# The low-temperature plasticity and deformation microstructure of SPD Al-Li alloy

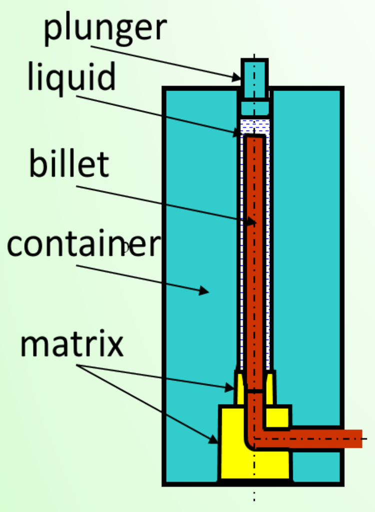
**T. Hryhorova[1], S. Shumilin[1], P. Zabrodin[1, 2], D. Drozdenko[3]**

[1]*B. Verkin Institute for Low Temperature Physics and Engineering of the National Academy of Sciences of Ukraine, 47 Nauky Ave., Kharkiv, 61103, Ukraine*
[2] *Czech Academy of Sciences, Institute of Theoretical and Applied Mechanics, Prosecka 809/76, 190 00 Prague, Czech Republic*
[3]*Charles University, Faculty of Mathematics and Physics, Department of Physics of Materials, Ke Karlovu 5, Prague, 121 16, Czech Republic*
*e-mail: grigorova@ilt.kharkov.ua*

The purpose of this work was to study the microstructure evolution of an ultrafine-grained Al-3.8 at.% Li alloy prepared by angular hydroextrusion. The mechanical properties of the samples were determined during uniaxial tension in the temperature range 4.2 – 400 K.

## Methods

The SPD method by Angular Hydroextrusion (AHE, 4 and 6 passes, $B_c$ route) method was used to form the ultrafine-grain microstructure of the alloy.



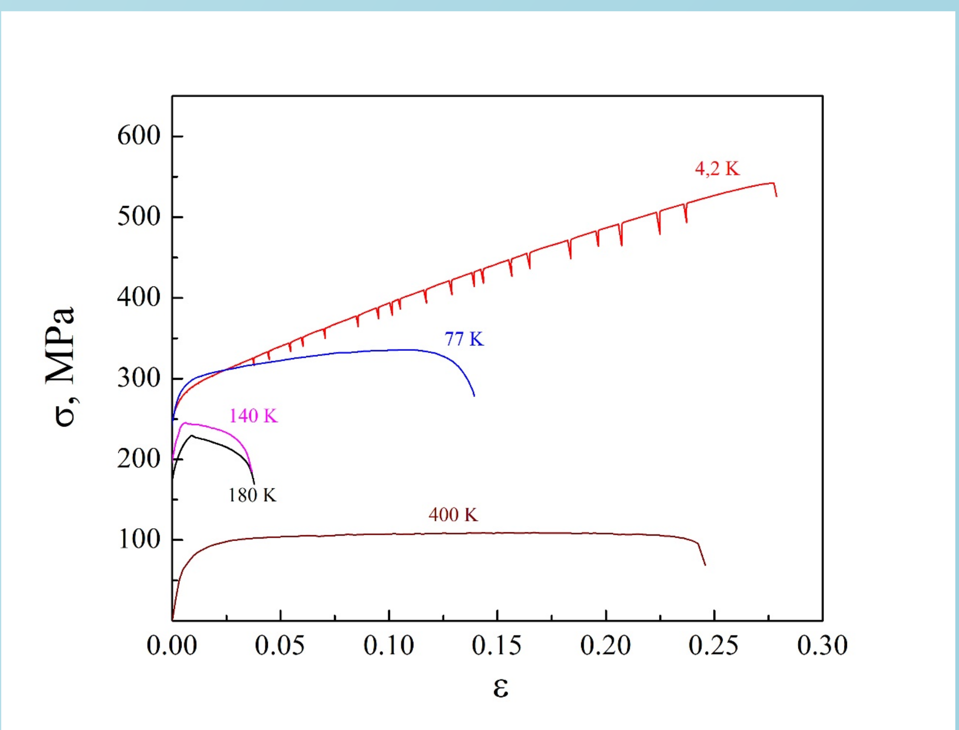

The flat dog-bone samples have been machined by electrical spark erosion and stamping from the ingots.

