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DRESDEN concept

Fakultät Mathematik & Naturwissenschaften, Fachrichtung Physik, Institut für Strukturphysik

Different ways of measuring texture gradients by diffraction

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Origin of texture gradients

Deformation processes are generally complicated due to frictional effects and flow instabilities causing texture gradients!

- **tension**
  necking (+ shear banding (SB))
- **compression**
  friction at anvils (+ SB)
- **torsion**
  per se strain gradient (+ SB)
- **bending**
  per se change from tension to compression + SB
- **wire drawing, extrusion**
  friction at die walls (+ SB)
- **rolling**
  friction at rolls (+ SB)
- **equal channel angular pressing (ECAP)**
  friction at channel walls (+ SB)

texture ⟷ properties ⟷ property gradient

Requirements for measuring specific texture gradients by diffraction

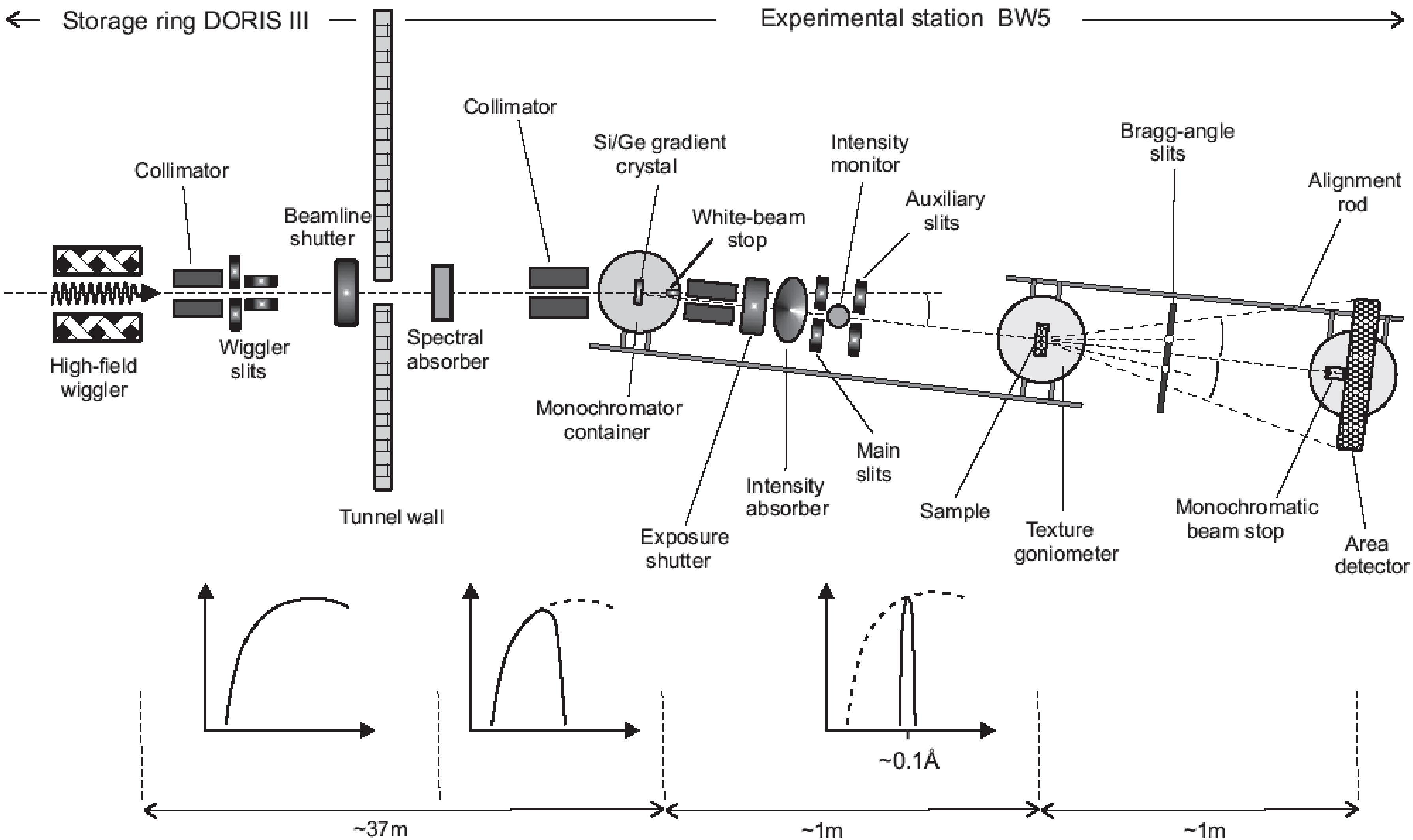
Radiation	$d_{1/2}$	Beam size	Grain statistics
X-rays (soft)	1-50 μm	cm^2	
X-rays (hard)	>1 mm	mm^2	
neutrons	>1 cm	cm^2	
electrons	< 1 μm	100 nm^2	problem

Examples:

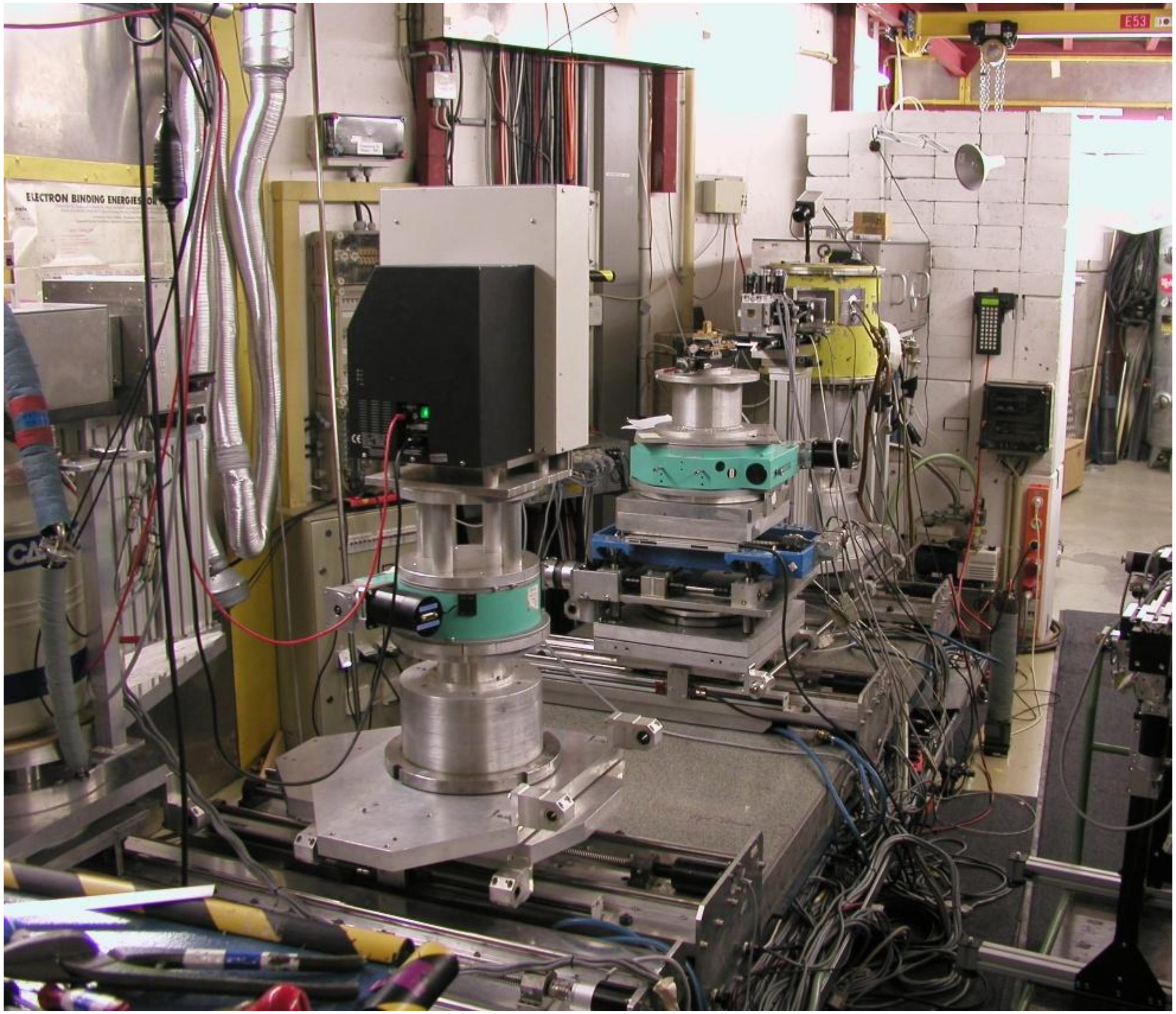
Texture gradient in ECAP by diffraction of synchrotron radiation

