Metal Structures in 4D

RISØ

Emerging order in dislocation structures during metal loading

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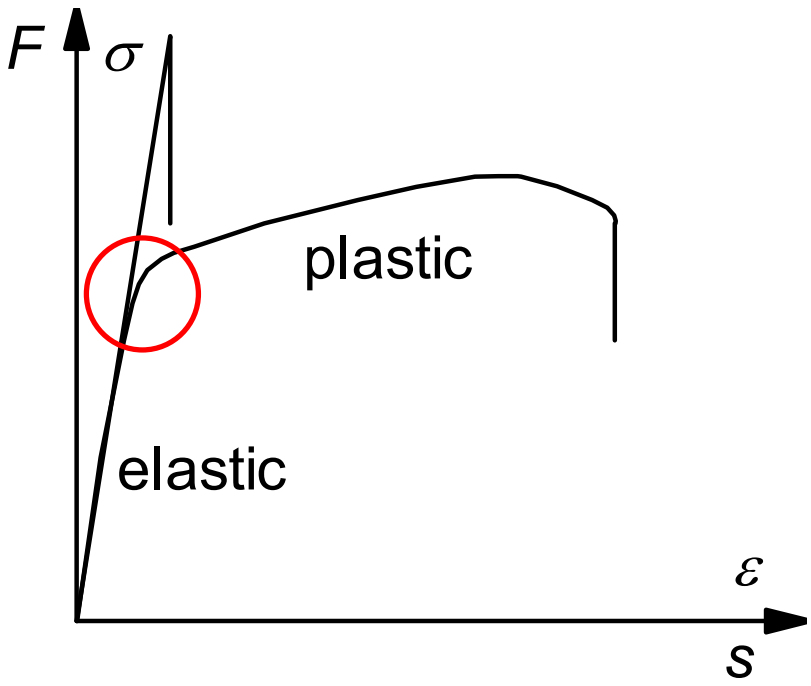
Plastic deformation of crystalline solids

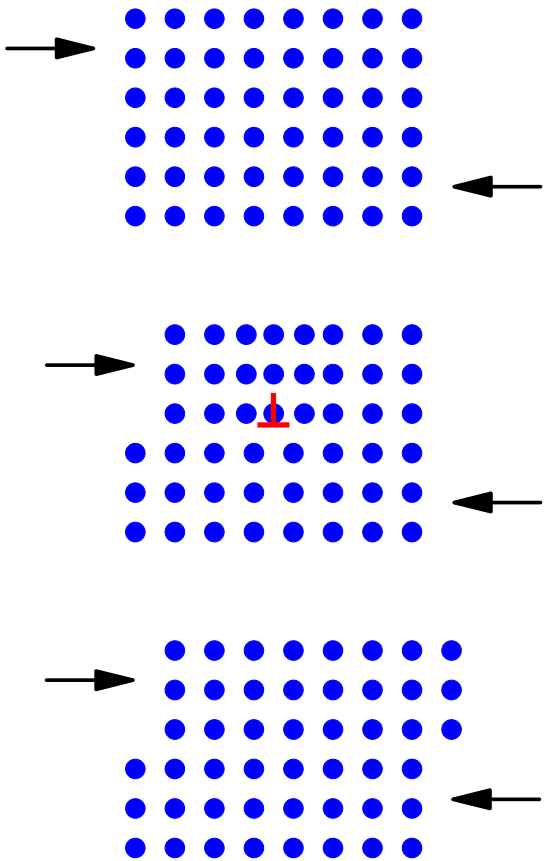


- Irreversible part
- Line defects:

