Tensile behaviour of thermally stable nanocrystalline bainitic steels

G. M. A. M. El Fallah, H. K. D. H. Bhadeshia

Department of Materials Science and Metallurgy, University of Cambridge, 27 Charles Babbage Road, Cambridge CB3 0FS, U.K.

Introduction

- Nanocrystalline steels (superbainite).
- Combination of strength and toughness.
- Aerospace applications and components in gas turbine engines.
- The aim of the current work is to design new nanocrystalline steel alloy.
- Two novel bulk nanocrystalline bainitic steels.

Alloy	C	Si	Ni	Al	Mo	Mn	Co	Cr
A	0.72	3.87	3.40	1.39	0.21	0.02	<0.01	<0.01
B	0.45	0.30	13.20	2.63	0.30	0.15	3.99	<.005

Table 1: Chemical compositions, wt%

Alloy	Transformation Temperature / °C	Time / h
A	260	24
B	250	120

Table 2: Heat treatment scheme for mechanical test samples.

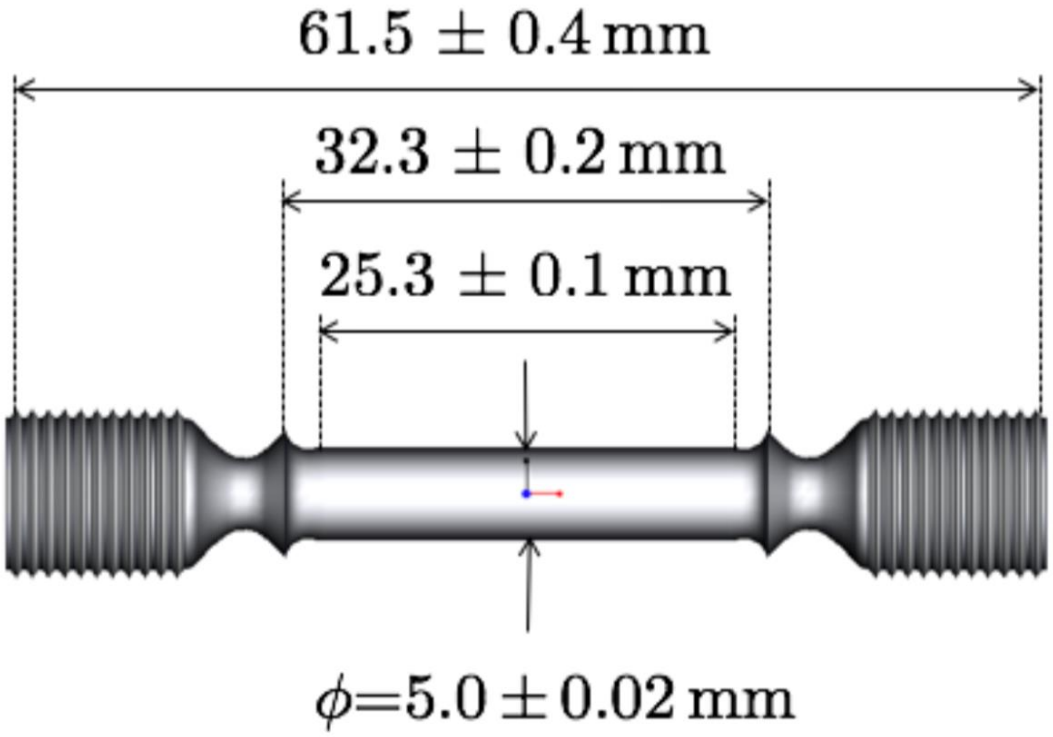
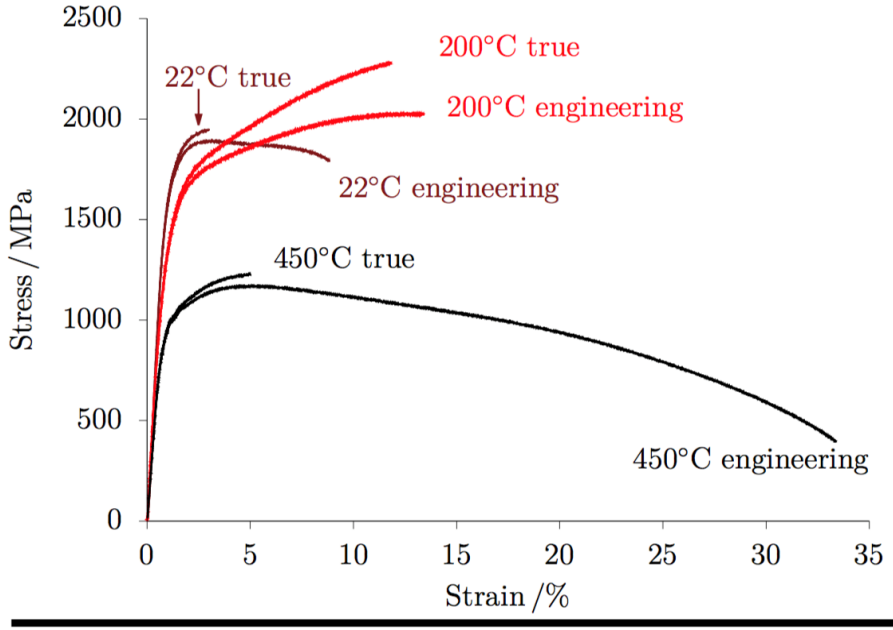
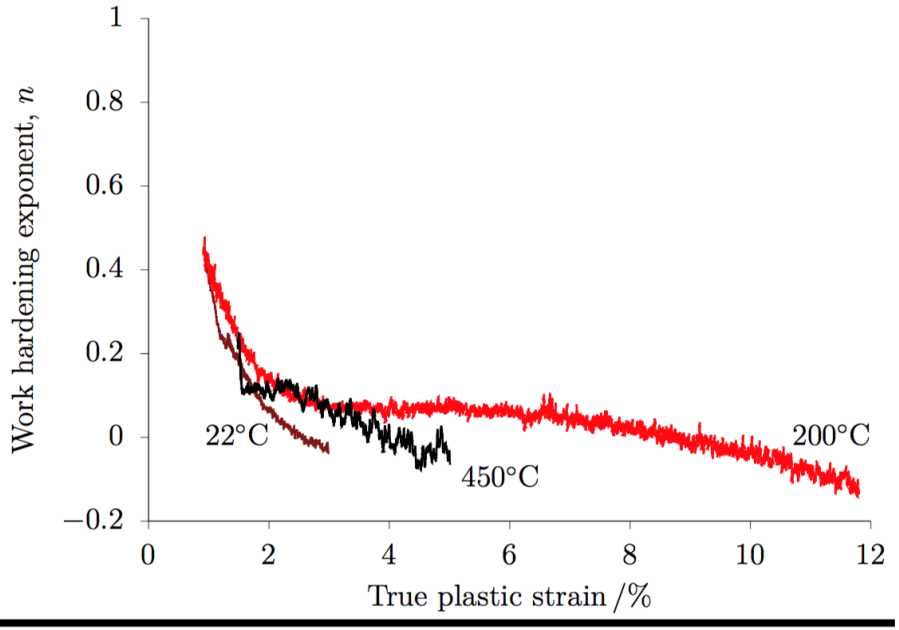


Figure 1: Sample geometry for tensile testing.

