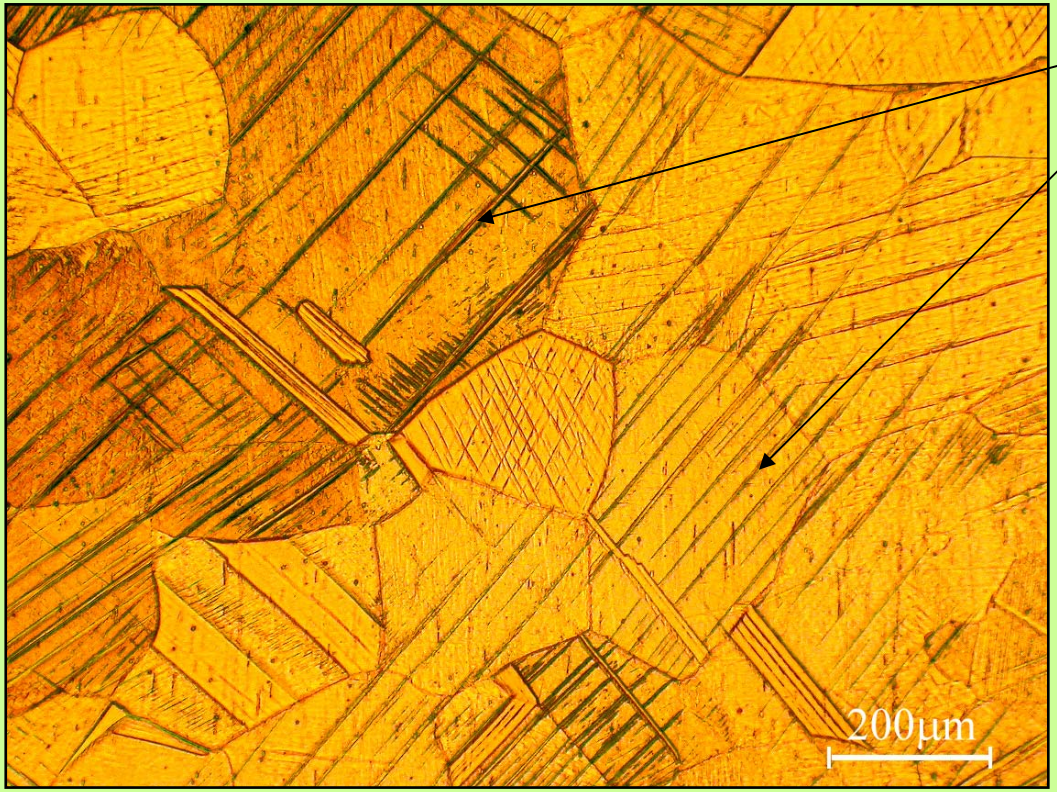
Structural changes in metals under high-rate deformation

A.M. Podurets*, V.A. Raevsky*, M.I. Tkachenko*, A.N. Balandina*, I.N. Kondrokhina*, O.N. Ignatova*, A.I. Lebedev*, V.G. Khanzhin†, J. Petit‡, M.A. Zocher♪

* Russian Federal Nuclear Centre, Sarov, Russia
† Moscow Steel and Alloys Institute, Russia
‡ CEG, Gramat, France
♪ LANL, Los Alamos, NM, USA

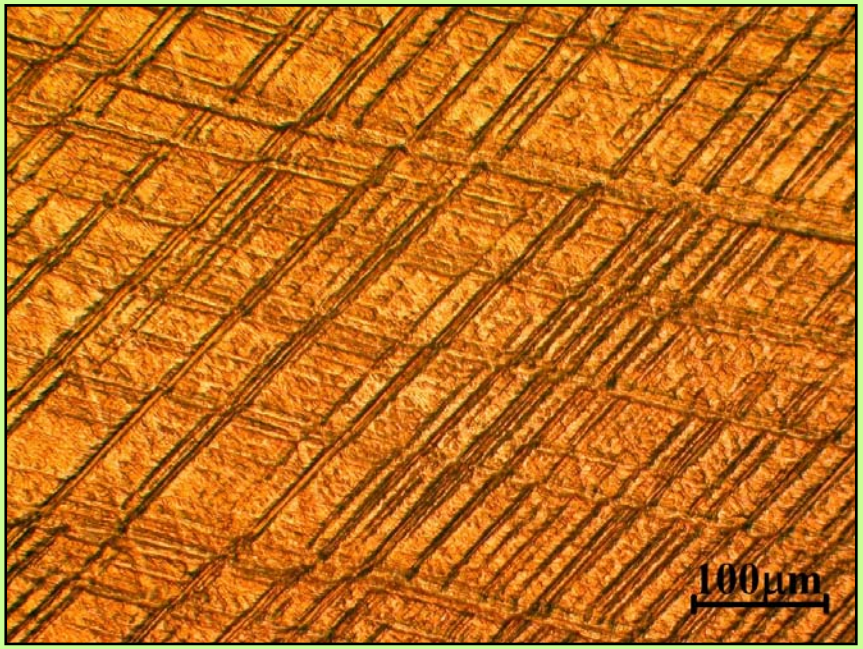
Joint U.S. – Russia Conference on Advances in Materials Science

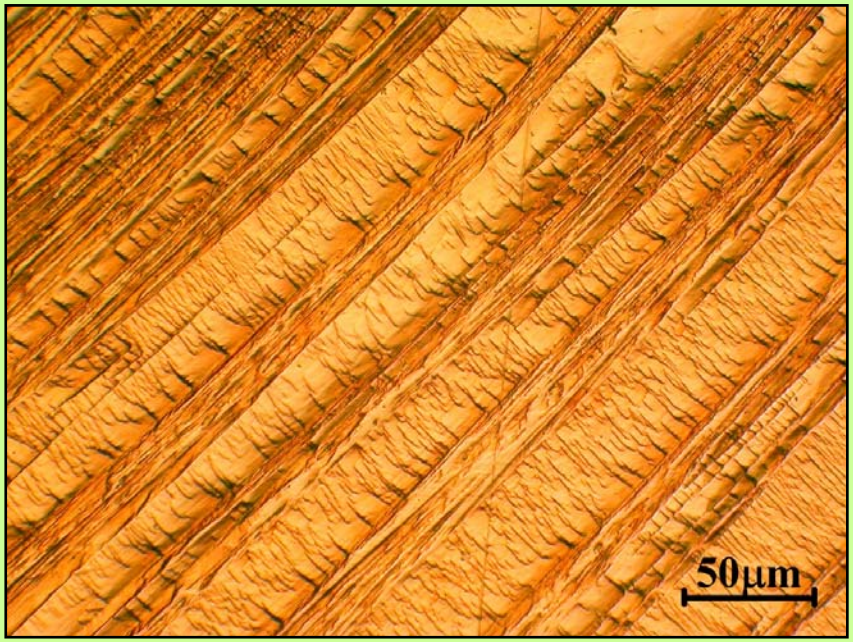


Bands of localized deformation

Microstructure of copper ($d \approx 350$ μm) after shock loading

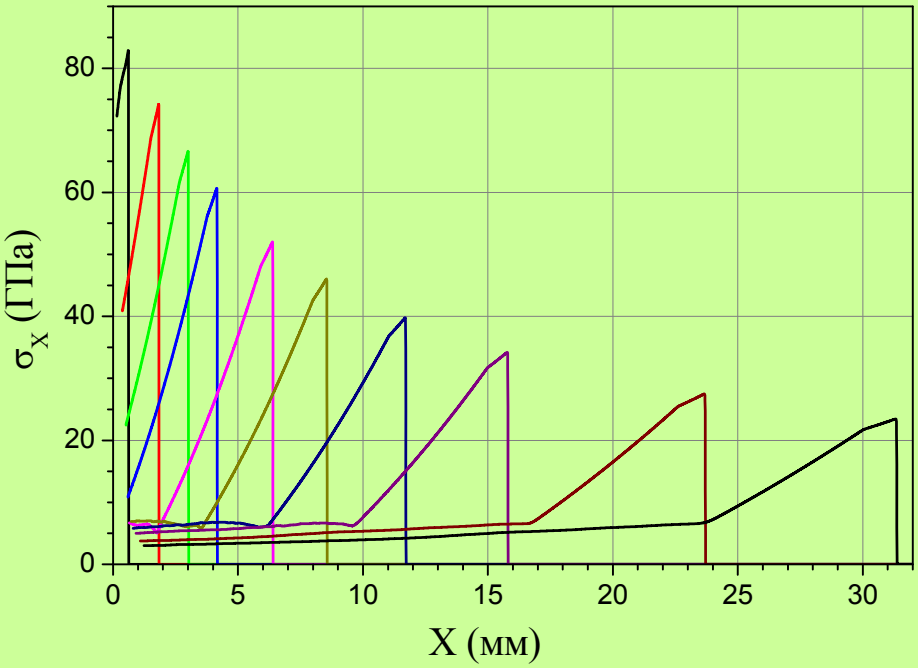
Bands of localized deformation in *Cu* single crystal



