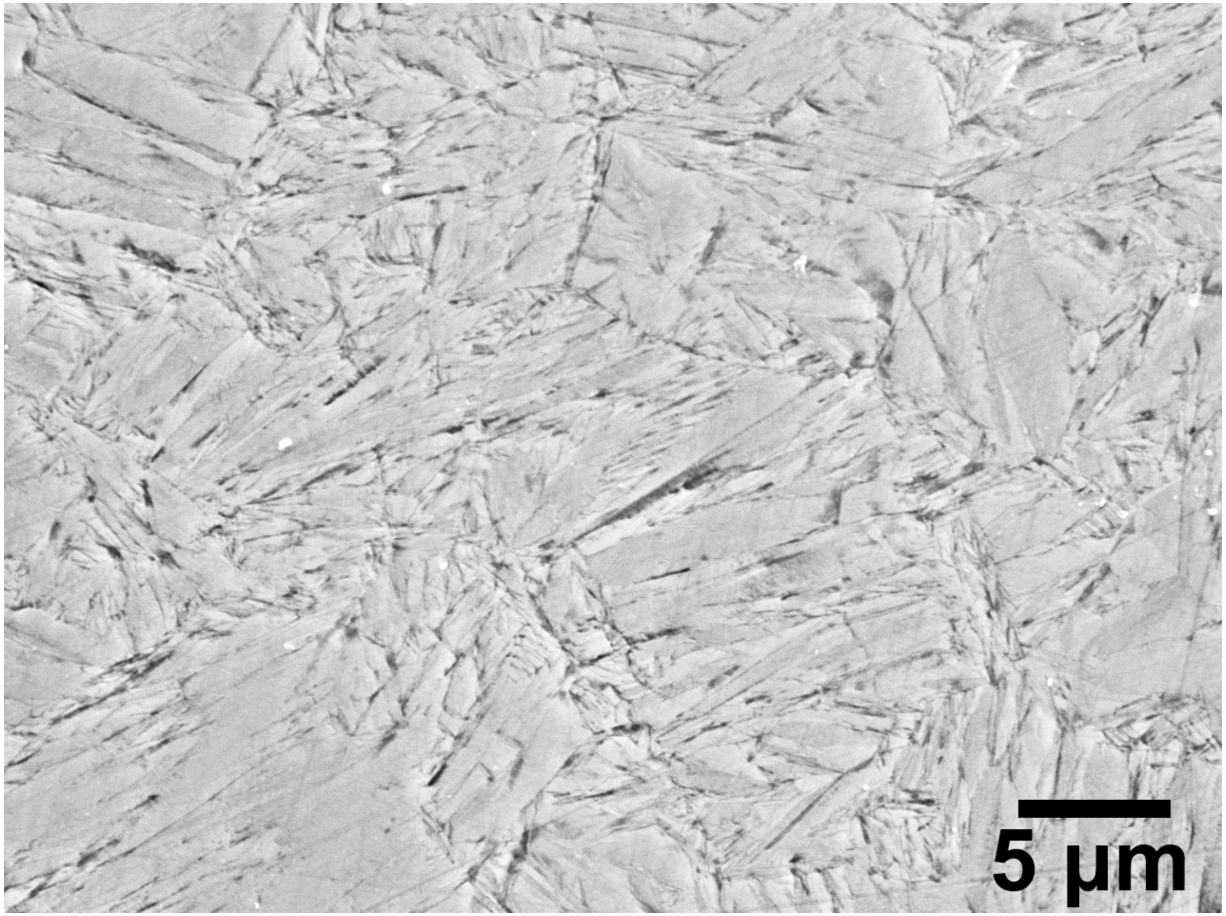
HV20: 753±4

α' transformed: 76.1%

850 ^oC: M_s at 126 ^oC
γ+ α'

