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DRESDEN concept

Faculty of Science, Department of Physics, Institute of Solid State and Materials Physics

Microstructure and texture evolution during severe plastic deformation of CrMnFeCoNi high-entropy alloy

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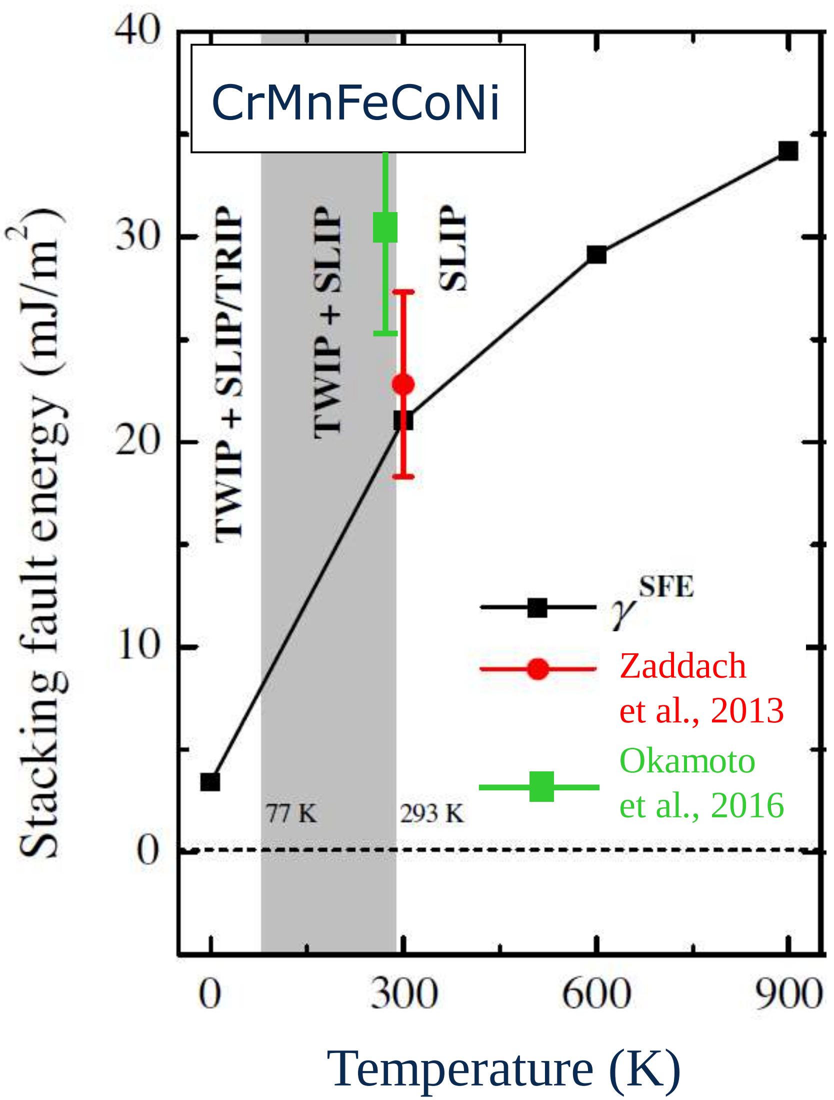
Motivation