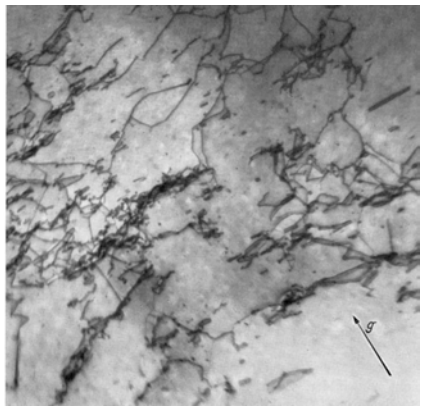
Dislocations

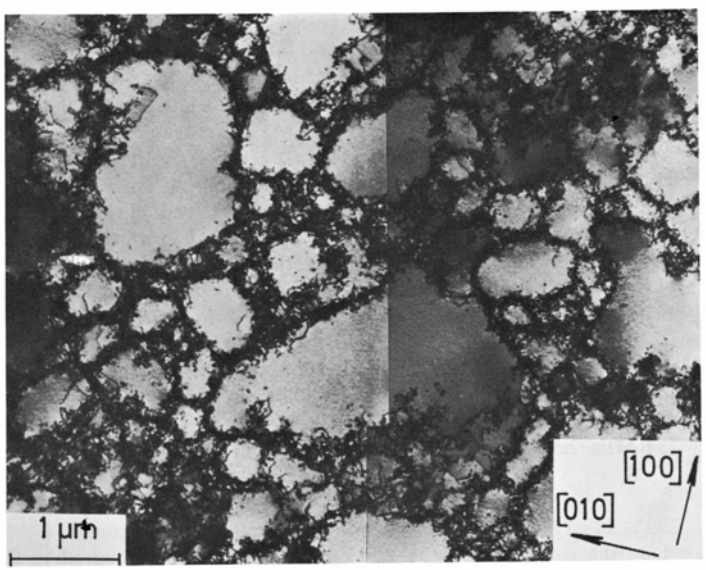
- Work hardening
- Typically 10^{16} m/m^3
- 10 million km in cm^3

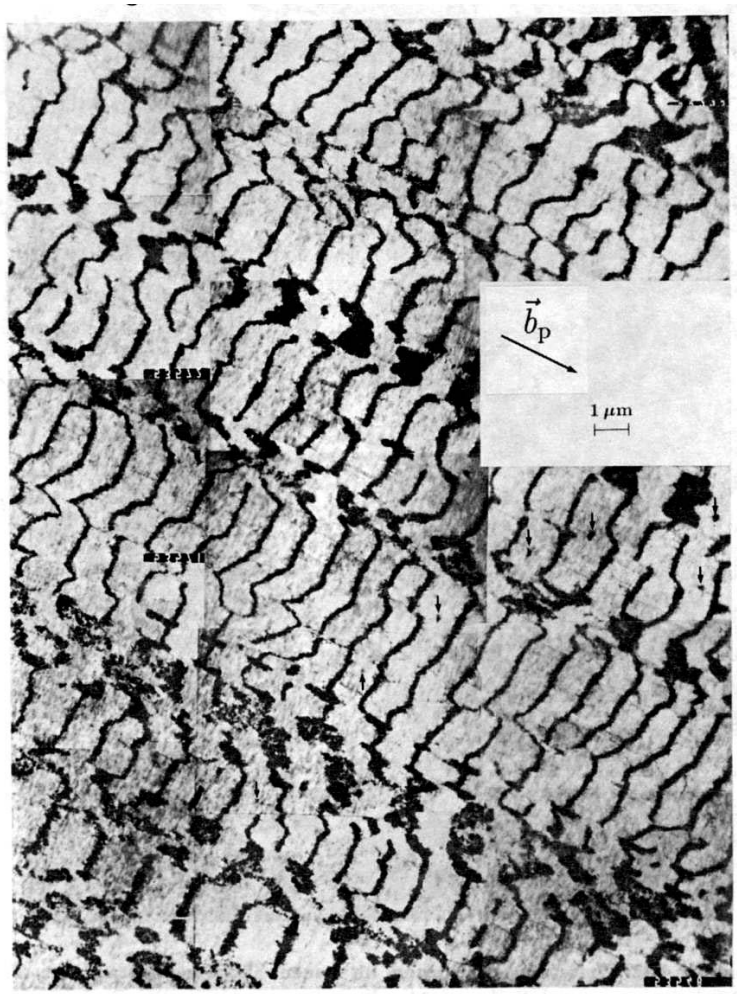
Dislocations



Dislocation structures (TEM)