Texture gradient in HPT nanomaterial by X-ray microdiffraction

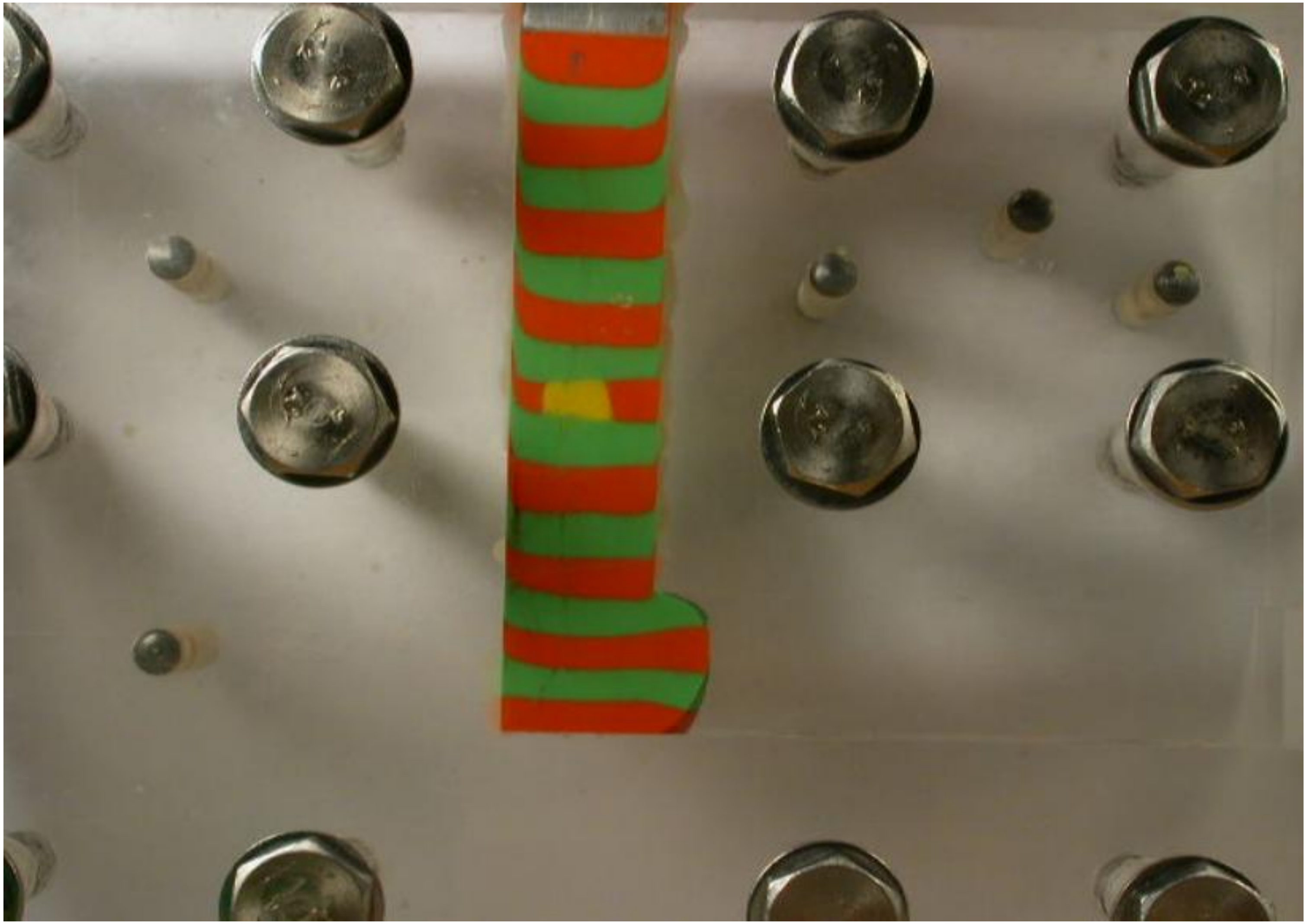
Experimental station BW 5 at HASYLAB



Diffraction of synchrotron radiation at BW5, DESY/HASYLAB in Hamburg

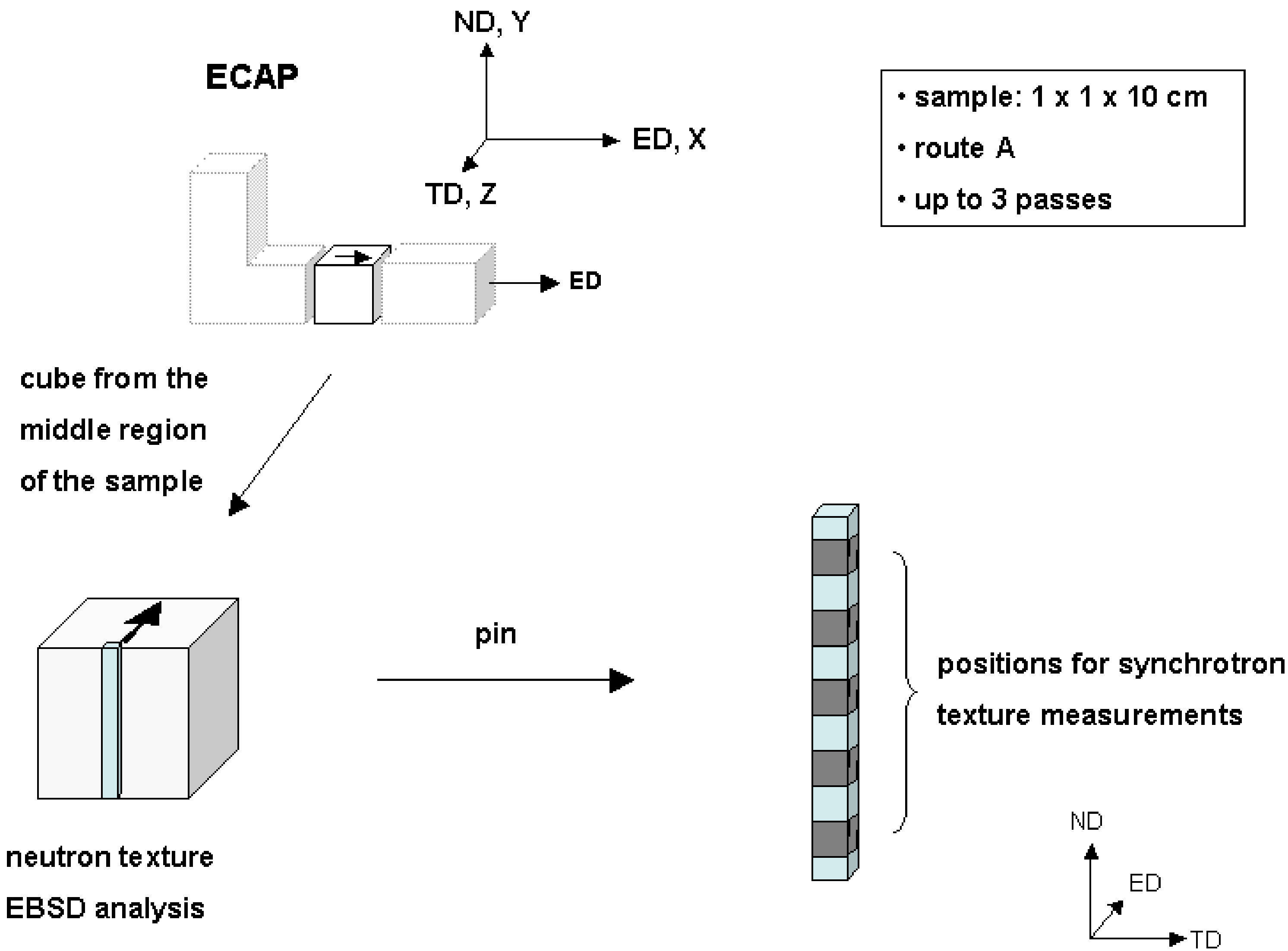


ECAP: friction

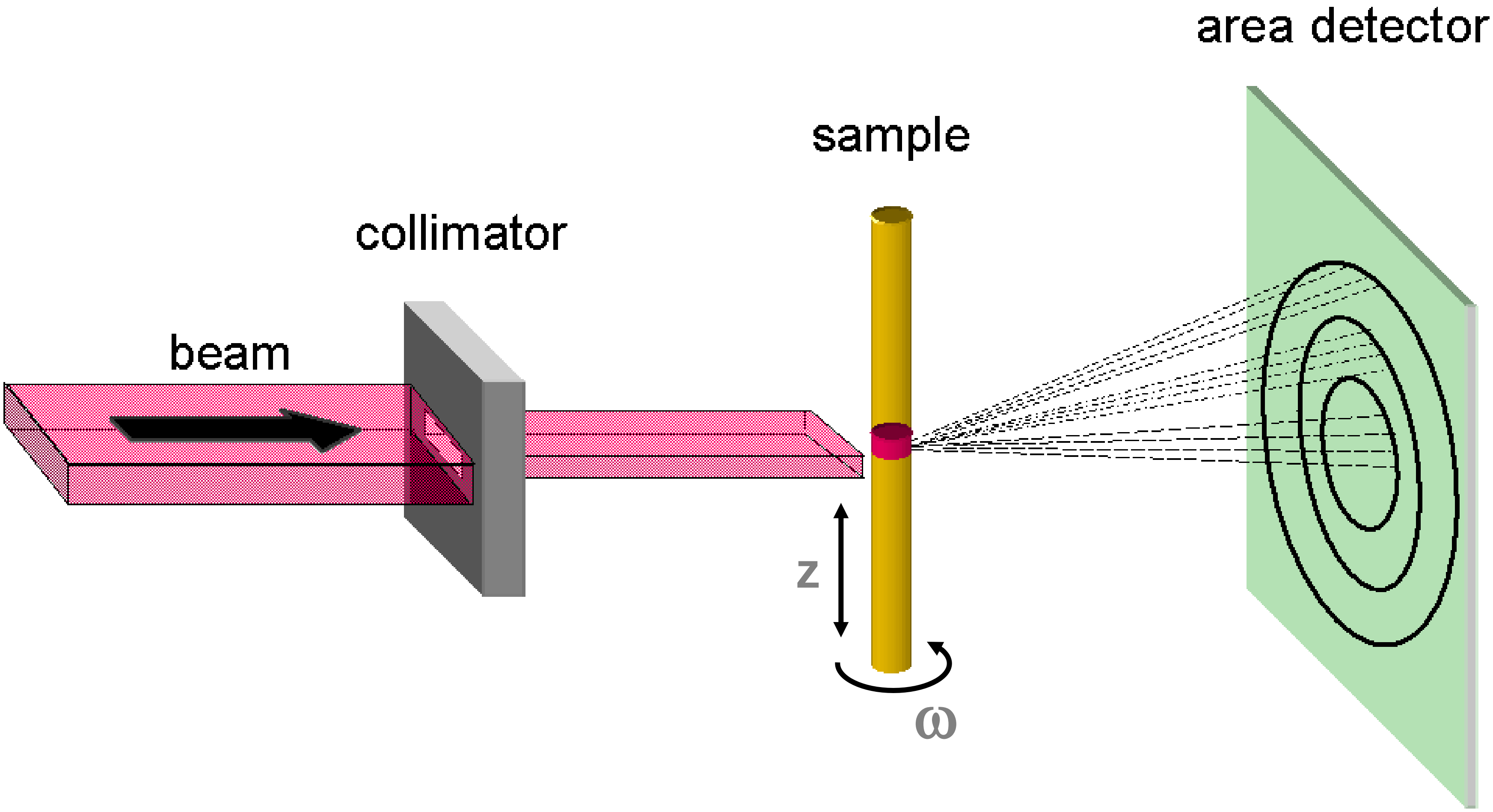


plasticine in ECAP die

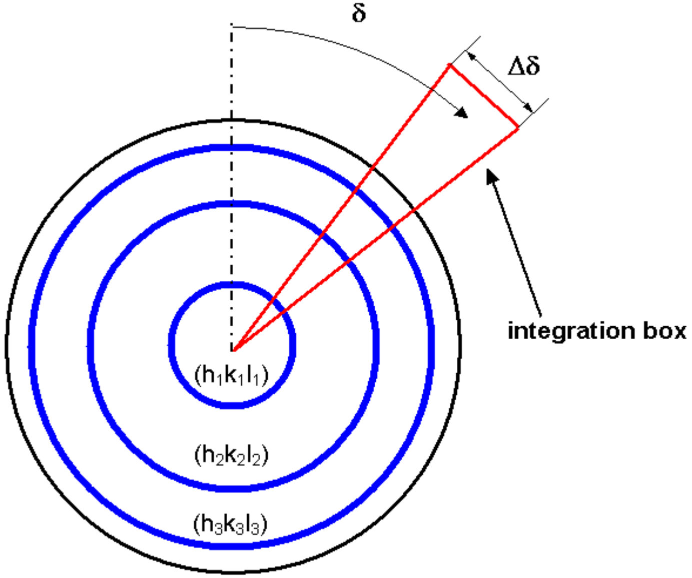
ECAP: sampling



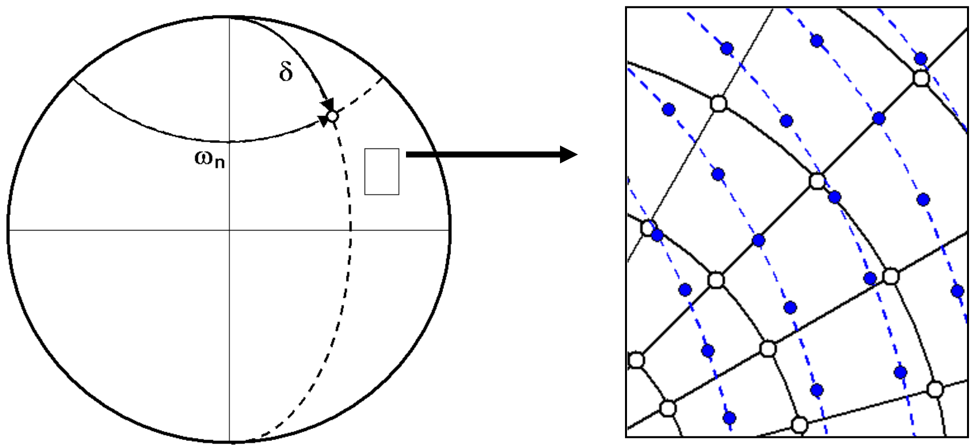
Texture measurements with synchrotron radiation