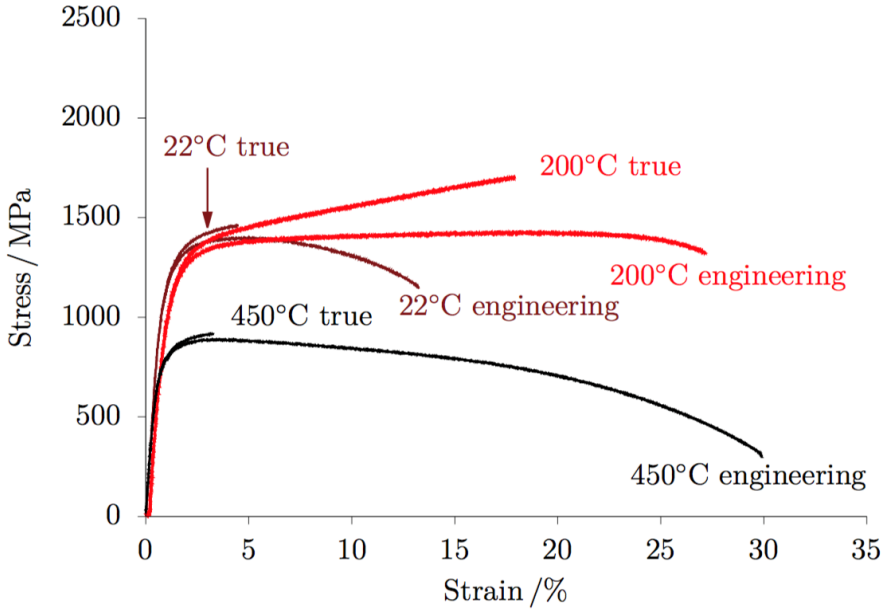
Tensile test Alloy A and work hardening exponent

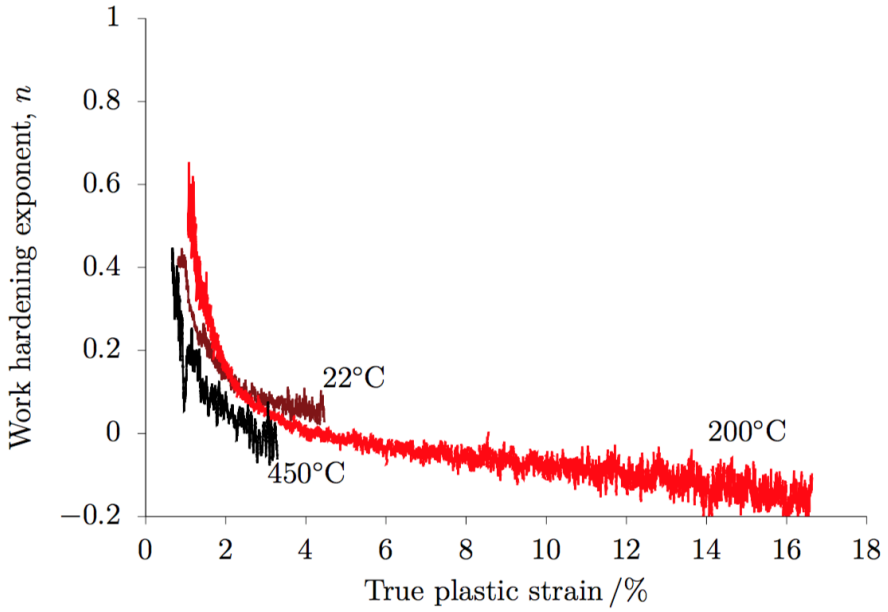




Alloy	Test Temp °C	0.2% PS MPa	σ_{UTS} MPa	U. Elon. %	F. Elon. %	R of A %
A	ambient	1516	1888	3.1	8.0	25.3
	200°C	1262	2024	12.7	12.2	16.5
	450°C	886	1169	-	28.1	79.9

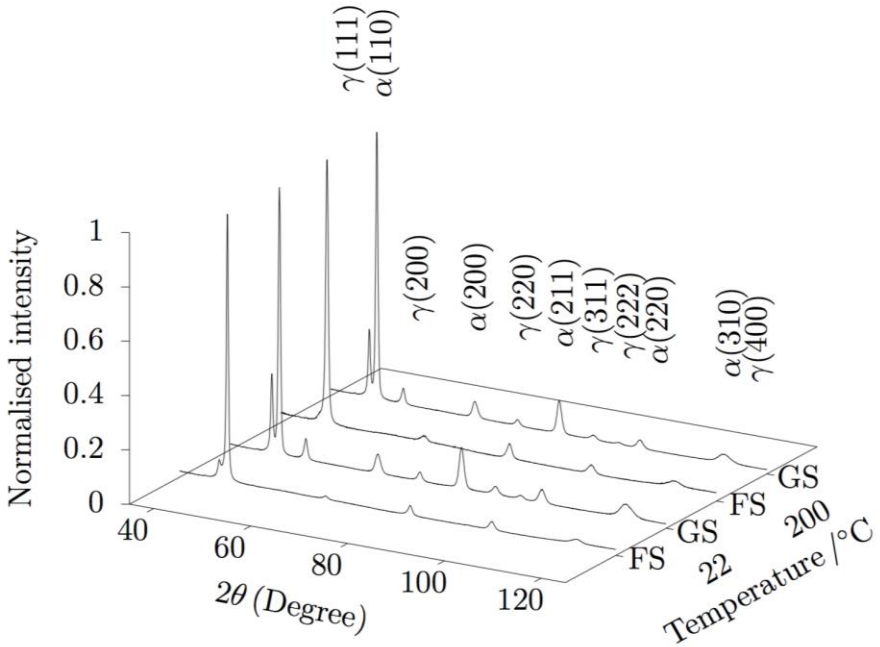
Tensile test Alloy B and work hardening exponent