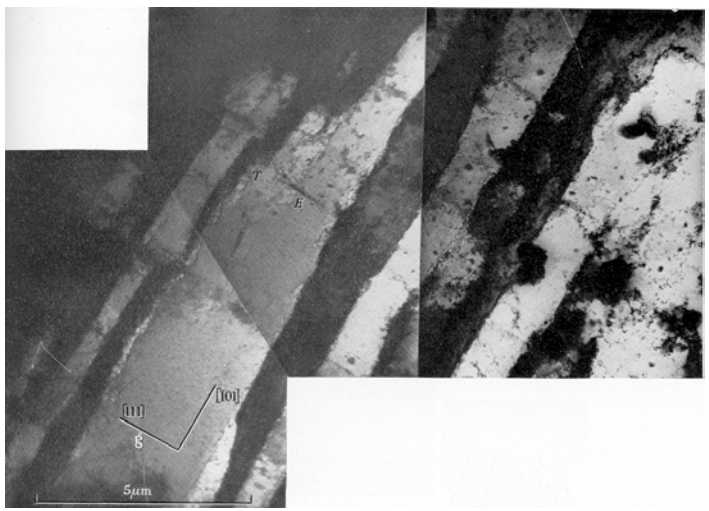




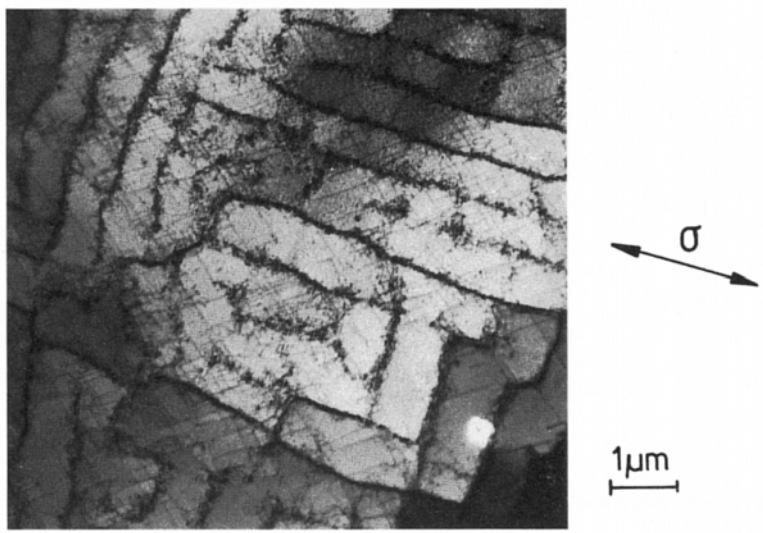


Dislocation structures (Concepts)