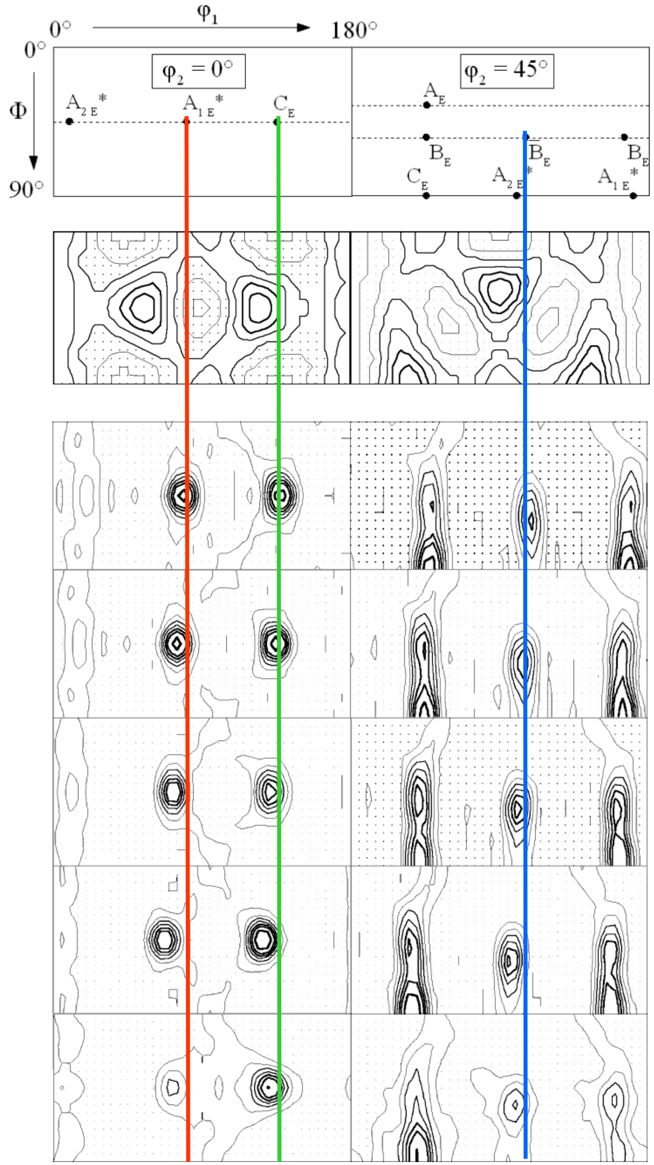
Data analysis



- read out of intensities along each Debye-Scherrer ring in steps of 5°
- intensity values are copied into the corresponding pole figure on an irregular grid
- interpolation on a regular 5°x 5° grid



Cu (route A, 1 pass): synchrotron texture



key figure

initial neutron texture

top

1 mm

3 mm

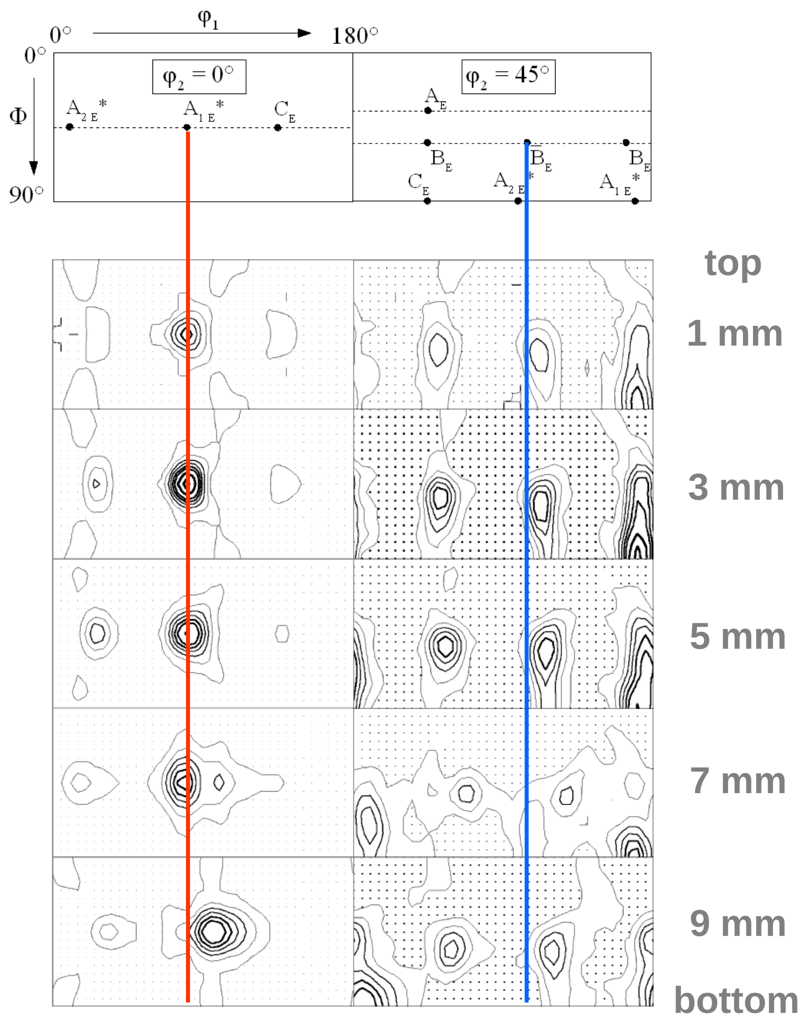
5 mm

7 mm

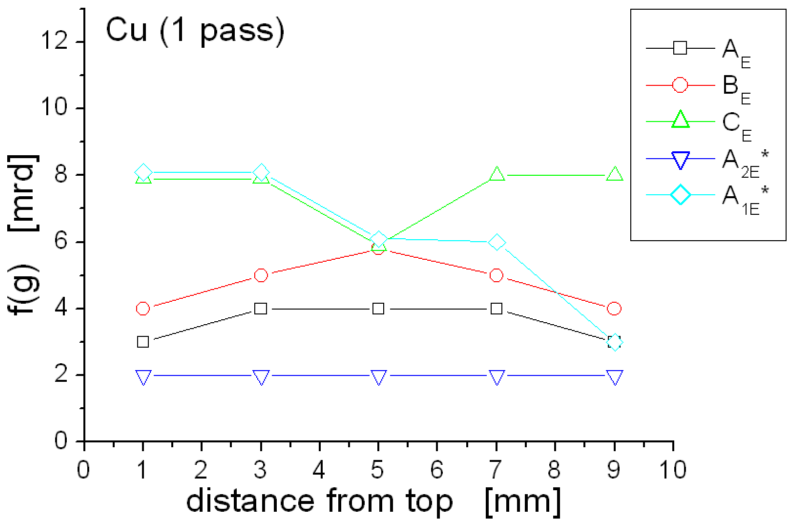
9 mm

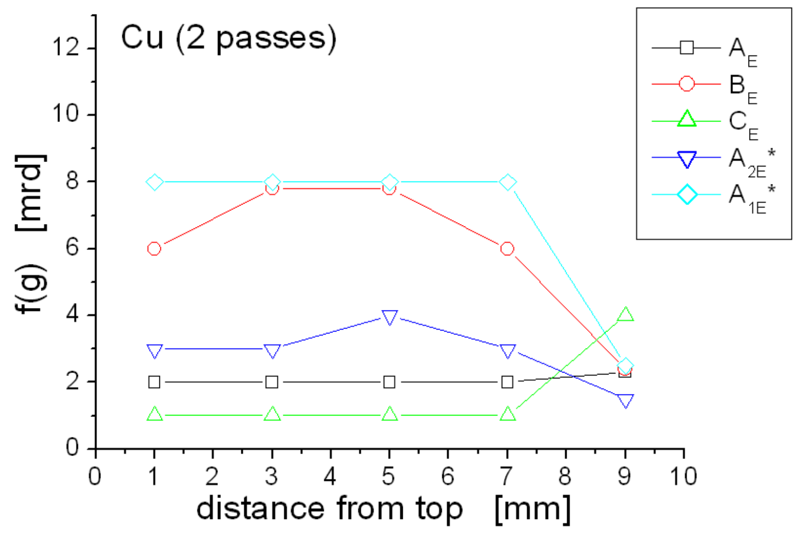
bottom

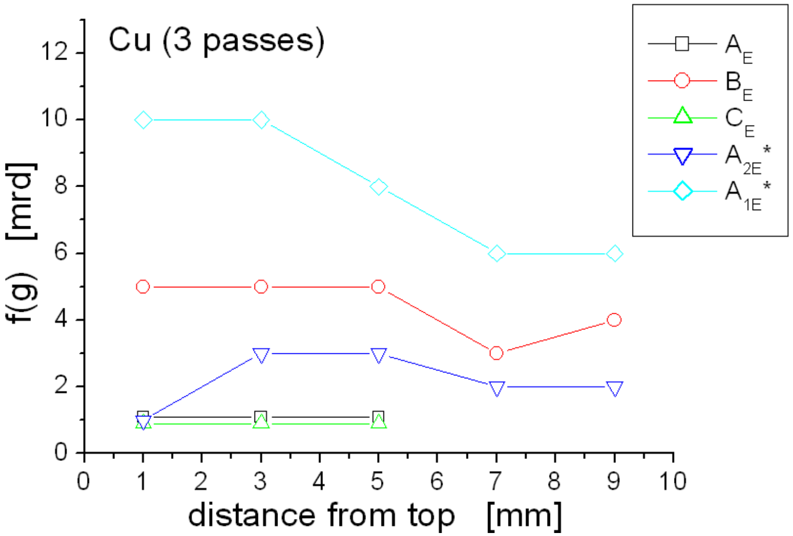
Cu (route A, 3 passes): synchrotron texture



