Karlsruher Institut für Technologie

Ductility in ultrafine-grained (UFG) tungsten foil:

Correlation between microstructure and mechanical properties

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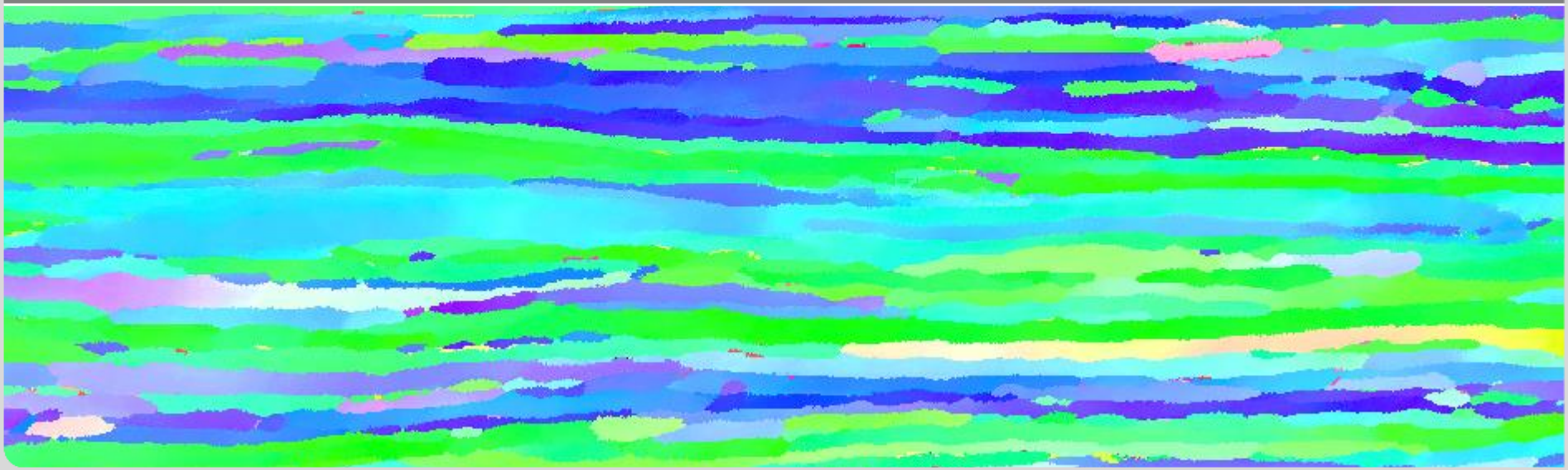
29.09.2016, MSE, Darmstadt

Institute for Applied Materials – Applied Materials Physics (IAM-AWP)