LEDS - Low Energy Dislocation Structures



Self-organization and patterning

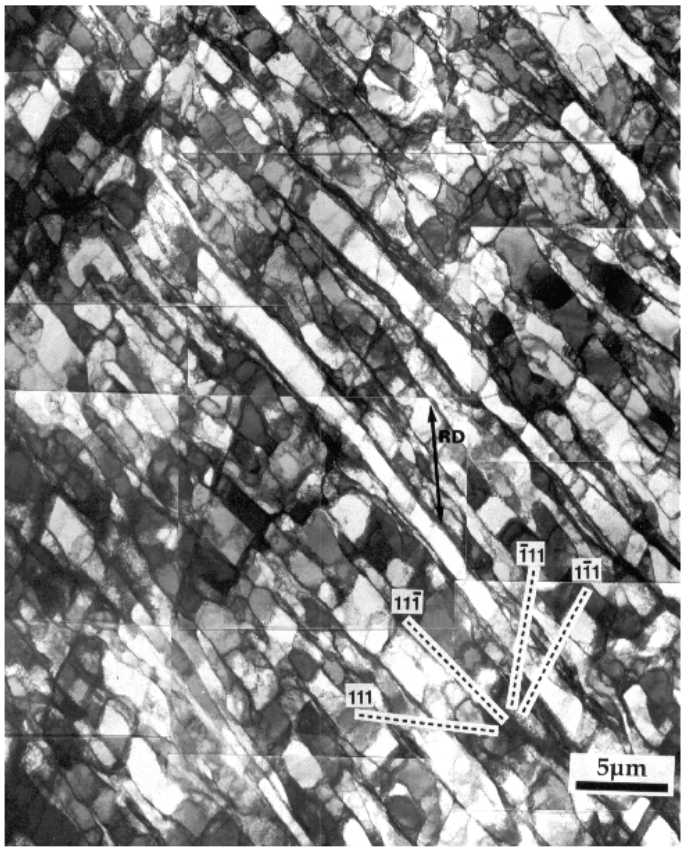


Energy versus Entropy

post mortem versus *in situ*

Emergence of dislocation structures

Evolution versus ‘Graveyard’



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XRD *in-situ* investigation

- broadening as signature of dislocations
- conventional: average over many grains

- goal: peak shapes of individual grains embedded in bulk during deformation
- collaboration Risø and XOR at APS

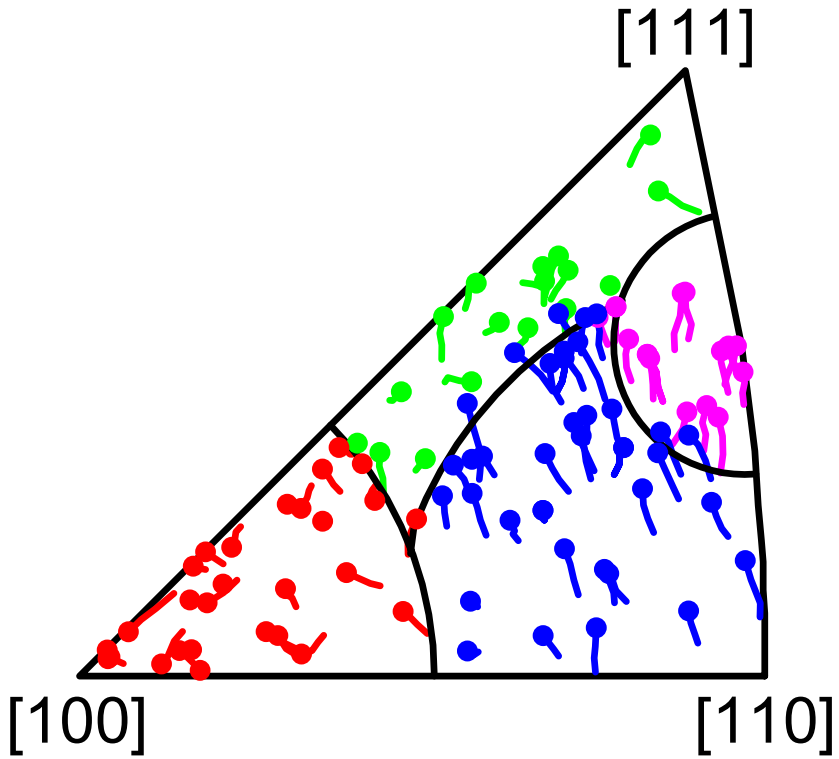
Lattice rotations of individual bulk grains

(Winther et al., Acta mater. 52 (2004) 2863)

3DXRD at ESRF

- tensile deformation of AA1050 to 6% strain

- rotation of tensile axis
- different directions
- towards [100]-[111]
- along [100]-[111]
- towards [111]



