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Enhanced Strength and Flexibility of Ni-Co Nanocomposites through Electrodeposition with SiC Nanoparticles and SDS Additive

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Abstract – This study focuses on the electrodeposition of Ni-Co nanocomposites using a modified Watts bath. The bath is supplemented with silicon carbide (SiC) nanoparticles and an organic additive, Sodium dodecyl sulfate (SDS). The objective is to investigate the influence of these additions on the structure, mechanical properties, and flexibility of the resulting coatings. Hardness and weight loss tests are conducted, and the coatings are examined through microscopy. In conclusion, this study successfully demonstrates the electrodeposition of Ni-Co nanocomposites with improved strength and flexibility. The incorporation of SiC nanoparticles and the use of SDS as a surfactant show promising results. These findings have practical implications for enhancing electroplating techniques in various industries.

Keywords – Ni-Co/SiC electrodeposit, Corrosion, Nano-structured, SiC nanoparticles.

I. INTRODUCTION

Over the past few years, there has been a growing interest in nanoporous materials among scientists and researchers. These materials possess various advantageous qualities including low mass density, large surface area, high strength, and enhanced performance in areas such as optics, electricity, heat, and catalysis. There are several potential applications for metals with nanoporous structures, including batteries, capacitors, magnetic storage devices, lightweight constructions, sensors, and water filtration systems. In recent times, there has been significant attention towards studying the production and properties of metal matrix composite coatings [1].

Sol-gel and electrostatic deposition techniques are among the commonly employed methods for manufacturing these coatings, particularly for thin films and metallic films [2-6].

The coatings mentioned earlier have found extensive use in various sectors, including magnetic sensor technology, micro electromechanical systems (MEMS), aerospace applications, and nanoelectromechanical systems (NEMS). Pure nickel (Ni) coatings have garnered significant interest due to their remarkable corrosion resistance and thermal oxidation resistance [1]. However, the introduction of cobalt (Co) into nickel alloys significantly affects the crystalline structure, morphology, and physical properties of the coatings. The co-deposition of nickel and cobalt during the production of Ni-Co alloy coatings follows an unusual process where the less noble component, Co, takes priority for deposition on the cathode surface over Ni. It is widely recognized that particle-reinforced composite coatings outperform conventional metal coatings. In the case of alloy coatings, insoluble particles are often incorporated to enhance the specific properties of the target components, capitalizing on the appealing properties of Ni-Co alloys [1].

II. MATERIALS AND METHOD

For the material preparation, the Ni-Co/SiC and sodium dodecyl sulfate (SDS) coatings were applied onto steel-type P265NB (0.19% C) substra-tes. Distilled water was utilized in the preparation of the electrolytes. The electrodeposition cell consisted of two nickel sheets with commercial purity (99.7%) serving as the anode, while a steel substrate was used as the cathode. Prior to deposition, the substrates underwent polishing and were washed with distilled water. To remove any grease or contaminants from the substrate, a cathodic degreasing process was employed using an alkaline solution containing a mixture of sodium hydroxide (NaOH) and sodium carbonate ($Na_2C\text{-}O_3$).

The morphology of the Ni-Co/SiC and SDS coatings was analyzed using a scanning electron microscope (SEM). The chemical compositions of the coatings were determined using energy-dispersive X-ray spectroscopy (EDX). Additionally, a corrosion test was conducted using the weight loss method. The substrates were immersed in an aggressive solution containing 3.5% sodium chloride (NaCl) at room temperature to evaluate their mass changes over time.

III. RESULTS AND DISCUSSION

Fig. 1 provide insights into how different quantities of SiC affect the Ni–Co content in the coatings. The samples were prepared with varying amounts of SiC and SDS concentrations of 5 and 10 g/l. The aim of Fig. 1 is to highlight the impact of different SiC levels on the Ni–Co content in the alloys. The findings of the study are as follows:

The morphology of the electrodeposited Ni Co/SiC deposits obtained from the solution bath was examined. Upon observation of the samples, it was observed that the Ni–Co/SiC composite deposit uniformly covered the entire surface of the samples, exhibiting a highly compact and homog-eneous structure. However, the SEM analysis revealed that when the SiC particle concentration was low, the deposits exhibited the presence of large clusters separated by cracks. The appearance of pores on the Ni–Co/SiC coatings was attributed to the entrapment of hydrogen bubbles during the deposition process. Notably, deposits with a lower SiC concentration exhibited a higher pore ratio. The incorporation of nanoparticles, such as SiC, facilitated the formation of fine-grained deposits. These nanoparticles served as multiple nucleation sites, thereby slowing down the crystal growth process and resulting in a refined granular structure.

