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Properties of Al_2O_3 nano-particle reinforced copper matrix composite coatings prepared by pulse and direct current electroplating

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ABSTRACT

Cu–Al_2O_3 nano-composite coatings have high potential for use in applications in which high mechanical properties together with high corrosion resistance are required. In the present study it is intended to produce copper nano-alumina composite coatings with various nano-alumina contents in order to investigate the effect of alumina reinforcement particles on corrosion resistance and mechanical properties such as hardness and wear resistance. The composite coatings were deposited using direct current (DC) and pulse current (PC) plating. The microstructures of the coatings produced from both methods were examined via scanning electron microscopy (SEM) and X-ray diffraction (XRD) techniques. The wear behaviors, micro hardness, coating thickness, corrosion rate and coating porosity were examined using appropriate methods. Compared to DC deposition, PC plating facilitated higher amounts of particle incorporation with more uniform distribution. The results indicated that the mechanical properties of the applied coatings with incorporated nano-alumina reinforcement were far more superior as compared to its own matrix as well as non-composite copper coatings. It was also found out that increasing the amount of nano-alumina content in the coating, led to enhanced general properties of the coatings.

1. Introduction

At present, nano-materials have many applications due to their unique characteristics. These characteristics can be further improved by means of obtaining uniform dispersion of nano-particles in their respective nano-crystalline matrix. Several techniques such as powder metallurgy, plasma spraying, laser deposition, mechanical alloying, etc. have been used in order to fabricate different types of composite materials Co–Al_2O_3, TiO_2–Al, and Cu–SiC [1–3]. It is expected that electrochemical techniques could play an increasingly significant role in nano-technology. Metal–matrix composite electrodeposition refers to electrolysis in which nano-particles are suspended in the electrolyte and are subsequently embedded in the electro-formed solid phase. The resulting composite possesses properties that differ from the bulk, depends on the degree and type of particle incorporation [4,5]. For example, in an investigation carried out by Zhu et al. on copper/SiC composites, they showed that nano-SiC particles dispersed in copper matrix have notable effects on the hardness and wear resistance of the composites [3]. So these composite coatings offer great potentials for various applications due to their superior characteristics that are not typically found in conventional coatings. These include increased strength, hardness, lower porosity and increased corrosion and wear resistance. As a result of the unique properties of these coatings, a number of industrial applications have emerged. For example, the combination of increased hardness/wear resistance and reduced localized corrosion results in an improved protective coating performance [5].

Thiemig et al. investigated the influence of pulse parameters on the electrocodeposition of alumina particles with copper and nickel metal matrix by means of DC plating, PC plating and pulse reverse plating [6]. They showed that a maximum incorporation of alumina was obtained in the case of PC deposition method. In other studies, they evaluated the influence of bath composition and pH on the electrocodeposition of Ni–Al_2O_3 and Ni–TiO_2 coatings [7,8].

Following the other experiments, PC method was chosen to deposit nano-alumina particles in this paper. A comparison was made between DC and PC electroplated coatings. The main scope of this study was the evaluation of the effect of nano-alumina content on the coating properties.

2. Experimental

The copper nano-alumina composite coatings were obtained from the acidic copper sulfate bath, whose composition and conditions are shown in Table 1.

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