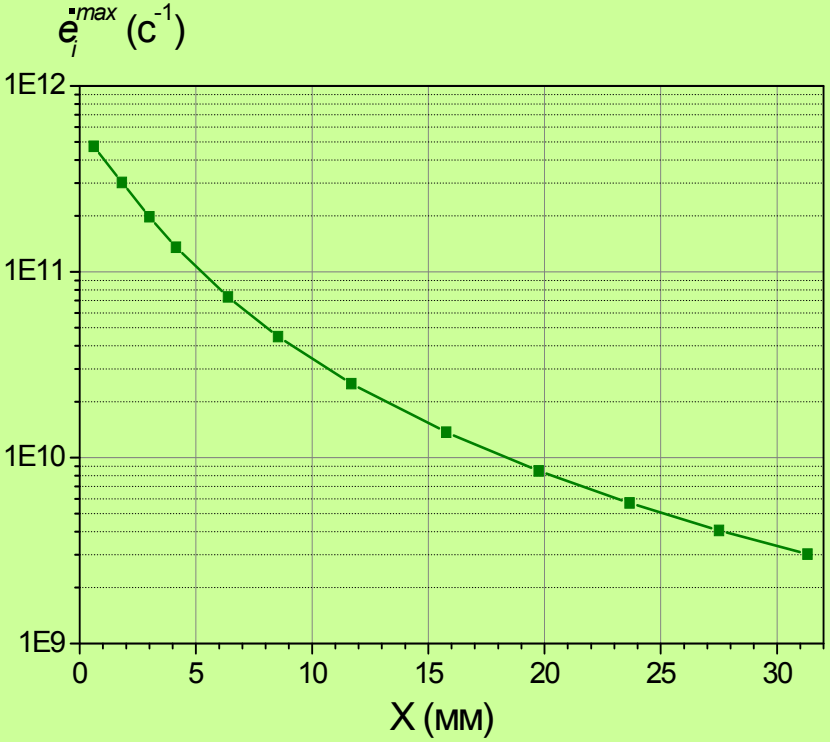


$$P \approx 40\ GPa$$

Experimental setup

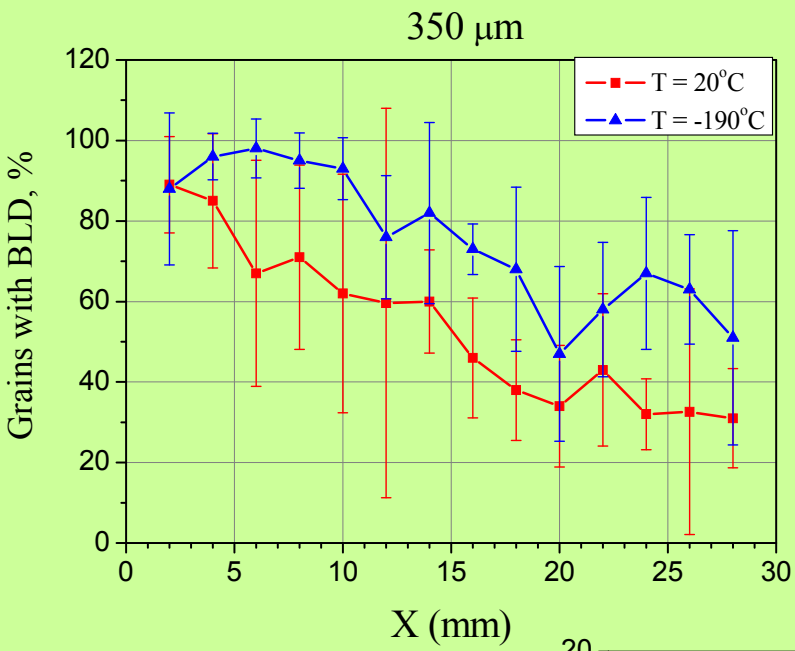


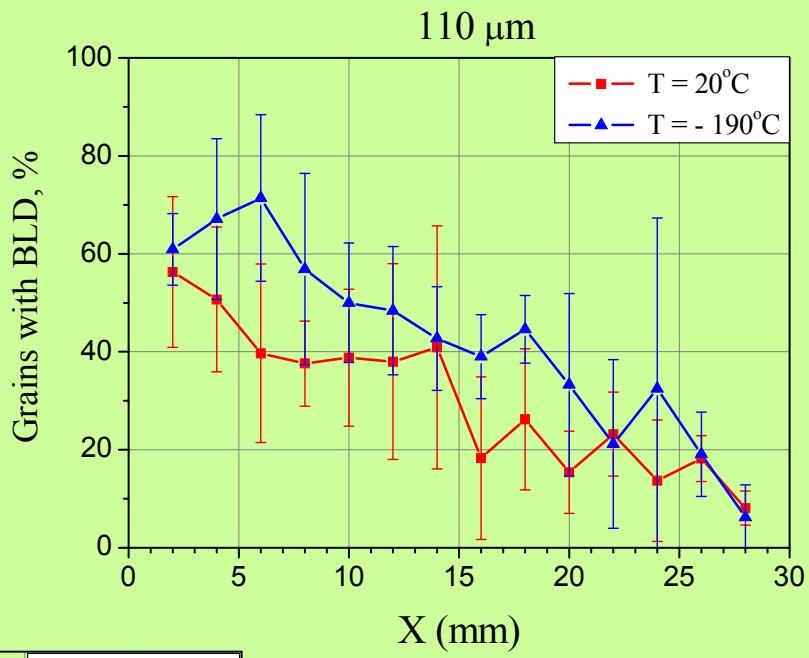
Calculated pressure profiles in the sample

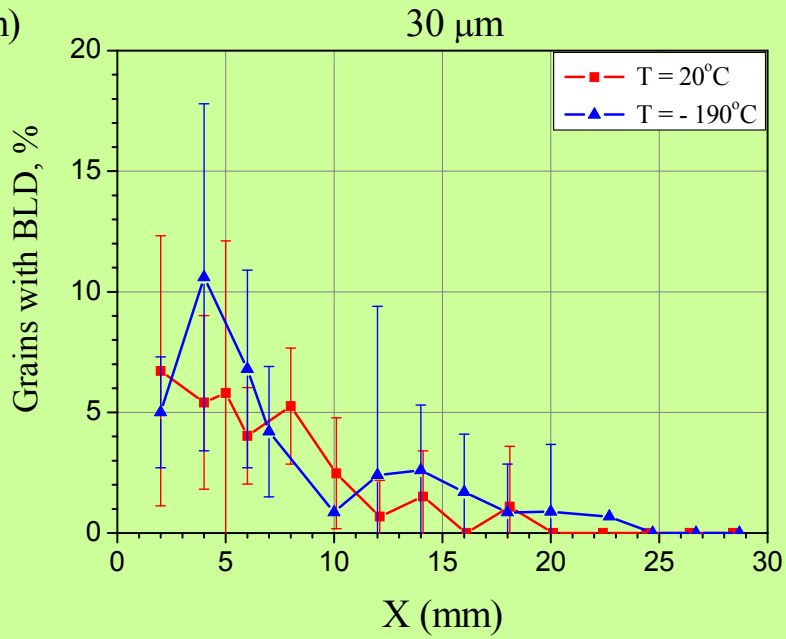


Maximal strain rate

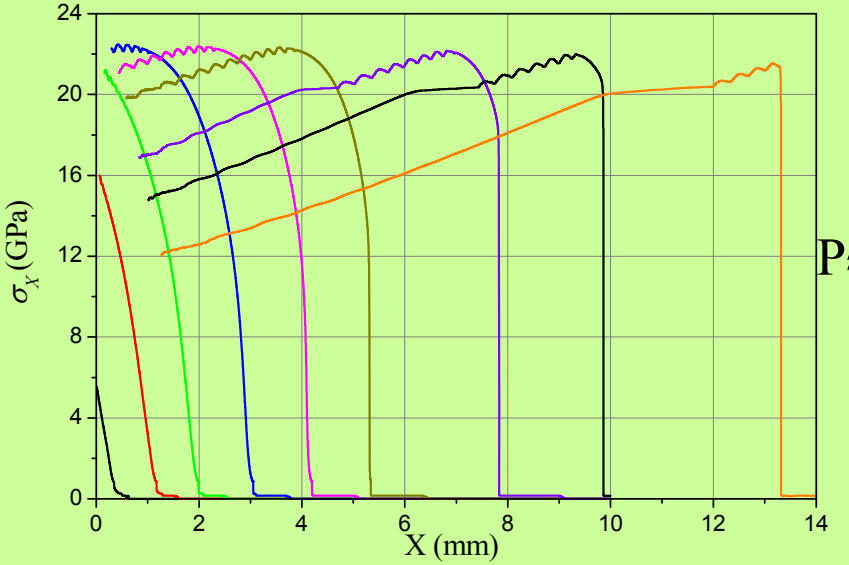
Grains with bands of localized deformation in loaded samples