In summary, Fig. 1 (a and b) present the influence of SiC quantities on the Ni–Co content in the coatings, with the study demonstrating the morphology of the electrodeposited Ni Co/SiC deposits. The results showcase the compactness, homogeneity, presence of pores, and fine granulation attributeed to the SiC nanoparticles incorporated within the deposits.

Fig. 1 (c and d) illustrates that the coatings obtainnned by incorporating SiC particles exhibit a significant level of co-deposition, with solid particles being uniformly dispersed within the Ni-Co matrix, covering the entire surface. The degree of co-deposition improves with an increase in the number of solid particles. Upon the addition of sodium dodecyl sulfate (SDS), the samples display a compact and homogeneous structure, free from pores or cracks.

The incorporation of solid particles leads to a positive charge on their surface due to the adsorption of metal ions and H^+ ions. This promotes the transfer of particles to the cathode surface through electrostatic attraction, resulting in a rapid increase in layer thickness as determined by light microscopy. The presence of surfactants, such as SDS, enhances the stability of the particle suspension and increases the wetting ability of the particles through adsorption phenomena. SDS imparts a positive charge to the solid particles and prevents their agglomeration by facilitating electrostatic attraction to the cathode surface. This is achieved because SDS acts as a neutral detergent.

The inclusion of sodium dodecyl sulfate (SDS) enables the film thickness to be increased, providing further enhancement to the coating.

The effect of SiC and sodium dodecyl sulfate (SDS) on corrosion was evaluated using the weight loss method. Fig. 2 demonstrates the reduction in weight loss and corrosion rate when the substrate (steel) is coated with a Ni-Co coating. The addition of solid particles (SiC) in the electrolytic bath at concentrations of 5 and 10 g/l results in a significant decrease in the corrosion rate.

This reduction in corrosion rate can be attributed to the presence of SiC in the Ni-Co deposit. The SiC particles occupy the pores within the deposits, thereby reducing the likelihood of chloride ion intrustion into the matrix, which is known to promote pitting attacks.