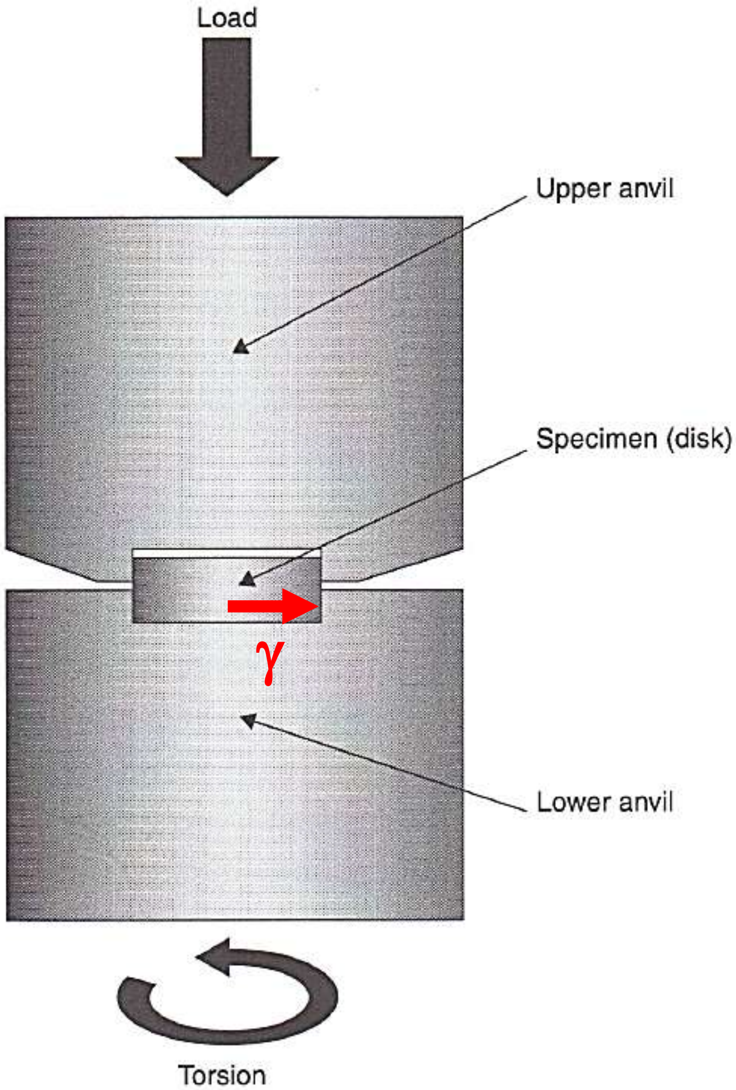


Question:

What can we learn from X-ray line broadening and texture about the deformation mechanisms?

Huang et al., 2015

High pressure torsion (HPT)



Shear strain

$$\gamma = \frac{2\pi N r}{h}$$

N …number of rotations

r … sample radius

h …sample hight

Hydrostatic pressure

7.8 GPa

Shear strains

0 - 170

X-ray Line Profile Analysis (XLPA): General effects to diffraction peaks

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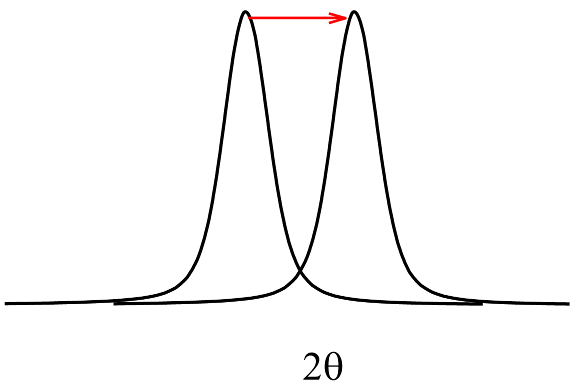
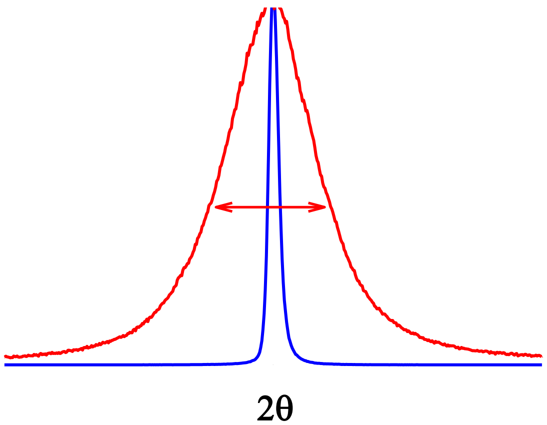
peak shift