The microstructure of the samples in the initial state and after deformation at various temperatures has been studied using a scanning electron microscope (FEI Zeiss Auriga Compact) equipped with the electron backscatter diffraction (EBSD) camera.

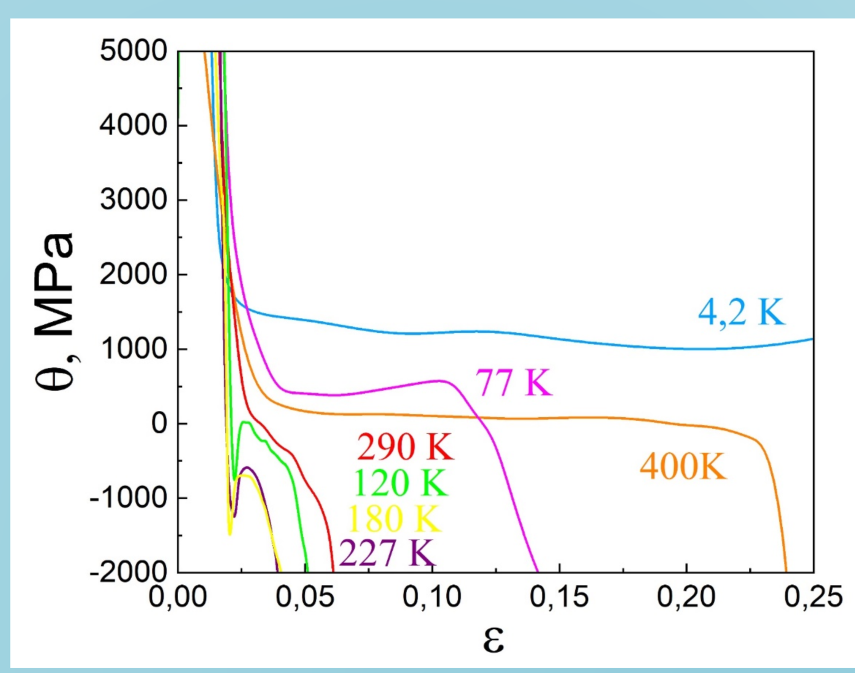
Plastic deformation was carried out by tension at a constant strain rate $\dot{\varepsilon} \sim 10^{-4}$ s$^{-1}$ in the temperature range of 4.2–400 K using special cryogenic high-performance equipment.

