Mechanical Properties Developed in Nanocopper by Sever Plastic Deformations

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The production of the nanostructure in compact metallic systems was studied e. g. in works [1-5]. The ECAP technology allows to obtain the very fine grained microstructure – the nanostructure by multiple pressings trough the die [6-9]. Statistic evaluations of the heterogeneity of nanostructures produced by plastic deformation were described [10]. Improved mechanical properties can be obtained by severe plastic deformation. High strength and ductility was reported for different systems [11-12]. Extremely fine grains with high angle boundaries were obtained, developing unique superplastic behaviour [13-14] explained by the mechanisms of grain boundary sliding or by the grains rotation [15-16]. Microstructure and properties and deformation mechanisms of nanomaterials are described in [17-23].

Commercial pure copper (99,9 Cu) was used as an experimental material. Bars in dimensions of 10 mm in diameter and 70 mm long were pressed at room temperature. A bar was pressed 10 times. The hydraulic press used for ECAP is able to produce a load of 1 MN. The deformed bars were then machined to the form of test specimens (Φ3 mm, 15 mm long, M5) for static tensile testing, hardness testing, metallography and TEM analysis by thin foils.

The used copper is coarse grained with a mean grain size of 50 μm, both the yield strength (R_p0.2) and ultimate tensile strength (UTS, R_m) are quite low, but the reduction of area (Z) is significant (65%). The change of strength properties (R_p0,2, R_m and HV10) as well as plastic properties (reduction of area Z) in dependence on the number of ECAP passes are in Fig. 1. At every next pressing the test piece position was about 180° rotated. Cold working is known to produce an increase in strength and the UTS value had after 10 passes increased from 275 MPa to 464 MPa. The hardness HV10 increased after 10 passes to 128. The reduction of area was selected as a measure of ductility because it is more sensitive to the local deformation in the neck of the broken tensile test specimen than the elongation to failure. It is important to note that the reduction of area is increasing with the number of passes with a similar trend as strength does. It is quite different as the classic behaviour of metals after plastic deformation.

In the tested range of deformation and grain size the dependence is in good agreement with the Hall-Petch equation, Fig. 2.

We have also analyzed the microstructure. The initial grains of Cu are equiaxed. The grain size decreased from an initial size of ~ 50 μm to 3 μm after 3, 5, 7 and 10 passes. Though, the rotation of the bars after every pressing was applied, the grain structure is not even anymore. The

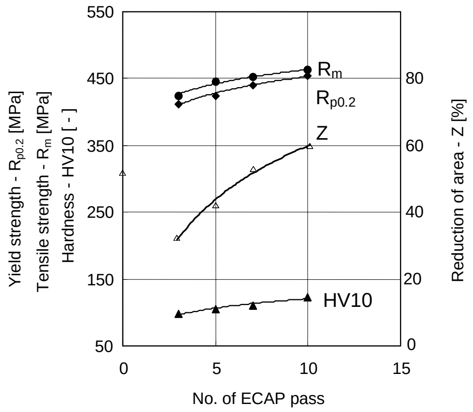

Fig. 1.

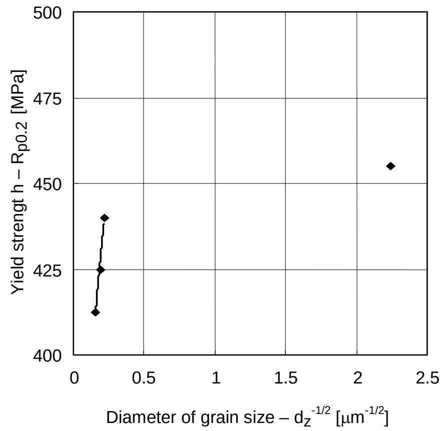

Fig. 2

grains are elongated in the direction of deformation and with prevailingly high angle boundaries. The heterogeneity can have a negative influence on the stability of properties. Significant changes in strength can be supported by grains with high angle boundaries, only. After the maximal plastic deformation (10 passes) the grains are on the limit of the resolution by metallography. The mean grain size was less than 1 μm. We have prepared thin foils to identify the grain size and to monitor the mechanism of grain forming by deformation in the neck. The TEM showed that the mean grain size was from 100 to 300 nm.

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