Tungsten foils

Tungsten is BRITTLE

tungsten as structural material

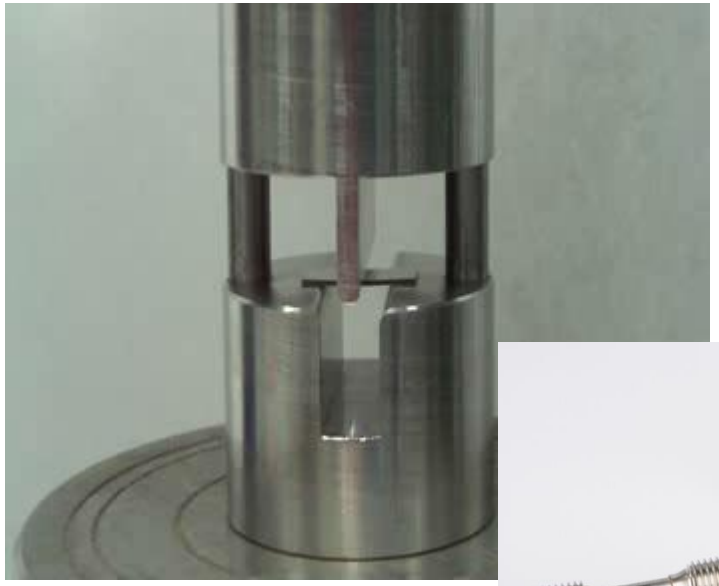
alloying

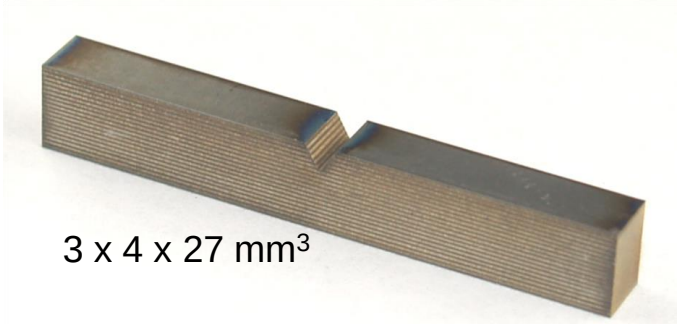
modification of microstructure

compound material

„ultrafine-grained“ (UFG) tungsten foil by cold rolling

W laminates



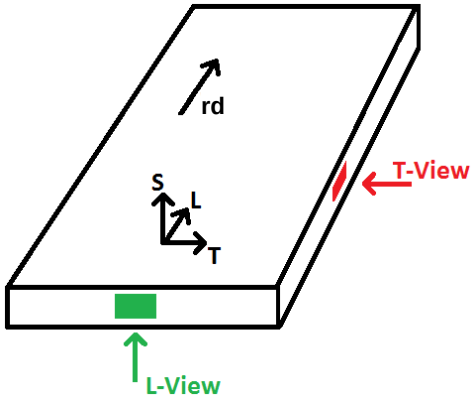


WHY ARE THESE FOILS DUCTILE?

Identification of deformation mechanisms

Materials

- exclusive tungsten foils from PLANSEE SE:
  - 5 sheets with different degree of deformation:
    1 mm – 0,5 mm – 0,3 mm – 0,2 mm – 0,1 mm
  - „cold rolling“ (rolling temperature << 1200°C)
  - One single sintered compact (> 99.97 wt.-% W)



degree of deformation & rolling paramter

thickness [mm]	sintered compact	5.5	1	0.5	0.3	0.2	0.1
φ_{TOTAL}	/	/	1.7	2.4	2.91	3.31	4
$T_{ROLLING}$	/	hot-rolling	cold-rolling				cold-rolling

I. DIRECT ANALYSIS: ELECTRON MICROSCOPY BASIS ANALYSIS MICROSTRUCTURE

II. INDIRECT ANALYSIS: MECHANICAL TESTING

a) Tensile tests

b) Strain rate jump tests

III. CONCLUSION & OUTLOOK

Microstructure

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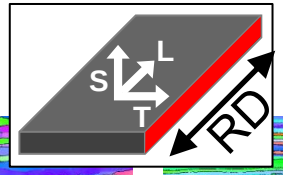
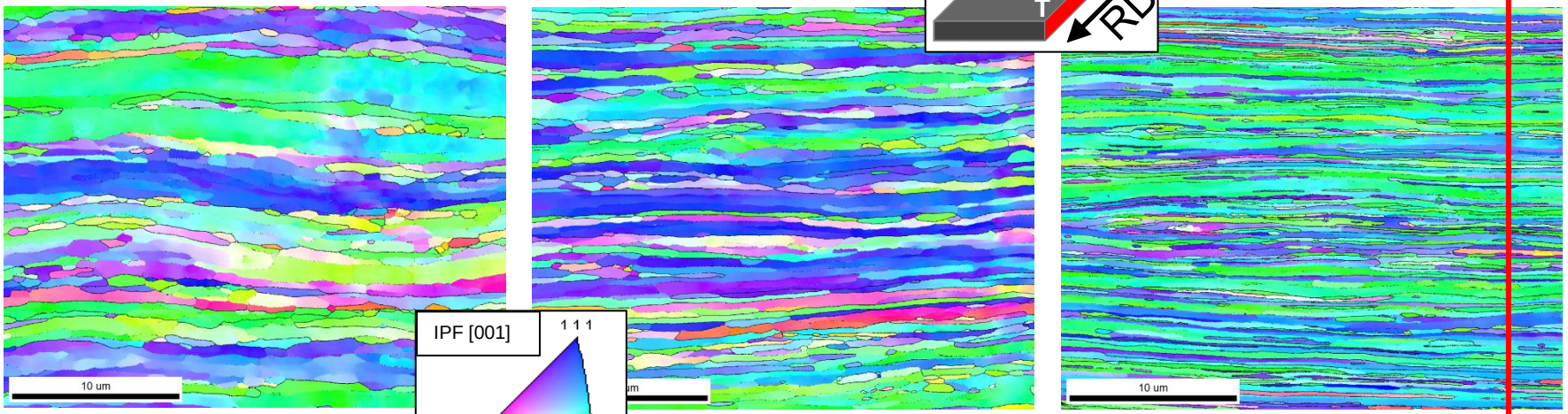
„T-View“