## Plastic deformation

Stress-Strain Curves



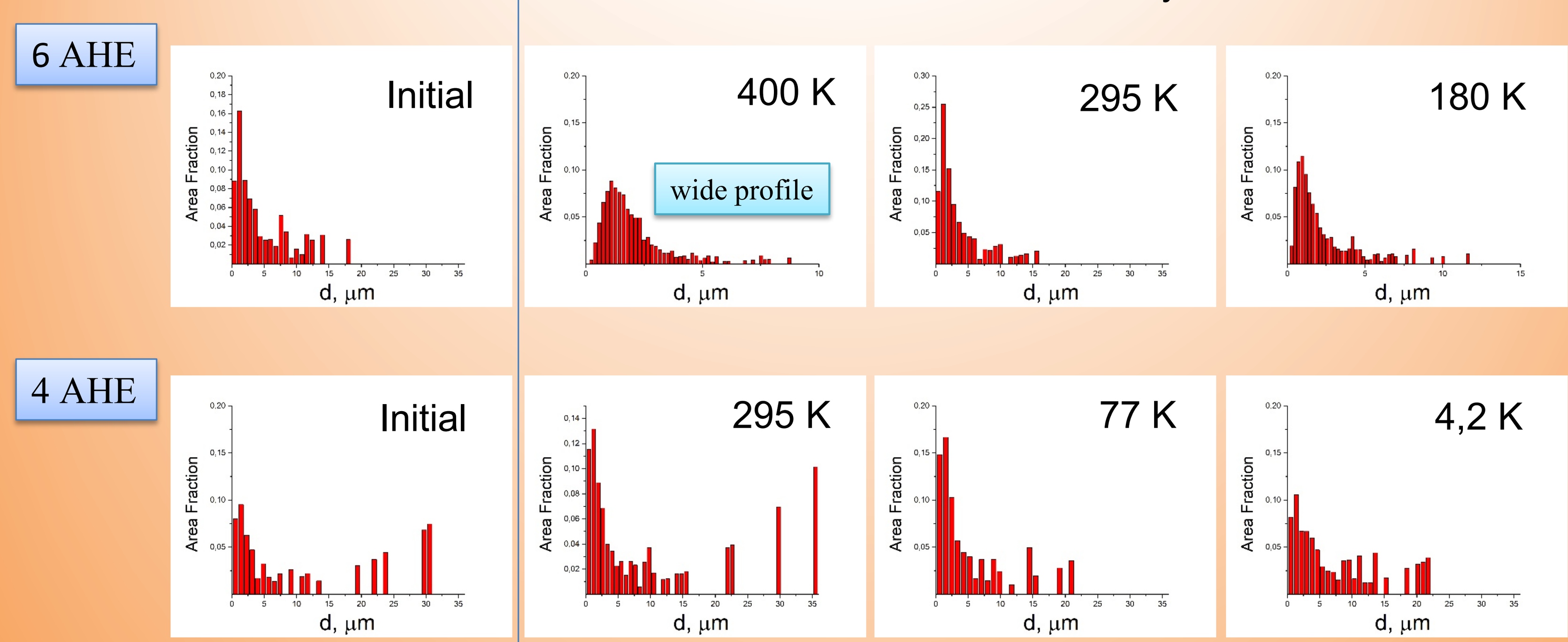

The effect of temperature and deformation on the strain hardening coefficient θ = dσ/dε




The deformation temperature strongly affects the plasticity and strength of Al-Li alloy polycrystals.

