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Short Communication

Development of high strength, high conductivity copper by friction stir processing

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ABSTRACT

The objective of this study is to obtain a high strength, high conductivity copper by friction stir processing. Three milli meter thick pure copper plate was friction stir processed to a depth of 2.8 mm at low-heat input conditions by varying the travel speed from 50 to 250 mm/min at a constant rotation speed (300 rpm) to obtain fine grains. Grain size of the nugget decreased from 9 to 3 μm and the hardness increased from 102 to 114 H_V by increasing the traverse speed from 50 to 250 mm/min. Yield strength, microhardness and ultimate tensile strength increased with decrease in grain size in the nugget region and the yield strength obeyed $\sigma_s = 223.8 + 0.07d^{-1/2}$ Hall–Petch relationship, where d is the grain size in m. Electrical resistivity measurement at room temperature showed that there was no change in the resistivity of the processed samples compared to the base metal.

1. Introduction

Pure copper is widely used in optical and electronic industries because of its high electrical, thermal conductivity and good corrosion resistance. However, in pure form it has poor strength, wear and fatigue resistance and hence is unsuitable for applications demanding high strength and wear resistance like contact terminals of electrical switches. Various techniques have been developed to increase the surface strength of pure copper including electroless deposition, accumulative roll bonding (ARB), spray forming. Ziyuan et al. [1] could achieve a uniform and continuous Ni–B coating on pure copper by electroless deposition and they found that the hardness increased and there was no effect on the resistivity of copper by Ni–B coating. Hosseini and Manesh [2] found that the electrical conductivity of pure copper decreased with increasing accumulative roll-bonding cycles up to six cycles and then increased up to eight cycles of ARB. Tensile strength and microhardness of the accumulative roll-bonding processed Cu samples increased with increasing the number of cycles and the elongation dropped abruptly at the first cycles, above which it increased slightly. Takata et al. [3] found that fabricating ultrafine grain microstructures by ARB with grain size of approximately 200 nm can significantly increase the strength of bulky materials without a loss of their electric conductivity. A high strength, high conductivity Cu–Cr–Zr–Mg alloy was prepared successfully by the spray forming process by Li et al. [4]. They found that the microstructure of the spray-formed preform was fine compared with that of the ingot metallurgy-processed counterpart and after hot rolling and appropriate heat treatment, a good combination of strength and electrical conductivity can be achieved.

In the present work, friction stir processing (FSP) of copper is carried out to increase the strength of copper with high conductivity at low-heat input conditions at a constant rotation speed and by varying the traverse speed and the effect of FSP on room temperature electrical resistivity of copper is studied. Xie et al. [5] demonstrated that copper can be friction stir welded at low-heat input conditions at constant traverse speed of 50 mm/min and by varying the rotation speed (400, 600, 800) and has shown that fine grain size is obtained in copper with increased hardness, strength and ductility. FSP is a solid-state surface engineering technique based on the principles of friction stir welding (FSW) [6,7] which can improve the strength [8], wear [9], corrosion [10,11] and fatigue resistance [12,13]. Mahmoud [14] found that the electrical conductivity of AA6063 Al alloy increased with FSP and it was highest when processed at rotation speeds of 315–500 rpm. Uzun [15] studied the electrical conductivity of friction stir welded SiC particulate reinforced AA2124 aluminium matrix composite and found that the conductivity increased in the weld zone compared to the base metal.

FSP uses a non-consumable tool with a specially designed tool and shoulder which rotates at a constant rotation speed and the work piece moves at a fixed traverse speed. The heat is generated by friction between the tool shoulder and the top of the work piece and plastic flow by the rotation of the pin tool. These thermo-mechanical conditions vary through the joint, introducing three distinct regions namely nugget or stir zone, thermo-mechanically affected zone (TMAZ) and heat affected zone (HAZ).

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