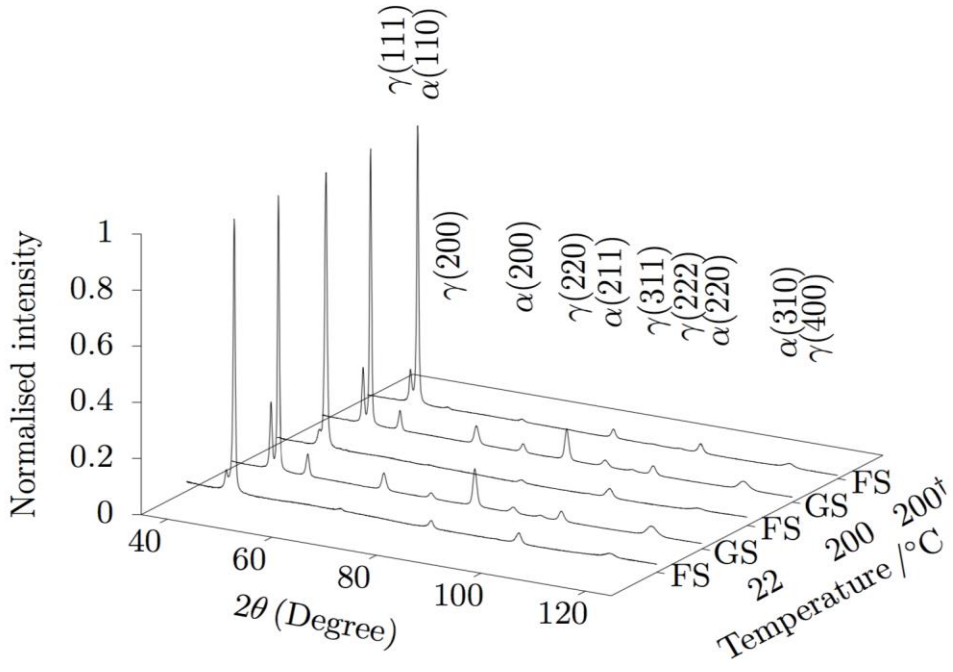


Alloy	Test Temp °C	0.2% PS MPa	σ_{UTS} MPa	U. Elon. %	F. Elon. %	R of A %
B	ambient	1036	1396	4.8	12.6	48.6
	200°C	889	1423	18.7	25.3	40.4
	450°C	695	888	-	25.1	84.4

