Room Temperature Plastic Flow Localization in a Mn-Alloyed Austenitic Steel

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Automotive Structural Steels (I)

desired properties of automotive steel structures :

Lower weight
- *Lower fuel consumption*
- *Lower pollution emission (Euro 4 – 5 …)*
- *Increase useful load (commercial vehicle)*
- *Lower cost*

Increased safety *Better crash energy absorption*

Dent resistance of automotive body components

Automotive Structural Steels (II)

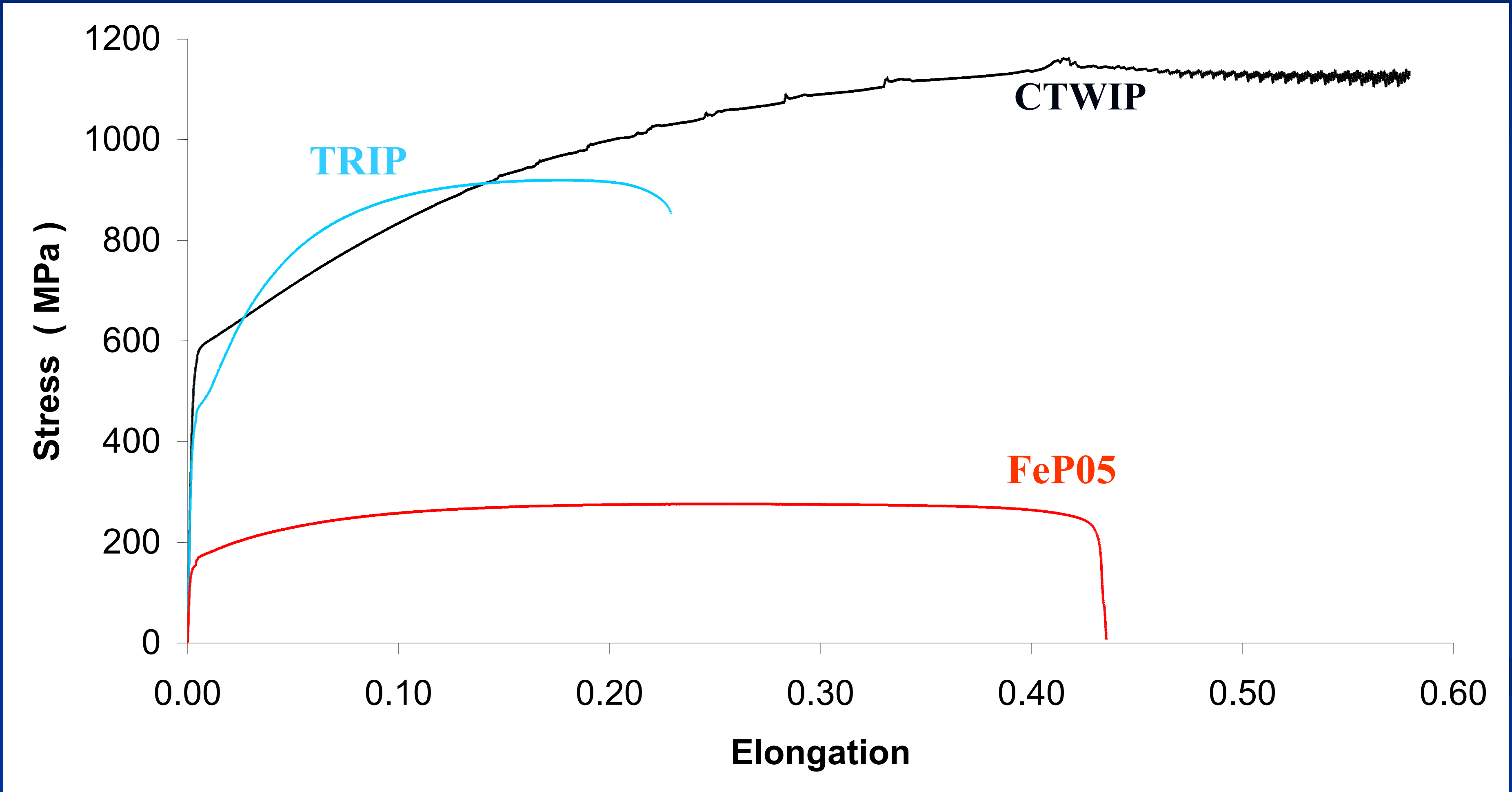
- Current high-strength automotive steels:
  - HSLA (High Strength Low Alloy steel)
  - Dual Phase
  - TRIP (TRansformation Induced Plasticity)
- Recently proposed:
  - TWIP (TWinning Induced Plasticity)

