Abstract

The present work deals with the evolution of nanostructure in $Cu_{100-x}Zn_x$ ($0 \leq x \leq 30$ wt.%) upon cryorolling. The effect of stacking fault energy (SFE) on the evolution of crystallite size (D), dislocation density (ρ_d), twin fault probability (β), extrinsic faults probability (EF), and their mutual interactions during cryorolling in pure copper (SFE 78 mJ/m^2) and copper–zinc alloys with varying Zn content of 10 wt.% (SFE 35 mJ/m^2), 20 wt.% (SFE 19 mJ/m^2), and 30 wt.% (SFE 14 mJ/m^2) have been studied in detail. The effect of cryorolling strain (ε_{CR}) up to 1.4 on the evolution of homogeneity and refinement in terms of twin lamellae thickness, twin spacing, and their distribution, have been studied using high-resolution transmission electron microscopy (HRTEM) and microhardness measurements. It has been revealed that cryorolling introduces nanotwins with varying lamellae thickness in the range of 28 - 170 nm in $Cu_{70}Zn_{30}$. X-ray peak broadening analysis of $Cu_{70}Zn_{30}$ has shown that the D reduces down to 20 nm at ε_{CR}= 0.95, which scales with the subgrain size in preexisting twin lamellae, as revealed under HRTEM. The effect of ρ_d and D on the strength of nanotwinned $Cu_{70}Zn_{30}$ has been correlated using an analytical model. The ρ_d, β, and EF increases, whereas, D decreases upon cryorolling and with the decrease of SFE. Accumulation of dislocations at the twin boundaries promotes grain refinement by forming subgrains inside the twin lamellae. Detail investigation on the activity of structural defects during cryorolling of Cu/Cu-Zn alloys has been done through resistivity, positron lifetime and Doppler broadening measurements. Nanoindentation studies have performed to understand the deformation kinetics of the cryorolled Cu/Cu-Zn alloys with high concentration of structural defects in term of strain rate sensitivity and activation volume. A micromechanical model has been used to demonstrate the effect of SFE and the role of structural defects during nanostructuring. The effect of annealing time and temperature on the compressive properties of nanocrystalline $Cu_{70}Zn_{30}$ cryorolled up to ε_{CR}= 0.4 has been studied. An anomalous increment in the compressive flow stress of about 20-25% has been observed during annealing at 165 °C and 200 °C. Characterizations of various structural defects from the x-ray peak broadening analysis and HRTEM have been performed in order to understand the anomalous annealing hardening behavior.

Keywords: Cu/Cu-Zn alloys, Cryorolling, Nanostructured materials, Grain refinement, Nanotwinning, Homogeneity, Microstructure, Mechanical properties.