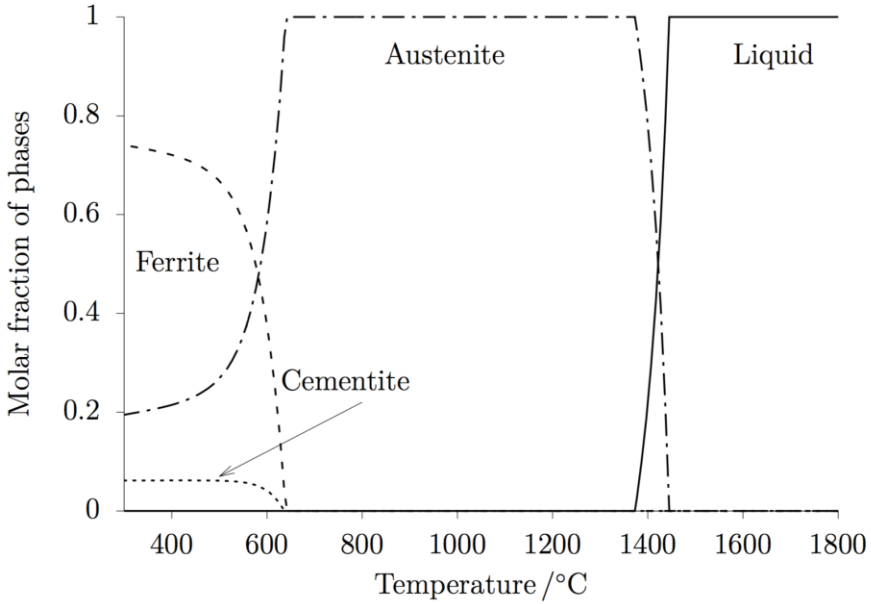
X-ray diffraction spectra



Alloy A

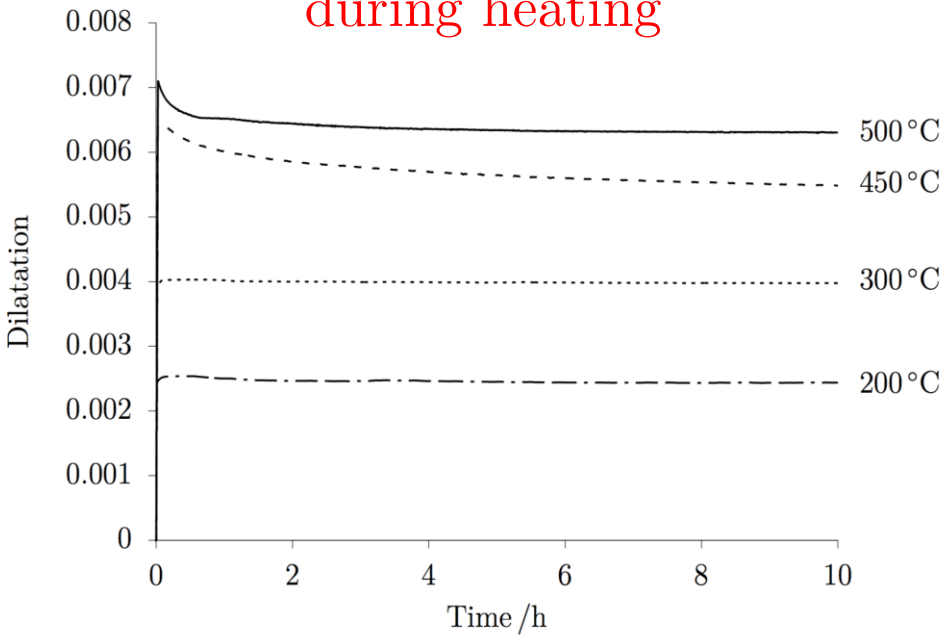


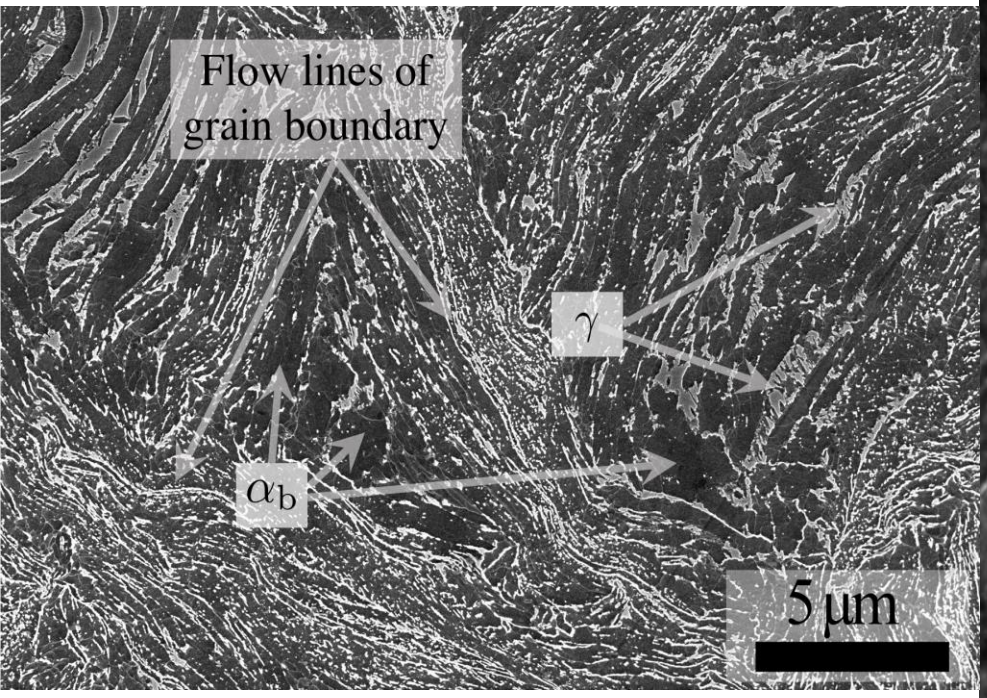
Alloy B

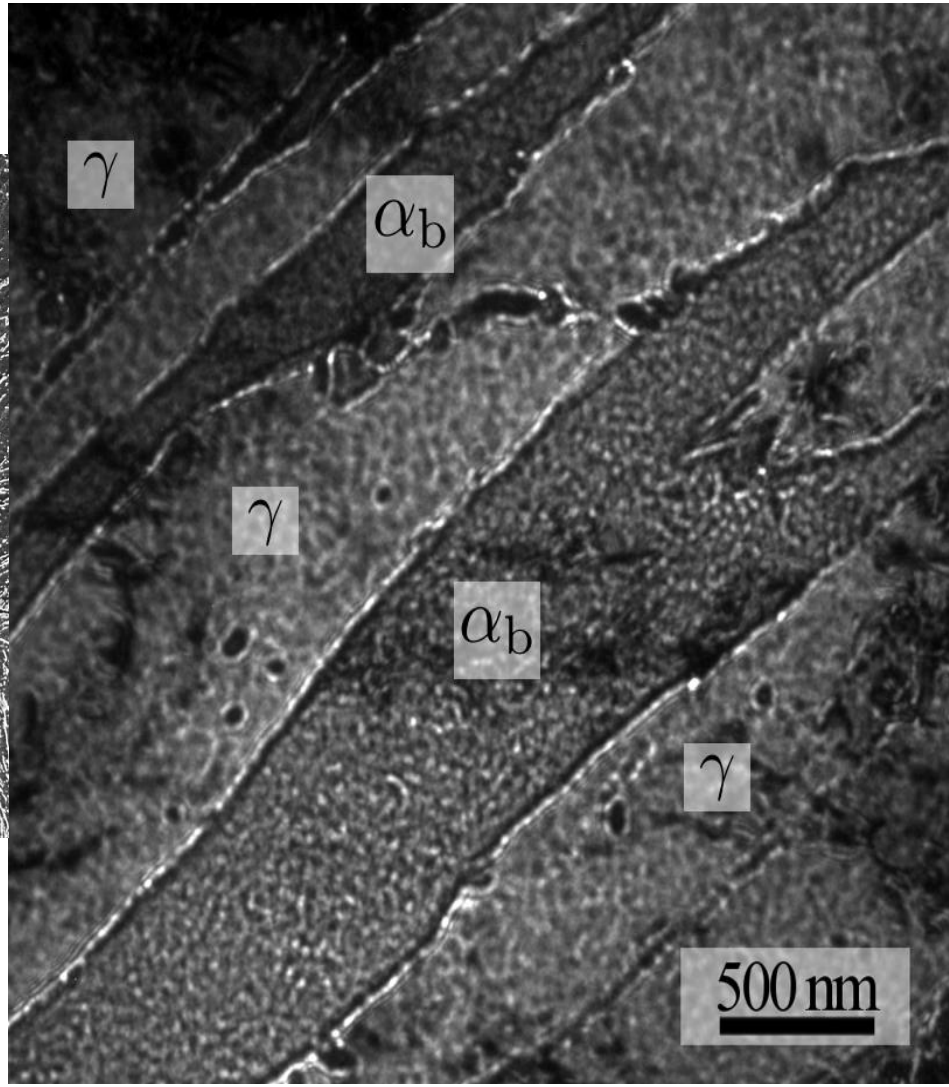


Phases fractions calculated for Alloy B (Thermo–Calc)