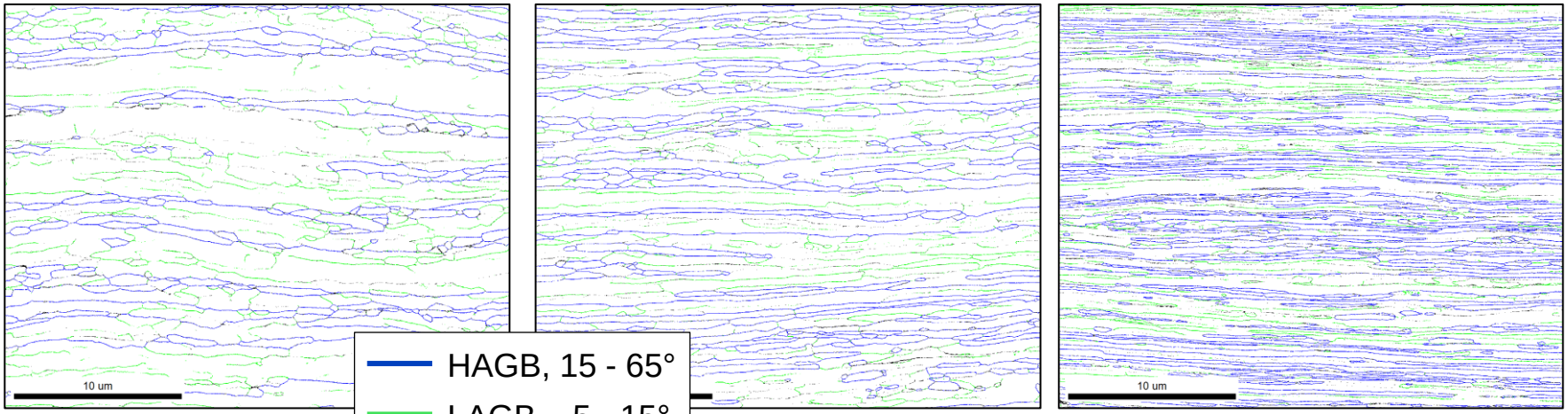
S-Direction

IPF



1 mm | 300 µm | 100 µm

GBs



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