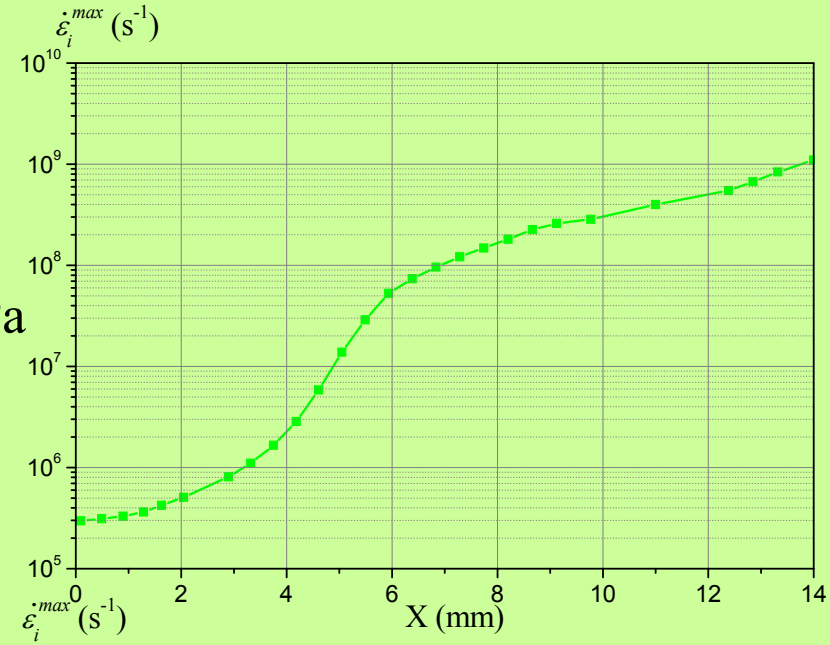


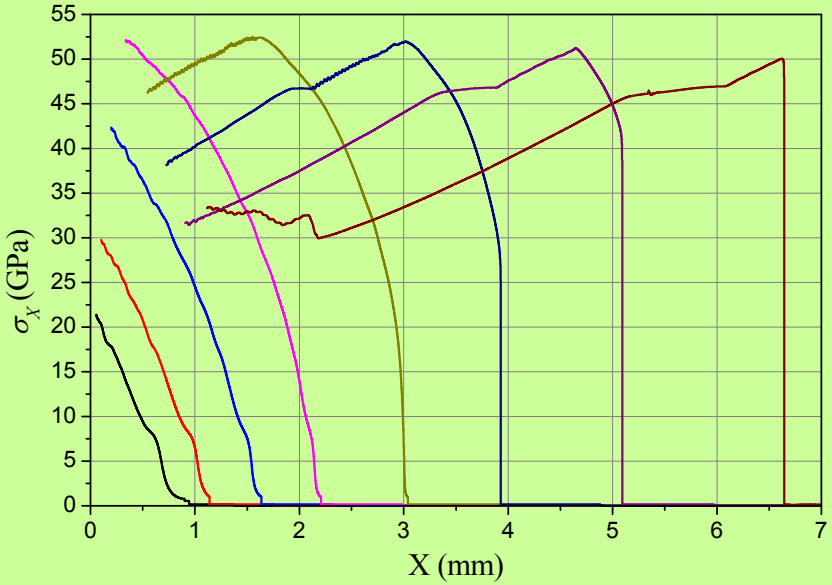


Calculated σ_X and strain rate profiles

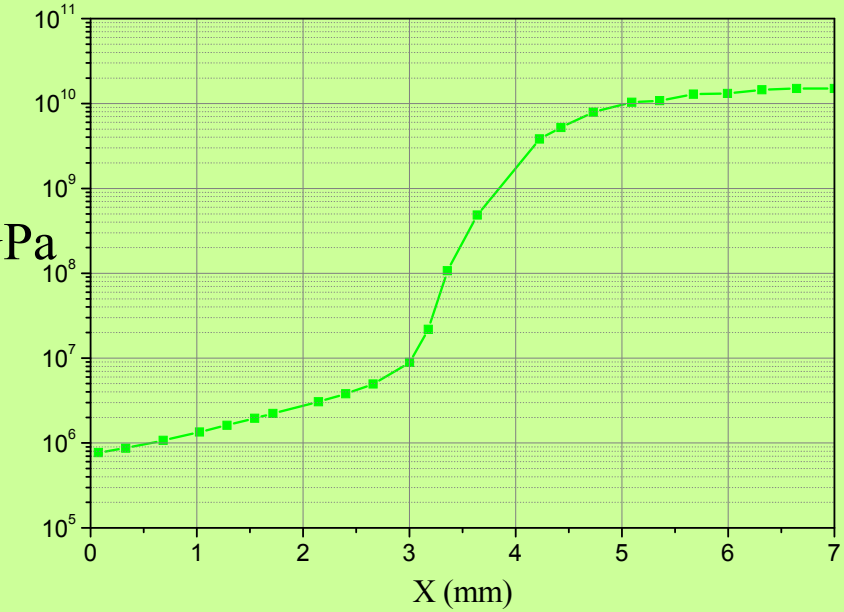


P≈20 GPa

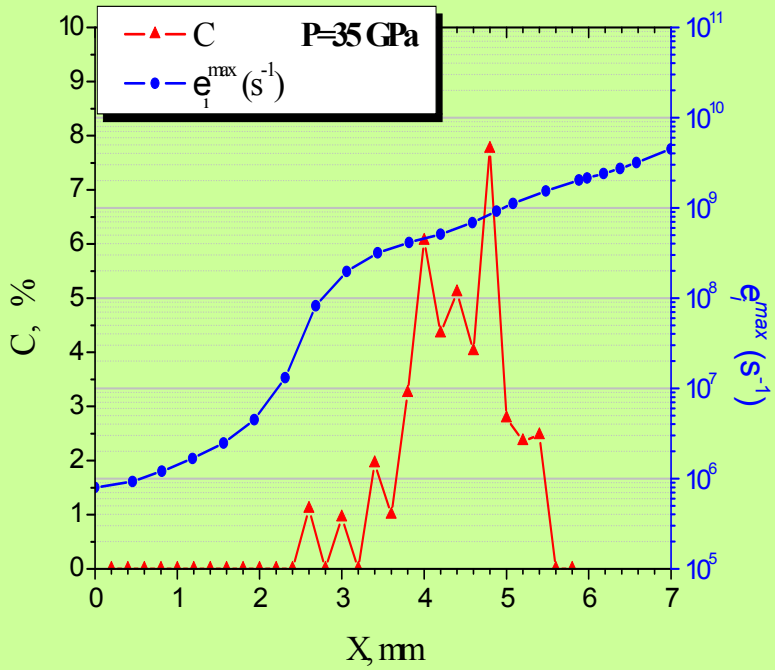


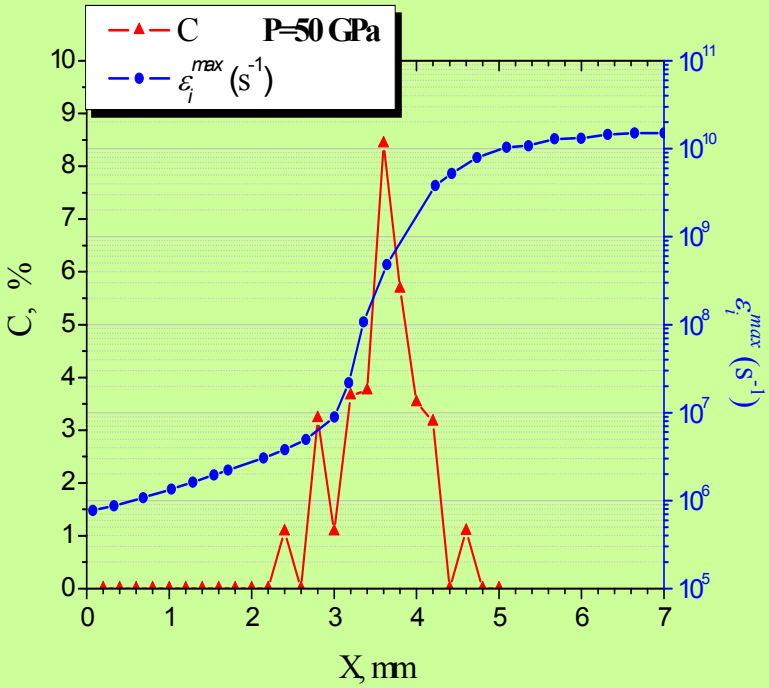


P≈50 GPa



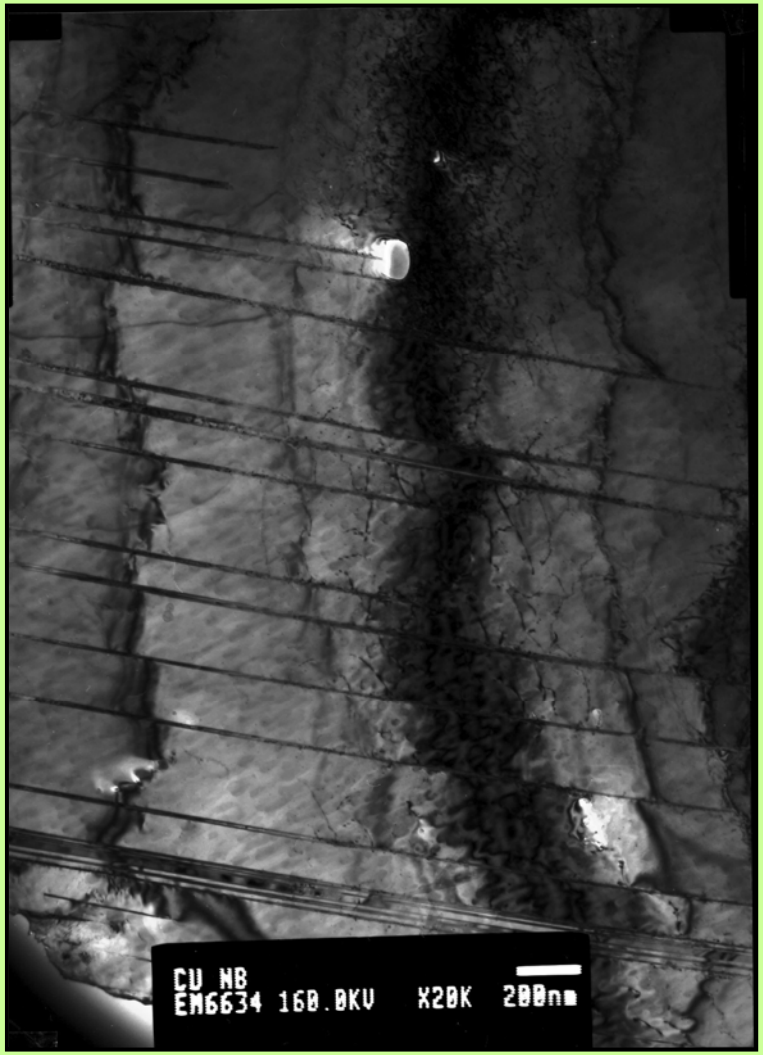
Concentration of grains with BLD



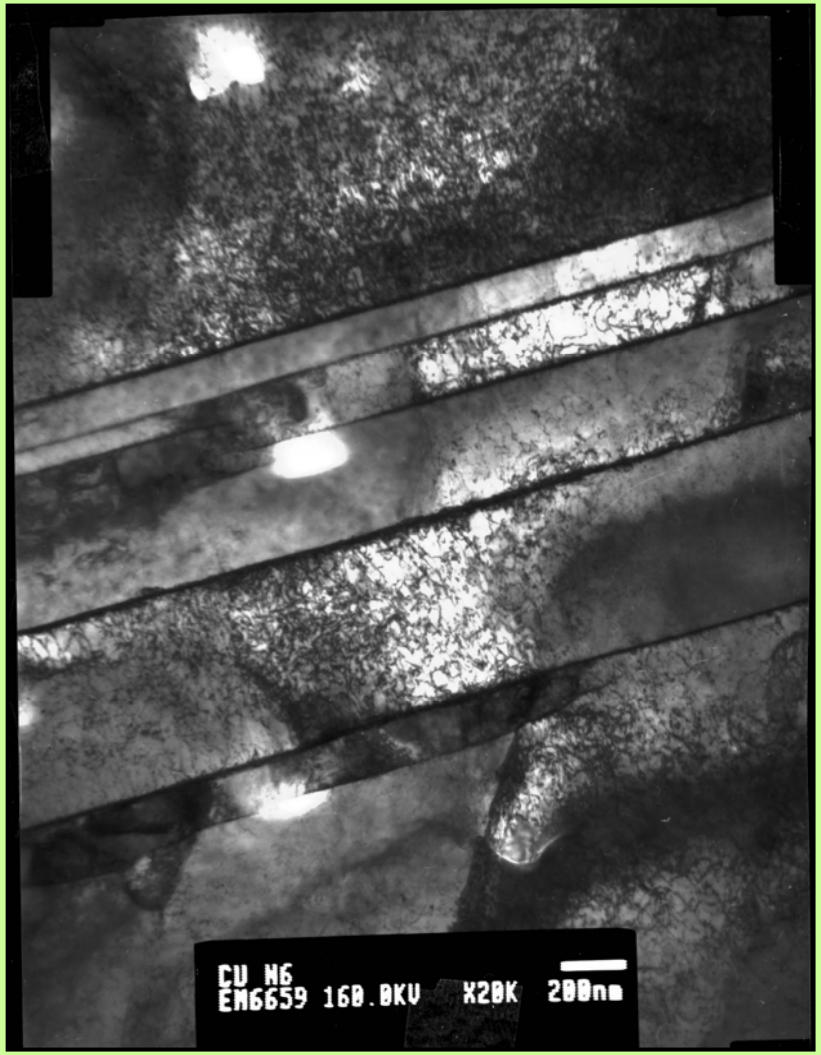


Formation of bands of localized deformation

- Shear bands form mainly in coarse-grain copper.
- When the pressure decreases the amount of shear bands decreases also, and their period increases. (In copper with the finest grain – 30 *μm*- shear bands disappear at P<30 *GPa*).