Dilatation for Alloy B during heating

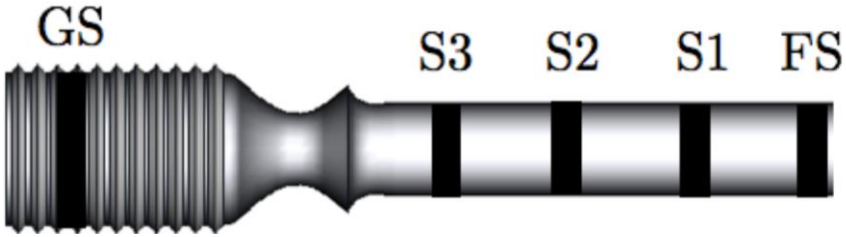


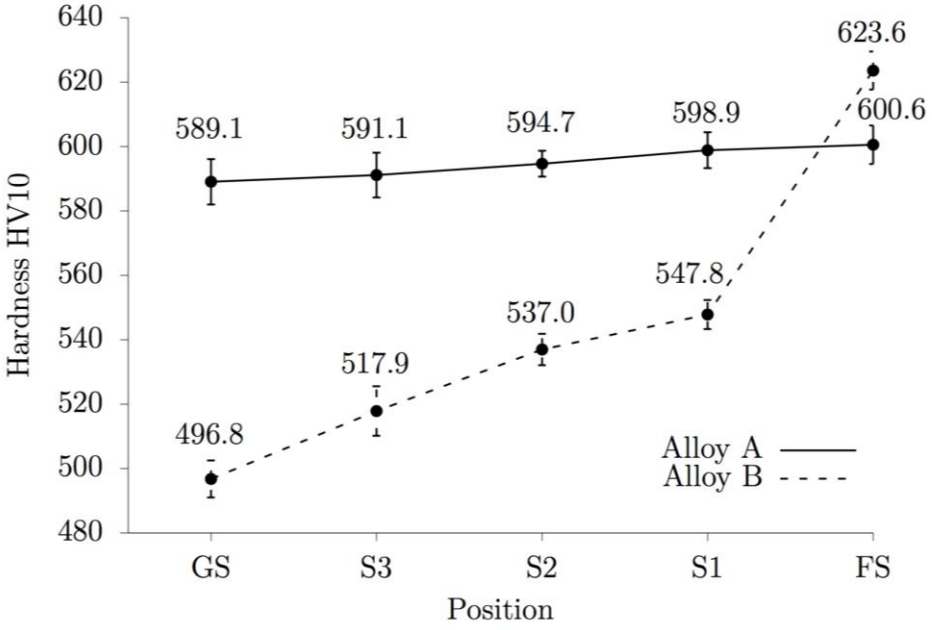


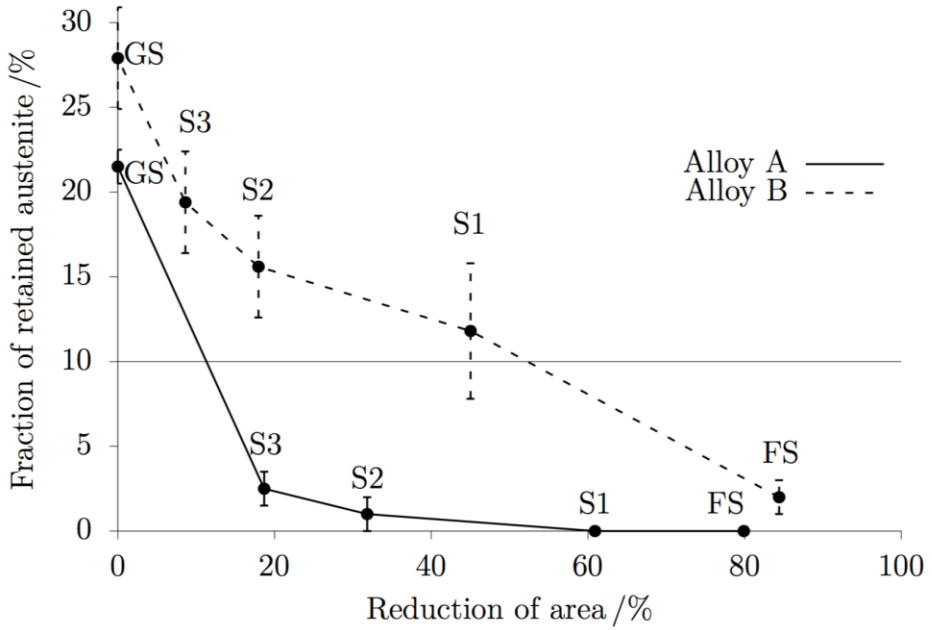


Alloy B 450°C
vicinity of the fracture surface

Deformed microstructure analysis of the 450°C

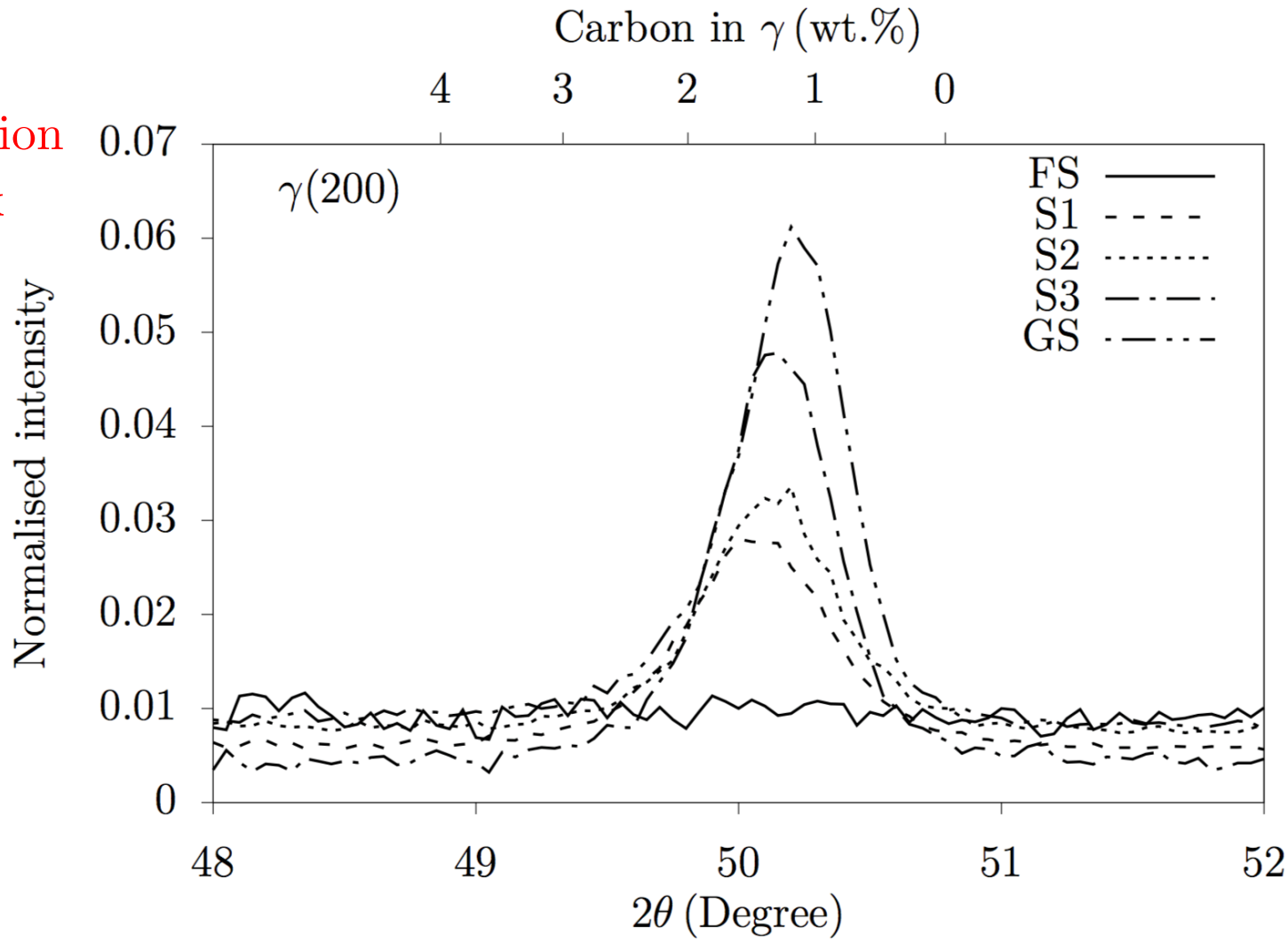