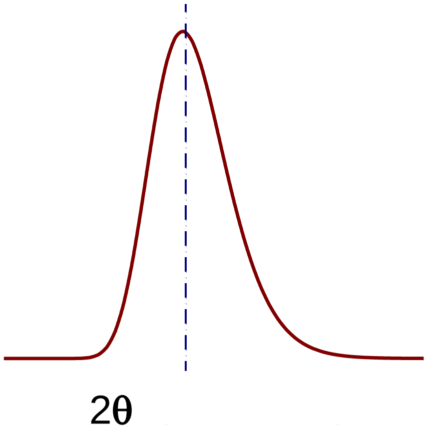
homog. global stresses

peak broadening



crystal „domain size“,
lattice defect densities

peak asymmetry



heterog. local stresses,
lattice defect distribution

Multiple Whole Profile Analysis: MWP-fit

$$I_{Meas} \iff I_{Strain} * I_{Size} * I_{SF,Tw} * I_{Instr} + BG$$

Measured pattern ***Physically modeled*** ***Experimentally determined***

Non-linear, least squares fitting

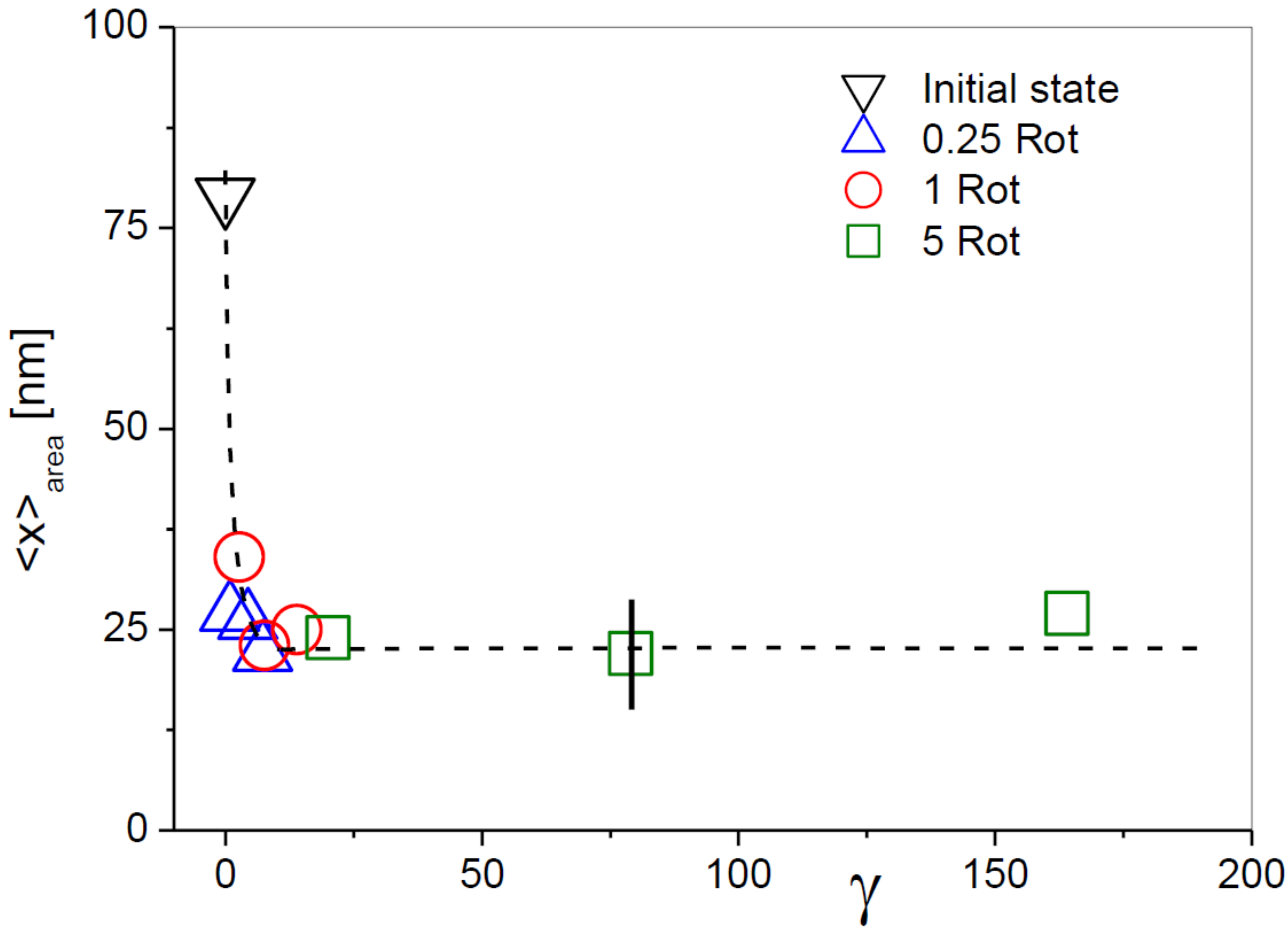
I_{Strain} : ρ, q, M, $M = R_e \rho^{1/2}$