- Lowering of temperature increases the shear bands formation possibility.
- When the strain rate increases the amount of shear bands increases also.
- The threshold of bands formation is : P~25GPa, $\acute{\varepsilon}$~$10^7 s^{-1}$



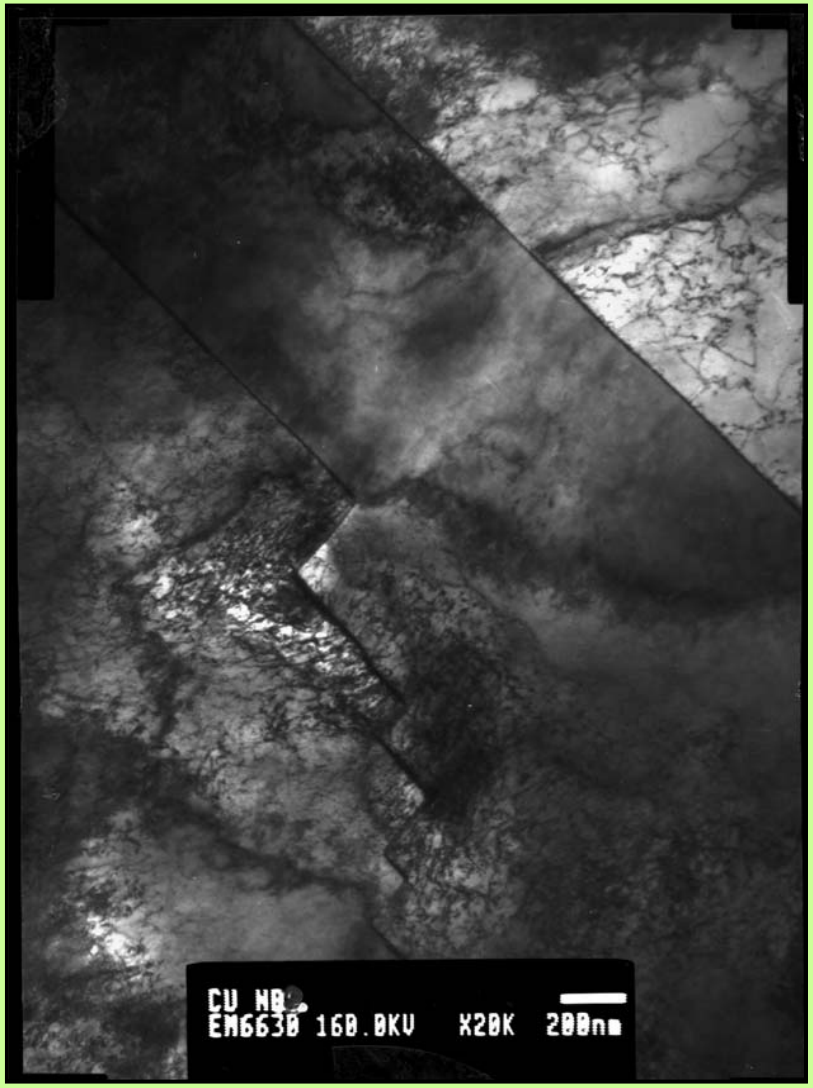
«Thin» twins, thickness u <10 nm
(P=18 GPa)



«Thick» twins, thickness u~100 nm
(P=58 GPa)

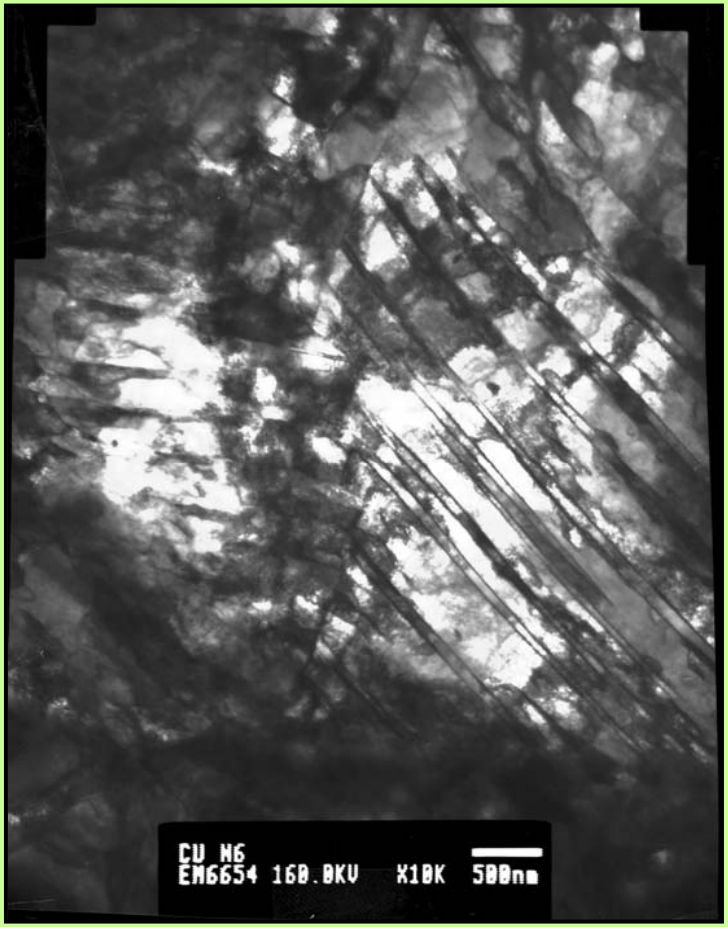
Form of twins

Twin shape as a lens (P=35 GPa)



Twin with noncoherent boundary (P=20 GPa)