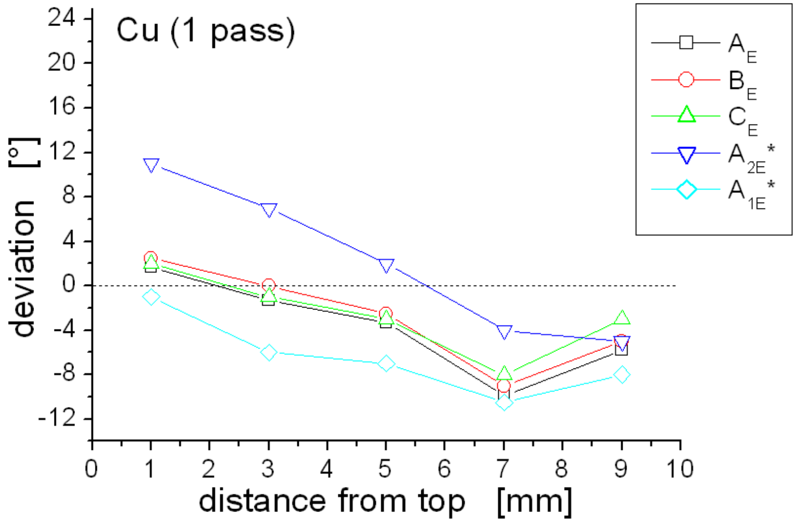
Cu: intensity of texture components

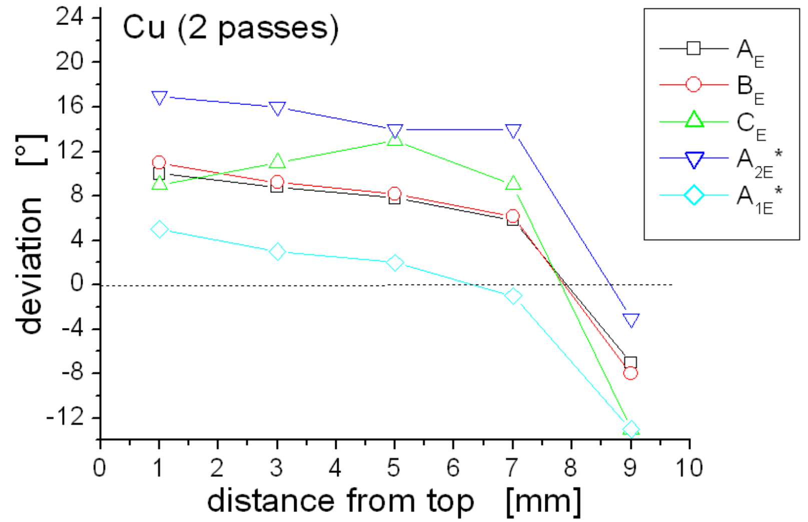


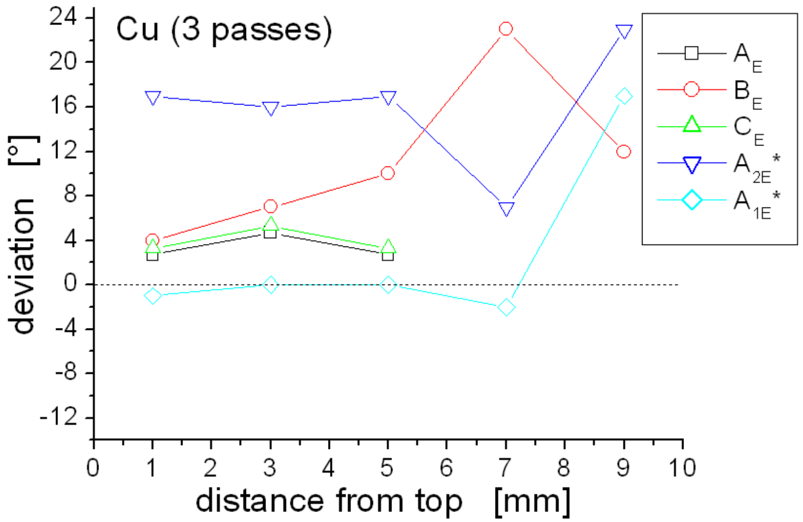




Cu: deviation from ideal components

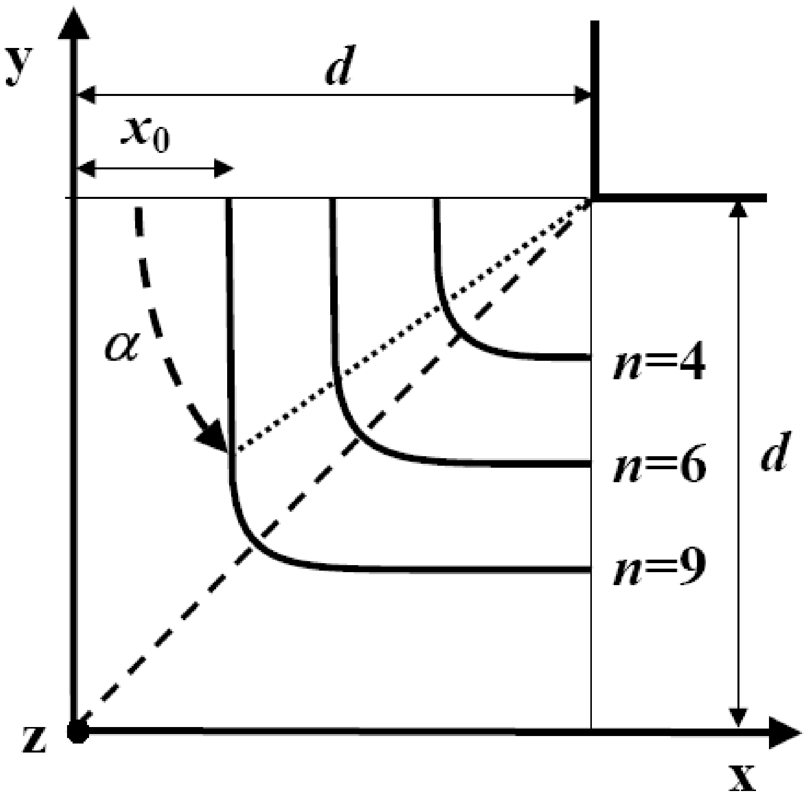






Negative φ_1 values indicate shift from ideal positions to the left in ODF

Tóth's flow line model of ECAP (I)



$$\phi = (d-x)^n + (d-y)^n = (d-x_0)^n$$

$$v_x = \lambda \frac{\partial \phi}{\partial y}, \quad v_y = -\lambda \frac{\partial \phi}{\partial x}$$

$$v_x = v_0 \left(\frac{d-y}{d-x_0} \right)^{n-1}, \quad v_y = -v_0 \left(\frac{d-x}{d-x_0} \right)^{n-1}$$

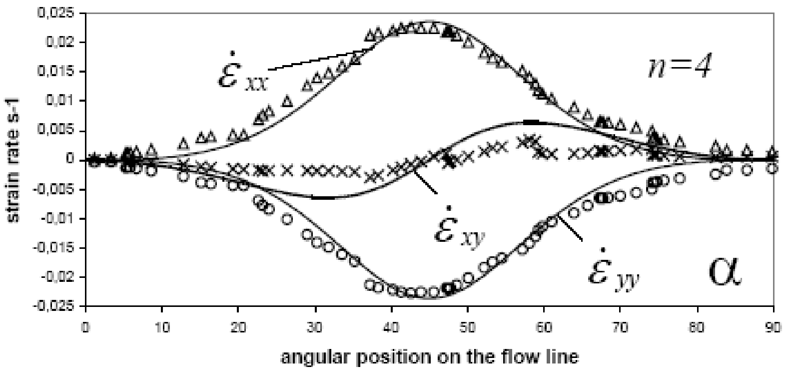
$$L_{xx} = \frac{\partial v_x}{\partial x} = -v_0 (1-n)(d-x)^{n-1} (d-y)^{n-1} (d-x_0)^{1-2n},$$

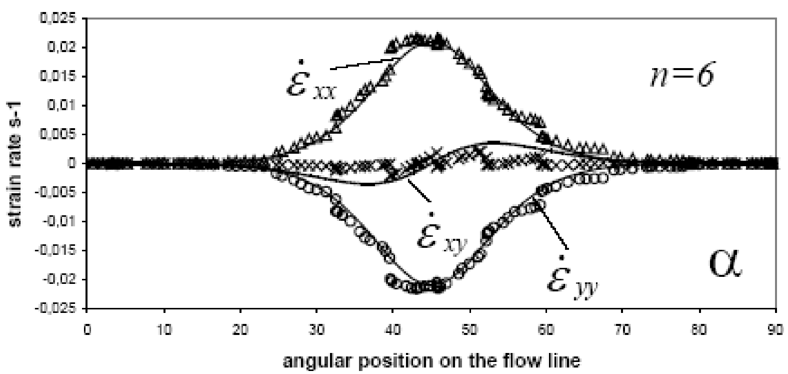
$$L_{yy} = -L_{xx},$$

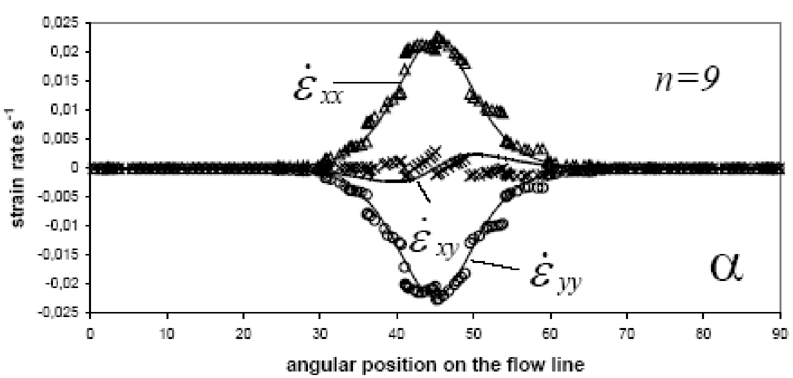
$$L_{xy} = \frac{\partial v_x}{\partial y} = v_0 (1-n)(d-x)^n (d-y)^{n-2} (d-x_0)^{1-2n},$$

$$L_{yx} = \frac{\partial v_y}{\partial x} = -v_0 (1-n)(d-y)^n (d-x)^{n-2} (d-x_0)^{1-2n}.$$

Tóth‘s flow line model of ECAP (II)





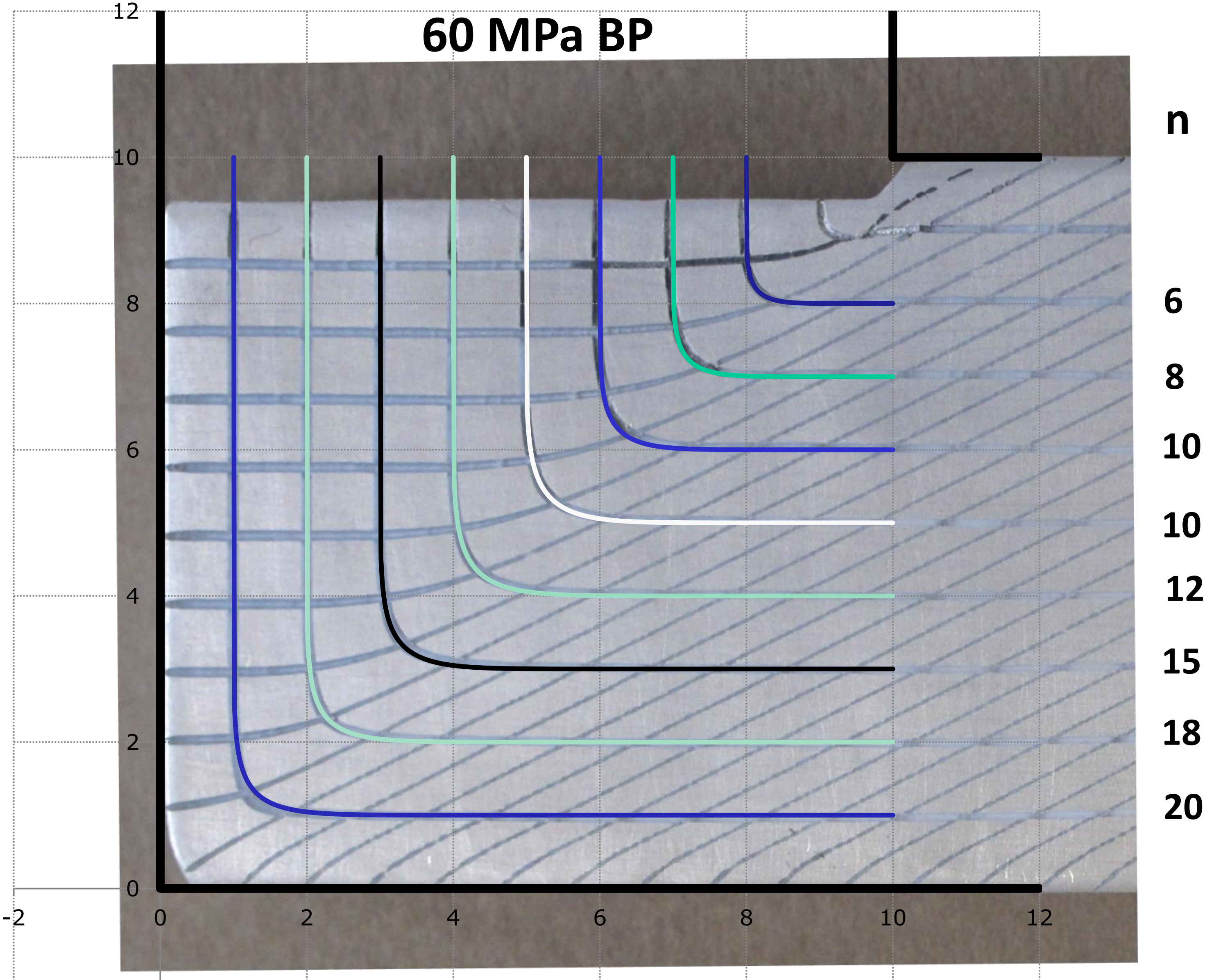


$$\dot{\varepsilon}_{xx} = -v_0\left(1-n\right)\left(d-x\right)^{n-1}\left(d-y\right)^{n-1}\left(d-x_0\right)^{1-2n},$$