High strength
High ductility
High energy absorption

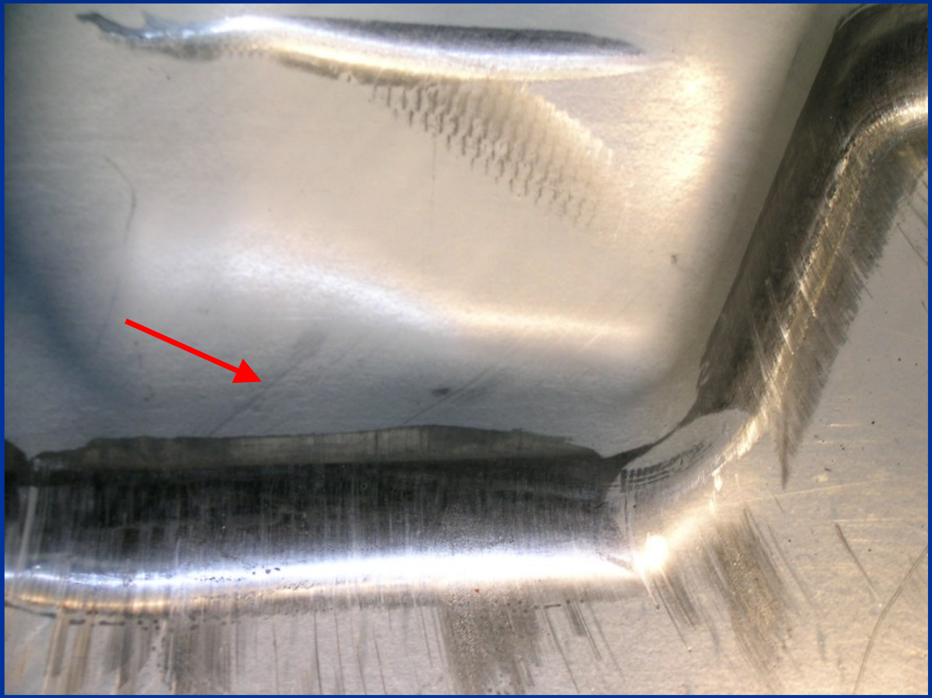
Examined here:
medium-C TWIP steel
(CTWIP)

Automotive Structural Steels (III)