I_{Size} : m, σ

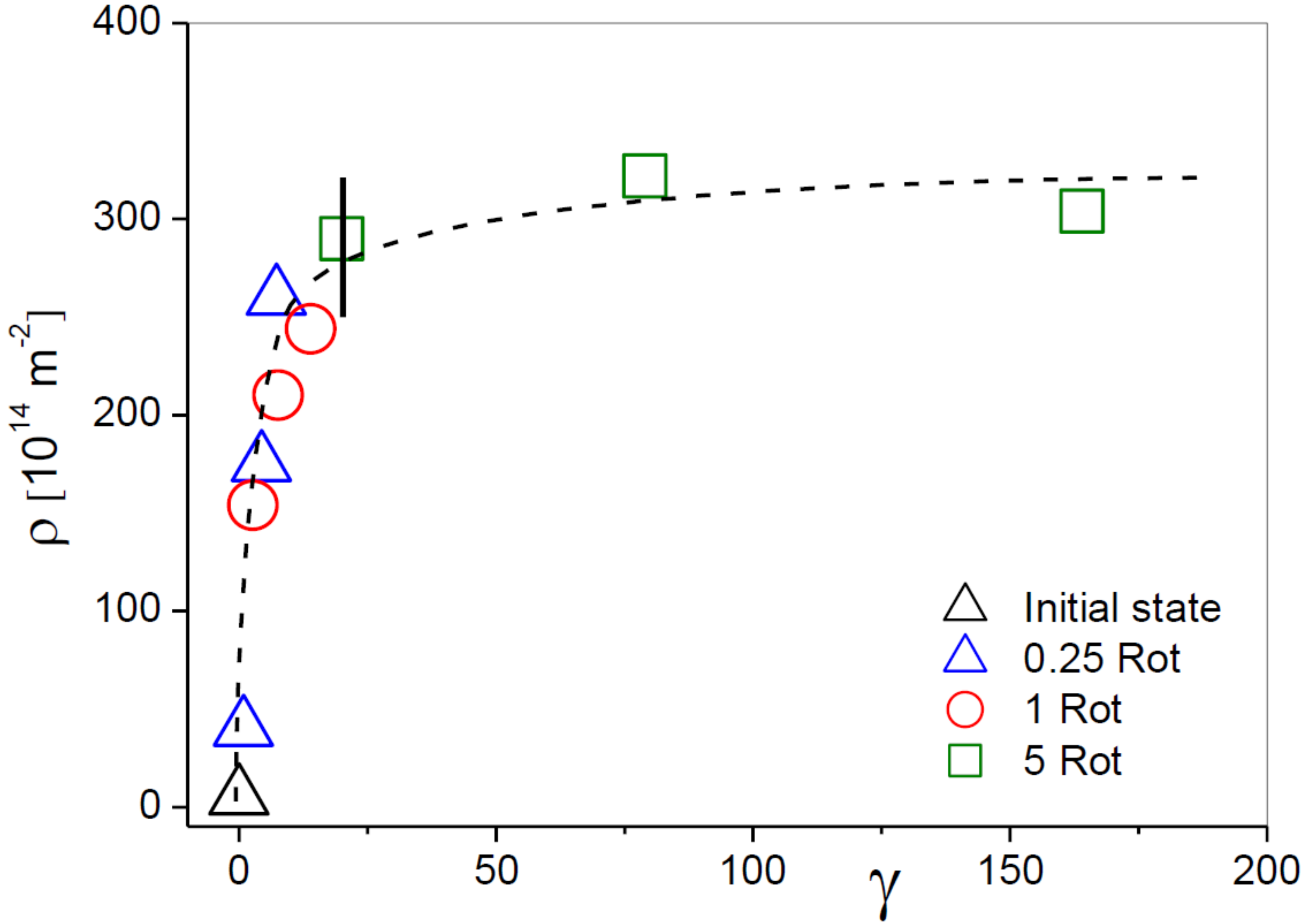
I_{SF} : α

I_{Tw} : β

Crystallite size



Dislocation density



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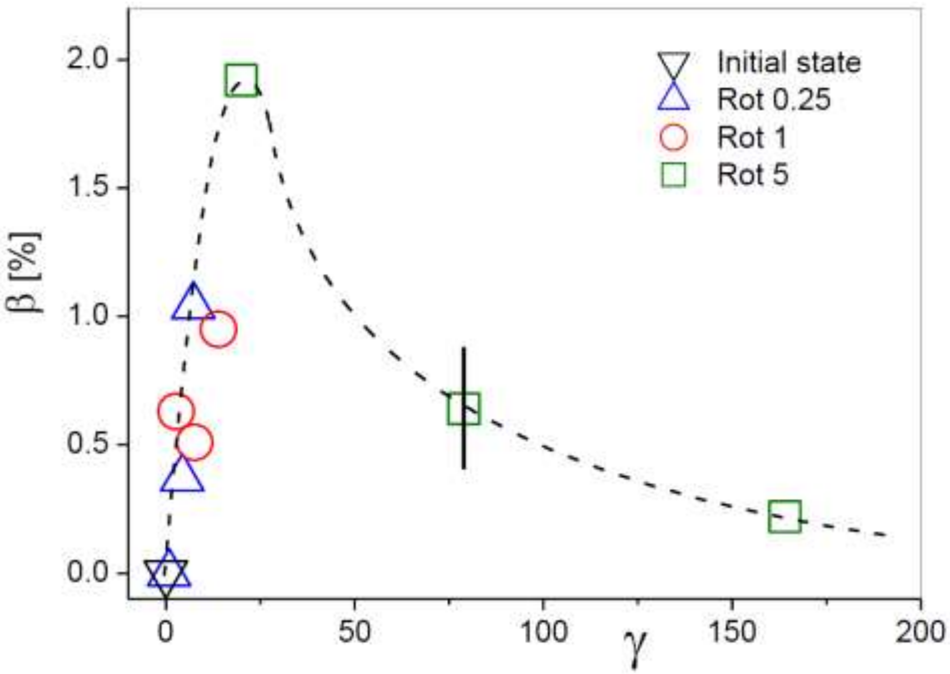
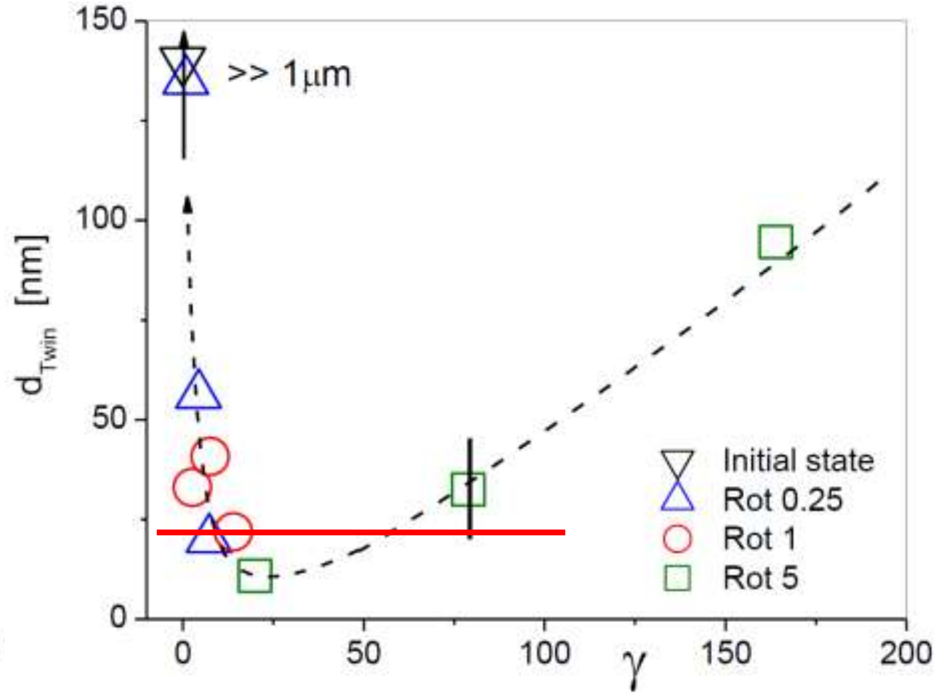
Twin density and twin spacing