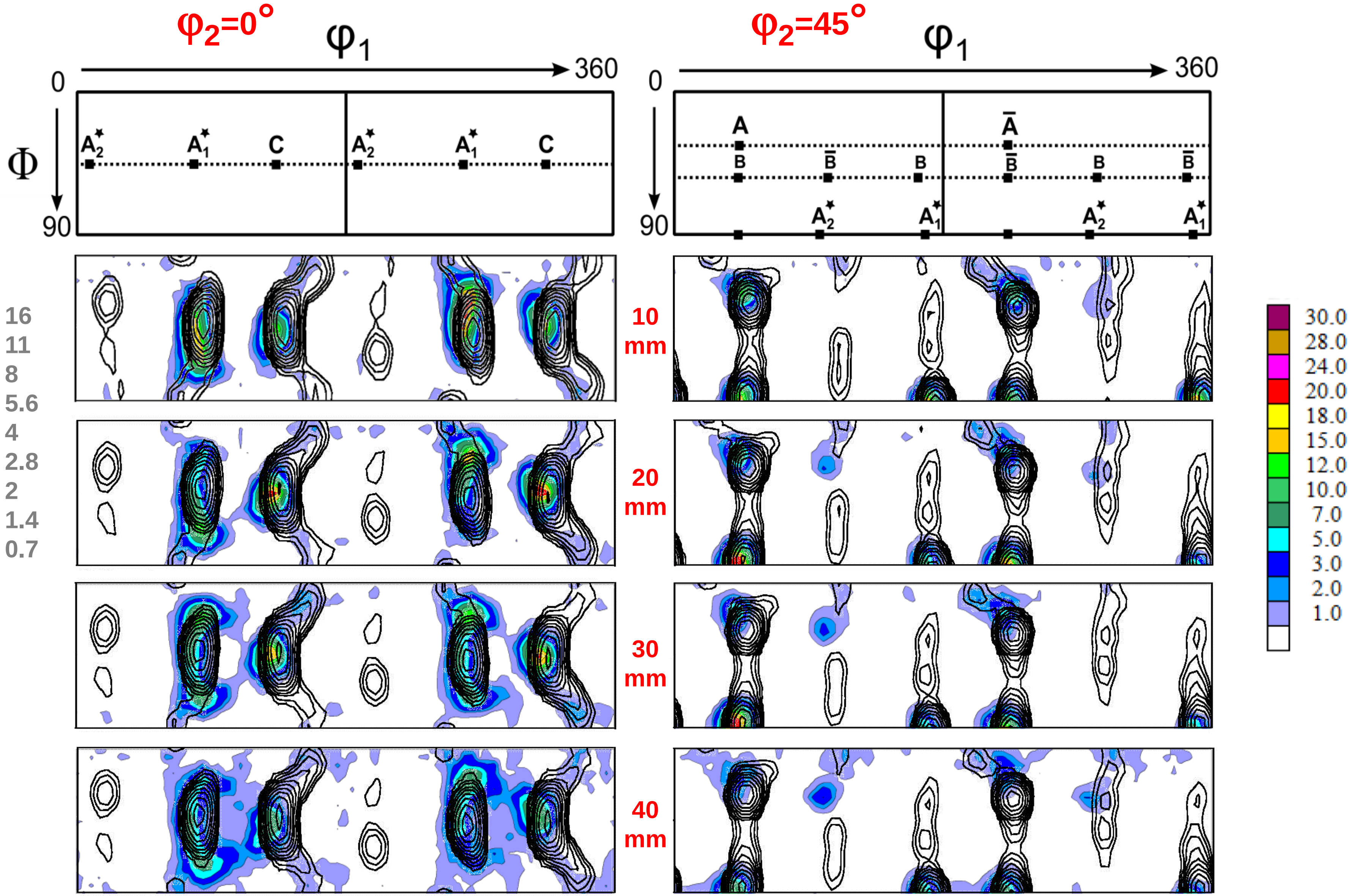
$$\dot{\varepsilon}_{yy} = v_0\left(1-n\right)\left(d-x\right)^{n-1}\left(d-y\right)^{n-1}\left(d-x_0\right)^{1-2n},$$

$$\dot{\varepsilon}_{xy} = \frac{1}{2}v_0\left(1-n\right)\left(d-x_0\right)^{1-2n}\left[\left(d-x\right)^{n}\left(d-y\right)^{n-2}-\left(d-y\right)^{n}\left(d-x\right)^{n-2}\right]$$

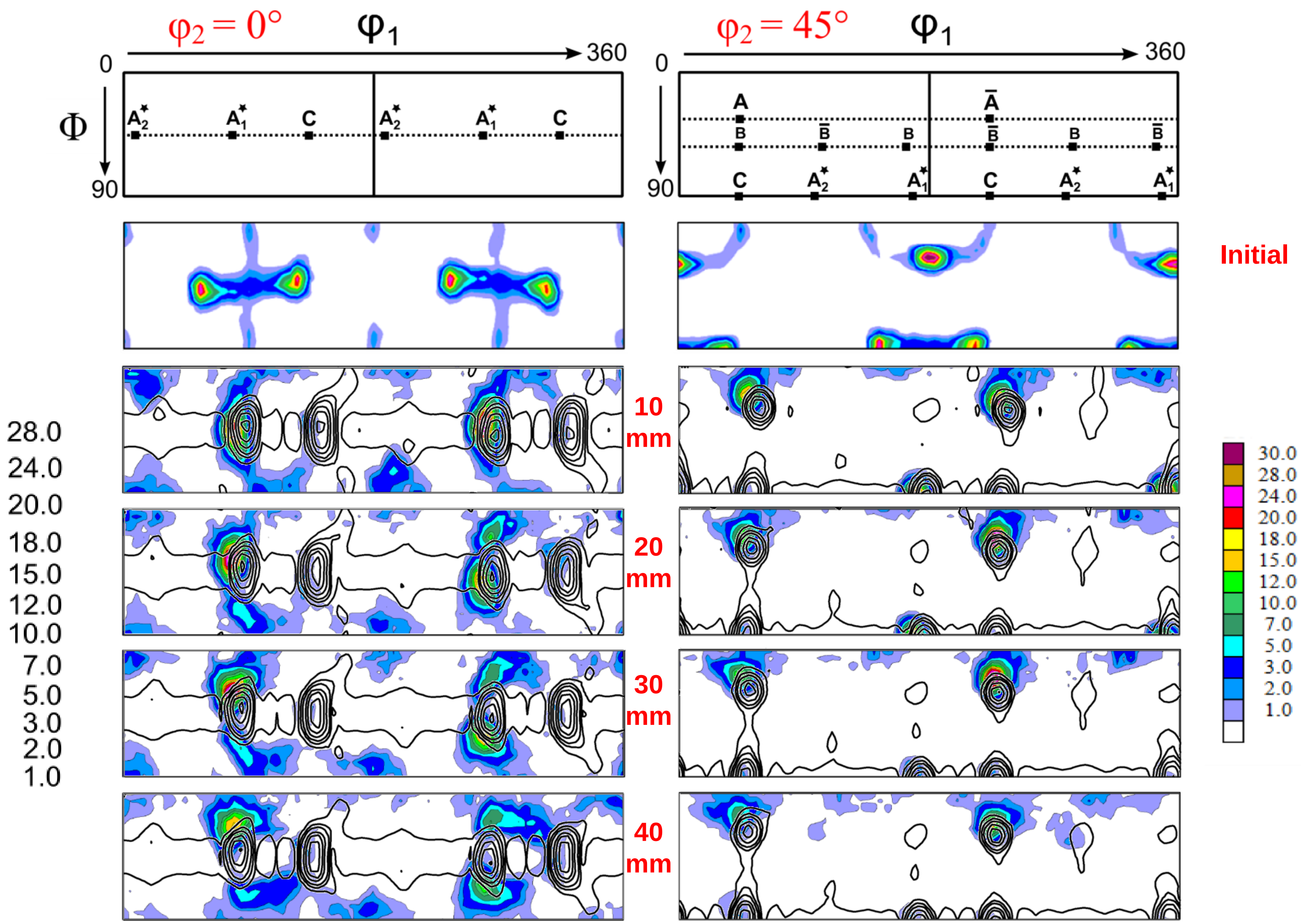
Flow line fit



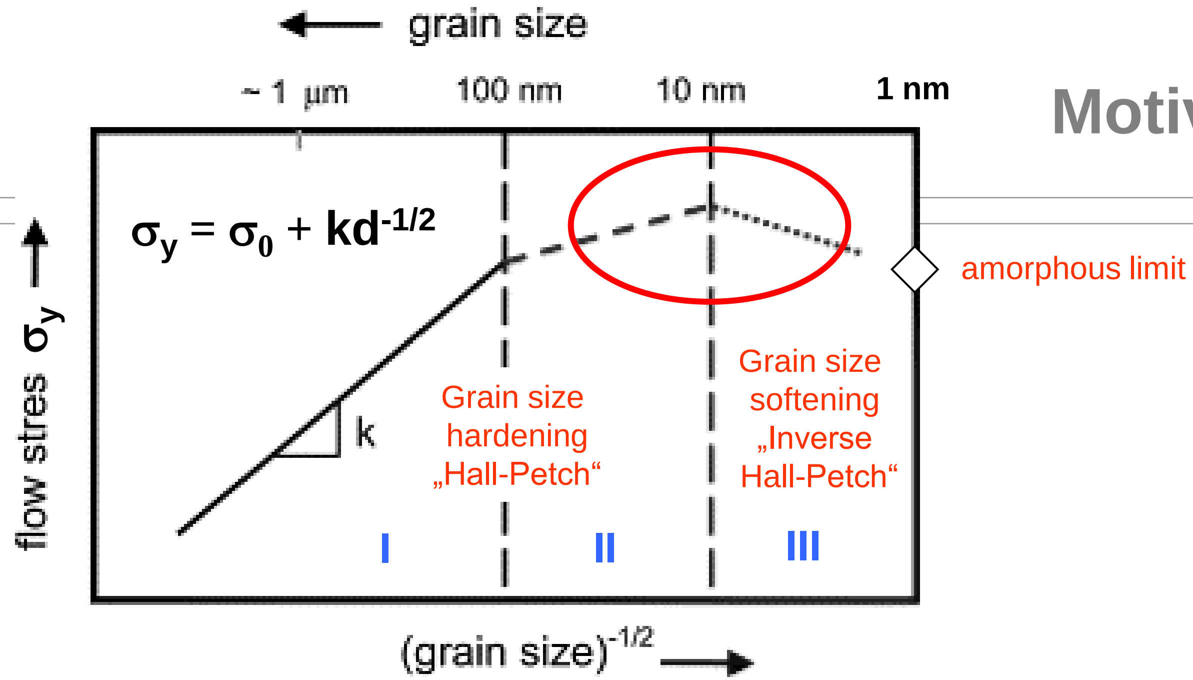
Comparison experiment - simulation
30 MPa BP, oct. + non-oct. slip