typical tensile curves



Deep drawing



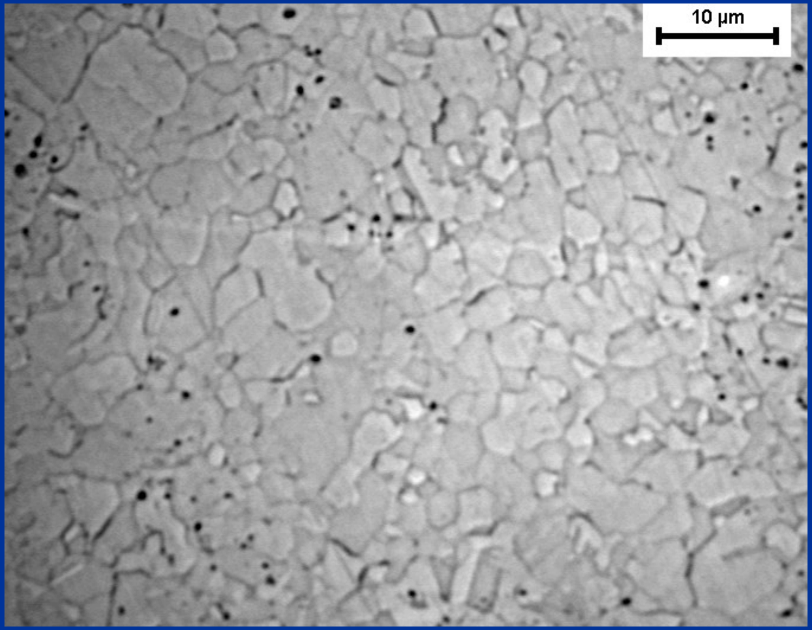
Localized deformation bands

Aesthetic defect

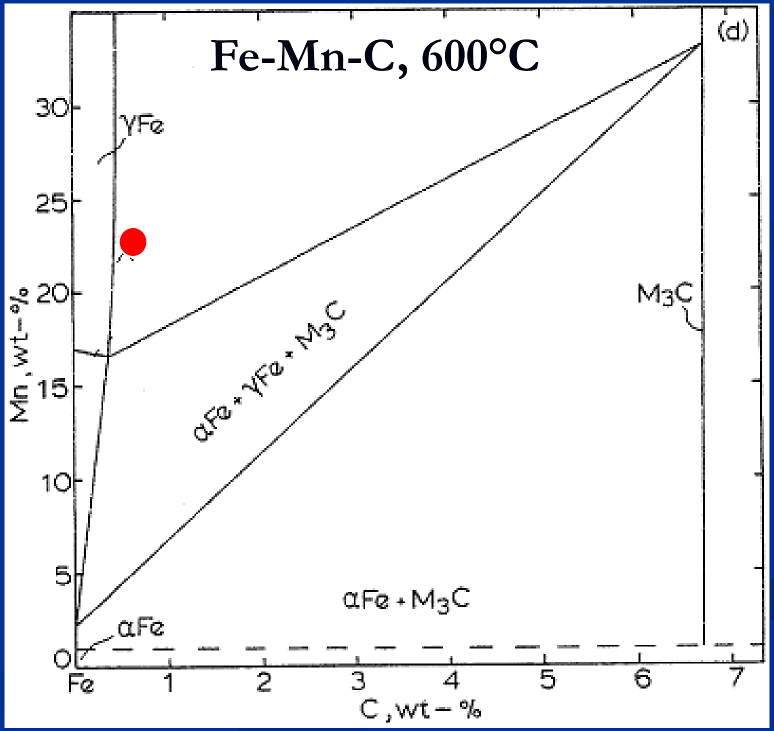
Examined CTWIP steel

steel	C	Mn	Ni	Si	Cr	P	S	V	Al
CTWIP	0.48	23.5	0.05	0.16	0.13	0.025	<0.001	0.22	<0.001

C**:** **increases YS and UTS** ***Mn:*** **stabilizes austenite, decreases SFE (→ twinning)**