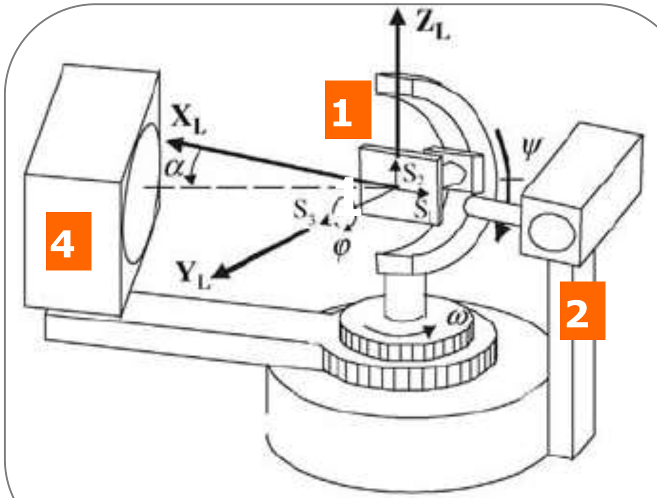


Texture measurement

Microdiffraction by *XRµD²*

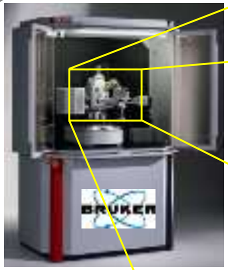
financed by Europa fördert Sachsen. EFRE Europäischer Fonds für regionale Entwicklung

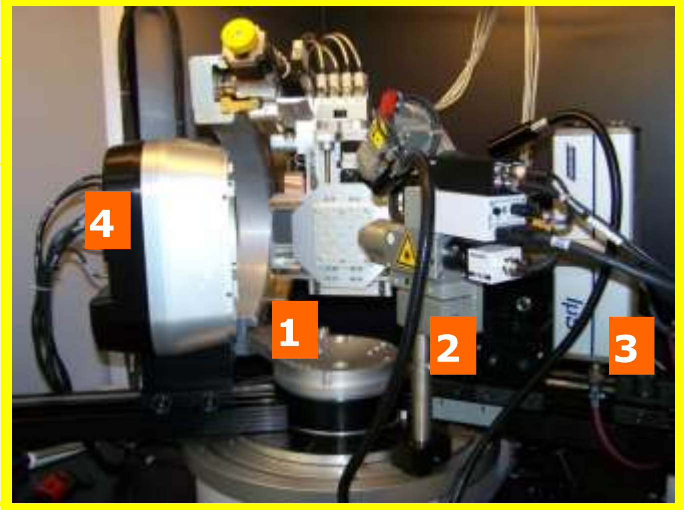
Measuring principle



[He, 2009]