Experimental setup

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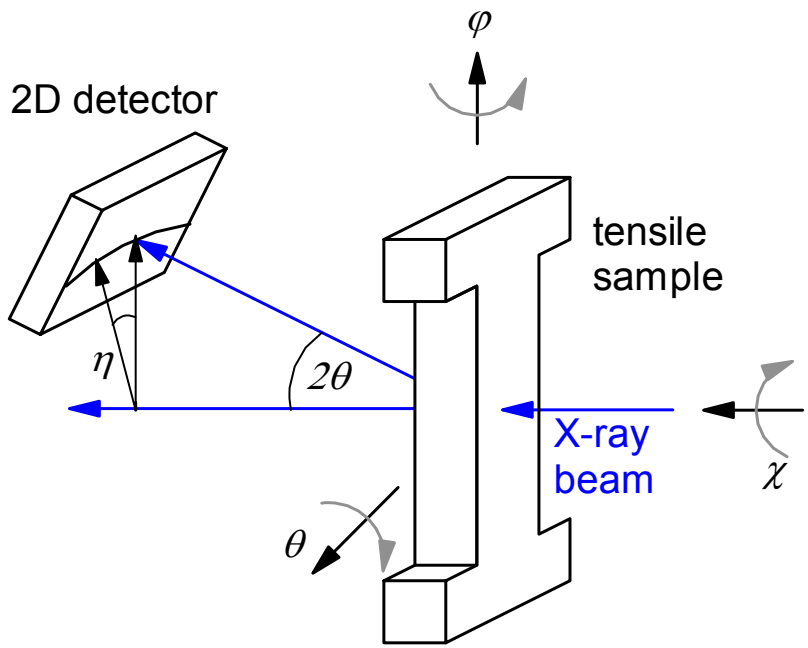
Beamline 1-ID-XOR

two area detectors

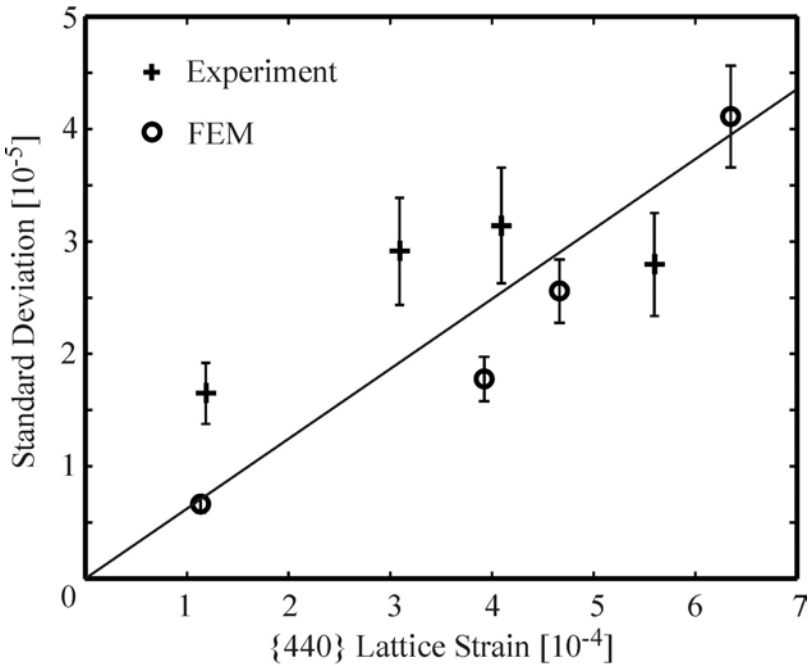
1. close to sample (20 cm): grain orientations
2. far from sample (3 m): peak shapes with high resolution



Elastic axial strains under load

(Lienert et al. 2004, Acta mater. in press)

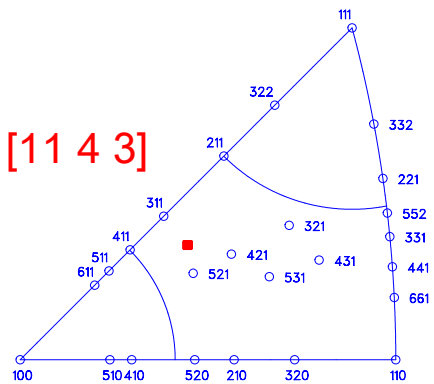
- Cu polycrystal
- tensile deformation up to 2%
- twenty grains with tensile axis within 2.5° from [110]
- 440 reflections
- comparison with finite element simulations of grain ensemble



