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Texture evolution via combined slip and deformation twinning in rolled silver–copper cast eutectic nanocomposite

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ABSTRACT

In this work, a silver–copper (Ag–Cu) nanocomposite with 200 nm bilayer thickness and eutectic composition was rolled at room temperature and 200 °C to nominal reductions of 75% and higher. Initially the material had a random texture and {1 1 1} bi-metal interface plane. X-ray diffraction measurements show that the Ag and Cu phases developed the same brass-type (or 'alloy-type') rolling texture regardless of rolling reduction and temperature. Transmission electron microscopy analyses of the nanostructures before and after rolling suggest that adjoining Ag and Cu layers maintained a cube-on-cube relationship but the interface plane changed after rolling. Polycrystal plasticity simulations accounting for plastic slip and deformation twinning in each phase were carried out to explore many possible causes for the brass-type texture development: twinning via a volume effect or barrier effect, Shockley partial slip, and confined layer slip. The results suggest that the observed texture evolution may be due to profuse twinning within both phases. Maintaining the cube-on-cube relationship would then imply that neighboring Ag and Cu crystals twinned by the same variant and on a twin plane non-parallel to the original interface plane. Explanations for this unusual possibility for Cu are provided at the end based on the properties of the Ag–Cu interface.

1. Introduction

Dislocation slip and deformation twinning are the two basic deformation mechanisms that account for most of the permanent deformation during room temperature rolling of face-centered cubic (fcc) metals. The propensity of the material to twin is significantly influenced by its stacking fault energy. Deformation twinning occurs readily in Ag, which has a relatively low stacking fault energy in the range of 19 ± 3 mJ/m^2 (Suzuki and Barrett, 1958; Tadmor and Bernstein, 2004). In contrast, twinning is not so easy in Cu, which has a markedly higher value of the stacking fault energy (with reports ranging from 36 mJ/m^2 to 80 mJ/m^2 (Carter and Ray, 1977; Coulomb, 1981; Hirth and Lothe, 1982)).

Deformation twins appear in Cu only under extreme conditions that generate high internal stresses. Twinning is, for instance, observed in shock-loaded single crystals (De Angelis and Cohen, 1964; Meyers et al., 2001), bi-crystals (Cao et al., 2010), and polycrystalline Cu (Smith, 1958; Gray et al., 1989; Meyers et al., 1995; Sanchez et al., 1997) at room temperature or at low temperatures 4.2 K and 77 K (Belwitt et al., 1957). Twins also have been found to form in Cu samples that had been severely rolled at cryogenic temperatures followed by high strain-rate loading (Yinmin et al., 2003) or near shear bands generated in material deformed by equal channel angular extrusion (Huang et al., 2006). Despite the extreme conditions, the twins in the above samples were relatively narrow, and it is unclear if the twin volume fraction was sufficient to be detected in a bulk texture measurement.

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