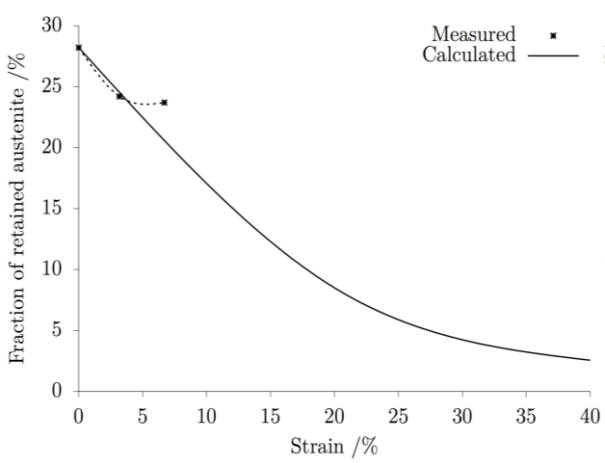
Effect of deformation on the X-ray peak

$\gamma(200)$ profiles of 450°C Allloy B

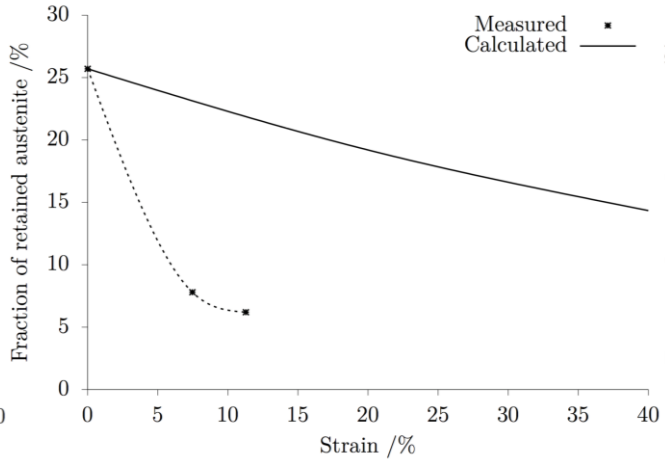


Stability of retained austenite

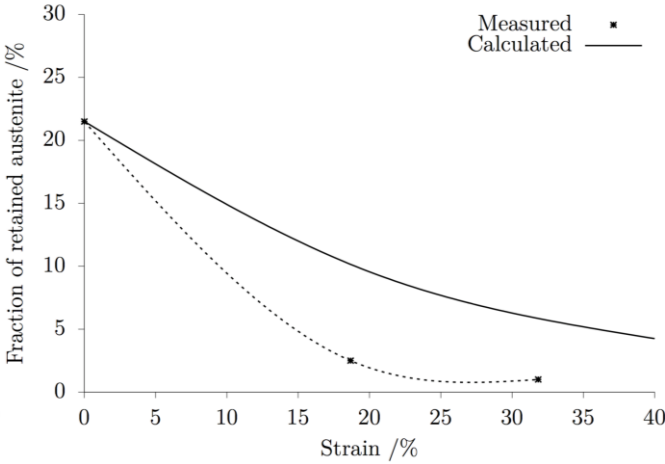
$$\ln\{V_V^{\gamma\circ}\} - \ln\{V_V^{\gamma}\} = k_\gamma \epsilon$$



