

Electroplating and characterization of Cr–Al₂O₃ nanocomposite film from a trivalent chromium bath

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Abstract

Purpose – The main aim of this study was to improve current efficiency and to obtain thicker coatings via aluminum oxide (Al₂O₃) addition to the chromium (Cr) (III) bath.

Design/methodology/approach – Pure Cr and nanocomposite Cr–Al₂O₃ coatings were electrodeposited from Cr (III) bath onto cathode copper substrates by conventional method. Dependence of current efficiency to current density, Al₂O₃ content and particle size were investigated.

Findings – Current efficiency increased with Al₂O₃ amount and decreased with Al₂O₃ particle size. Maximum current efficiency was achieved at 25 A/dm² for pure Cr and 30 A/dm² for composite coatings. Al₂O₃ bath content, current density and stirring rate increased the coating Al₂O₃ weight per cent significantly. Addition of Al³⁺ bath composition inhibited nanoparticle agglomeration, increasing film homogeneity. Cr–Al₂O₃ nanocomposites showed higher microhardness and better corrosion resistance than pure Cr layer.

Originality/value – Cr (III) is not as toxic and as carcinogenic as Cr (VI) which is widely used for Cr electroplating these days. Low current efficiency and poor product quality are, however, major drawbacks of the former. This paper describes significant improvements obtainable by addition of Al₂O₃ nanoparticles to the Cr (III) bath for increasing the microhardness, the corrosion resistance and the current efficiency of the deposition.

Keywords Coatings and linings, Nanocomposite, Al₂O₃ nanoparticle, Corrosion resistant, Trivalent chromium, Electrodeposition, Thick films

Paper type Research paper

1. Introduction

Conventional chromium (Cr) plating from electrolytes containing Cr (VI) has a history of > 120 years. The goal of the process has been improvement of hardness, brilliance, abrasion resistance and corrosion protection (Saravanan and Mohan, 2009; Zeng *et al.*, 2006; McDougall *et al.*, 1998; Edigaryan *et al.*, 2002). Breathing in Cr (VI)-containing environments can, however, irritate the nose, damage the lungs, produce hyperemia, cause stomach and intestine malfunction and result in ulceration and inflammation of mucous lining of the respiratory tract. Cr (VI) electrolyte, therefore, needs substitution with a non-toxic Cr-bearing agent (Baral and Engelken, 2002; O'Brien *et al.*, 2003). In many countries such as the USA, electroplating and anodizing tanks of Cr (VI) are a major source of highly toxic/carcinogenic emissions (Baral and Engelken, 2002). Regulations, therefore, are established for the restriction of Cr (VI) usage in the USA, the European Union, Japan and China, and their discharge into waste streams is strictly prohibited (Zeng and Zhang, 2008).

Widespread investigation on Cr plating from trivalent baths has been reported by previous researchers (Song and Chin,

2002). As Cr (III) does not pass through transporters residing within the cell membrane, its behavior has been considered non-carcinogenic (O'Brien *et al.*, 2003). Its main advantage is due to the non-toxic behavior of Cr³⁺ (Song and Chin, 2002). As reported in the literature, the current efficiency of Cr (III) plating is very low (Zeng and Zhang, 2008). Thick trivalent Cr deposits cannot be developed easily. The maximum Cr thickness obtained from commercial trivalent baths is < 10 μm (Song and Chin, 2002) and Cr coatings from Cr (III) baths exhibit an amorphous structure (Zeng and Zhang, 2008). These limitations make Cr deposition from Cr (III) baths inapposite for hard Cr, wear-resistance and other functional applications.

Particle-reinforced metal matrix composites commonly exhibit wide engineering applications due to their improved hardness and higher wear and corrosion resistance when compared to pure metal or alloy (Vaezi *et al.*, 2008; Ataee-Esfahani *et al.*, 2009; Salehi Doolabi *et al.*, 2012). In recent years, successful co-deposition of ultra-fine particles such as metallic powders, hard oxides (aluminum oxide [Al₂O₃], SiO₂ and TiO₂), carbides [tungsten carbide (WC) and silicon carbide (SiC)], multiwall carbon nanotube, diamond and polymers with a metal or alloy matrix has been reported, and their corresponding structures and properties have been investigated by many researchers (Gyftou *et al.*, 2008; Survilienė *et al.*, 2001; Arami *et al.*, 2007; Narayan and Chattopadhyay, 1982). According to the previously published data, dispersion of second-phase particles into the amorphous materials has resulted in reduction of layer brittleness.

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