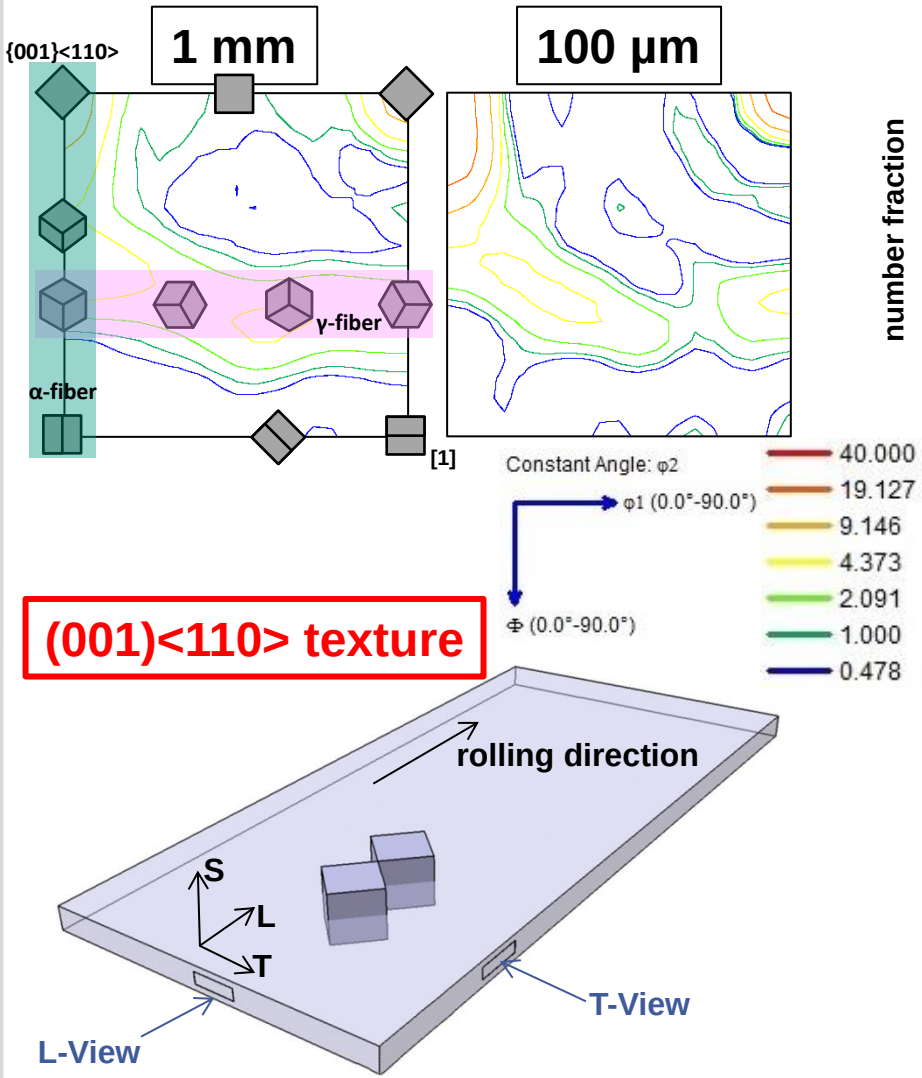
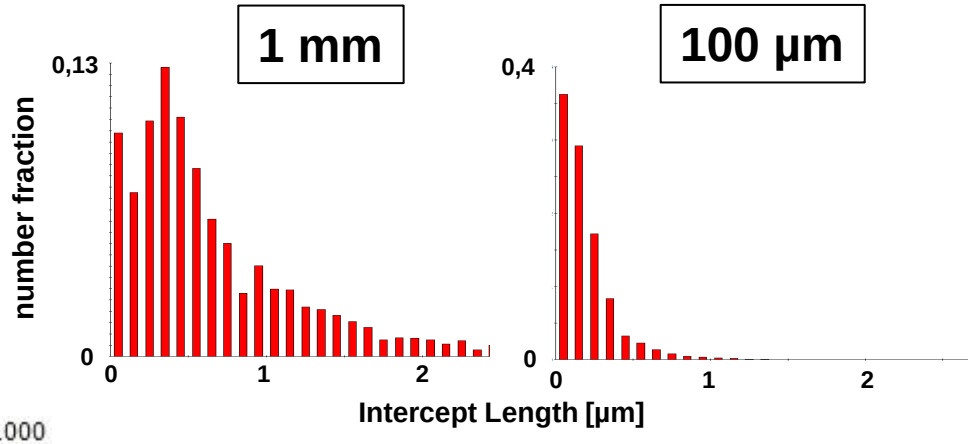
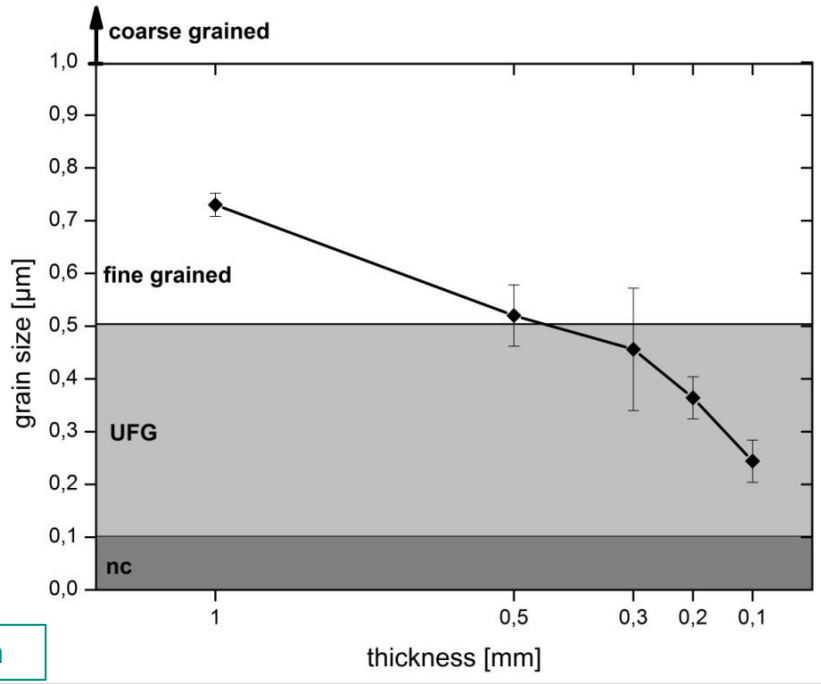
MSE, Darmstadt, 2016