Bruker AXS D8 Discover

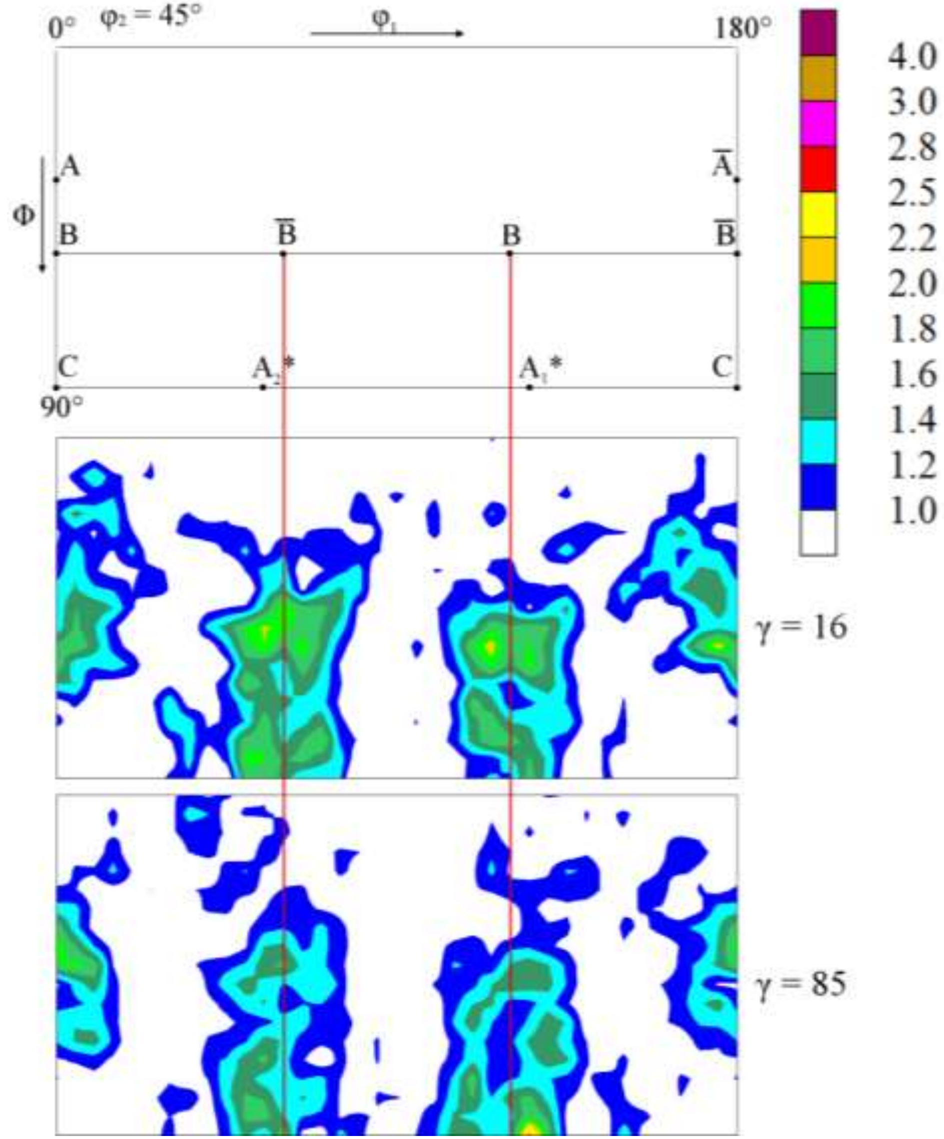




Equipment:

1. Eulerian cradle with xyz-stage
2. Laser-video microscope
3. Low-power microfocus X-ray tube *IµS*
4. 2D detector *VÅNTEC 2000*

Texture


0°
φ2 = 45°
φ1
180°
A
Ā
Φ
B
B̄
B
B̄
C
A2*
A1*
C
90°
4.0
3.0
2.8
2.5
2.2
2.0
1.8
1.6
1.4
1.2
1.0
γ = 16
γ = 85