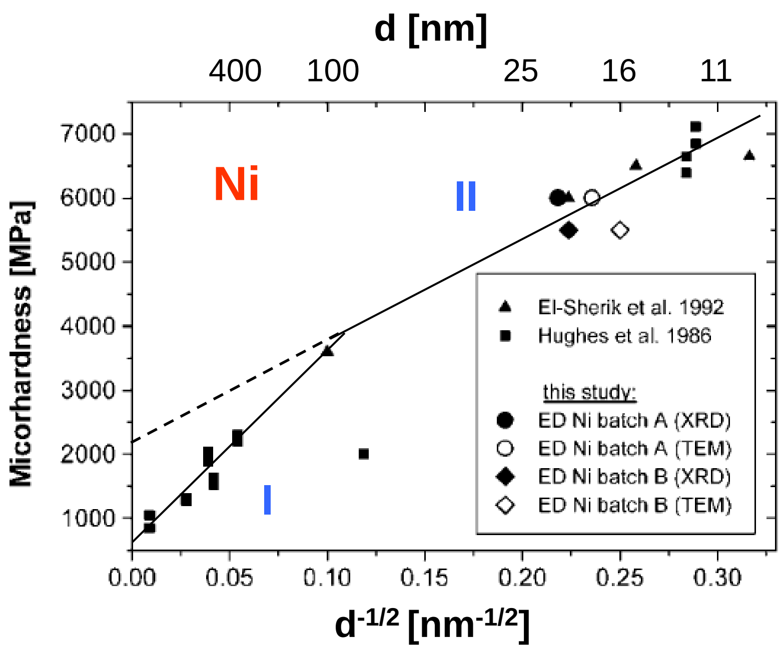


Comparison experiment – simulation
60 MPa BP, oct. + non-oct. slip

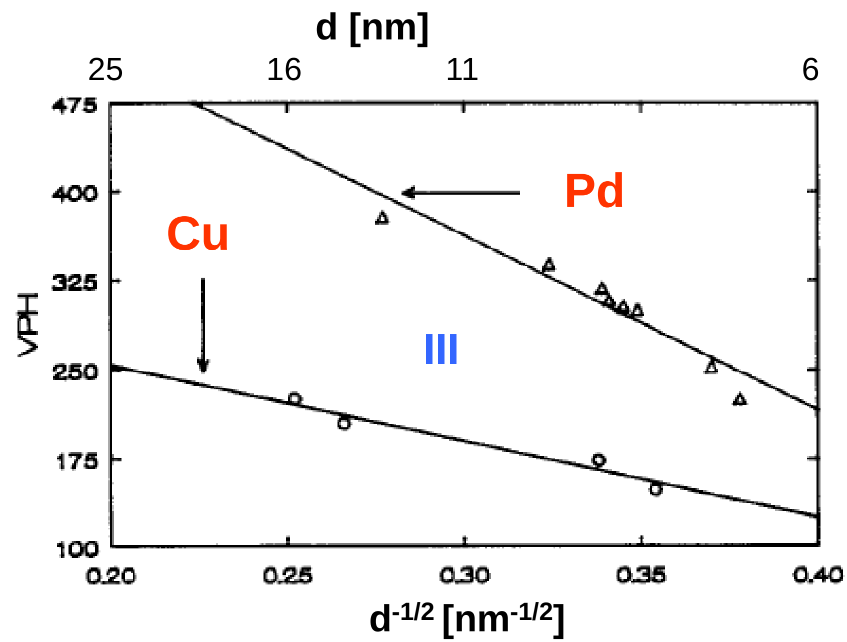


Motivation



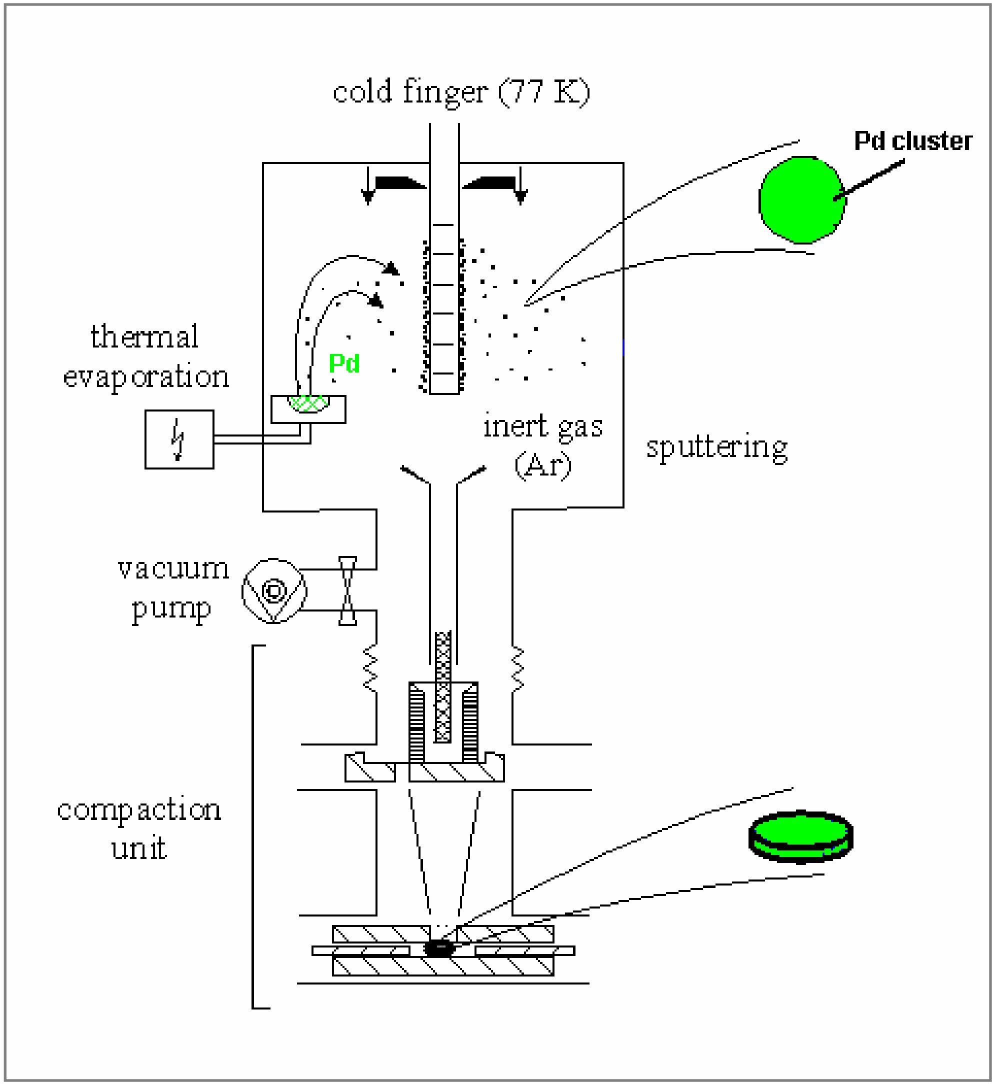


Dalla Torre et al., 2002

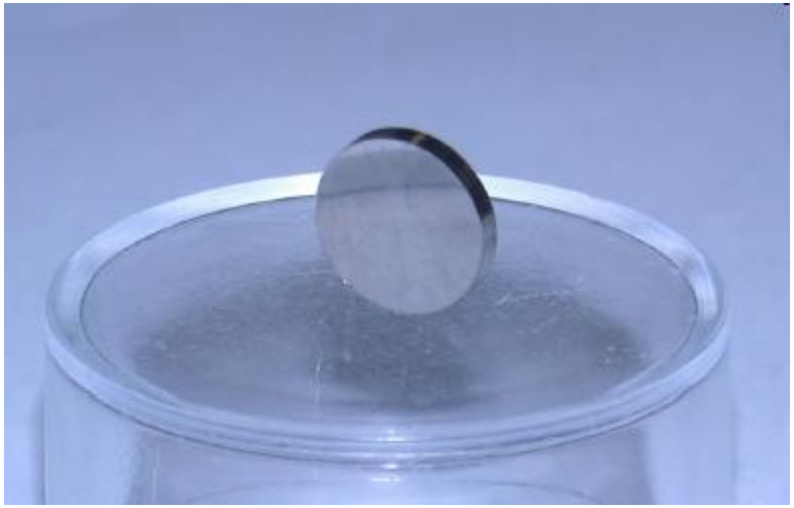


Chokshi et al., 1989

nc sample preparation using inert gas condensation



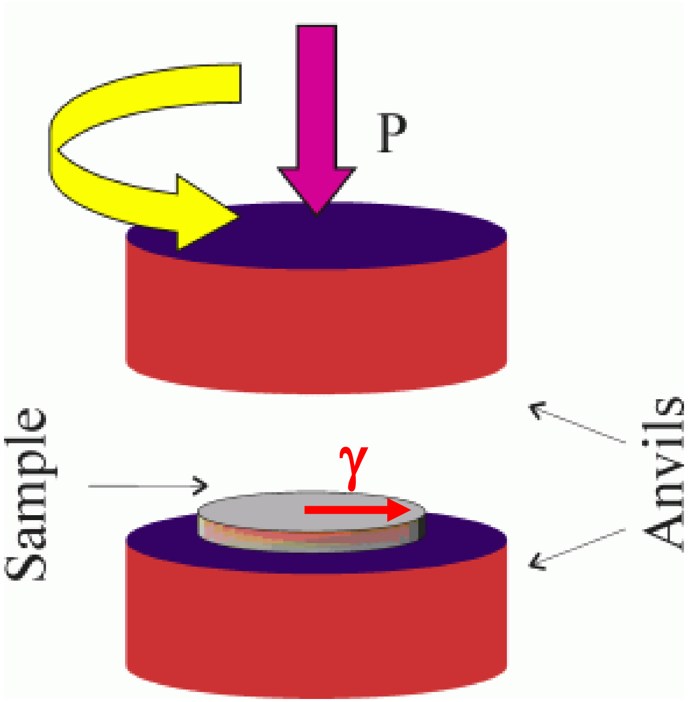
igc pellet



Ø = 8 mm
l = 0.3 – 0.5 mm

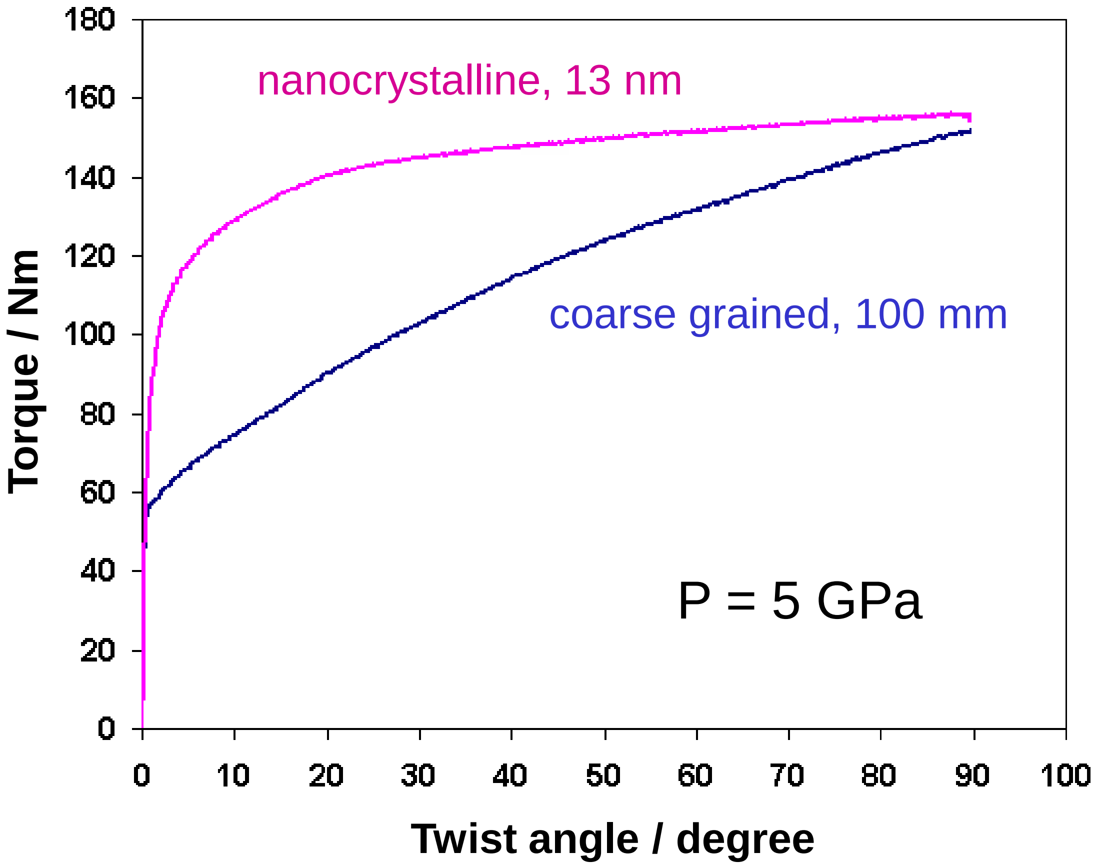
Work in collaboration with Yu. Ivanisenko