Parallel location of twins



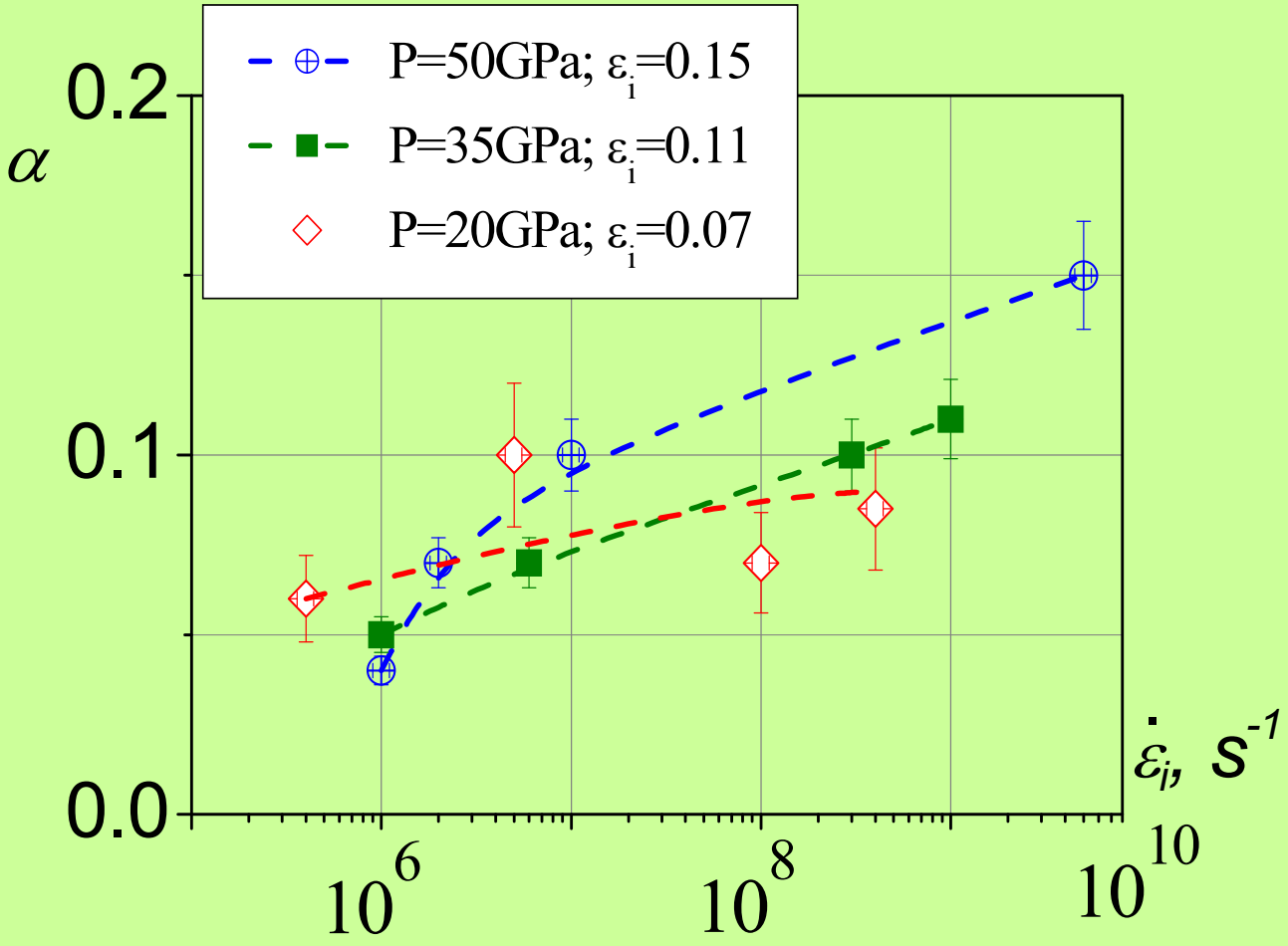
P=58 GPa

P=20 GPa

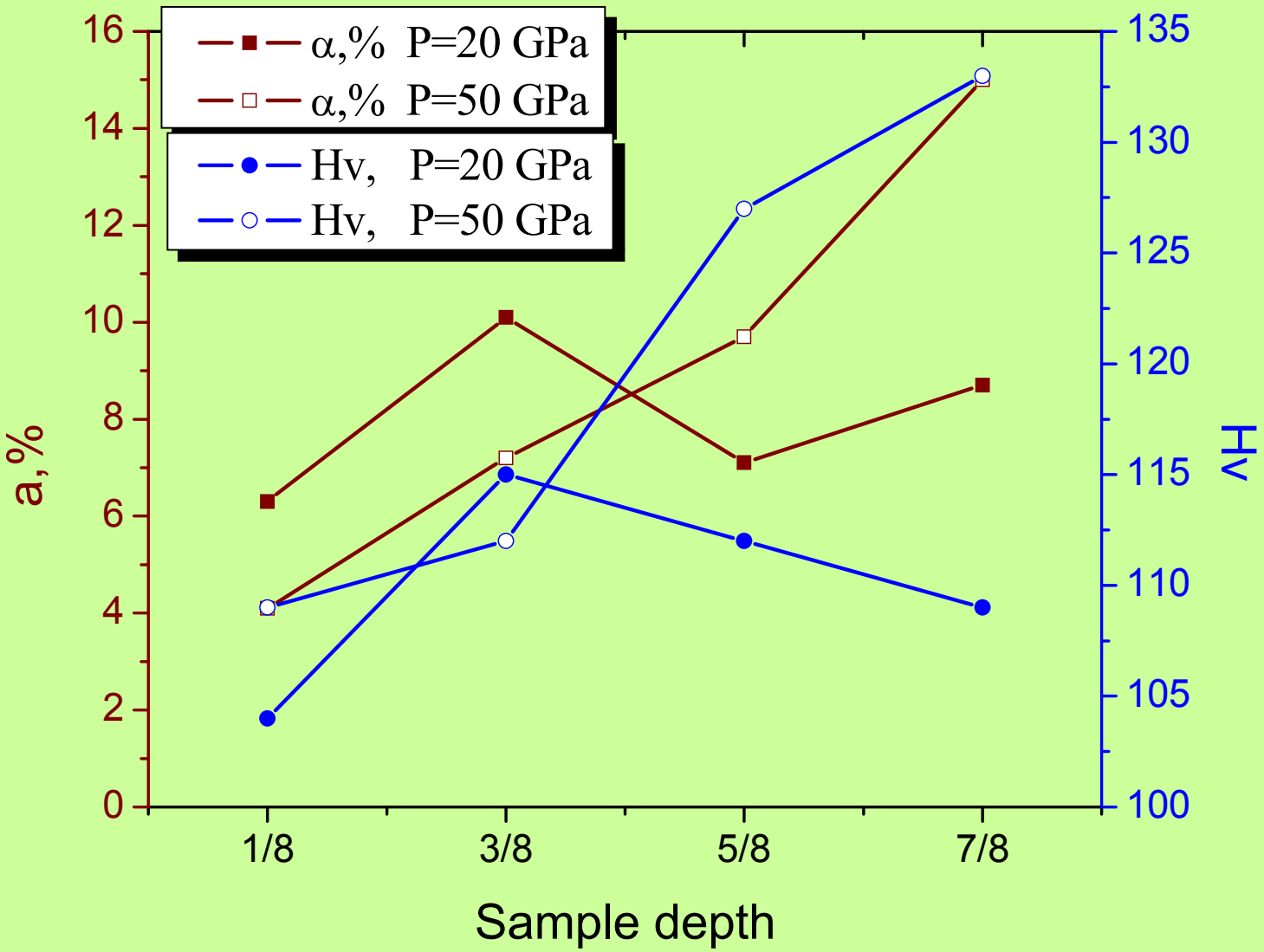
BLD formed by twins

P=20 GPa

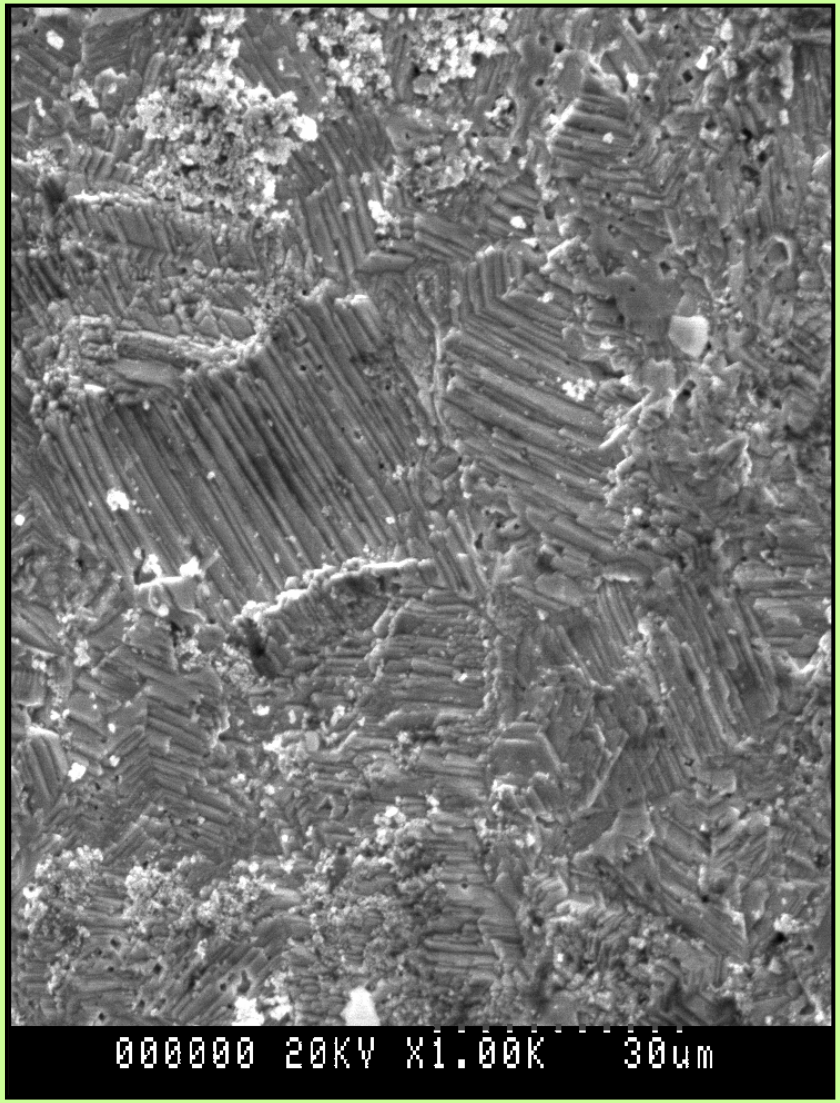
Dependence of volume fraction of twins, α, on loading conditions