## Grain Size

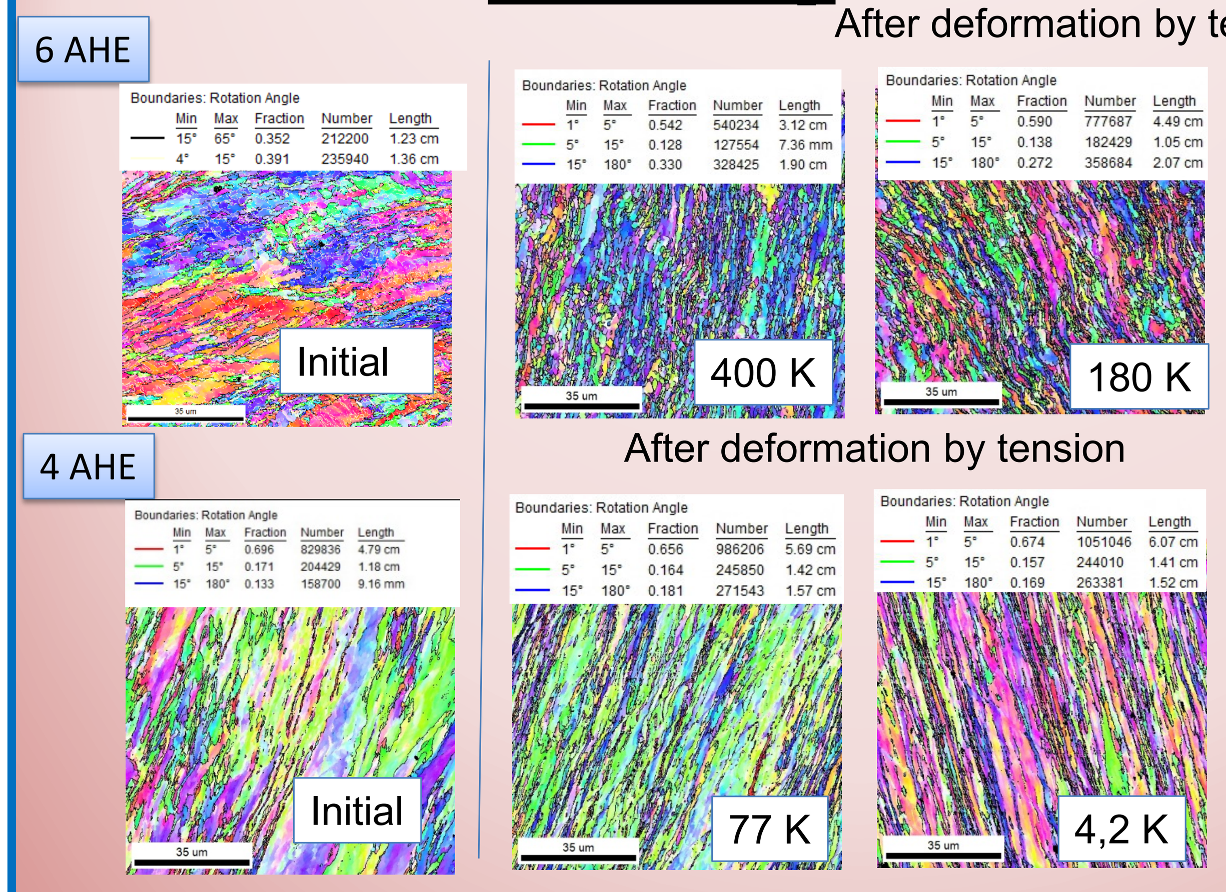
After deformation by tension




The average initial grain size is 2 µm; individual grains up to 30 µm are also observed.

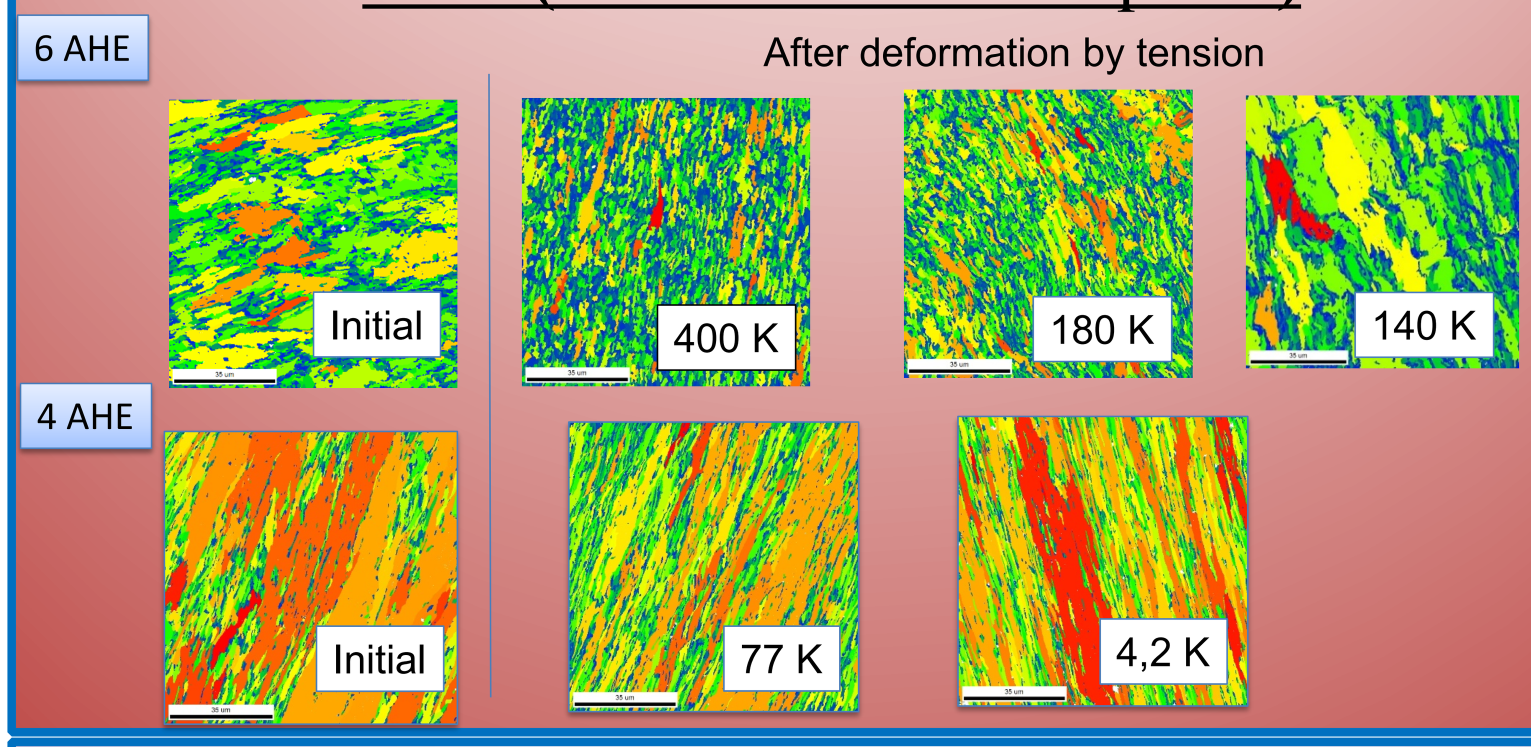
The average grain size decreases with deformation induced by tension, and this effect stronger at lower deformation temperature.