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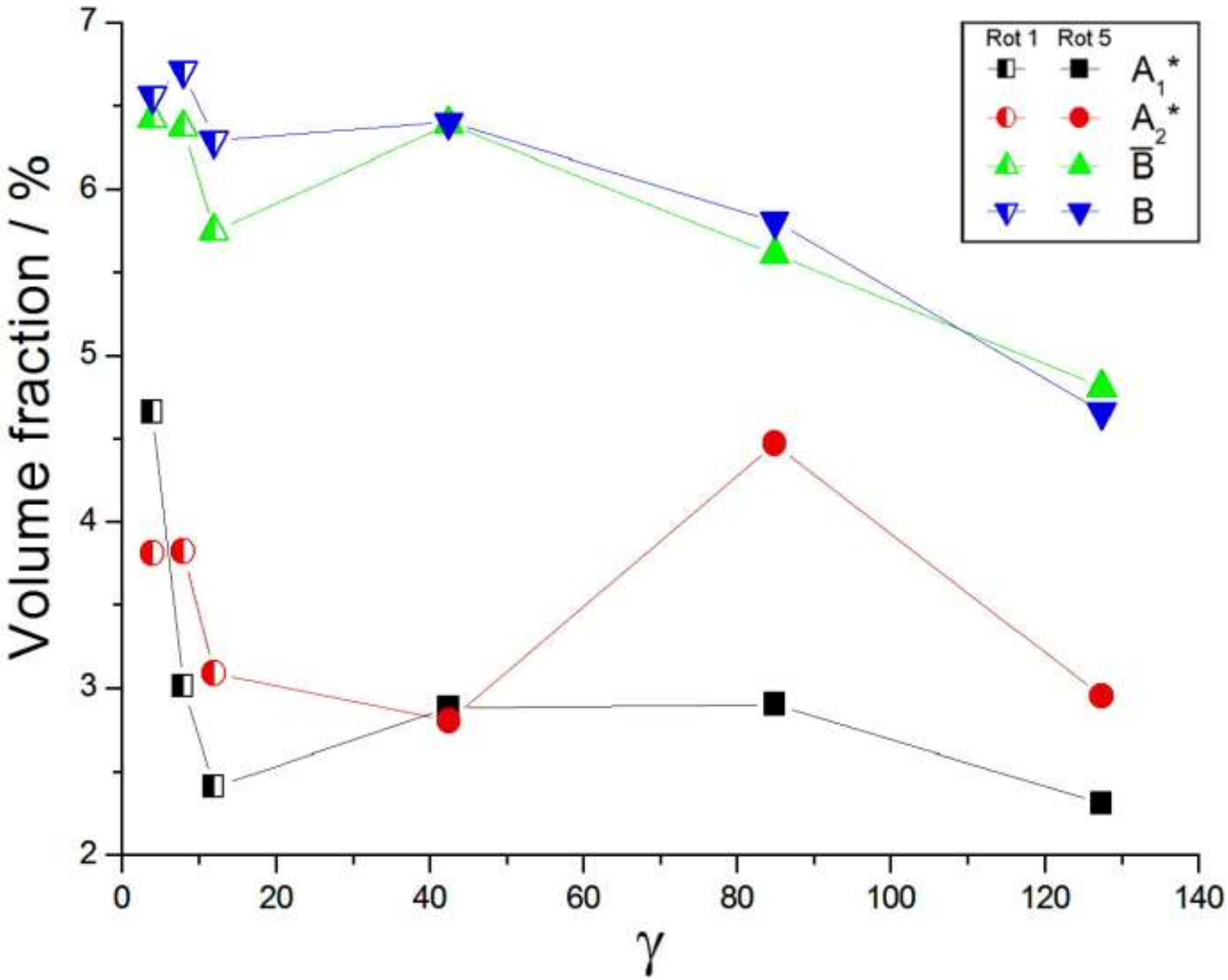
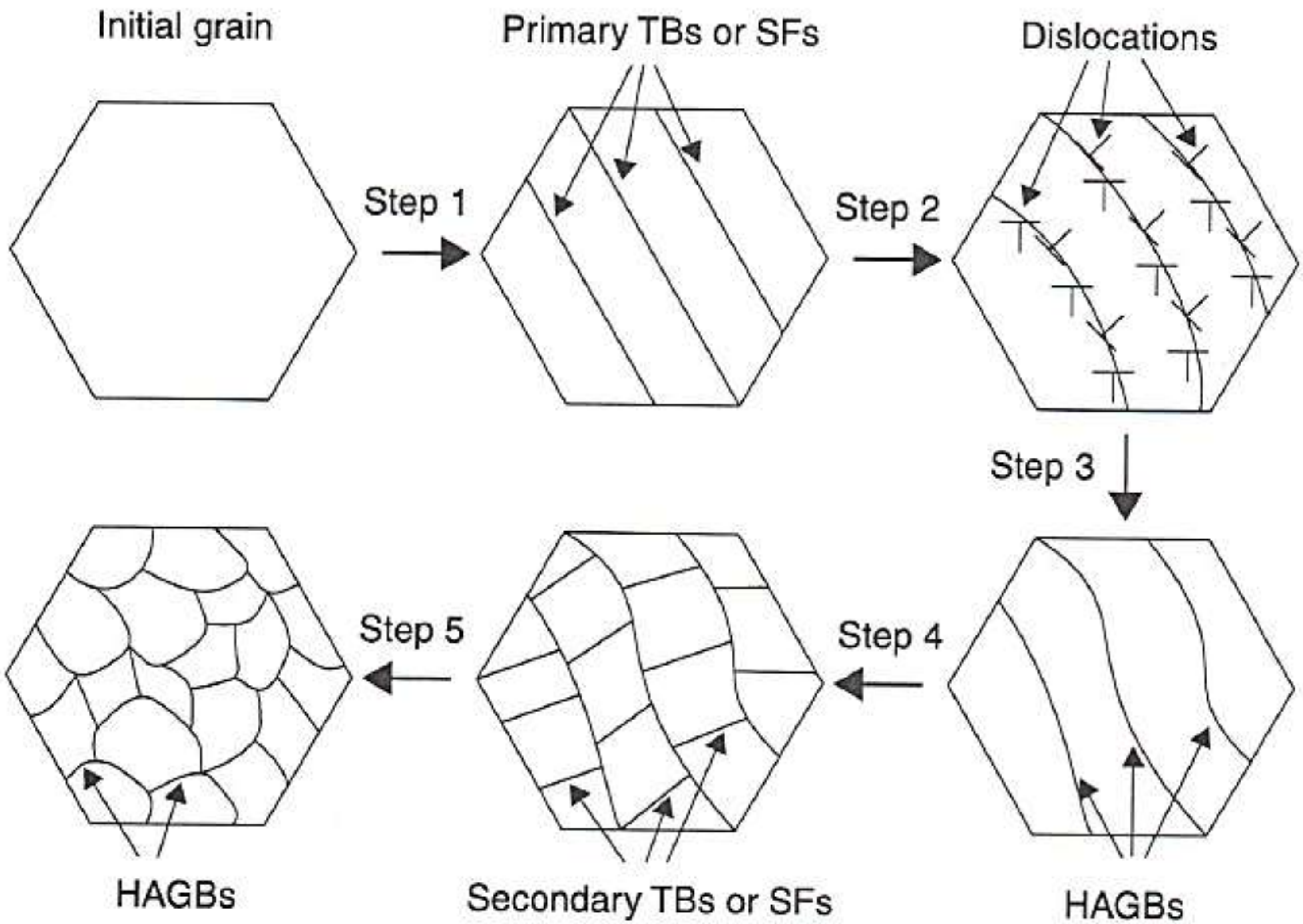
Texture components in simple shear deformed fcc metals

