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Corrosion behavior of Electro-deposited Ni-$Cr_2O_3/Sn0_2$ coatings on mild steel

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ABSTRACT

The increasing use of mild steel in diverse environments and under different conditions requires the increased interest in research into these groups of specific steels with attention to their moderate corrosion rate and performance. The electrochemical study of Ni-$Cr_2O_3/Sn0_2$ coating was studied using potentiodynamic techniques. The microhardness properties of the deposits were studied using Emco microhardness tester. The effect of $Cr_2O_3/Sn0_2$ on nickel-based coatings was investigated to analyze the corrosion resistance of the coating by using the polarization method. The result indicates a reduction in corrosion rate with the addition of $Cr_2O_3/Sn0_2$ and the hardness of the coated sample also reduced drastically with the addition of $Sn0_2$ to the bath.

Keywords: Mild steel, Corrosion, Hardness, Electrolyte, Acid, NaCl.

1. Introduction

The foremost utilized fabric within the world as a result of its mechanical and structural properties, and cost-effectiveness, which is broadly used in numerous manufacturing firms consisting of aviation, oil-refining technology, and maritime applications like cargo ships, docks, and turbines is known as mild steel. However, one of the challenges in industries that are managing with disruptive media particularly seawater is mild steel corrosion resistance improvement [1, 2]. There are diverse strategies for mild steel corrosion prevention [3-8]. The need for alloying components such as those found in stainless steel implies that the iron in mild steel is subjected to oxidation (rust) in case not appropriately coated. Mild steel coating with c defensive materials such as ceramic coatings is one of the foremost viable strategies [9-12]. The compelling defenders of mild steel against the corrosive environment are Aluminium (Al), Titanium (Ti), Molybdenum (Mo), and Ni-Mo alloys coatings [3, 13].

There are different sorts of particles utilized in nanocomposite deposition. These includes; ZrB_2, Si_3N_4, Al_2O_3, and Co_3O_2, MoS_2, SiC, WC, carbon nanotubes, graphene, and diamond [14-18]. The chromium oxide (Cr_2O_3) is an inorganic compound and antiferromagnetic solid which have excellent self-mating and anti-galling properties. This ceramic oxide is recommended for resistance to wear by rough grains, hard surfaces, and molecule disintegration. Tin oxide ($Sn0_2$) is additionally found interesting, the electrochemistry of its nanoparticles has been scrutinized in numerous studies that they exhibit novel semiconducting behaviour that is suitable for thin-film engineering and utilitarian coating applications.

Surface engineering of mild steel involves altering the microstructures of the metallic surface framework in arrange to affect useful properties that have the capabilities of diminishing the degradation and extending lifespan over time. This is often accomplished by making the surface tough to the environment in which it will be utilized. Within the past few a long time, nanotechnology has found its application in the manufacture of metal coatings for improvement of surface protection. Their ease of incorporation, uniform scattering achieved, and the great properties transferred into metal matrix have expanded the intrigued of analysts. They display one of the kind properties that are absent within the conventional bulk materials of the same kind [14]. It has been displayed by numerous researches that the incorporation of these nanocomposite materials into conventional coatings can progress the corrosion resistance, thermal steadiness, wear resistance, mechanical, and bio-compatibility properties [15-20].

Moreover, electrodeposition is the foremost broadly utilized, fetched successful strategy of nickel-based matrix composite coating due to its exact ability to control the operational process with minimal operating temperature and pressure [21]. Additionally, it permits the use of cheaper metals such as steel or zinc as the primary material in which nanomaterials are deposited for the desired properties and protection [22-25].

Hence, this work aims to use the electrodeposition technique to incorporate Ni-Cr_2O_3/SnO_2 coatings on mild steel and study the correlation of the corrosion response.

2. Methodology

2.1 Materials, Sample Preparation, and Bath Formulation.

Mild steel samples were used for the electrodeposition process with a dimension of 40mm x 40mm x 2mm. The specimens were metallographically prepared by grinding using the stepwise abrasion papers of size 320 to 1200 microns and polish to finish. The polished specimens were degreased with ethanol, connected as the cathodes, and suspended in the bath. The anodes were connected as Ni stripes of approximately 99.98%Ni. All the chemicals were dissolved in distilled water and their composition is shown in Table 1. The electrodeposition parametric processes were kept constant as shown in Table 2:

Table 1: Chemical Compositions of the Electrolytic Baths.