High pressure torsion (HPT)



http://www.ipam.ugatu.ac.ru/spd.html

Pd-10at.%Au



Work in collaboration with Yu. Ivanisenko

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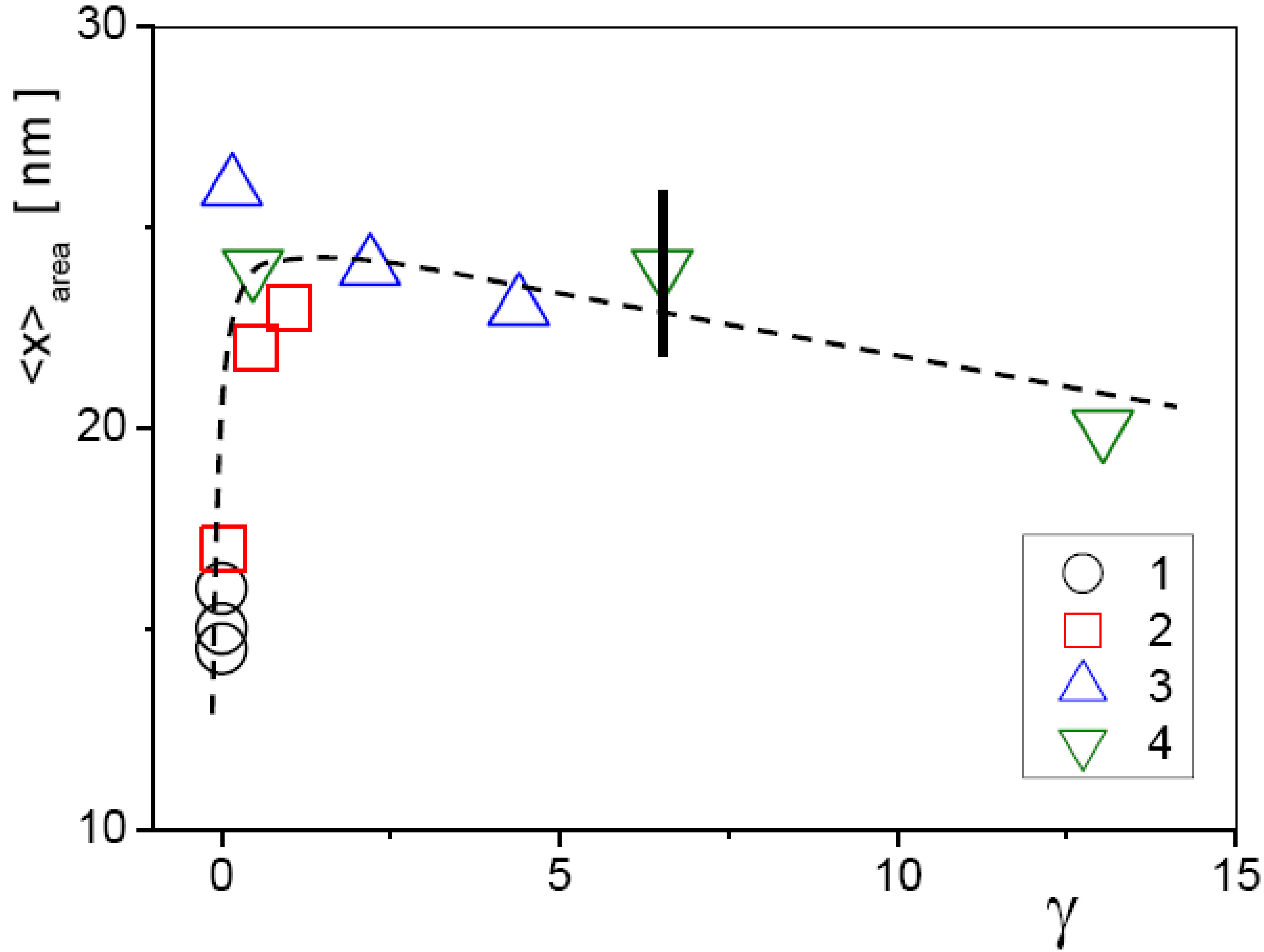
Grain size – shear strain



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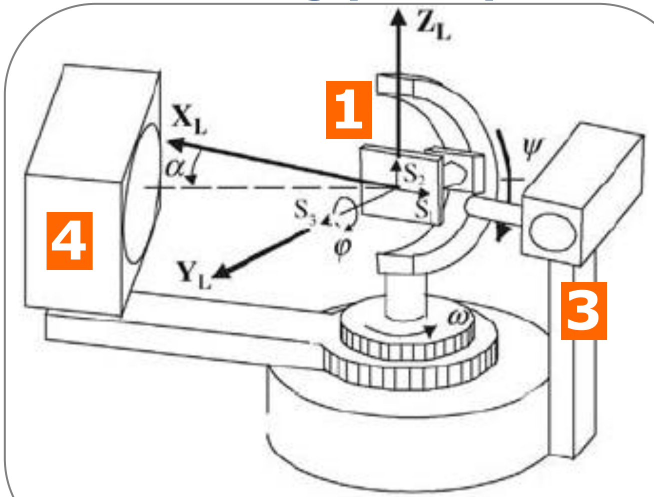
Texture measurement

Microdiffraction by *XRμD²*

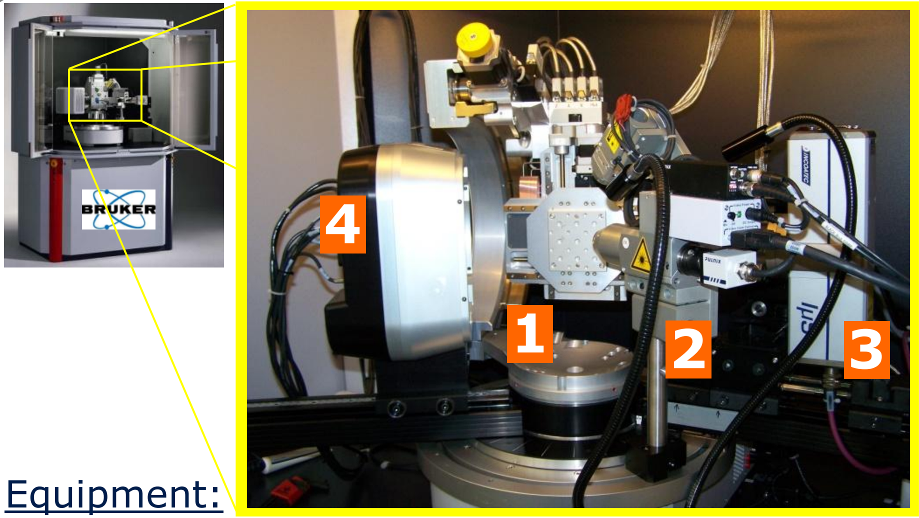
financed by EFRE
Europa fördert Sachsen.
Europäischer Fonds für regionale Entwicklung

