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STRENGTH AND PLASTICITY OF SPD COPPER AT LOW TEMPERATURES

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Summary. *Main microstructural features of ultrafine-grained polycrystalline oxygen-free copper obtained by direct and equal-channel angular hydrostatic extrusion were studied by EBSD and XRD methods. The effect of microstructure on the temperature dependences of the yield stress was investigated using tensile tests in the insufficiently studied temperature range of 4.2–300 K.*

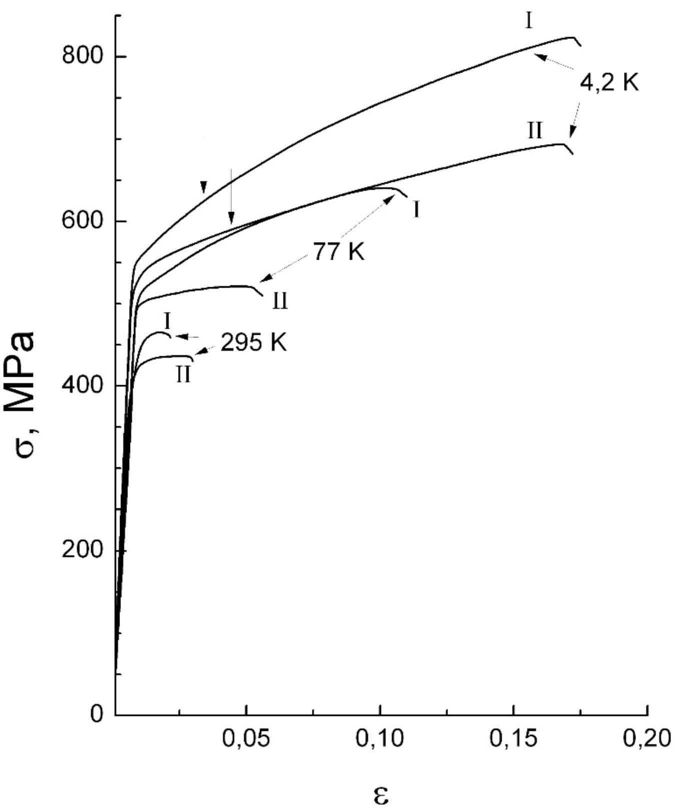
Keywords: *Ultrafine grained materials, copper, yield strength, low temperature, dislocations, thermally activated deformation.*

One of the ways to increase a material's strength is to refine its microstructure down to a sub-micron scale by severe plastic deformation (SPD) methods. All these materials exhibit strengths which is superior to that of common polycrystals at room and elevated temperatures. However, the mechanisms of plastic deformation of materials characterized by a high density of grain boundaries are not fully understood as yet and are the subject of ongoing research. A logical goal is to extend the range of ultra–fine grained materials to be studied and also to broaden the temperature range of experiments. The aim of our work is to compare the microstructure and low temperature strength and ductility of polycrystalline oxygen free copper (Cu–OF) processed by direct hydroextrusion (DE) and equal channel angular hydroextrusion (ECAE).

Polycrystalline copper after DE (samples I) and after ECAE (samples II) were deformed in a deformation machine with a liquid-helium cryostat in the temperature range 4.2–300 K in the quasi-static tensile mode at a constant piston speed, corresponding to the initial strain rate 10^{-4} s^{-1}.

The analysis of the samples texture by the method of inverse pole figures shown that as a result of DE, the {111} planes of the grains are oriented predominantly perpendicular to the extrusion direction, while after four ECAE passages the distribution of the pole density in inverse pole figures in the extrusion direction is more uniform with slight predominance of the {012}, {013}, and {025} planes. Also, EBSD-analysis shown that samples II have a smaller grain size (about 0,5 μm), a higher proportion of high angle boundaries, increased dislocation density and the absence of sharp texture as compared to samples I.

With decreasing temperature: (1) the yield stress of all the samples increases (pic. 1), and for a fixed temperature, the strength of samples I is higher than that of samples II; (2) the ductility of all the samples increases, and the ductility of samples I at 77 K is much higher than that of samples II. At a temperature of 4.2 K, there are periodic stress jumps on the tension curves, i.e., plastic flow of ECAE and DE polycrystals becomes macroscopically unstable above a certain critical strain. The amplitude and frequency of the stress jumps increase with the strain but appear to depend weakly on the extrusion geometry.



Pic.1. Stress–stain curves for UFG polycrystalline Cu-OF plotted in true coordinates at three different temperatures: samples after DE (I) and four ECAE runs (II). The vertical arrows indicate the onset of jump–like deformation

It was found that an increase in the strength of polysrystals resulting from the extrusion is determined not only by an increase in the density of dislocations and grain boundaries, but also by the orientational texture, which depends significantly on the extrusion geometry.

From thermal activation analysis of temperature dependences of the yield strength, it was found that in the temperature range of 77–200 K the plastic deformation is determined by a thermally activated mechanism of crossing the forest dislocations, and empirical estimates of the parameters of this mechanism were obtained. Deviations (anomalies) of the temperature dependences of plasticity parameters from those expected for a simple crossing mechanism were observed at temperatures below 77 K and above 200 K.

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