Microstructure: texture







microstructure of cold rolled UFG-W: C. Bonnekoh, B09, 3:30 pm

[1] Interpretation ODF-function: E. Bruder, PhD-Thesis, TU Darmstadt, 2010

I. DIRECT ANALYSIS: ELECTRON MICROSCOPY

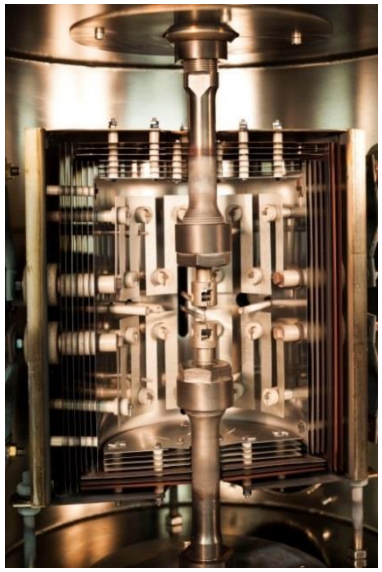
II. INDIRECT ANALYSIS: MECHANICAL TESTING

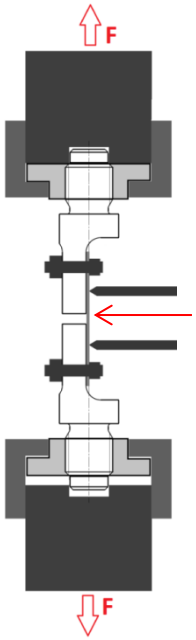
a) **tensile tests**

b) strain rate jump tests

III. CONCLUSION & OUTLOOK

Tensile tests





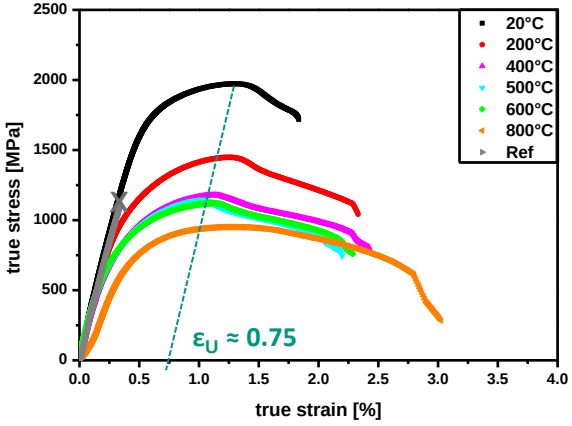
W300: pronounced hardening

plastic deformation

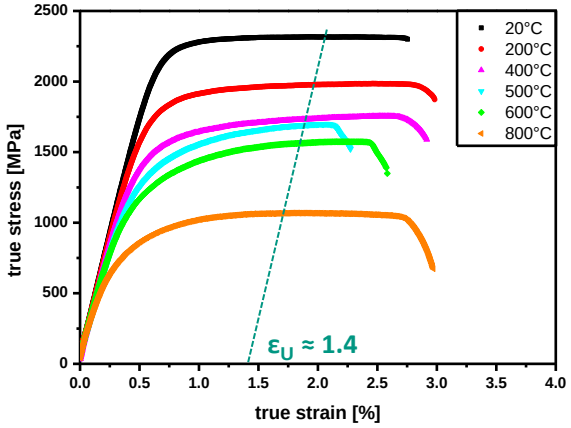
W100: elastic – ideal plastic

