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Microstructure and properties of Cu-Cr powder metallurgical alloy induced by high-current pulsed electron beam

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Abstract：This paper is to investigate the microstructure and properties of Cu-Cr alloys induced by high-current pulsed electron beam (HCPEB) irradiation. Microstructure of the alloying layer was studied by means of X-ray diffraction (XRD), scanning electron microscope (SEM), and transmission electron microscopy (TEM). The microhardness and friction property were also tested. The microstructure reveals that craters were formed which were fused and eliminated to form flat surface with increase of the pulse number. Additionally, the inter-diffusion of Cu and Cr elements caused component homogenization of the surface melted layer. Besides, the fine grains/particles and Cu (Cr) solid solution were formed. Those factors accounted for a significant increase in microhardness. The lowest COF and wear rate were attributed to the ultrafine Cr particles in the hard Cu matrix.

Keywords: High-current pulsed electron beam (HCPEB), Cu-Cr alloys, Microstructure, Microhardness, Wear behavior

1. Introduction

Copper (Cu) is widely used in manufacturing fields such as power, electronics and plastic forming due to its excellent ductility, conductivity and thermal conductivity [1]. However, because of relatively poor strength and wear resistance, Cu and its alloys cannot meet the application requirements of high intensity and conductivity such as vacuum circuit breaker contact materials, trams and electric trains overhead conductors [2]. At present, many investigations reported that the second phase element has been added in Cu substrate to improve mechanical properties [3-5]. Cooper-chromium (Cu-Cr) alloy has been a hot topic in recent years due to its good conductivity and high mechanical strength [6-8]. However, it is difficult to produce fine Cu-Cr alloy due to almost immiscibility of Cu-Cr system [7]. For example, Cu-Cr composite prepared by powder metallurgy (PM) shows low density and hardness [9]; the cost of high temperature sintering is high and the efficiency is low [10]. Therefore, these unfavorable factors have hindered the extensive use of Cu-Cr alloys.

Because the surface properties essentially determine the lifetime of component, it is a convenient and effective way to prepare a layer of reinforcement on the surface of Cu-Cr composite to improve the surface performance. High-current pulsed electron beam (HCPEB) is a kind of advanced technology of surface modification in recent years [11-13], with short pulse time (~ several μs) and high energy (10^8-10^9 W/cm^2) etc. Under HCPEB irradiation, the beam energy is transferred into the surface layer within a fairy short period of pulse in vacuum chamber, which leads to extremely rapid heating, melting, even evaporating, and followed by rapid solidification (10^7~10^9 K/s). Simultaneously, many non-equilibrium microstructures were formed in the modified layer such as supersaturated solid

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