Concentration of twins and microhardness



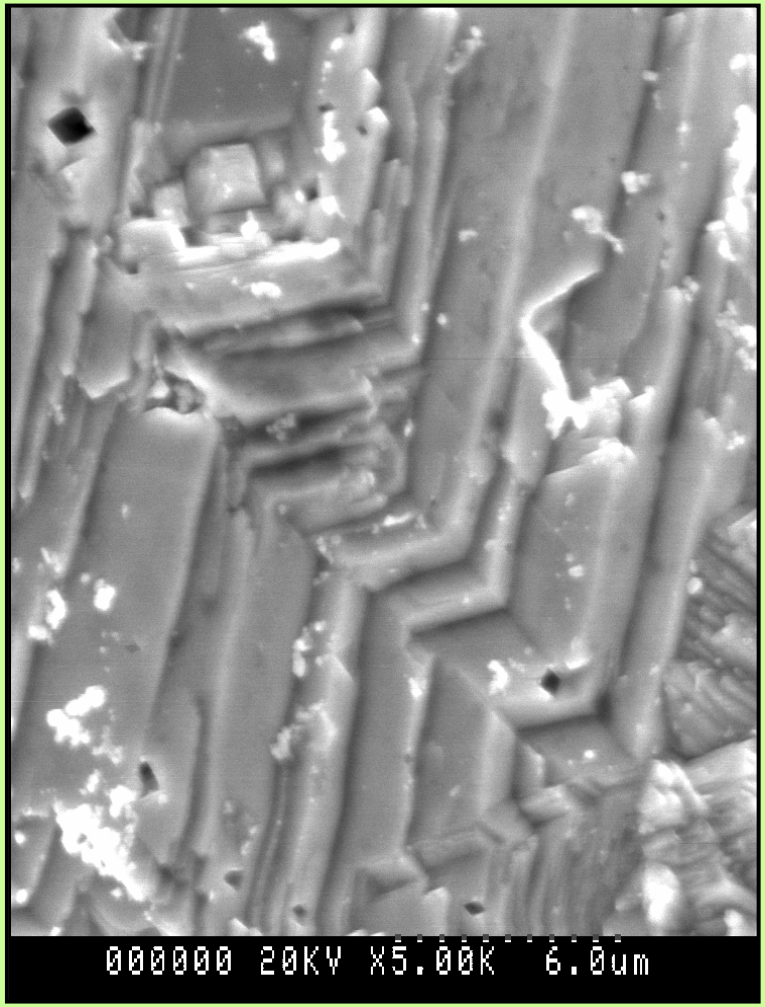
Scanning electron microscopy



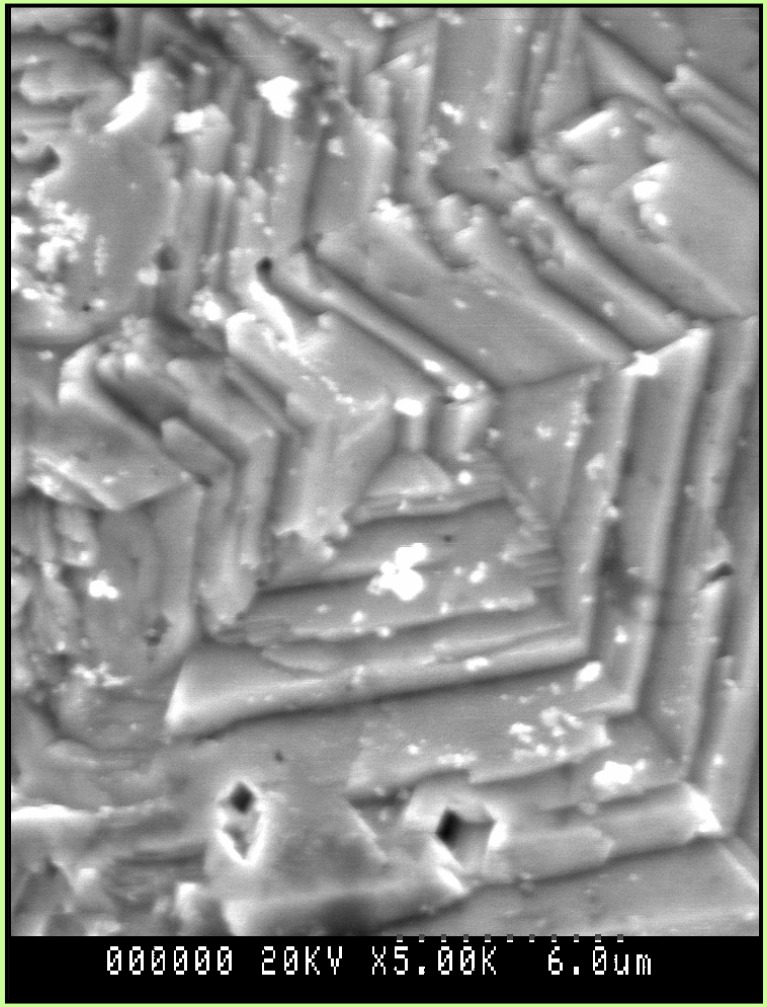
Surface after high-rate strain with deep relief (58 GPa)

Relief of surface of coarse-grain copper after low-rate strain

Microelements of deformed surface

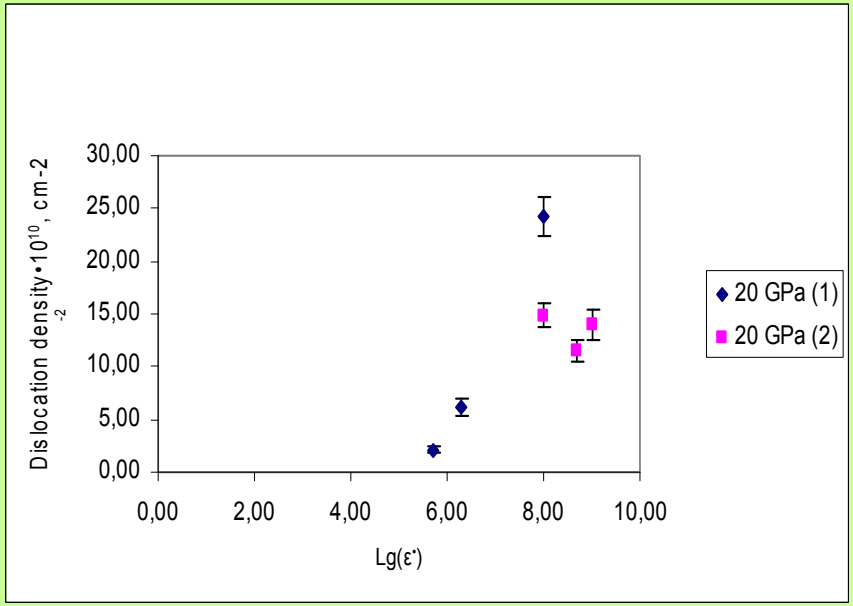


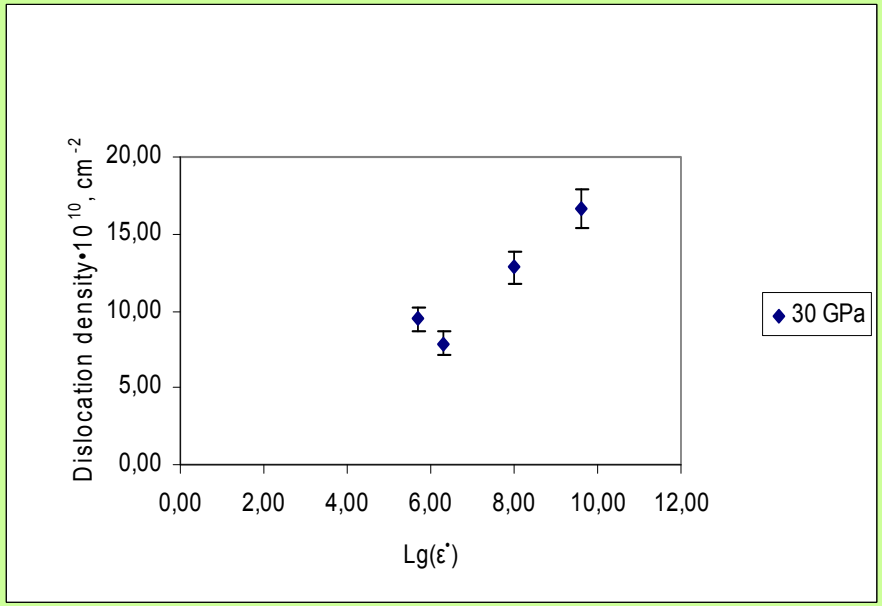
P=20 GPa

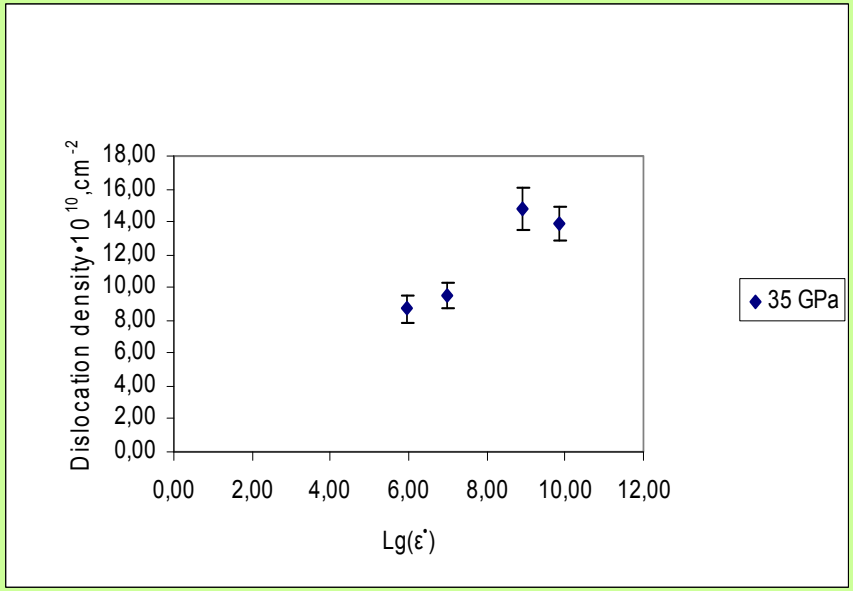


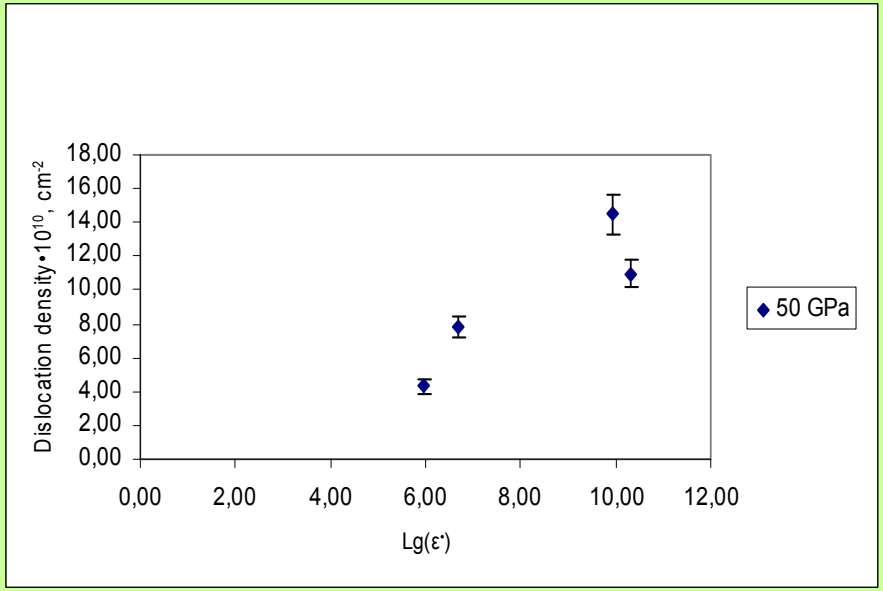
Shear bands in triple joint of grains
P=20 GPa