average grain size = 2.5 µm

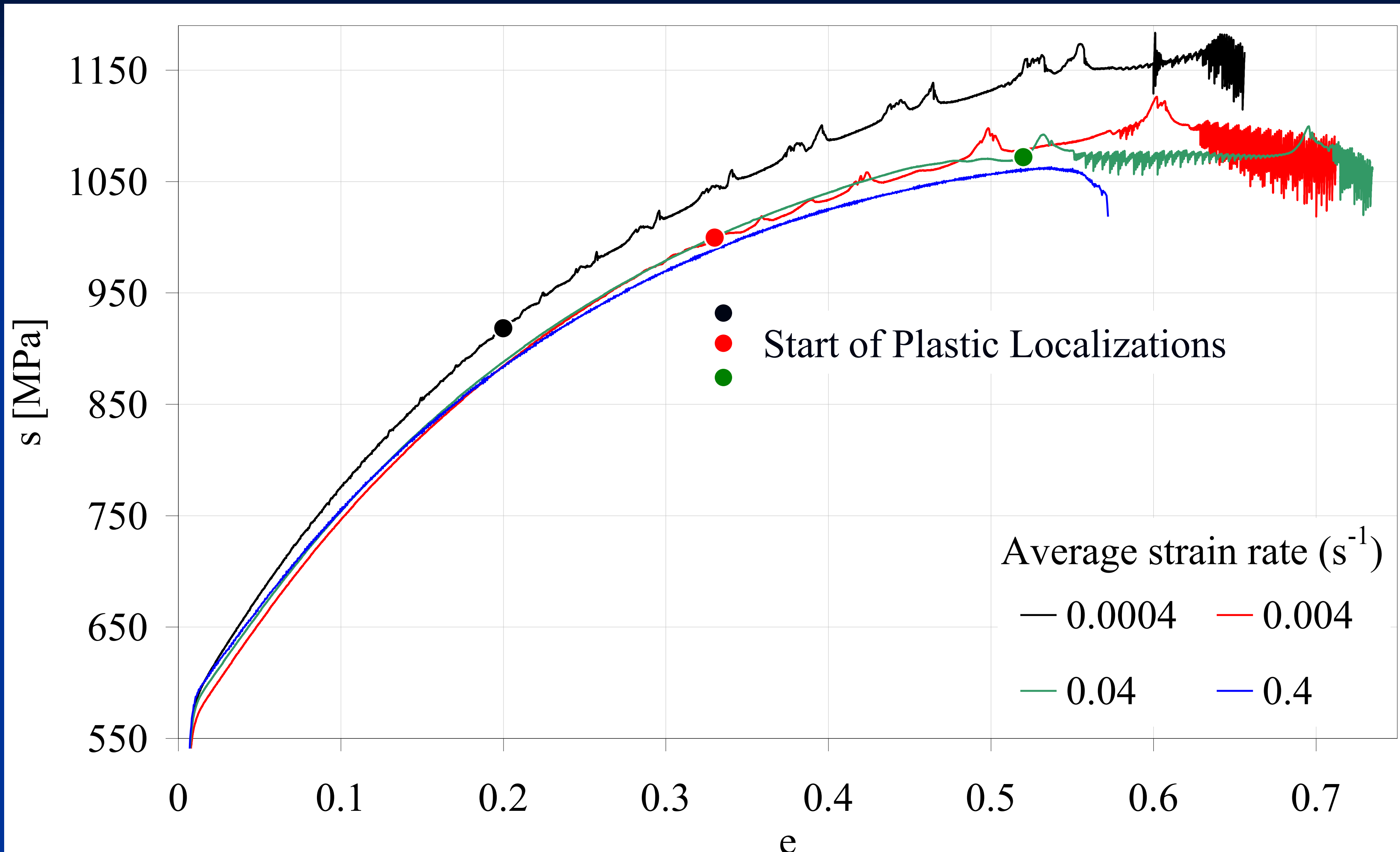


Tensile test results

Cross-head speed	Strain rate (mean)	Yield strength	Tensile strength	Uniform elongation	Strain hardening exponent	ε_{PL}*
mm/s	s^{-1}	MPa	MPa	%	-	-
0.06	0.0004	555	1180	65	0.35	0.2
0.5	0.004	540	1125	70	0.37	0.33
5	0.04	552	1100	72	0.37	0.52
40	0.4	557	1065	56	0.34	Not observed

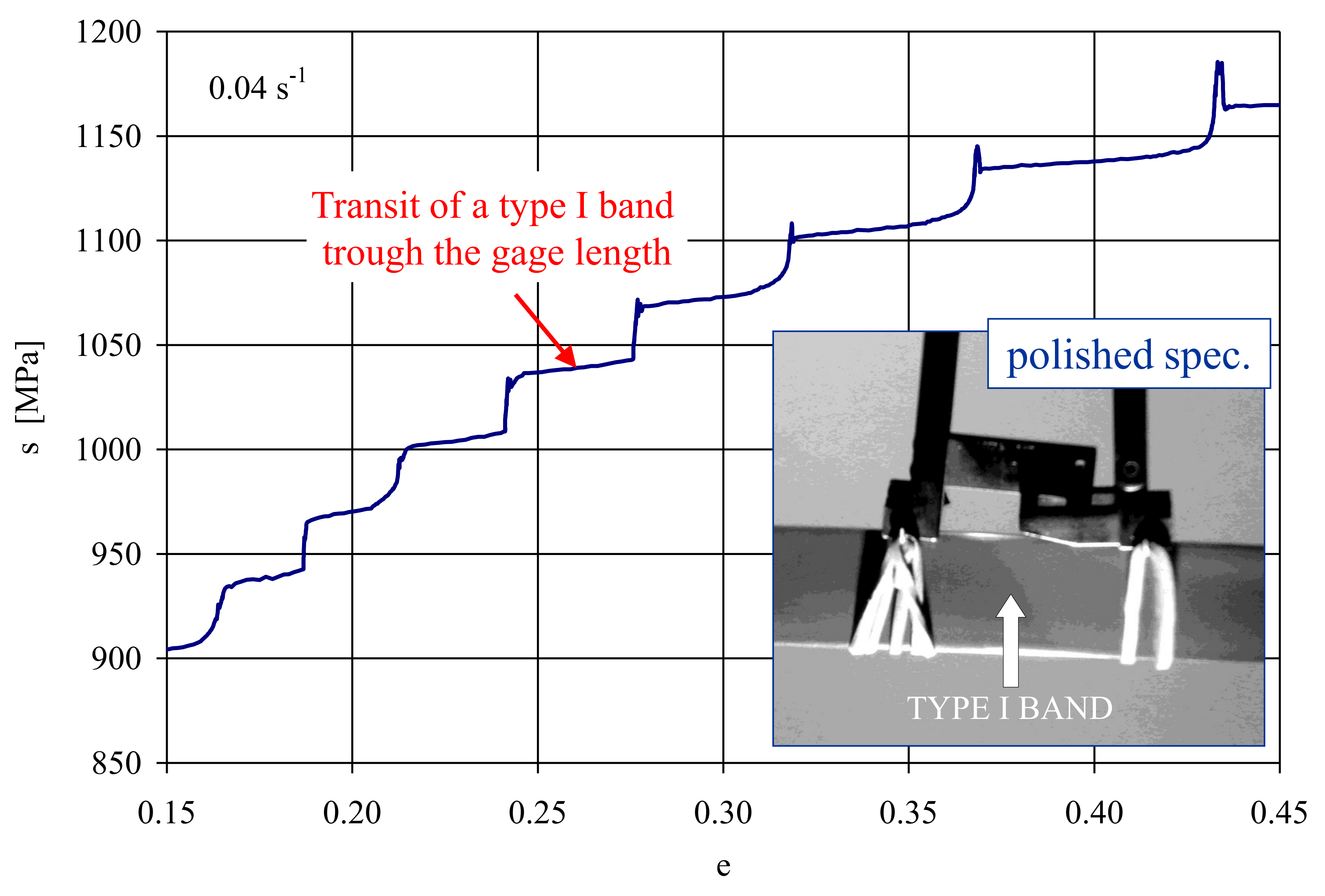
ε_{PL}: strain at onset of Plastic Localization (PL)