enhanced uniform elongation

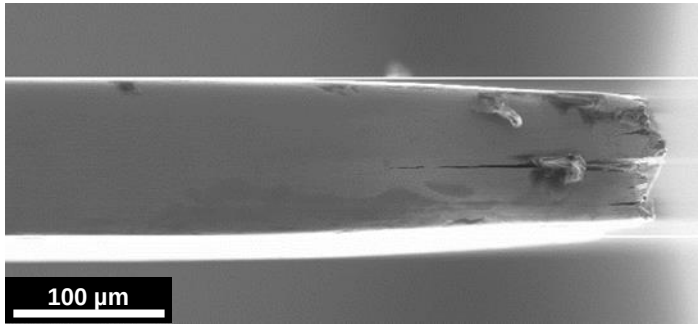
W300



W100

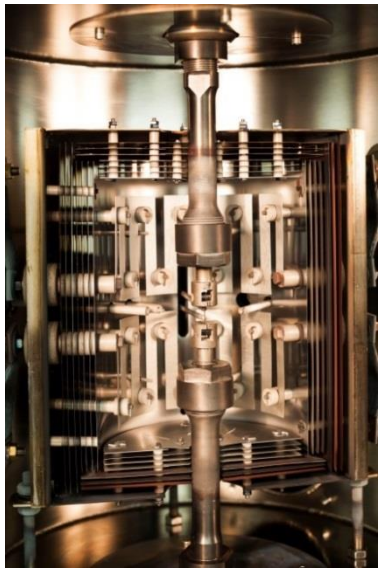


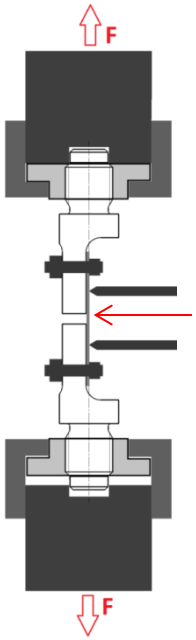
necking:



[1] Argon, Acta Metall. Mater. 14 (1966)

Tensile tests





W300: pronounced hardening

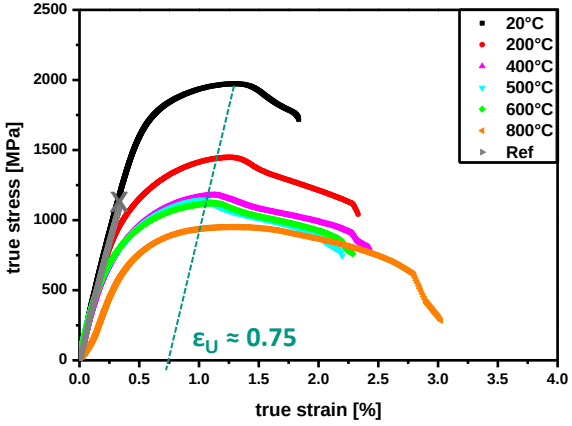
yield phenomenon after R_m

similar to W_{sc} in [110] [1]

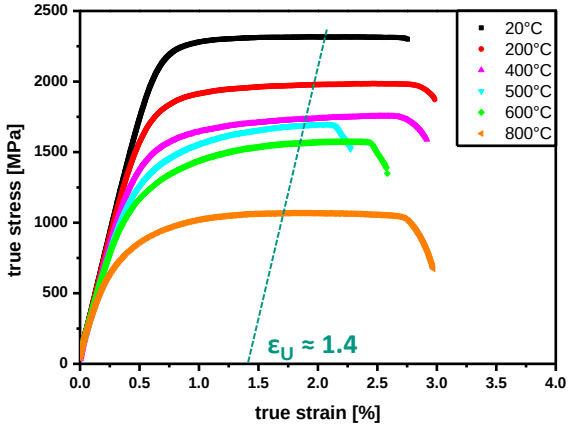
W100: elastic – ideal plastic

enhanced uniform elongation

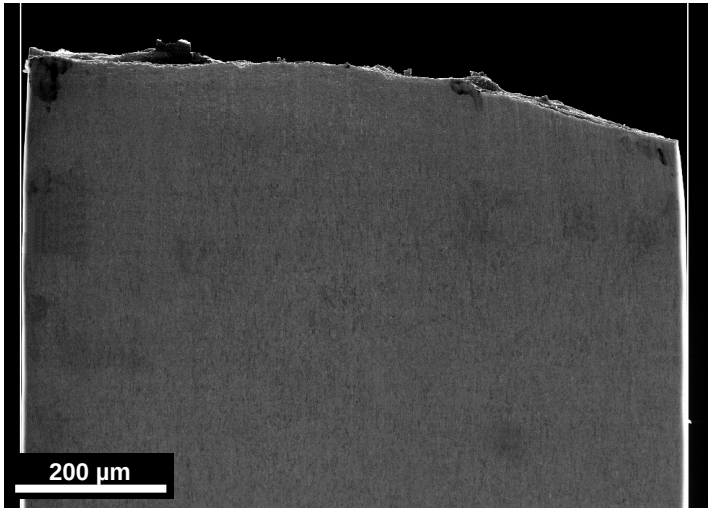
W300



W100



necking:



[1] Argon, Acta Metall. Mater. 14 (1966)

