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Nanoindentation Studies of Metallic Cu-CuZr Composites Synthesized by Accumulative Roll Bonding

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Abstract : Materials with microstructural heterogeneity have recently attracted dramatic attention in the materials science community. Although most of the metals are identified as crystalline, the new class of amorphous alloys, sometimes are known as metallic glasses (MGs), exhibited remarkable properties, particularly high mechanical strength and elastic limit. The unique properties of MGs led to the wide range of studies in developing and characterizing of new alloys or composites which met the commercial desires. In spite of applicable properties of MGs, commercializing of metallic glasses was limited due to a major drawback, the lack of ductility and sudden brittle failure mode. Hence, crystalline-amorphous (C-A) composites were introduced almost in 2000s as a toughening strategy to improve the ductility of MGs. Despite the considerable progress reported in previous studies, there are still challenges in both synthesis and characterization of metallic C-A composites. In this study, accumulative roll bonding (ARB) was used to synthesize bulk crystalline-amorphous composites starting from crystalline Cu-Zr multilayers. Due to the severe plastic deformation state, new CuZr phases were formed during the rolling process which was reflected in SEM-EDS analysis. EDS elemental analysis showed the variation in the composition of CuZr phases such as 38-62, 50-50 to 68-32 at Cu-Zr % respectively. Moreover, TEM with electron diffraction analysis indicated the presence of both crystalline and amorphous structures for the new formed CuZr phases. In addition to the microstructural analysis, the mechanical properties of the synthesized composites were studied using the nanoindentation technique. Hysitron Nanoindentation instrument was used to conduct nanoindentation tests with cube corner tip. The maximum load of 5000 µN was applied in load control mode to measure the elastic modulus and hardness of different phases. The trend of results indicated three distinct regimes of hardness and elastic modulus including pure Cu, pure Zr, and new formed CuZr phases. More specifically, pure Cu regions showed the lowest values for both nanoindentation hardness and elastic modulus while the CuZr phases take the highest values. Consequently, pure Zr was placed in the intermediate range which is harder than pure Cu but softer than CuZr phases. In overall, it was found that CuZr phases with higher hardness were nucleated during ARB process as a result of mechanical alloying phenomenon.

Keywords : ARB, crystalline-amorphous composites, mechanical alloying, nanoindentation hardness
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