Tensile Stress-Strain curves



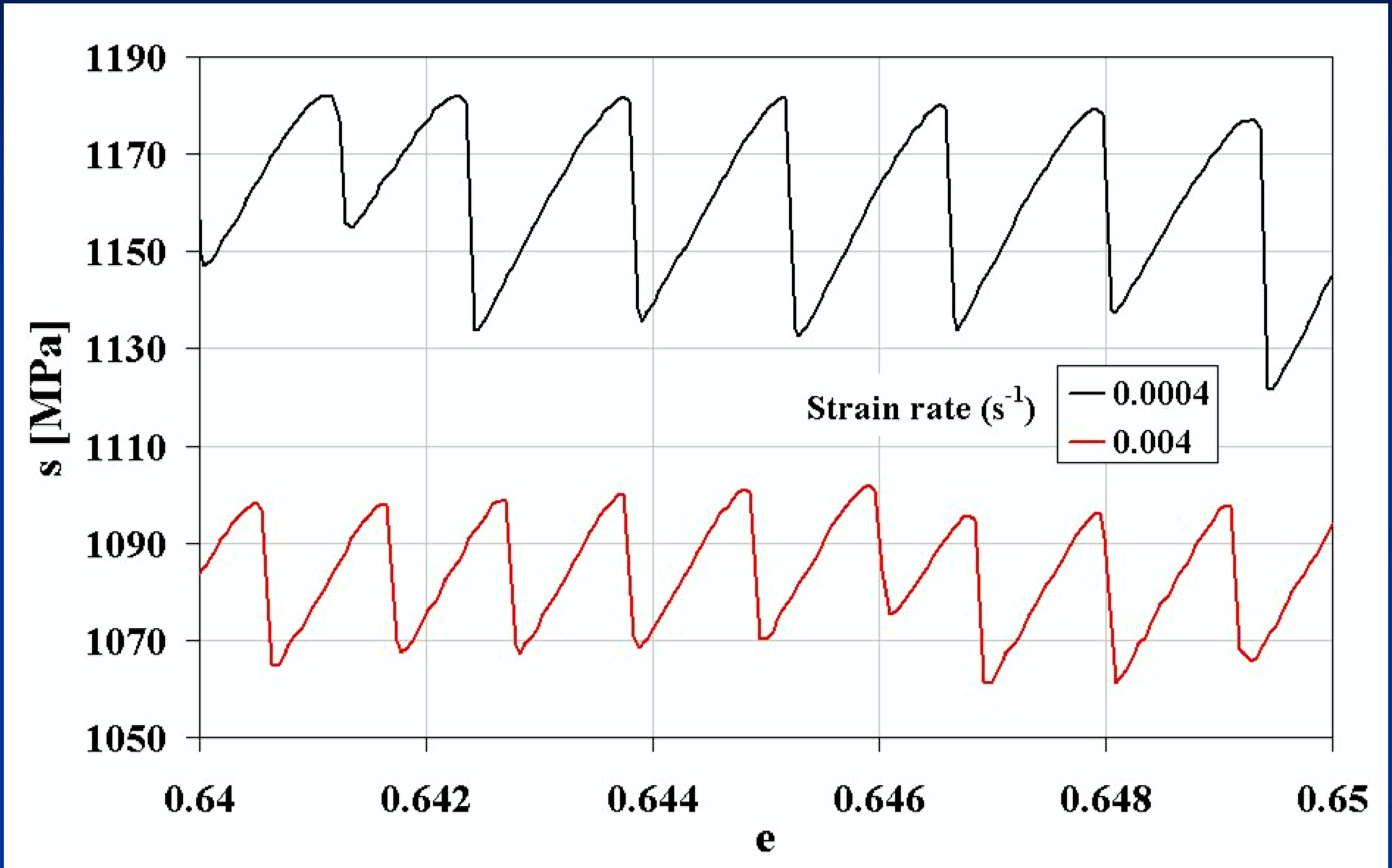
Strain calculated from the cross-head displacement