I. DIRECT ANALYSIS: ELECTRON MICROSCOPY

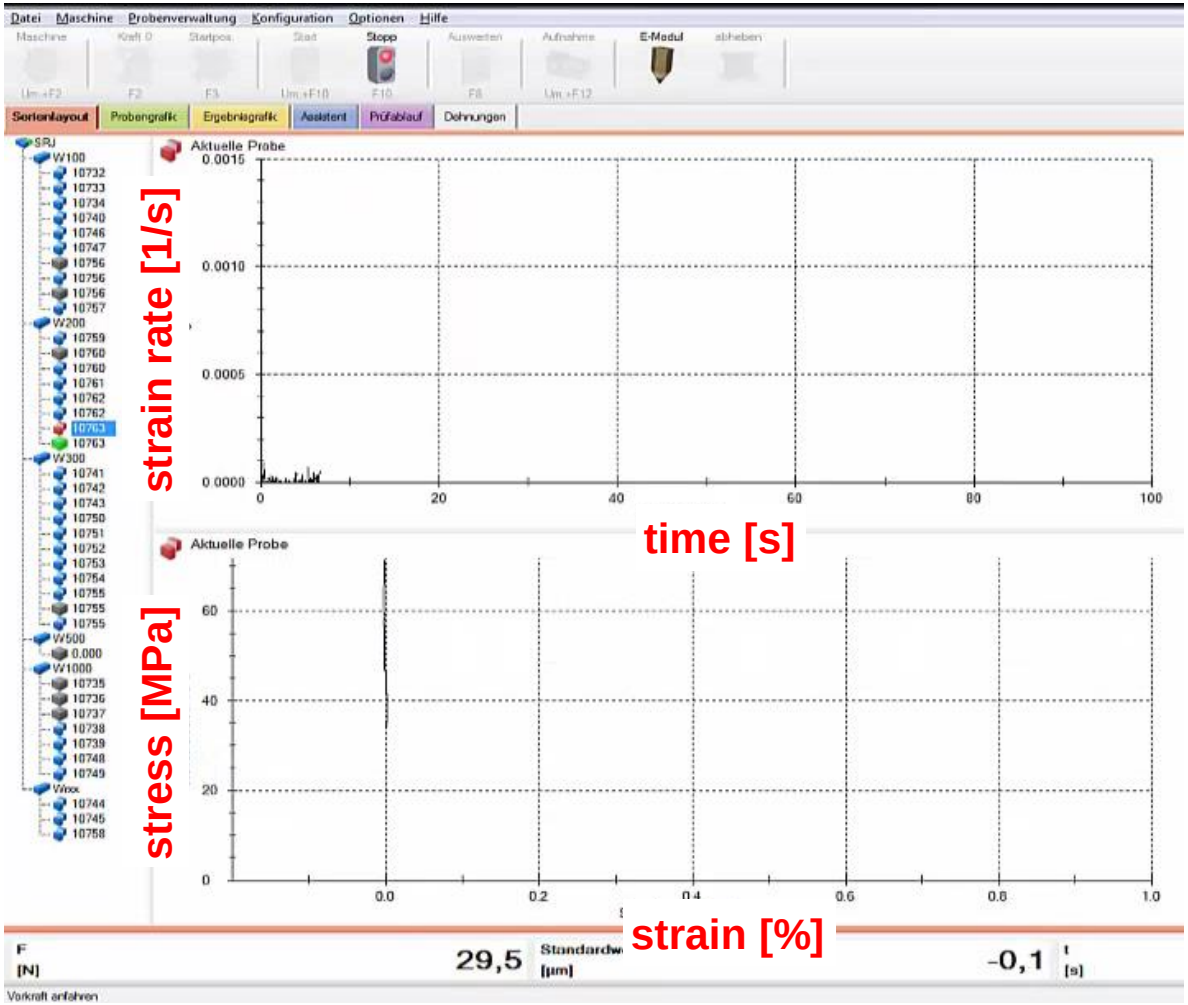
II. INDIRECT ANALYSIS: MECHANICAL TESTING