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*

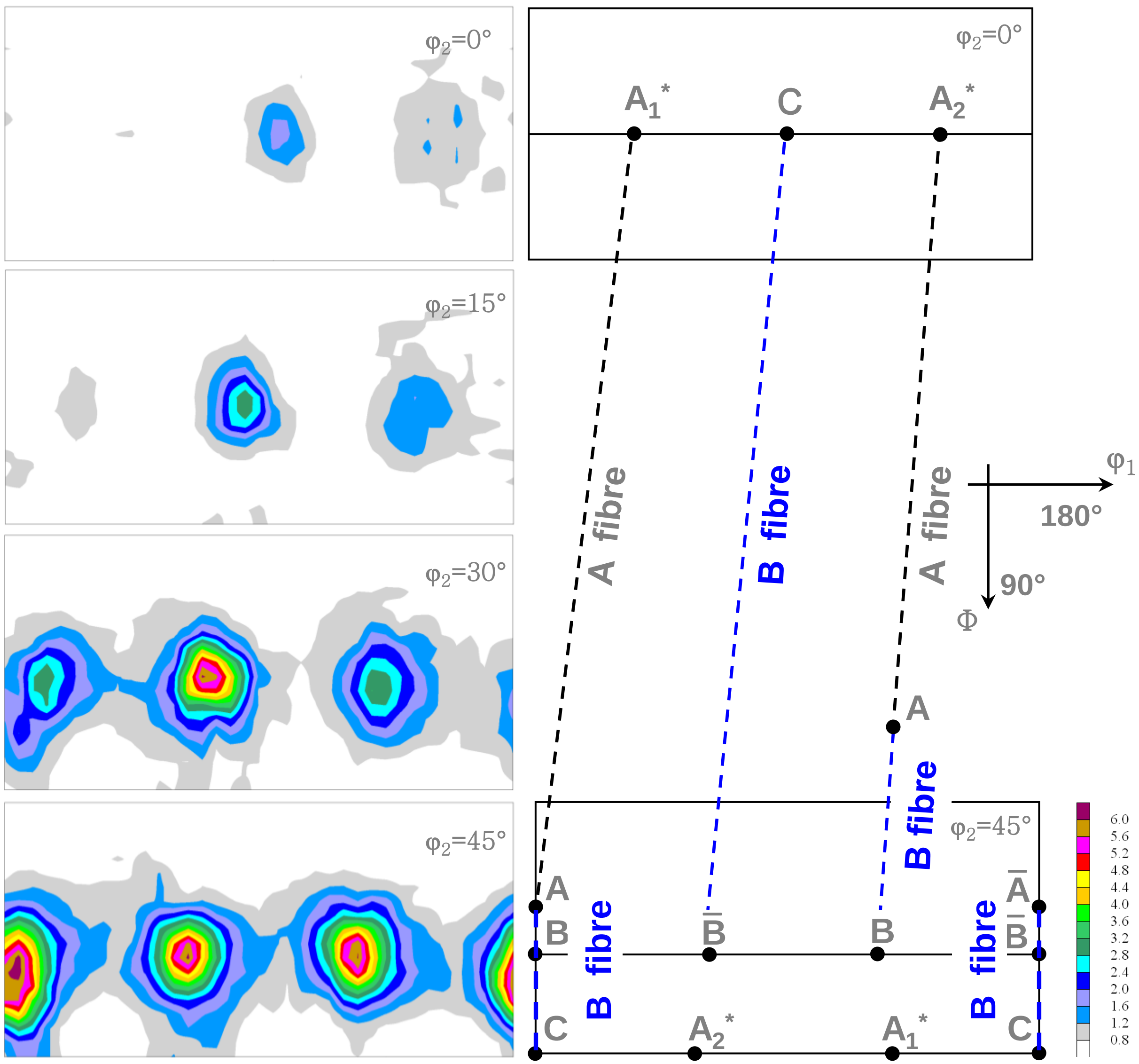
4 2D detector *VÅNTEC 2000*

Aims

correlated & spatially resolved

- **texture**
- stress

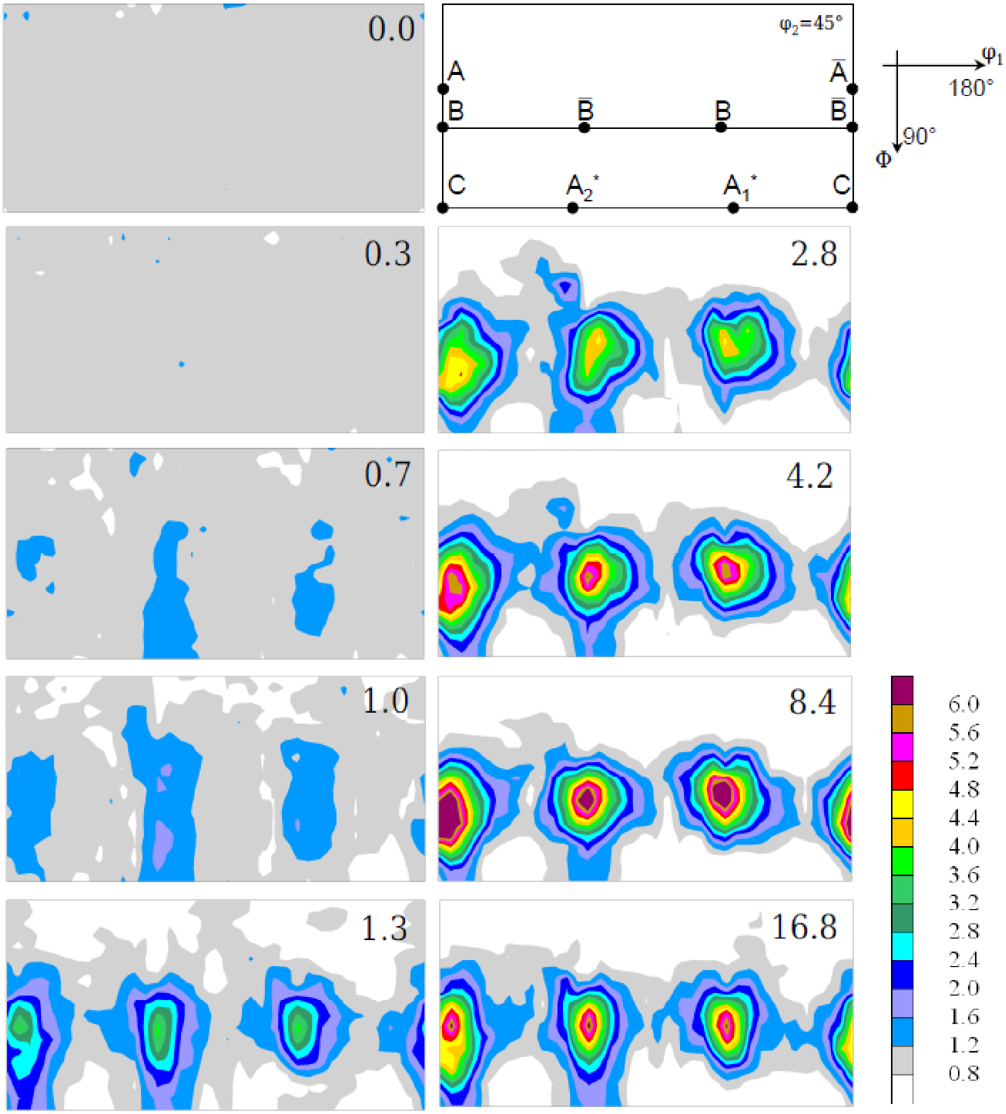
Texture after a shear strain of 12.6



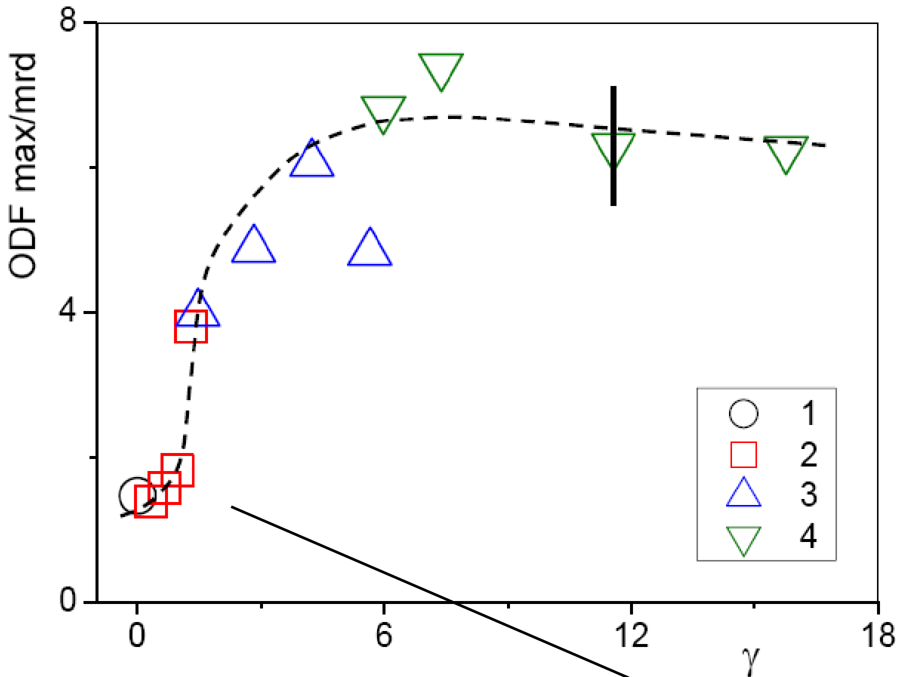
Texture components in simple shear deformed fcc metals

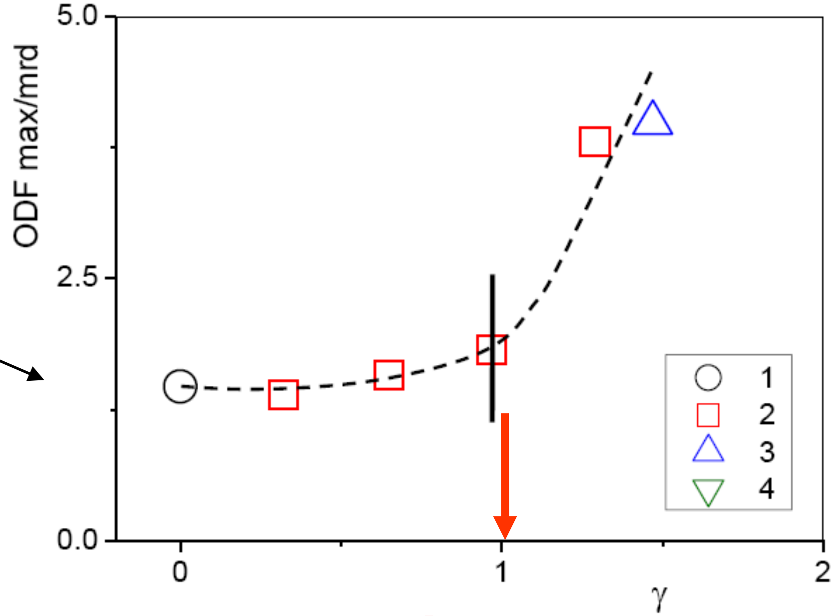
Component designation	Miller indices {shear plane }<shear direction>	Euler angles [°]		
		φ_1	Φ	φ_2
A	$\{1\bar{1}\bar{1}\}\langle 110\rangle$	0	35.26	45
$\bar{A}$	$\{\bar{1}11\}\langle\bar{1}\bar{1}0\rangle$	180	35.26	45
$A_1{}^*$	$\{\bar{1}\bar{1}1\}\langle 112\rangle$	35.37 125.37	45 90	0 45
$A_2{}^*$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

Texture development with shear strain



Texture development with shear strain





d = 20nm

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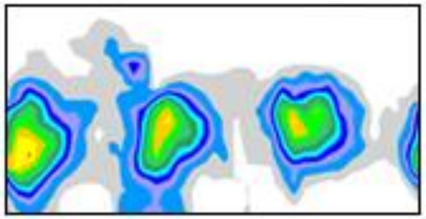
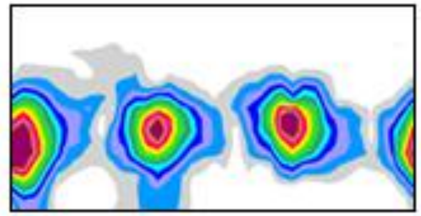
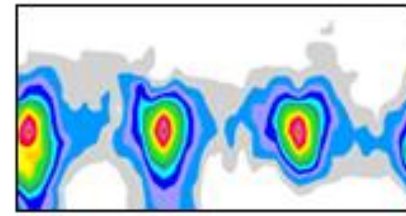
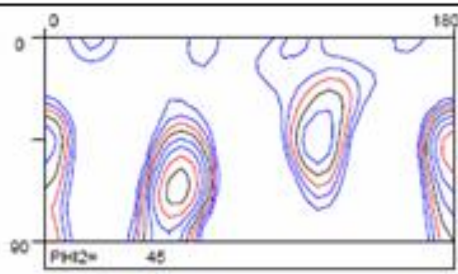
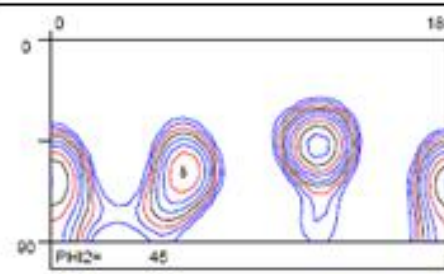
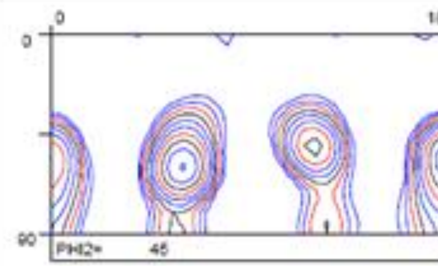
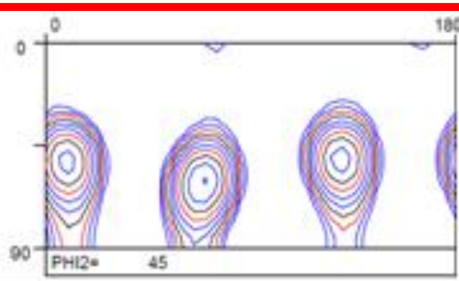
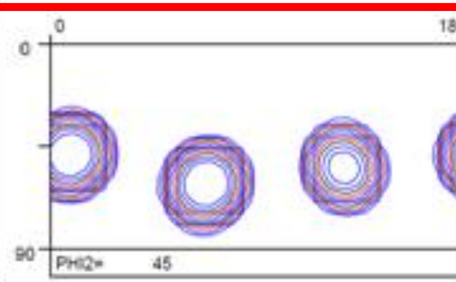
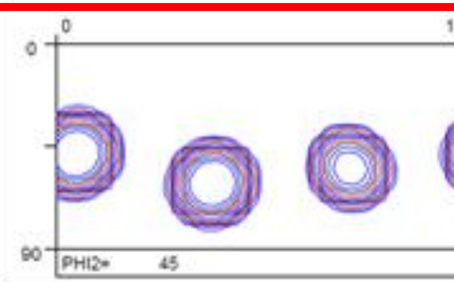
Modelling of texture development

	$\gamma = 2.83$	$\gamma = 8.38$	$\gamma = 16.76$
Experiment			
Taylor with <110>+<112> CRSS 1.5 : 1			
Taylor with GBS and <110>+<112> CRSS 1.5 : 1			

Contribution of GBS to total strain: 30%

Conclusions

- Choice of radiation, beam size, grain statistics are important for measuring texture gradients.

- Texture gradients in deformed polycrystals are more the rule than the exception.

- Texture gradients lead to gradients in anisotropic properties.

- Texture gradients in torsion deformed samples can be used to show the texture deveopment with shear strain.

Thank you for your kind attention !

Physics Building, Dresden University of Technology

Photo: A. Pukenas

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	$d_{1/2}$ [µm] Cu Kα (λ = 1,54 A)	10^4 $d_{1/2}$ [cm] Neutronen (λ = 1,5 A)
Pb	2	2,3
Cu	15	0,8
Al	53	6,3
Fe	3	0,5
SiO_2	76	2,5
$CaCo_3$	36	2,1
$NaAlSi_3O_8$	81	2,5
NaCl	42	0,7
$CaSO_4$	32	2,5
PbS	4	3,5
ZnS	24	6,0
Fe_2O_3	6	0,8