Type I Plastic Localizations



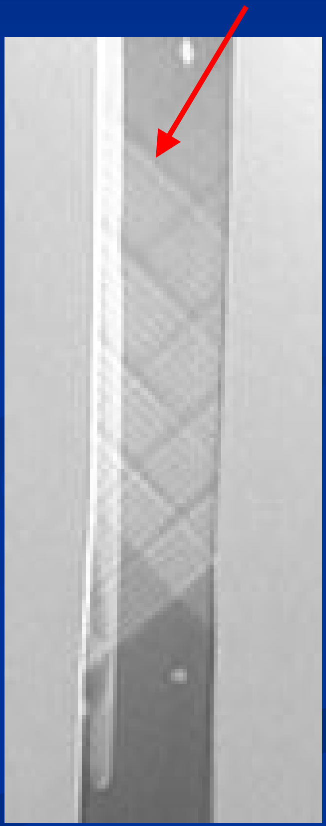
Strain calculated from the gage displacement

Type II Plastic Localizations

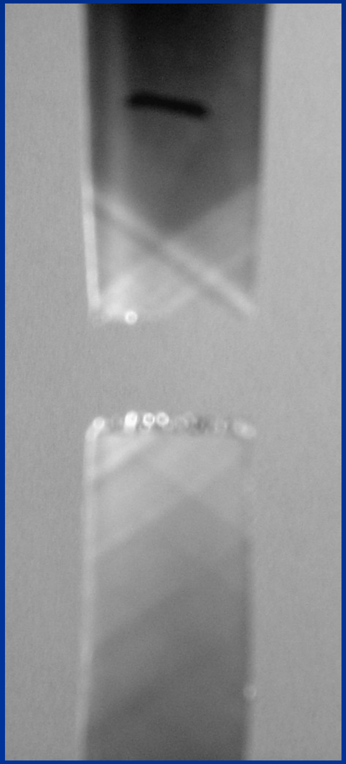
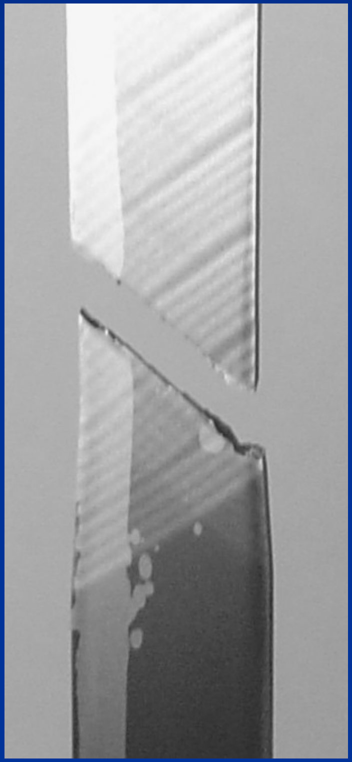
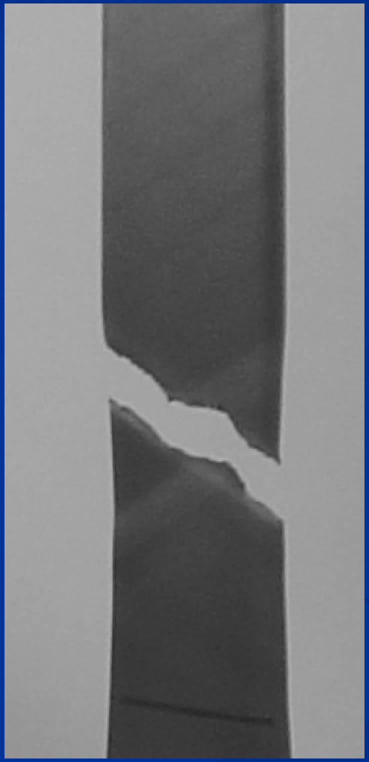
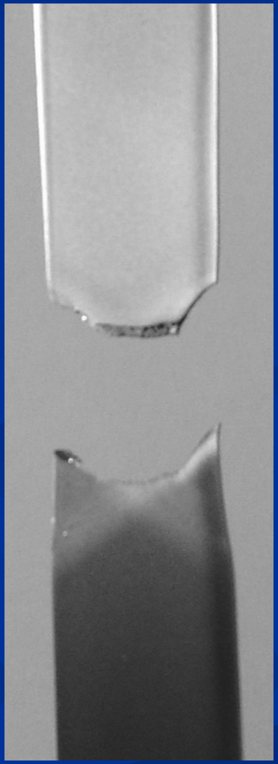