22°C



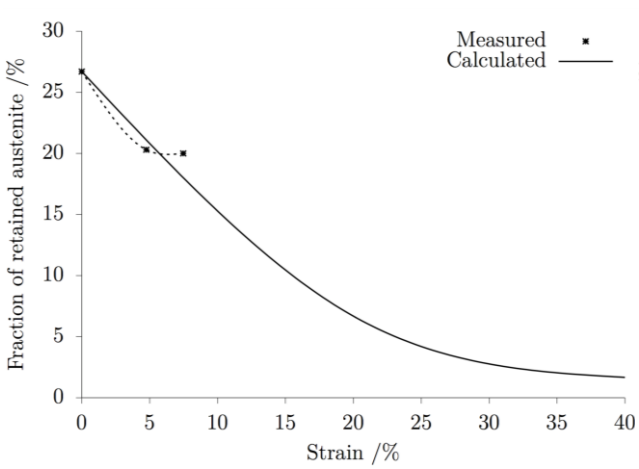
200°C



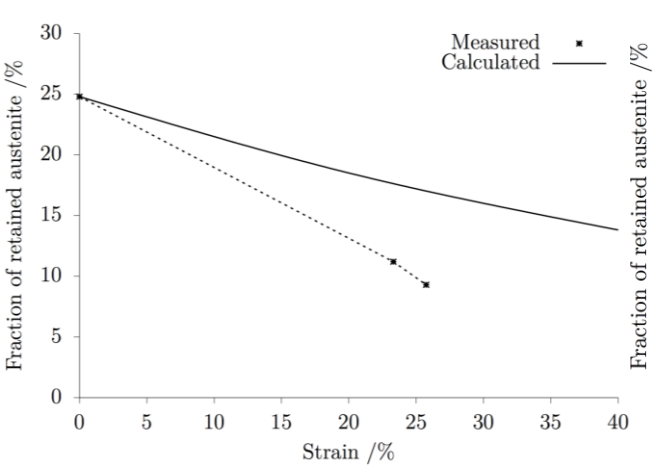
450°C

Alloy A

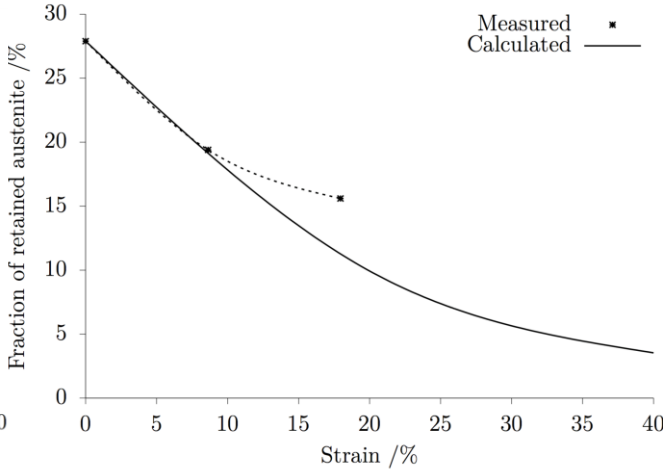
Stability of retained austenite



22°C



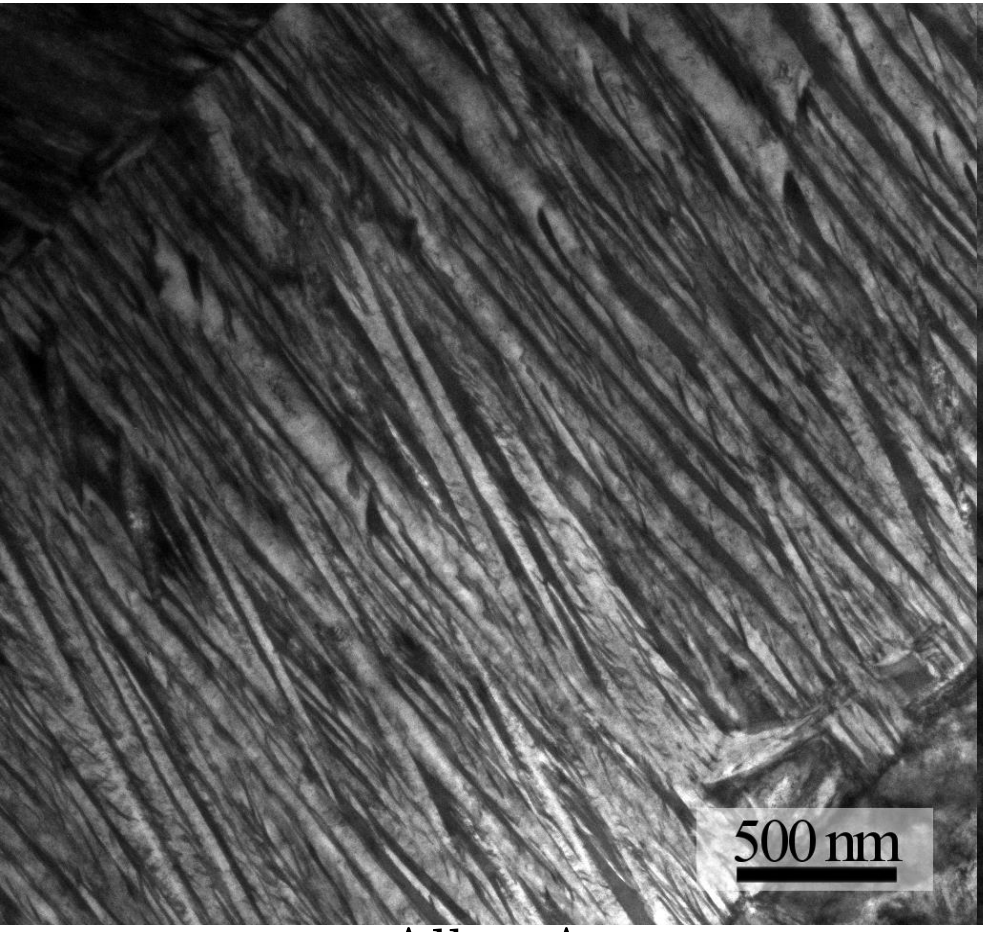
200°C



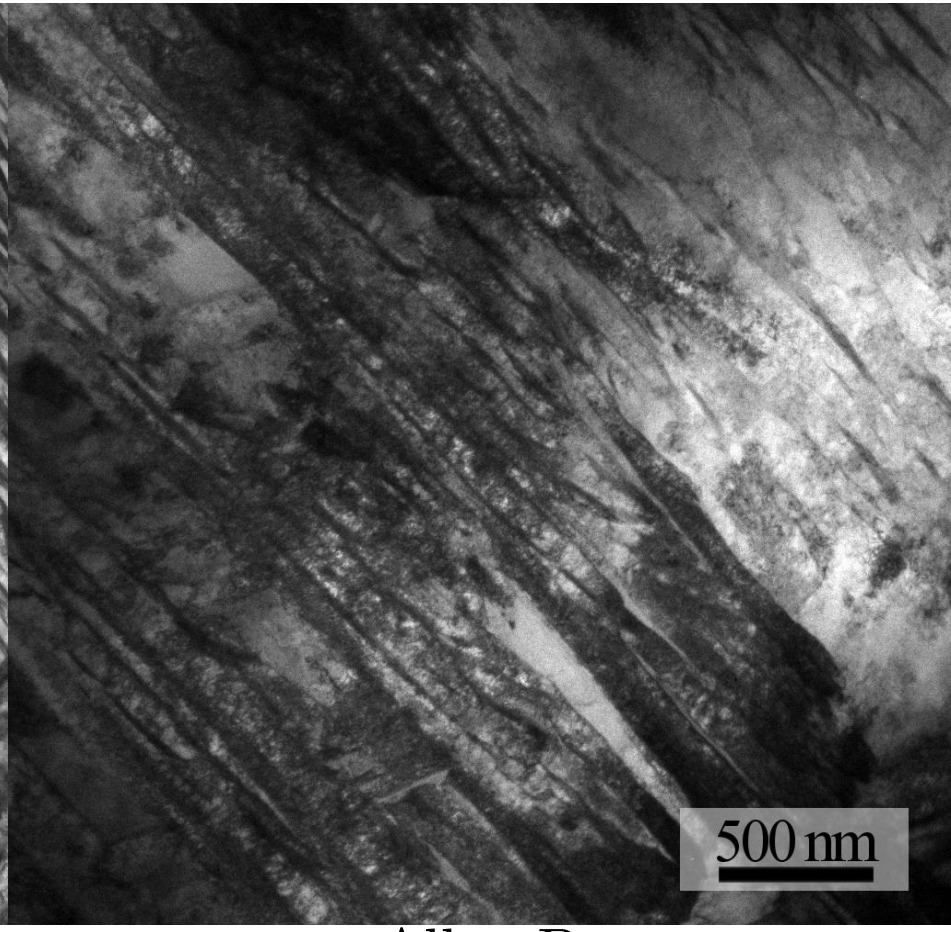
450°C

Alloy B

Bright field images as transformed

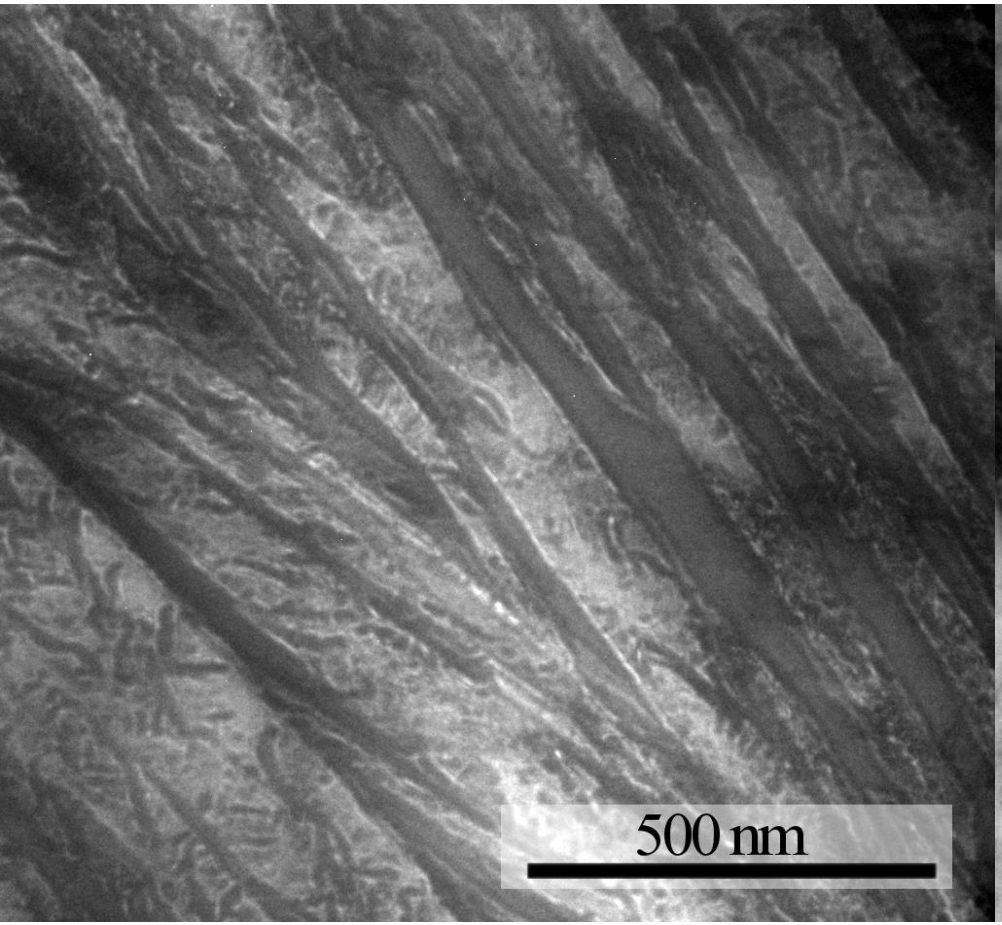


Alloy A

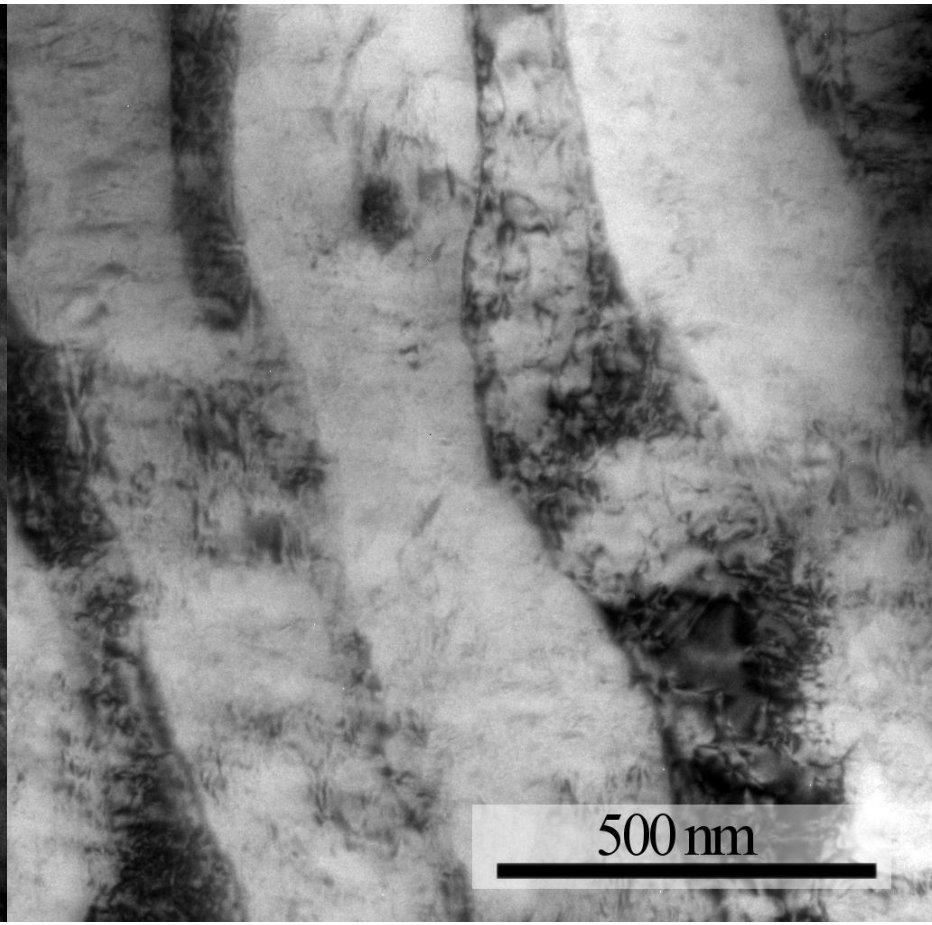


Alloy B

Bright field images as transformed tested at 200°C



Alloy A



Alloy B

Summary

- Testing at ambient temperature resulted in a typical of very strong materials. However, limited though reasonable ductility, (strength excess of 1.5 GPa).
- Tensile testing at 200°C led not only to an increase in strength but at the same time, a remarkable increase in ductility for both alloys.
- When testing the structure at 450°C, there is a dramatic collapse in the uniform ductility due to the rapid onset of plastic instability.