STRUCTURAL AND PHISICAL - MECHANICAL TRANSFORMATIONS IN COPPER DURING SEVERE PLASTIC DEFORMATION

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The results are obtained on the change in the structure and physical properties of copper after cold deformation in the initial state and after cold ECAP deformation (t = 20°C) the route Bc with 2, 4, and 8 passes. After eight passes a structure is formed, which consists of a grid with grains in (0, 3 - 5 *μm*). The total area of grains with high-angle boundaries has changed after 8 passes to 35%. The change in the velocity of longitudinal acoustic waves depends on the changes in the structure of copper: the appearance of deformation bands and boundary grains: the band slip (after 2 passes) and the bands meso (after 4 passes) and grains with the large - angle of boundary (after 8 passes).

1. Introduction

The production of ultrafine-grained materials by the method of equal-channel angular pressing relates to promising technologies [1-10]. The use of copper in industry is well known due to many valuable qualities. Copper M1 is used for current conductors, rolled and high-quality bronzes that do not contain tin; for the manufacture of cryogenic equipment. To apply the ECAP processing method to the industry, there must be justification. It is known that a well-developed structure, for example, on copper, can be obtained only after 16 passes of ECAP. After 8 passes, the longitudinal length of the work piece is reduced by a factor of 2. The use of material after ECAP at intermediate stages of development becomes relevant. Interruption of the ECAP makes it possible to obtain a product with increased strength, so the consumption of the material will decrease for the production of the product. To understand the properties of the resulting material, it is necessary to study the sequence of structural transformations at important stages of the ECAP. It is important to take into account that the ECAP simultaneously realizes the processes of dynamic recrystallization and strain hardening.

Task: to reduce the number of passes during the ECAP processing. The sample was deformed and later subjected of ECAP. Purpose: to accelerate the processes of severe plastic deformation. Obtain a state of developed plastic deformation at an earlier stage of deformation.

2. Experimental Procedure

For the study, a copper rod M1 with a diameter of 20 mm was obtained, in the initial large-crystalline state and after 2, 4 and 8 passes of equal-channel angular pressing along the B c route at room temperature.

The microstructure was studied with a *Neophot-32* metallographic microscope and a *TESCAN VEGA II* scanning electron microscope. The microstructure was observed in cross section. X-ray diffraction analysis was carried out on diffractometer using CoKα - radiation in the range of angles 2*θ* from 40 to 115. The regions of coherent scattering were determined.

Acoustic tests were conducted by an echo-pulse method. For the measurement we used a device consisting of a generator, probing the action of piezoelectric signals, a high-frequency amplifier, a digital oscilloscope of the *SCOPE 1000VS PC* and a PC with GOST 23829-85. The central frequency of the piezoelectric transducers was ~ 5 MHz. Microhardness was measured in accordance with the standard procedure in accordance with GOST 5490 – 76.

Results and discussions

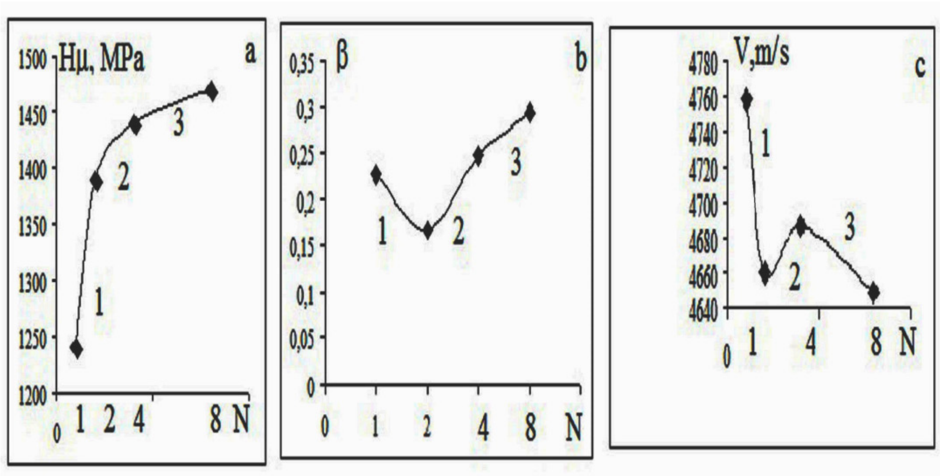

Figure 1 shows: microhardness (H $^{\mu}$), the data of X-ray difraction analysis β (311) and acoustic tests (Vlong) for large - coarce size and after 2, 4, 8 passes (N).

It is which change in the broadening of the X-ray line (311) and the velocity of longitudinal waves from the number of passes during ECAP processing are seen (Valong).
In the presented graphs of Fig. 1, we can distinguish three sections marked with the section of 1, 2 and 3.

At section 1 of Fig. 1, the physical properties change: decrease of the broadening of the X-ray line β (311) and in the velocity of longitudinal waves and the increase of microhardness. The broadening of the diffraction lines of the ECAP, should the formation of sizes of crystallites, block structures (regions of coherent scattering) or crystal lattice distortions. On section 1 (initial - 2 passes) - increase of the broadening β is due to the micro stressing strength of the 2 kind (size less of `1 *μm*), that arise in the material during deformation [11]. The changes were: decrease is β of 0,2268 to 0,1661 and in the regions of coherent scattering (RCS) with increase of sizes D of 130nm to 177nm and decrease of speed of elastic waves (Valong) at 4760 - 4660m/s. Such changes in the deformed material can mean relaxation processes.