Component designation	Miller indices {shear plane}<shear direction>	Euler angles [°]		
		φ_1	Φ	φ_2
A	$\{1\bar{1}\bar{1}\}\langle 110\rangle$	0	35.26	45
$\bar{A}$	$\{\bar{1}11\}\langle\bar{1}\bar{1}0\rangle$	180	35.26	45
A_1*	$\{\bar{1}\bar{1}1\}\langle 112\rangle$	35.37 125.37	45 90	0 45
A_2*	$\{11\bar{1}\}\langle 112\rangle$	144.74 54.74	45 90	0 45
B	$\{\bar{1}12\}\langle 110\rangle$	0 120	54.74 54.74	45 45
$\bar{B}$	$\{1\bar{1}\bar{2}\}\langle\bar{1}\bar{1}0\rangle$	60 180	54.74 54.74	45 45
C	$\{001\}\langle 110\rangle$	90 0	45 90	0 45
<111> or A fibre	$\{111\}\langle uvw\rangle$			
<110> or B fibre	$\{hkl\}\langle 110\rangle$			

Volume fraction of texture components



Microstructure development



Wang et al., 2010

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Summary

During HPT CrMnFeCoNi HEA shows severe grain refinement.

The steady state crystallite size is 24 nm.

The dislocation density saturates at 3 × $10^{16}/m^2$.

The twin density goes over a maximum of 2% at a certain shear strain.

The weak texture is a dominant brass-type shear texture, in agreement with the medium/low stacking fault energy.

Take home message:

During HPT deformation of CrMnFeCoNi HEA mainly occurs by slip of partial dislocations emitted from the grain boundaries accompanied by twinning and grain boundary sliding.
The latter two processes lead to texture randomization.
Multiple twinning leads to a strong grain refinement.

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Thank you for your kind attention !

Recknagelbau, Physics Building, Dresden University of Technology

Photo: A. Pukenas