Microstructure of Cu–Co alloy after severe plastic deformation studied by electron backscatter diffraction

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In the last two decades, the process of severe plastic deformation (SPD) of bulk metallic materials has been shown to produce ultrafine-grained (UFG) structures. Even though the grain size is strictly not in the nanometre range, there has been considerable amount of research work on the structure and properties of materials processed by this technique [1,2]. Prominent among SPD techniques are equal-channel angular pressing (ECAP) and high-pressure torsion (HPT). Bulk UFG materials produced by SPD techniques have consistently shown superior properties over their coarse-grained counterparts. Nevertheless, to encourage wide applications of UFG materials, it is necessary to further explore efficient manufacturing techniques, conduct theoretical modelling of manufacturing processes and materials performance, and investigate the link between microstructures and enhanced properties in UFG materials.

At present, ECAP is the most developed of all potential SPD techniques for achieving very significant grain refinement in metallic materials [3,4]. A key advantage to this technique (as compared to HPT) is producing large bulk billet with low porosity suitable for further mechanical testing. However, fabrication of homogeneous UFG microstructures by ECAP is a complex process since the number of passes and the selected processing route can be very important parameters. The primary microstructural change associated with ECAP is the introduction of a very high density of dislocations into the crystalline lattice. However, ECAP may also influence the microstructure in other significant ways. The high pressure involved in the processing may lead to the fragmentation and decohesion of precipitates. Furthermore, depending upon the processing regimes, ECAP may lead also to precipitate dissolution and/or precipitate formation and coarsening. The interactions between these various processes will depend in practice upon both the alloy composition and the pressures and temperatures used in the pressing operation. In this work we report on our preliminary results of microstructural study of Cu–2wt.%Co alloy processed by ECAP.

The experimental alloy was cast and annealed at 1000°C for 10 hours followed by water cooling. Both scanning and transmission electron microscopy (SEM and TEM) confirmed homogeneous coarse grained microstructure with low dislocation density and with all Co dissolved in the matrix. Microhardness and elastic modulus measured by depth sensing indentation test at load 100mN were (1150±50)MPa and (135±5)GPa respectively. ECAP was conducted at room temperature with a die having internal angle of 90°. Up to twelve subsequent extrusion passes were performed at speed of 10mm/min. The billet was rotated by 90° in the same direction after each pass (route B_C) [5]. Polished sections perpendicular to extrusion direction were studied after 1, 2, 4, 8 and 12 passes using electron backscatter diffraction (EBSD) technique in a TESCAN LYRA 3 XMU FEG/SEM×FIB scanning electron microscope equipped with Nordlys EBSD detector by Oxford Instruments with Channel5 and AZtecHKL software.

Starting from the grain size well above 1mm in the annealed as-received state, ECAP subsequently reduces grain size down to the submicron level (see examples after 1, 4 and 12 passes in Fig. 1). Significant changes in the grain size as well as in the relative amount of high angle grain boundaries were observed between 2^{nd} and 4^{th} ECAP pass (Fig. 2). Further increasing number of passes mainly improves the microstructure homogeneity. The mean grain size after 12 ECAP passes reached 0.3µm. Pure Cu 99.99% processed in the same way and reported in our previous work [6] ended at about 0.6µm. Further comparison with pure Cu shows that the grain size homogenization expressed by coefficient of variation is shifted towards higher number of ECAP passes. Microtexture analysis showed the tendency to form texture with crystallographic planes {110} parallel to the ECAP specimen cross section (Fig. 3) similar to our observations in pure Cu [7].

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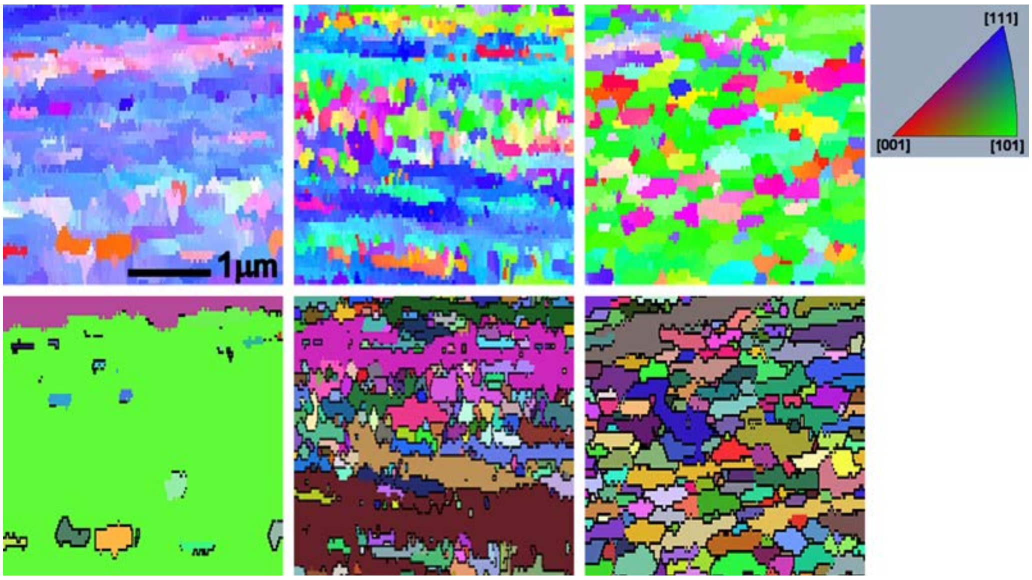

Figure 1. *Subgrain and grain structures of ECAP Cu–2wt.%Co solid solution. Upper row: normal direction after 1, 4 and 12 ECAP passes. Bottom row: grains separated by high angle boundaries (i.e. with misorientation $\theta \geq 15°$).*

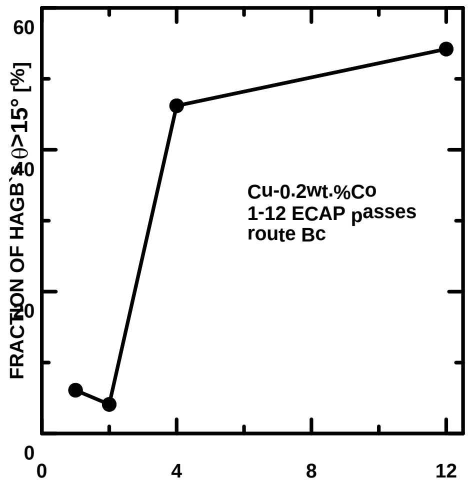

Figure 2. *Evolution of relative amount of high angle grain boundaries in course of ECAP processing.*

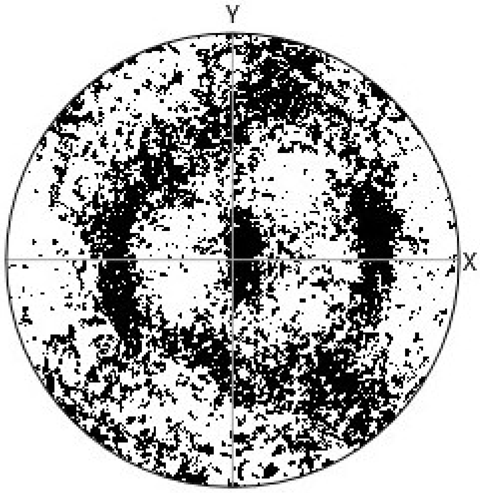

Figure 3. *Characteristic texture developed after 12 ECAP passes (pole figure ⟨101⟩).*