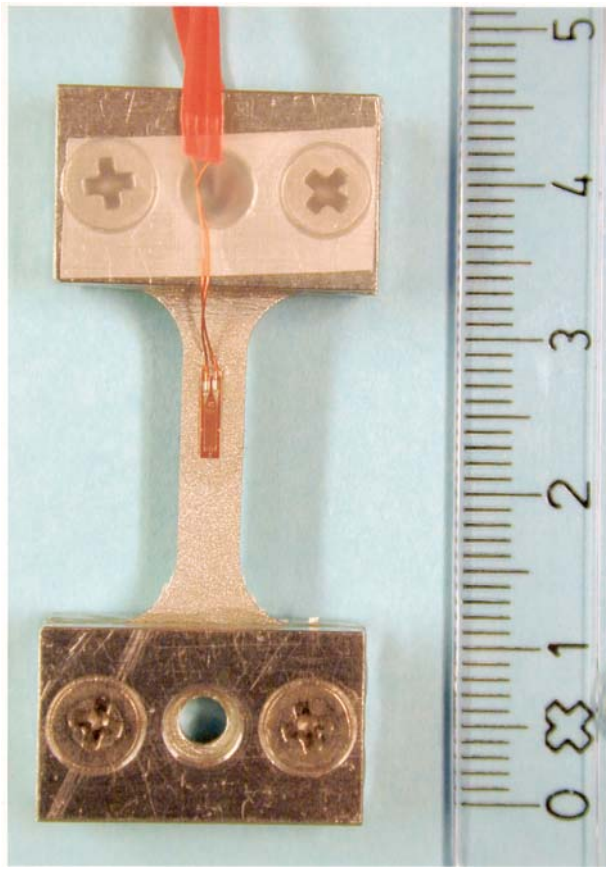
Feasibility study

(Pantleon et al. 2004, Mater. Sci. Eng. A in press)