Strain calculated from the gage displacement

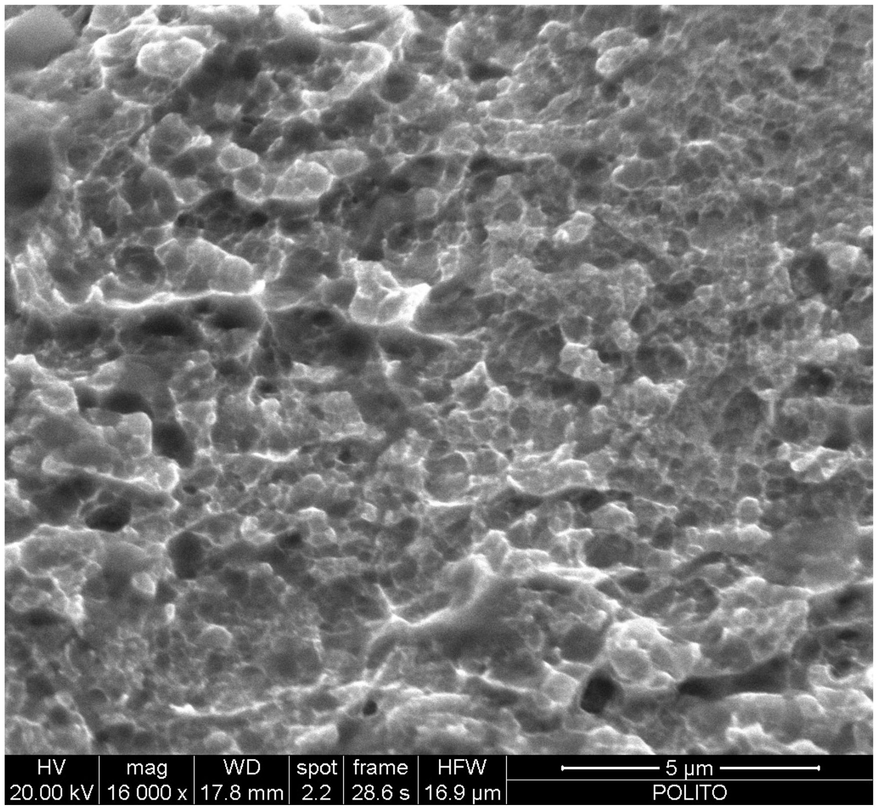
crossed type II stationary bands



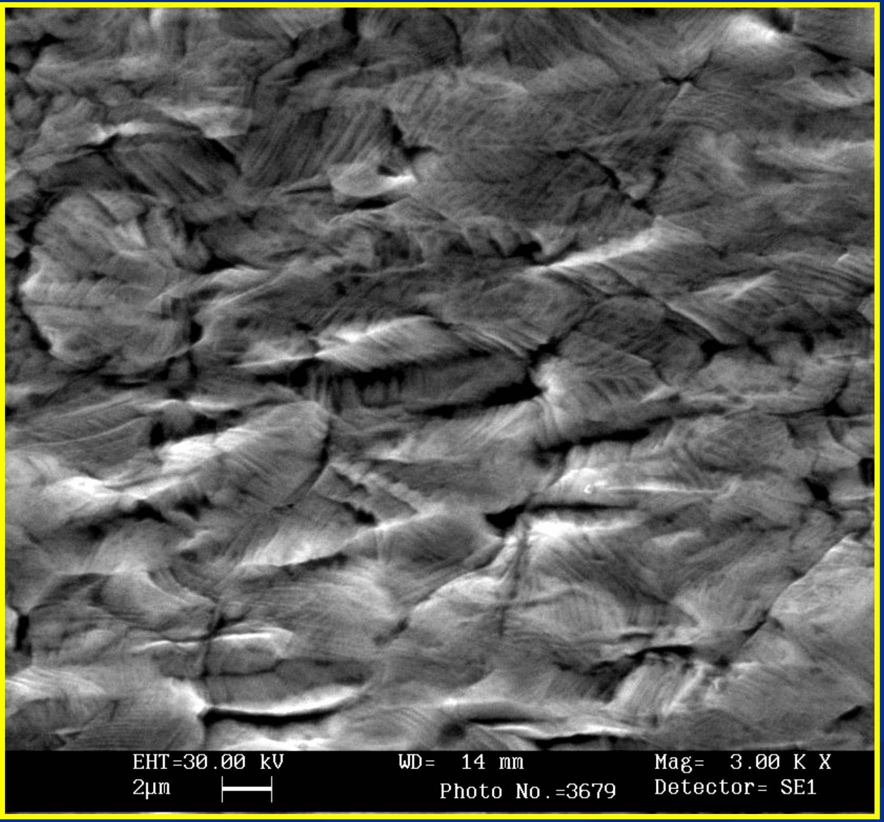
Macroscopic Fracture Mode

$0.0004\ s^{-1}$	$0.004\ s^{-1}$	$0.04\ s^{-1}$	$0.4\ s^{-1}$
			

SEM analyses

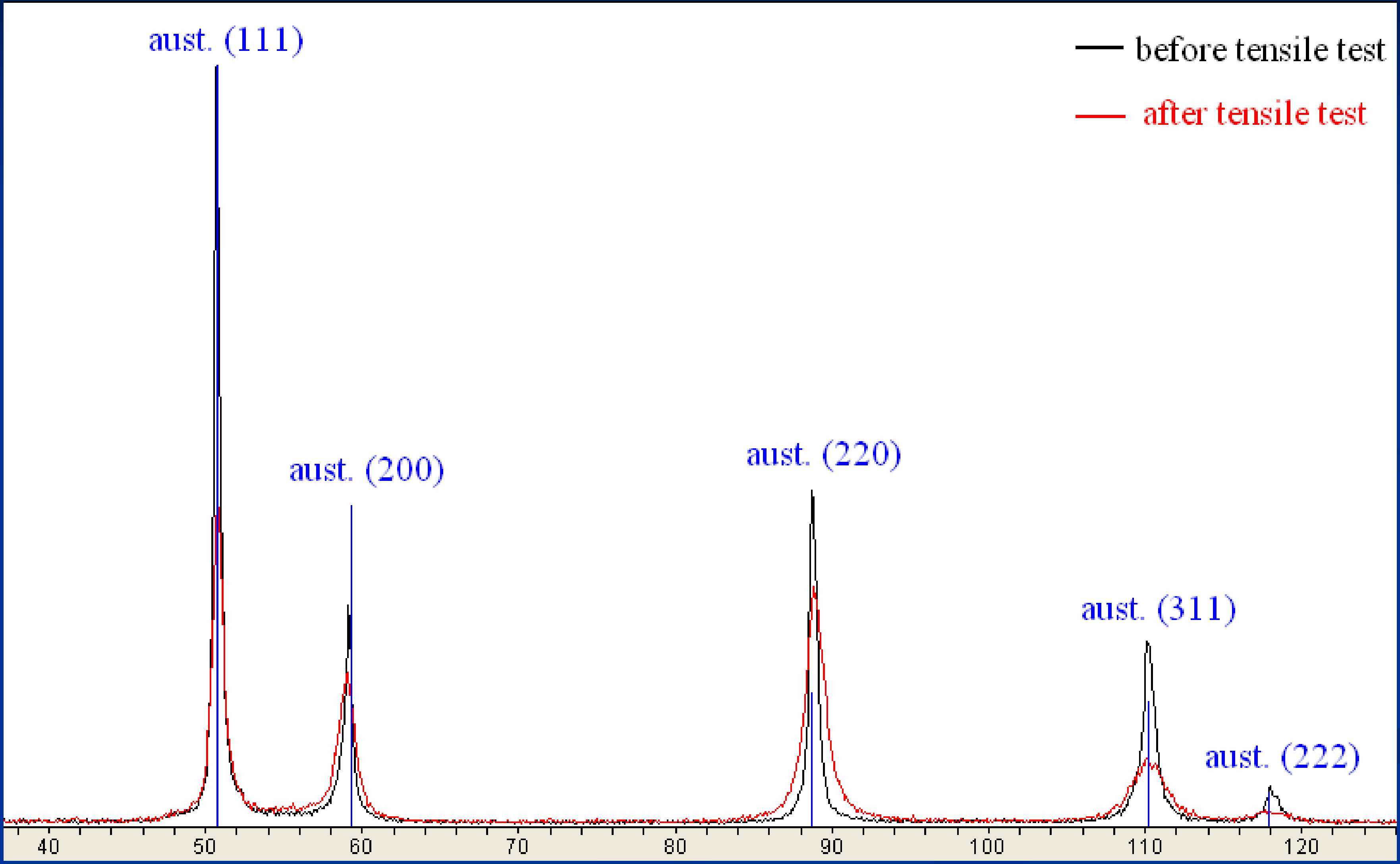


Fracture surface (microvoids)



Plastic deformation relief on the previously polished specimen surface

X-Ray Diffraction



Discussion - Portevin-Le Chatelier (PLC) Effect

- Plastic instabilities due to inhomogeneous plastic deformation
- occurring in limited strain-rate and temperature ranges
- due to a negative strain rate sensitivity
- in turn possibly due to Dynamic Strain Aging (DSA)

Known band types:

- ❑ **A** : propagate continuously along the tensile axis
- ❑ **B** : oscillatory / intermittent propagation
- ❑ **C** : appear suddenly and do not propagate

Conclusions

- The CTWIP steel exhibit a favorable combination of strength and ductility
- It also exhibit PLC effect at R.T. for strain rates less than 0.4 s^{-1}
- Both type A and C (I and II herein) bands were observed
- This may arise from interactions between solute C atoms and mobile dislocations, yielding a negative strain rate sensitivity