Chapter 4
Advancements in Electrodeposition Techniques for Enhancing Copper-Based Composite Coatings: A Comprehensive Overview

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ABSTRACT

Copper coatings are recognized for their outstanding corrosion resistance, wear resistance, and mechanical properties in diverse industrial applications. However conventional electrodeposition techniques often encounter challenges such as nonuniform growth and rough surface formation. This chapter reviews strategies to overcome these limitations by integrating external forces and additives into the electrodeposition process. The study explores the effects of different parameters on the coatings' microstructure, surface morphology, and microhardness. The impact of additives like leveling, grain refining, and brightening agents is examined. Additionally, electrochemical measurements evaluate the additives' effect on corrosion resistance. By optimizing deposition parameters and incorporating additives, significant improvements in copper coatings can be achieved. This review provides insights into the mechanisms of electrodeposition and offers strategies for enhancing the performance and durability of these coatings, promising wider industrial applications.

1. INTRODUCTION

Electrodeposition stands out as a versatile and cost-effective method to meet the growing demands for advanced materials. It enables the production of protective coatings that combine high corrosion resistance with a smooth finish, fulfilling both aesthetic and functional requirements across modern industries. Known for its simplicity and adaptability, this technique is widely employed in key sectors such as automotive and aerospace. Despite its traditional roots, it remains a focal point of contemporary research, where the optimization of deposition parameters paves the way for the development of ultrafine structures and innovative materials tailored to the most demanding applications (Aliofkhazraei et al., 2021; Maniam & Paul, 2020).

Copper electroplating, a particularly popular electrochemical process, has garnered significant attention due to copper's unique properties, including excellent thermal and electrical conductivity, malleability, resistance to corrosion, and strong adhesion to diverse substrates (Aribouet al., 2023, 2024; Bommireddy et al., 2022; Dini et al., 2010). These qualities make copper an essential material in industries like aerospace, automotive, electronics, telecommunications, and energy storage (Hao et al., 2023; Jourdain, 2013; Roy et al., 2023; X. Wang et al., 2020). Copper electroplating is especially prized for its ability to produce high-quality metallic coatings that enhance performance, durability, and functionality while also providing a cost-effective and efficient manufacturing solution (I. O. Mladenović et al., 2022a; Sy et al., 2022).The process involves depositing copper metal from a solution