Dislocation density dependence on strain rate at different pressures

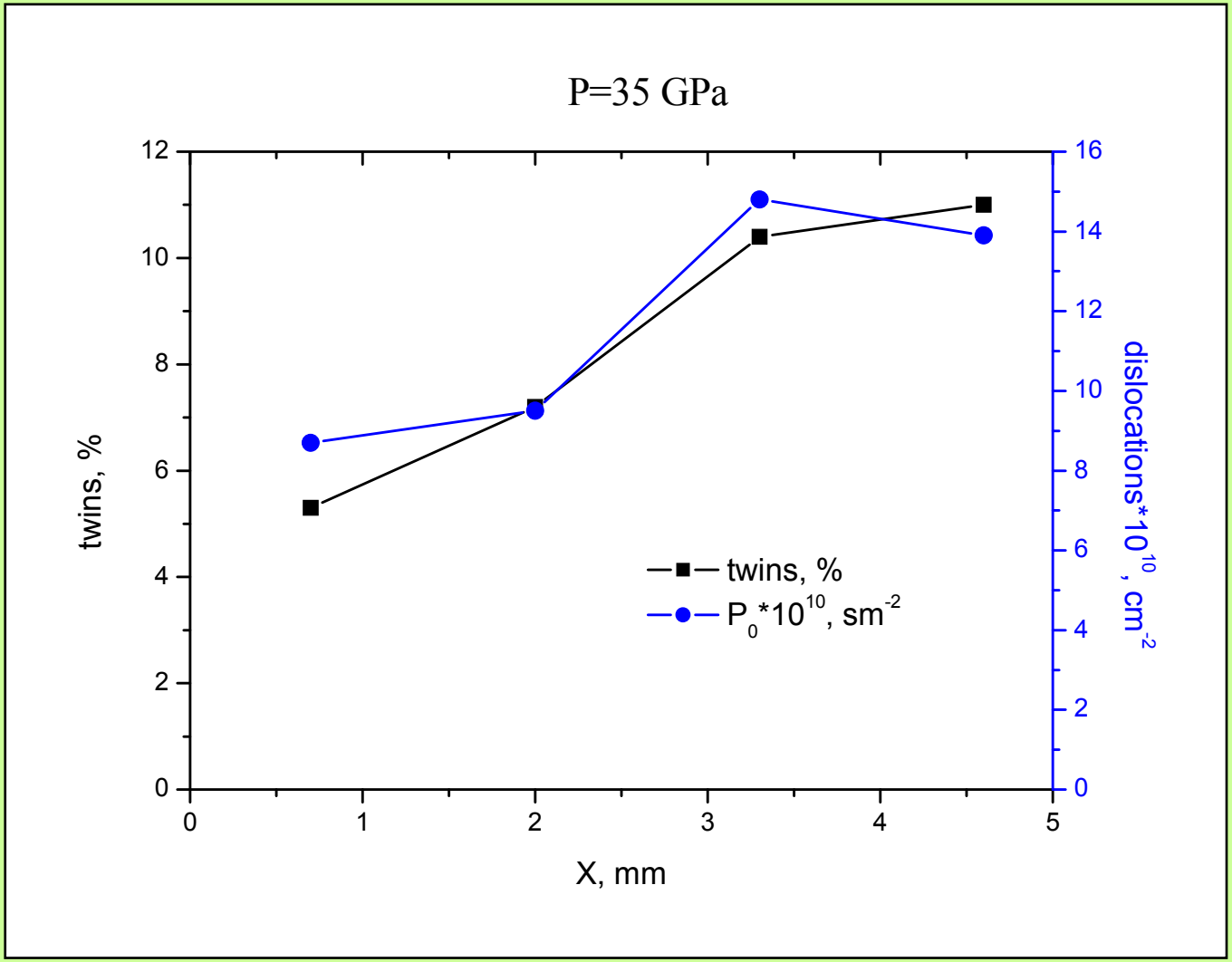




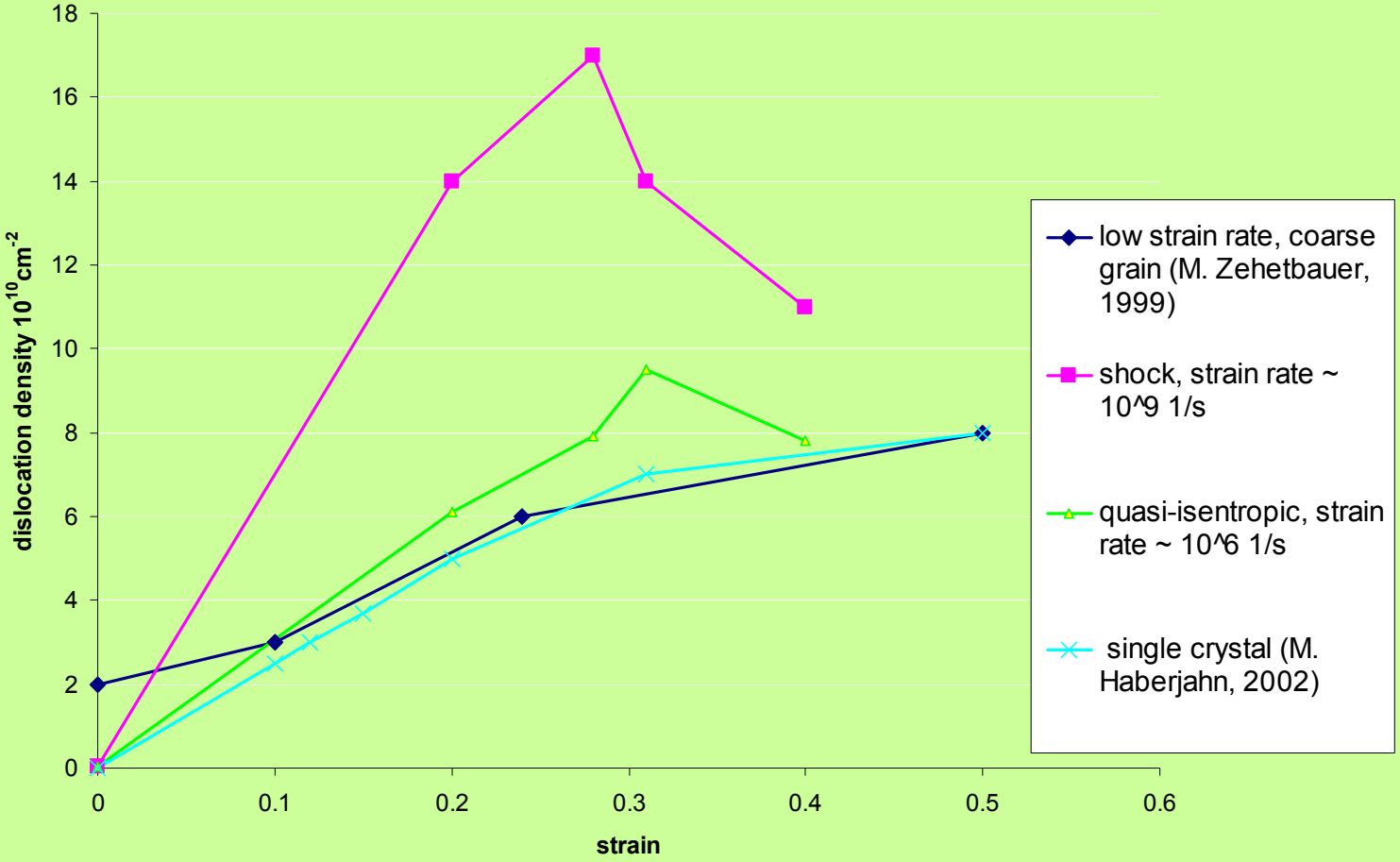




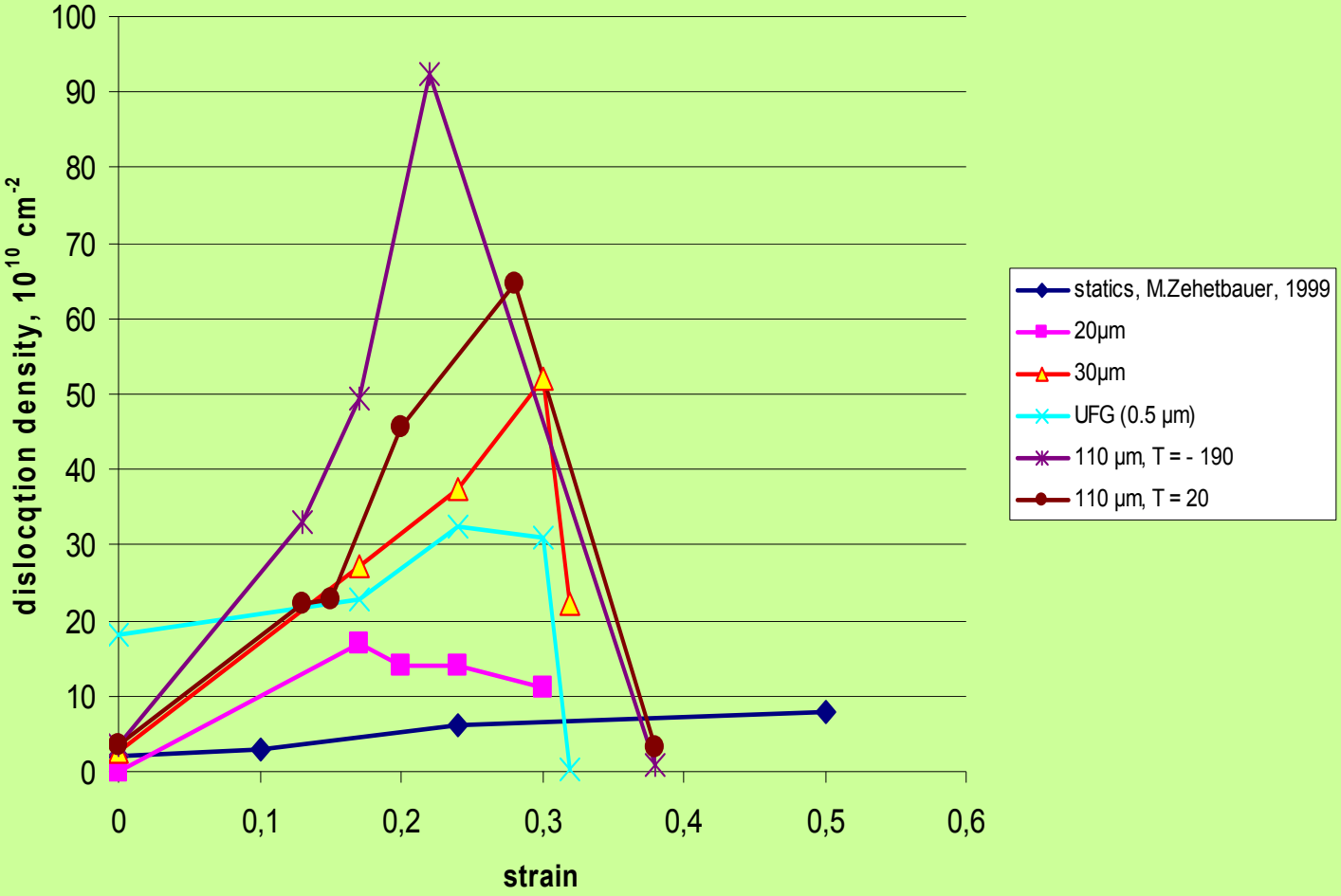
Twins and dislocations, 35 GPa



High and low strain rate: comparison

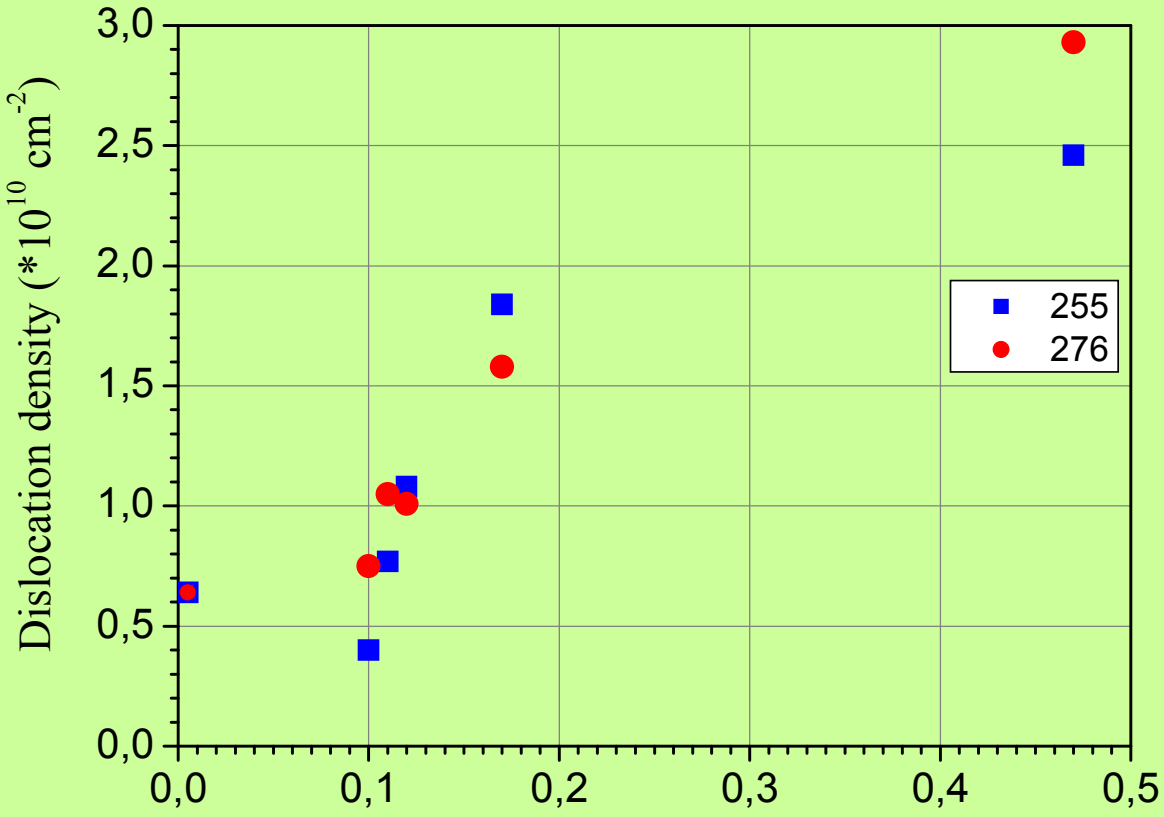


Dislocation density in copper after shock loading

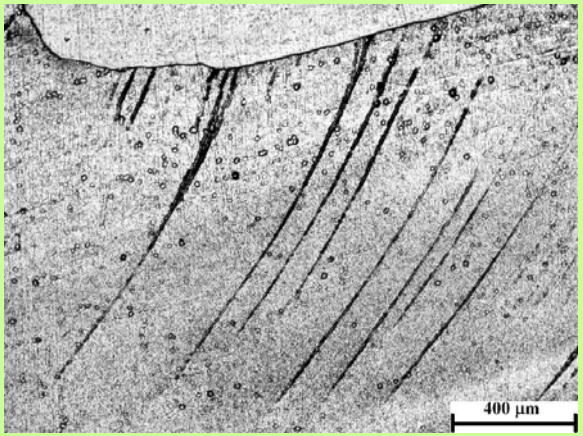


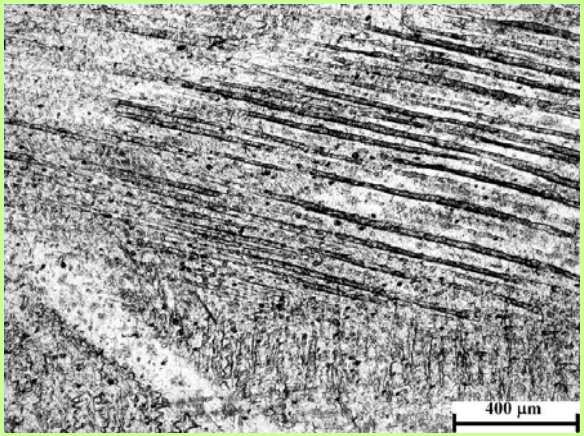