HV20: 756±7

α' transformed: 75%



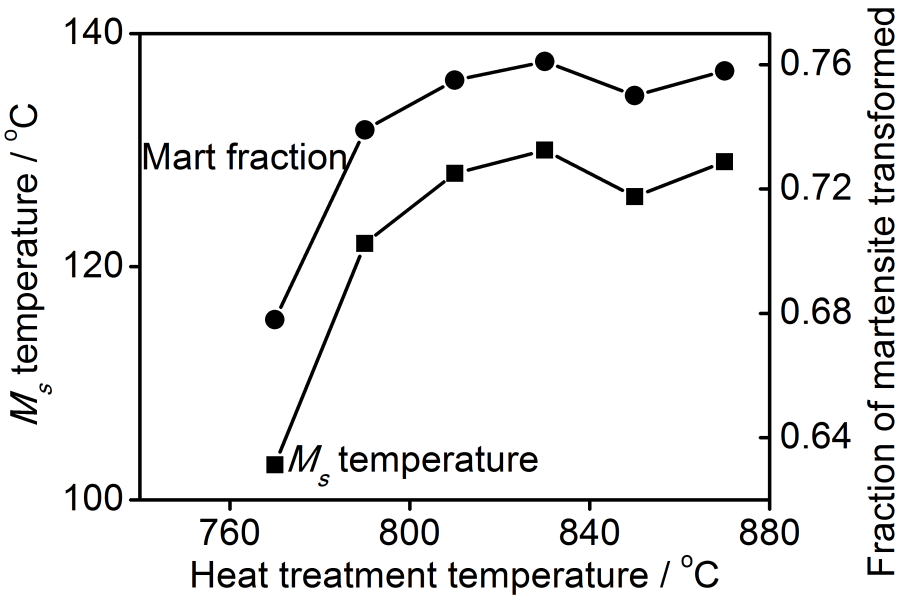
870 ^{o}C: M_s at 129 ^{o}C

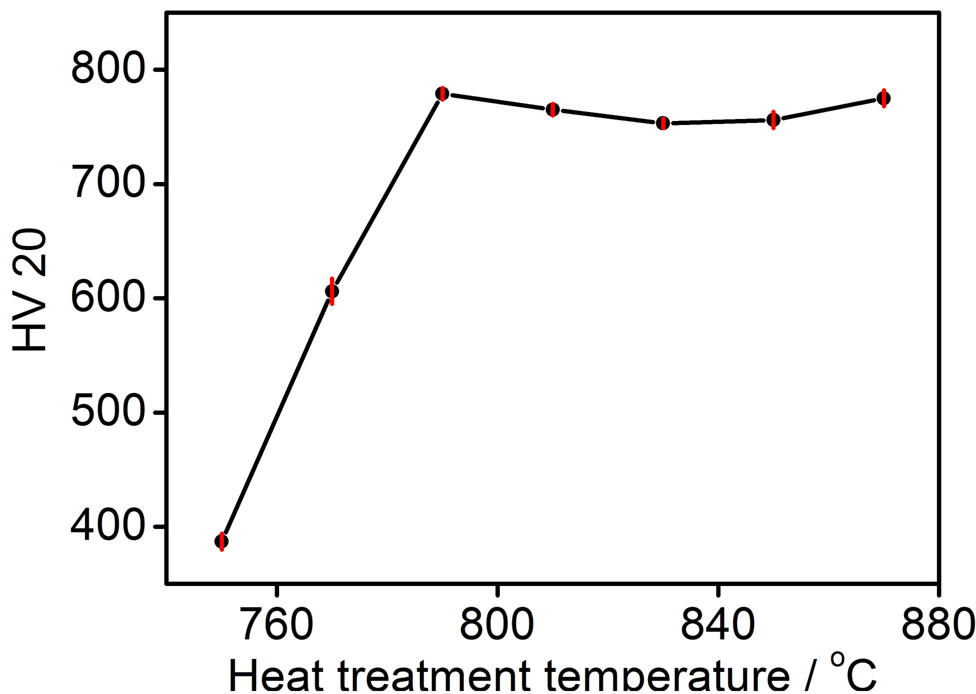
γ+ α’

HV20: 775±7

α’ transformed: 75.8%

Effect of heat treatment temperature on the microstructure and hardness





Influence of sub-zero refrigeration on the retained austenite content of 52100 steel

Austenitisation		Tempering		Sample temperature (°C)	Ageing time (h)	V_γ
T_γ (°C)	t_γ (h)	T_T (°C)	t_T (h)			
840	$\frac{1}{3}$	–	–	Ambient		11
				−196	100	10
850	$\frac{1}{4}$	–	–	Ambient		10
				−80	1	5
955	$\frac{1}{2}$	177	2	Ambient		24
				−73	1–3	20–21
				−177	1–3	17–18
955	$\frac{1}{2}$	204	2	Ambient		10
				−73	1–3	8–9
				−177	1–3	8
955	$\frac{1}{2}$	204	2	Ambient		10
				−73	1–3	8–9
1150	?	–	–	Ambient		25
				−196	$1\frac{1}{2}$	9

[H.K.D.H. Bhadeshia, Steels for bearings, Progress in Materials Science 57 (2012) 268–435]

Conclusions

- Density reducing ~8% due to 5wt% aluminium addition in 52100 bearing steels
- Networks carbide being avoided in as-rolled materials owing to the enhanced eutectoid carbon content by aluminium addition
- Hardness achieved slightly being higher than 1wt% carbon contained 52100 alloys
- Aluminium suppressing the retention of austenite, but not sufficient in this 5wt% Al – 1.2 wt%C alloy

Further research

- Tempering for transit carbide precipitation
- Higher aluminium for 1.2 wt% carbon contained 52100 alloy to suppress retention of austenite