On section 2 (2 - 4 passes of ECAP) the changes were: β for 0,1661 to 0,2476 and D of 177 nm - 118nm and accordingly the speed of elastic waves increases. It can be seen, that these changes are mirror with section 1. See explanations for changes in the description of the structure.

On the section 3 (4 - 8 passes of ECAP) increase β for 0, 2476 to 0, 2932 and the decrease of D of 118 nm by 100nm, but it is decreasing speed of longitudinal waves, which is typical for the newly structure of the material.

Metallographic analysis on the optical (Fig.2 a, b, f) and scanning microscope (Fig. 2 c, d, e) showed that the change of the original coarse-grained grain takes place gradually and has its own peculiarities after 2, 4 and 8 passes. Let us dwell on this in more detail.

After 2 passes, a nonuniform subgrain structure with small-angle grain boundaries was formed, the presence of which confirms the absence of their correct form (Fig. 2 b, c). At the same time, studies of the fine structure have shown that it consists of grains with small - angle boundaries formed from the walls of dislocations. The presence of a large number of slip lines (1 *μm*) indicates an increased number of dislocations, which in turn reduce the velocity of longitudinal elastic waves [12, 13].

After the 4 passes (Fig. 2, f) of the ECAP, the microstructure represents the unevenly arranged bands of the different colors found after etching. Meso - band on a photo is of dark color, width is less 1 *μm*. Different color after etching characterizes zones with different deformation studies: dark color zone - with increased deformation and less deformation - the light color zone. The appearance of anisotropy increases the velocity of longitudinal waves.

After 8 passes (Fig. 2 d, e), the microstructure represents a grid in the form of parallelograms, with dimensions of 2×5 *μm*. On the perimeter of which there are grains 0,3 *μm* - of dark color, and the middle of the parallelogram contains grains of light color with small-angle boundaries. Can be seen, that the grains has acquire the correct faceting,

characteristic of the large-angle boundaries. Explain uneven etching of grains can be explained by varying degrees of deformation. It is known that when the deformation is increased, the material is etched more intensively in the chemical reagent.
The formation of an unevenly deformed structure during ECAP is associated with the process of dynamic recrystallization. When newly formed recrystallized grains with low dislocation density are saturated again with dislocations, since the deformation continue. The repeatedly alternating cycles of dynamic recrystallization and cold hardening of recrystallized grains correspond to the steady state with an invariable middle grain size, like grains 0.3 micrometer of dark color [14].

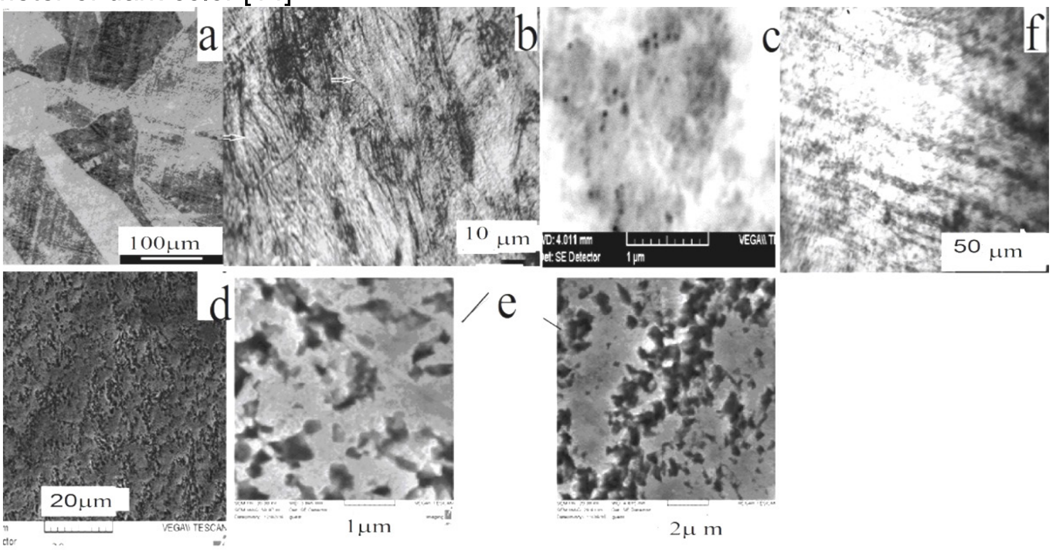

Figure 2 - The initial large-crystalline microstructure of copper M 1(a), after 2 passes (b, c) and after 4 passes (f) and 8 passes (d, e) of ECAP processing

Conclusions. The use of double deformation makes it possible to obtain a structure with many slip lines of one width at an early stage. The after 2 passes (fig 2.b) is presence of a large number of slip lines indicates an increased number of dislocations and at the same time this is the period of relaxation relative to the initial state.
The change in the velocity of longitudinal acoustic waves depends on the changes in the structure of copper. After 2 passes, slip bands of 1 *μm* width are formed and the velocity decreases; after 4 passes, meso-bands appear and the velocity increases; after 8 passes a network structure is formed, in which the grain has a boundary and the velocity decreases.

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