- Aluminium AA1050
- selected bulk grain

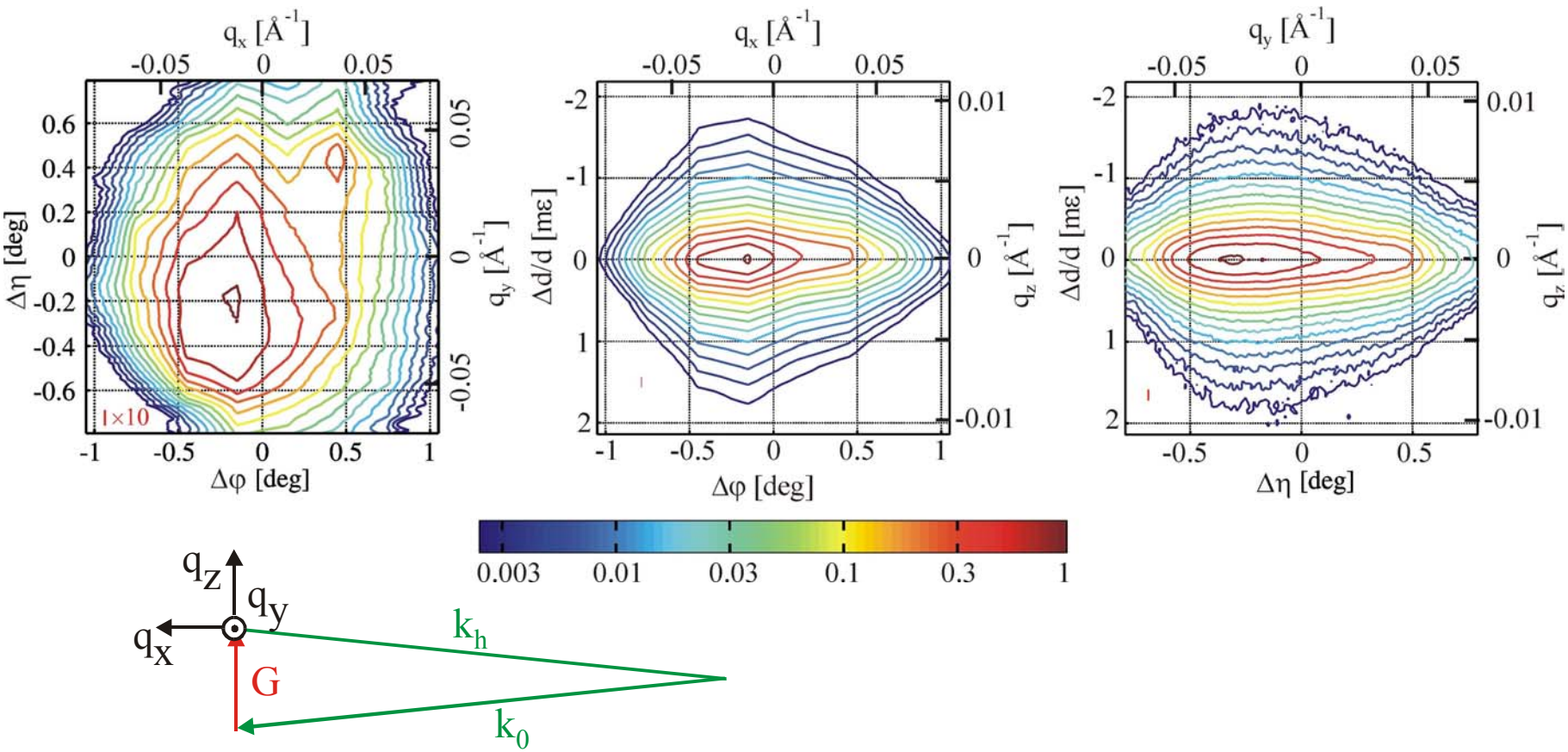


- tensile straining to 4.5%
- peak shape for 20 reflections



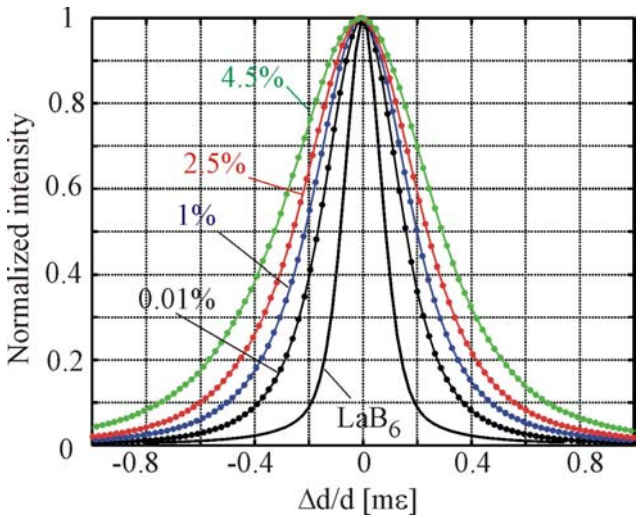
Reciprocal space projections

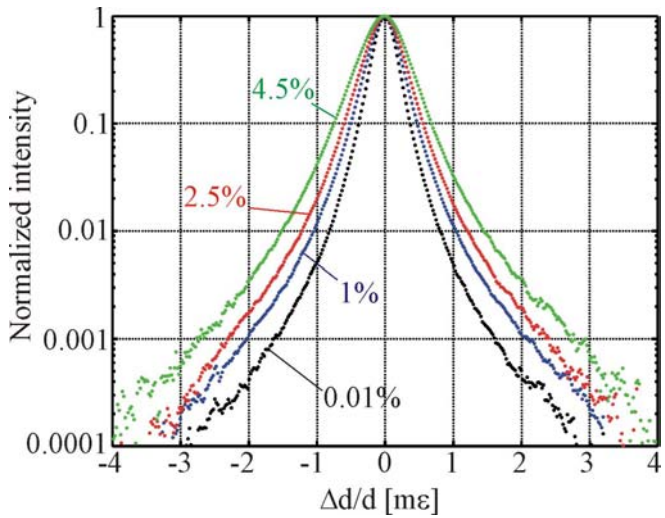
$\bar{1}13$ reflex after 2.5 % strain



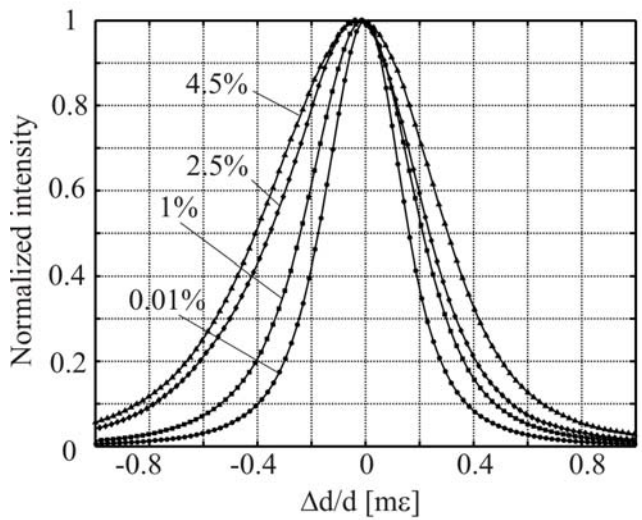
Radial peak profiles

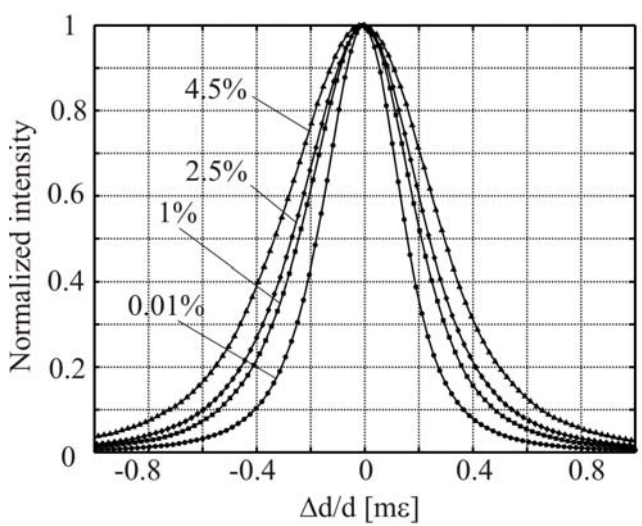
$\bar{1}13$
χ=66.3°
symm





$1\bar{1}3$
χ=86.0°
asym
'side'

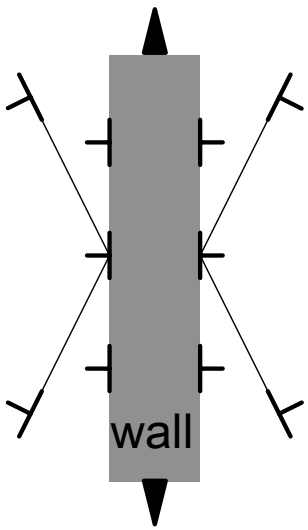




$11\bar{3}$
χ=80.7°
symm
'side'

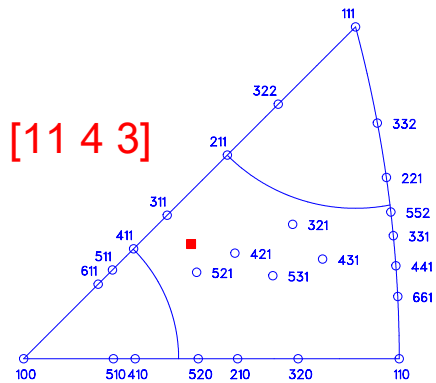
Peak profile asymmetry and microstructure

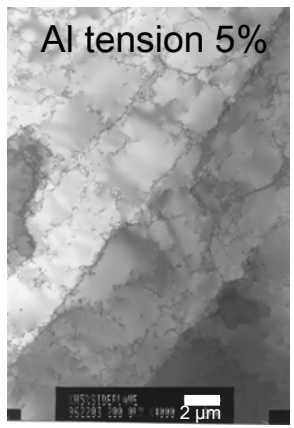
- internal stresses
  (Mughrabi et al. 1986)



- isotrop cell structure
- ‘axial’ vs. ‘side’ case

- tensile deformed Al
  (Huang, Hansen 1997)





TD

- boundaries aligned with slip plane

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Achievements

- proven functionality in interrupted tests
  - 3D reciprocal space maps
  - azimuthal and radial broadening
- first dynamic observation of peak profiles from an individual bulk grain with high resolution