Dislocation density in Ta in shock wave

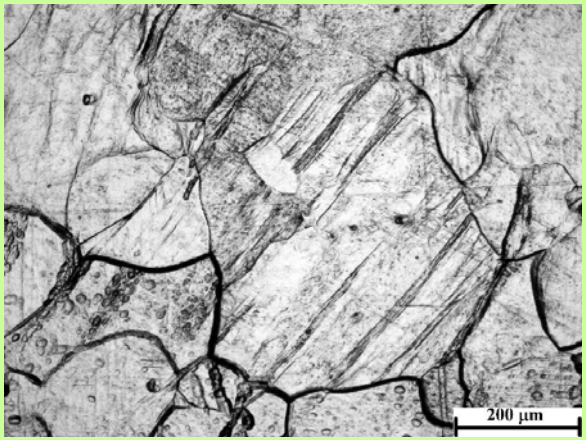
(# 255 – T = 20°C, # 276 – with cooling down to –190 °*C*)

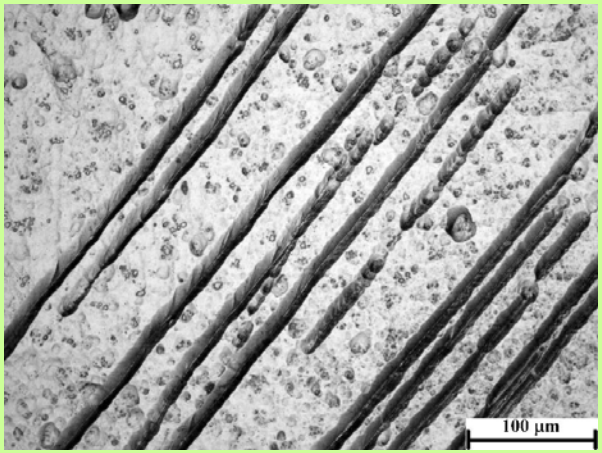
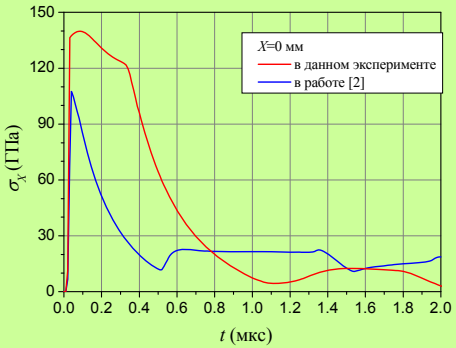


Bands of localized deformation in tantalum









Sample	% of BLD-containing grains
100-20 *GPa*, T = 20°C, τ~ 0.2 μs	1,5
100-20 *GPa*, T = 20°C, τ~ 0.2 μs	4,6
100-20 *GPa*, T = - 190°C, τ~ 0.2 μs	1,6
120-30 *GPa*, T = - 190°C, τ~ 0.5 μs	**18**