Effect of High-Pressure Torsion and Natural Ageing on Hardness, Electrical Resistivity and Fatigue Properties of Commercially Pure Cu

Commercially pure Cu was processed through high-pressure torsion (HPT) at a pressure of 6 GPa starting from ¼ up to 50 turns. These samples were then naturally aged for 1.75 years under the laboratory condition. Subsequently, microhardness, electrical resistivity, and fatigue response of samples in bending were evaluated and correlated with microstructure. Grain size monotonically decreased with the number of HPT turns and became saturated at ~300 nm after an equivalent strain of ~40. Low-angle grain boundaries and subgrains were formed at onset of straining, which converted into high angle grain boundaries upon further straining. Hardness of the freshly processed samples monotonically increased with the HPT strain and saturated at the value of 155 HV; however, the samples processed to a shear strain of 2 to 20 and naturally aged by 1.75 years demonstrated a remarkable drop in the hardness values. Interestingly, the natural ageing was not effective in changing the hardness of HPT processed samples strained up to very high shear strains. Electrical resistivity of the HPT processed samples after natural ageing as well as freshly prepared samples showed a non-monotonous variation with the HPT strain, wherein it increased and then decreased and finally again started to increase with increasing shear strain. Maximum increment in the resistivity was about ~27% as compared to an annealed Cu sample, whereas microhardness increased by ~ 240 %. On other hand, during fatigue testing, the area of fraction of surface cracks increased monotonically with the stress in both annealed and HPT processed samples. Furthermore, HPT processed Cu samples showed lesser fraction of surface cracks at low stresses, which indicates that HPT process assisted the suppression of surface crack formation and growth of cracks during the initial stages. In addition, fatigue crack growth resulting in same decrease in the stiffness of the sample occurred at a slower rate in the HPT processed samples as compared to the annealed sample. An overview of the observed properties, based on correlation with microstructure conducted using electron back-scattered diffraction and transmission electron microscopy, will be discussed.