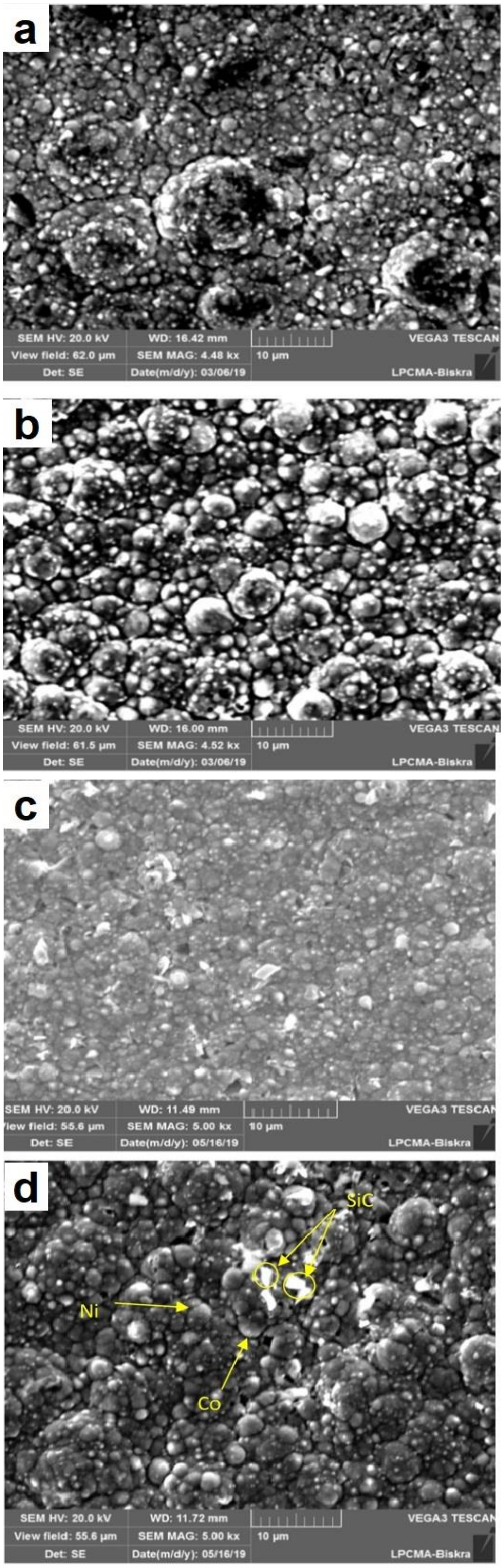

Fig. 1. SEM images of : Ni–Co/SiC coatings at: (a) 5 g l^{-1}, (b) 10 g l^{-1}. SEM images of Ni–Co/SiC with organic additive (SDS) coatings at: (c) 5 g l^{-1}, (d) 10 g l^{-1} [1].

Furthermore, upon the addition of SDS, the surface corrosion rate of Ni-Co reaches its lowest value at a SiC concentration of 10 g/l, as indicated in Table 1.

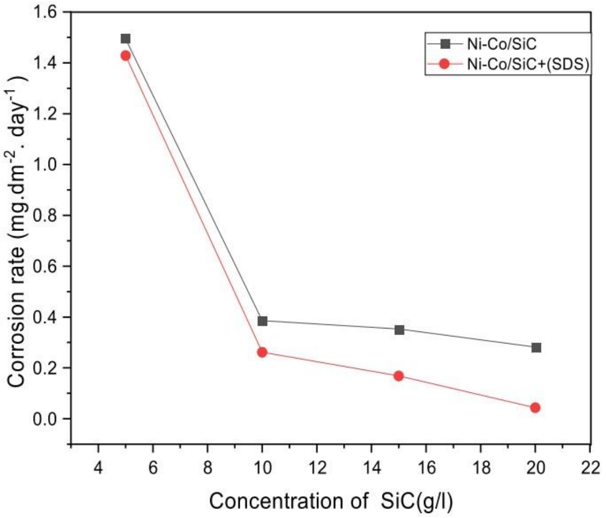

Fig. 2 depicts the variation of the corrosion rate as a function of SiC concentration, along with the influence of sodium dodecyl sulfate (SDS) [1].

This decrease suggests that the SDS facilitates the incorporation of more SiC particles, filling the remaining pores on the coated substrate's surface. As a result, the surface of the substrate is improved, leading to enhanced corrosion resistance.

Table 2. Presented the results of the corrosion test conducted using the weight loss method [1].

Samples	Corrosion test	
	Without add SDS	With add SDS
Ni/Co plus 5 g l^{-1} of SiC	1.494	1.428
Ni/Co plus 10 g l^{-1} of SiC	0.386	0.261

IV. CONCLUSION

Investigations have revealed that SiC particles can be co-deposited with a Ni-Co matrix on steel samples. The incorporation of SDS demonstrates remarkable properties for the substrates. The thermal shock test confirms that the Ni-Co/SiC alloy coatings, along with the organic additive SDS, exhibit excellent adhesion to steel substrates. Upon analyzing the surface morphology of the coatings, it is evident that fissures and porous surfaces are present, indicating that the addition of SiC has contributed to a slight enhancement in the structural properties of the samples. However, when compared to the inclusion of sodium dodecyl sulfate

(SDS), it is observed that more SiC part-icles fill the fissures and porous surfaces, resulting in a further improvement in the beneficial prop-erties of the sample's surface. Furthermore, the corrosion test demonstrates that the weight loss is reduced to a greater extent when the organic add-itive SDS is added, as compared to the inclusion of SiC particles alone. The addition of SDS facilitates rapid film growth and improved crystallization, leading to enhanced corrosion resistance prope-rties.

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