## EBSD Map

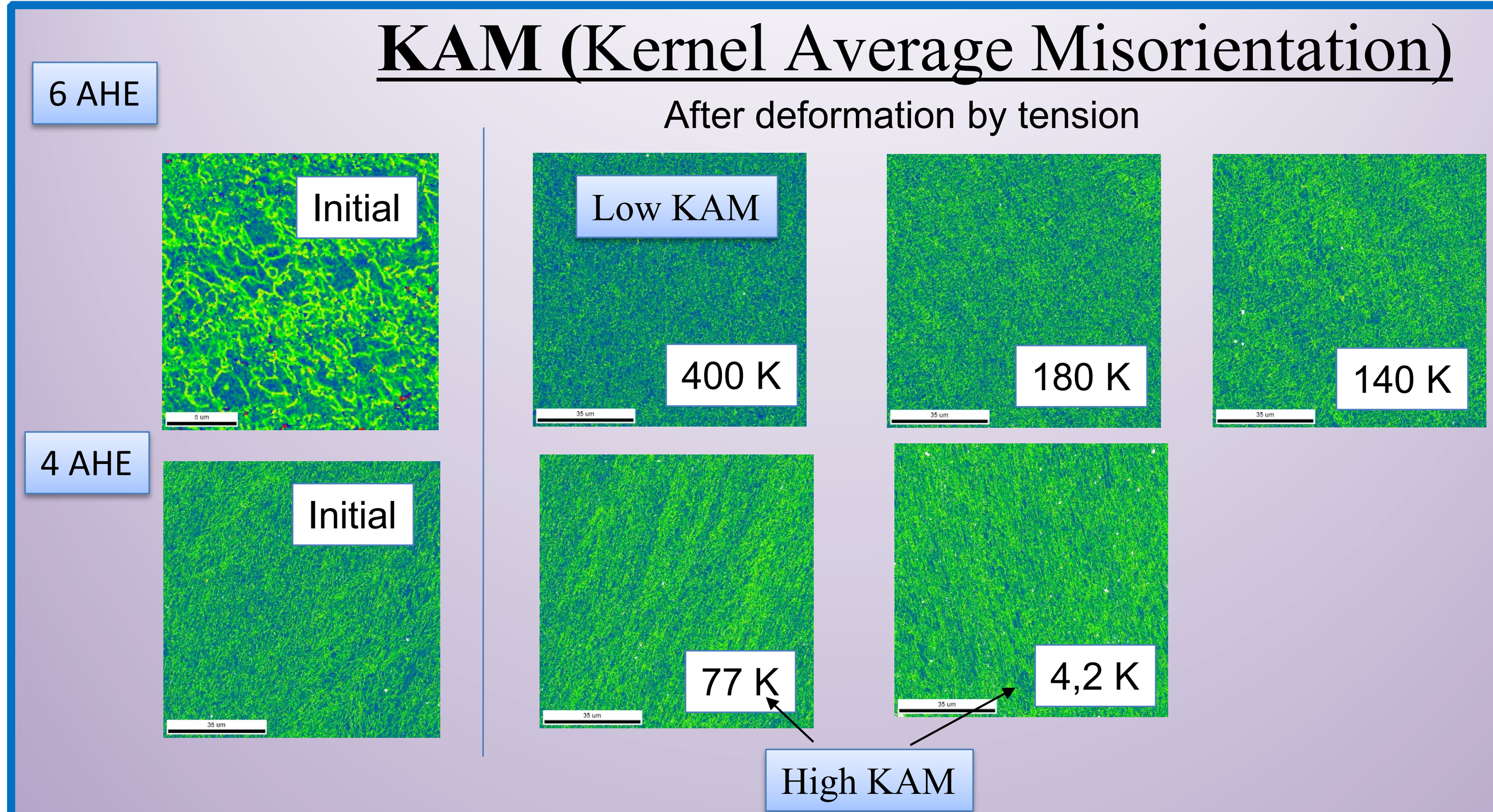



After 4 passes of hydroextrusion - a banded structure with raighter borders is clearly visible