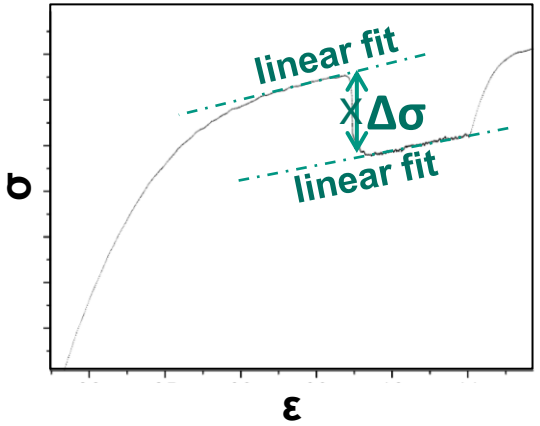
a) tensile tests

b) strain rate jump tests

III. CONCLUSION & OUTLOOK

Strain rate jump tests





strain rate sensitivity:

$$m = \left(\frac{\Delta ln\sigma^*}{\Delta ln\dot{\varepsilon}}\right)_{T,\,\varepsilon_{pl}}$$

activation volume:

$$\vartheta = M_T \cdot k \cdot T \cdot \left(\frac{\Delta ln\dot{\varepsilon}}{\Delta\sigma}\right)$$

(M_T: Taylor factor, k: Boltzmann constant)

I. DIRECT ANALYSIS: ELECTRON MICROSCOPY

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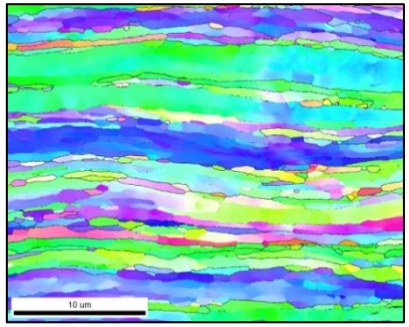
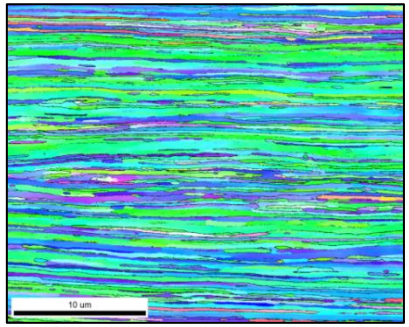
III. CONCLUSION & OUTLOOK

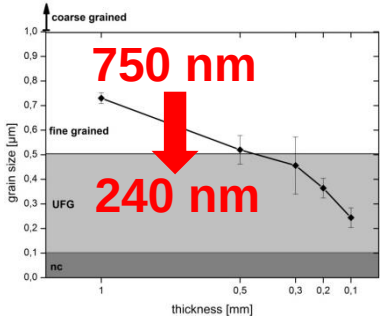
Identification of deformation mechanisms

direct

microstructure







+

indirect

tensile tests

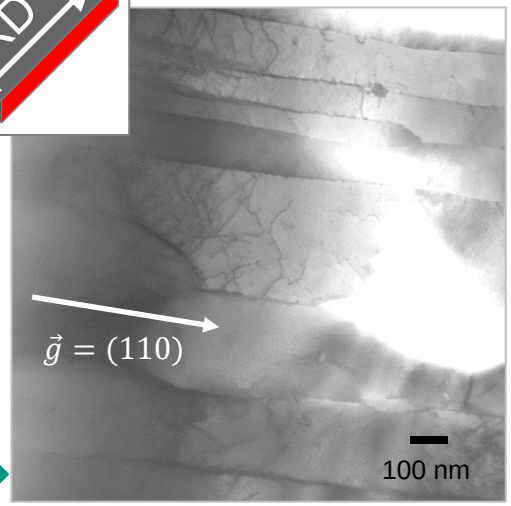
screw dislocation

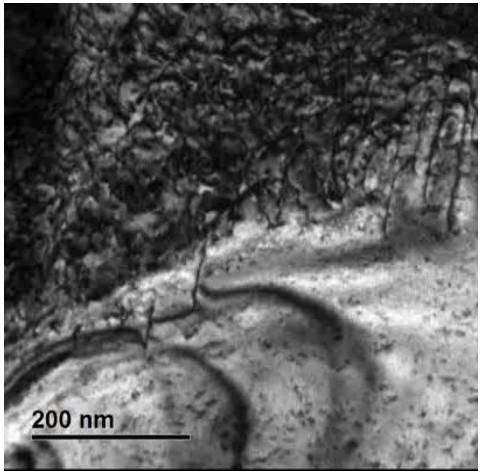
SRJ tests

GB-mediated plasticity

Outlook

dislocations





M. Klimenkov et al. (2015)

Thank you for your attention!

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