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Wetting of grain boundaries in ultrafine-grained copper by liquid bismuth

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Severe plastic deformation is widely used for producing ultrafine-grained metallic materials. High-pressure torsion (HPT) processing results in high strength and homogeneous ultrafine-grained microstructure of the processed material. Such microstructures, however, exhibit poor thermal stability. Selective doping of the grain boundaries with impurities is one of the ways to stabilize the microstructure.

In the present work, we studied the effect of liquid Bi on the microstructure evolution of ultrafine-grained Cu at elevated temperatures. Cu polycrystals (mean grain size about 100 nm) were produced employing the HPT method. We characterized the microstructure of Cu samples subjected to post-deformation isochronal (1 h) annealings in the temperature range of 500 - 900 ºC, with and without the presence of liquid Bi.

The surface of the pure Cu and Cu-Bi samples annealed between 500 and 700 °C exhibits a bimodal microstructure, which implies the presence of ultrafine grains formed as a result of grain refinement during HPT, and much larger recrystallized grains with a size increasing with annealing temperature. The influence of Bi on the microstructure evolution of Cu polycrystals becomes evident after annealing at the temperature of 600 °C. The near-surface grains grow much faster in Cu-Bi samples than in pure Cu, which can be caused by Bi-induced increase of the grain boundary mobility and concomitant acceleration of grain boundary migration in Cu. The grain growth is accompanied by the penetration of liquid Bi and wetting of the grain boundaries. Partial and pseudopartial wetting occurs at the temperatures below 700 °C, whereas at higher temperatures a sharp increase of the fraction of fully wetted grain boundaries is observed. Micrometer-thick intergranular liquid phase layers penetrate into the bulk of the samples, preceded by the nanometric intergranular film of the Bi-rich phase (of 2-4 nm in thickness). Inclusions of Bi phase were not revealed in twin boundaries due to their lower diffusivity compared to that of random high-angle grain boundaries.

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