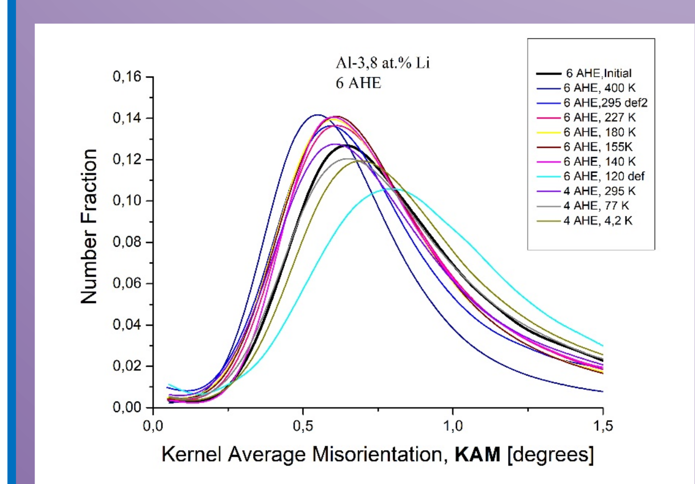
## GOS (Grain Orientation Spread)




## KAM (Kernel Average Misorientation)




The microstructure of the sample deformed at 400 K is characterized by a high density of high-angle grain boundaries and low internal strains (indicated by low kernel average misorientation – KAM), indicating the dislocation annihilation processes.
The samples after deformation at lower temperatures are characterized by high internal deformations and a high density of low-angle grain boundaries. Furthermore, there is a tendency for the density of geometrically necessary dislocations (GND) to increase with a decrease in the deformation temperature.

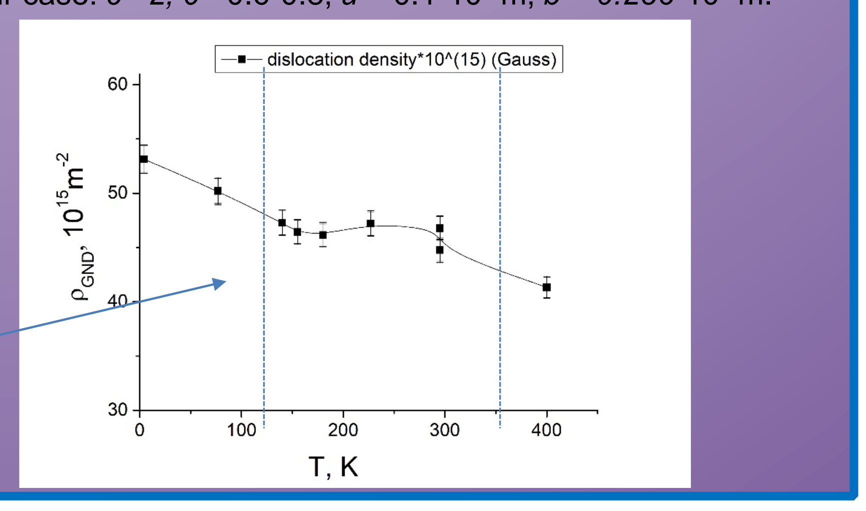



Geometrically Necessary Dislocations (GND) density

$$\rho = c\theta/ub$$

where *c*- coefficient of (1-5) (we choose 2 as medium value; *θ* – misorientation angle (average KAM), *u*– distance used for evaluation of the misorientation angle; *b*– burgers vector of aimed dislocations.
In our case: *c* =2, *θ*= 0.6-0.8, $u = 0.1 \cdot 10^{-6}$m, $b = 0.286 \cdot 10^{-9}$m.

Three areas can be distinguished
- 4.2-100 K
- 140-295 K
- 400 K and possibly higher




## SUMMARY

- It is shown that after AHE, a mixed grain structure is observed with a large number of grains of the order of 1-2 $\mu$m and individual large grains of the order of 10 $\mu$m with a high dislocation density, both inside and at the grain boundary.

- A comprehensive analysis of the microstructure showed that the micro-structure of polycrystals after tension exhibits an elongated structure in the loading direction.

- Tensile deformation of Al-3.8at. %Li after AHE leads to the average grain size decreasing.
- As a result of low temperature deformation, an increase in the dislocation density inside the grain is observed, in contrast to the Al-Li alloy deformed at 400 K, where a decrease in the dislocation density occurs due to an increase in the activity of recovery processes in micrograined Al-Li at a given temperature.