Chemical composition	Bath 1 (g/L)	Bath 2 (g/L)	Concentration Bath 3 (g/L)
Ni Chloride	100	100	100
Potassium Chloride	60	60	60
Glycine	15	15	15
Boric Acid	15	15	15
Thiourea	15	15	15
Chromium Oxide	-	10	10
Tin Oxide	-	-	10

Table 2: Electroplating Operational Parametric Process

Parameters	
Time	20 min.
Voltage	3.5 V
Current	2.0 A
Temperature	28°C
pH	4.4

2.2 Hardness Analysis

Vickers micro indenter was employed to measure the hardness of the coated composites. A diamond pyramid became pressed towards the specimen leaving a diamond imprint on the coatings. A force of

50kgf was employed to indents for a dwelling time of 10s. The mean value was computed using an average distance of the indents.

2.3 Corrosion Testing

The corrosion evaluation was carried out using the FRA2 ,uAutlab type III Potentiostat. This was done at room temperature by employing a three-electrode system in a simulated 3.65%NaCl medium. The working electrode of coated mild steel, the counter electrode of platinum rod, and the Ag/AgCl reference electrode were connected and subjected to a scan rate of 0.01V/s settled between ±1.5 mV to obtain anodic and cathodic polarization curves. Thus, Tafel extrapolation was utilized to examine the corrosion rate, and other other corrosion data (s).

3. Results and Discussion

3.1 Microhardness Analysis.

The hardness of the uncoated mild steel and the nickel composite coatings are displayed. The enhancement in composite hardness can be observed on all the coated composite in relative to the uncoated mild steel as appeared in Figure 2. An increase in the Cr_2O_3 nanoparticle concentration in the bath solution of Ni developed electrolyte comes about an improvement of hardness potential. From the obtained results, the coated samples revealed a moderate microhardness within the range of (150-275 HV) for Ni-Cr_2O_3-SnO_2, Ni, and Ni-Cr_2O_3 coatings. The inclusion of $Sn0_2$ can be observed to contribute intrinsically to the hardness prowess of the coated composite. Also, Ni-Cr_2O_3 being a ternary coating system, show an appreciable coating execution in all respects with the significant impact of approximately 275 HV. This depicted that a test coated with Ni-Cr_2O_3 maximumly yields higher microhardness than a sample coated with Ni-$Cr20_3$-SnO_2 and Ni.

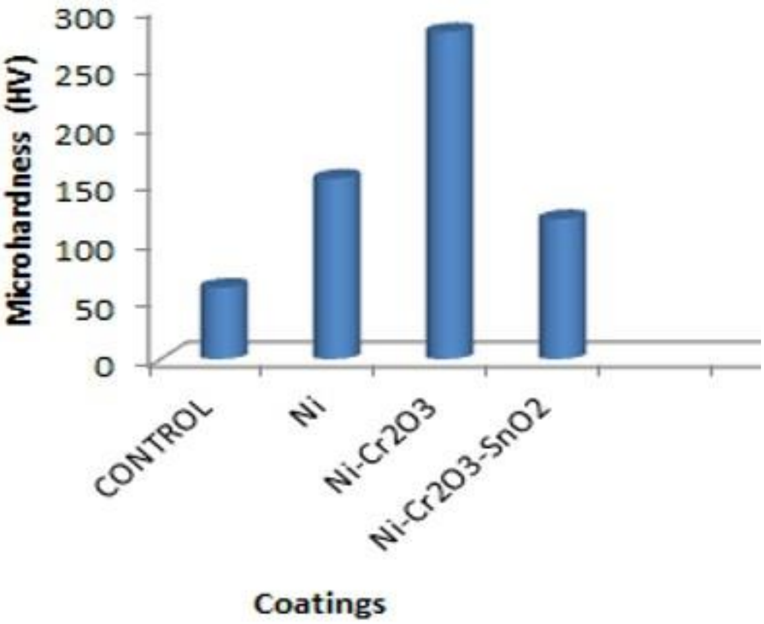

Figure 1: Variation of the Coating Thickness with Coating Composition

3.2 Corrosion Investigation of the Composite Coatings.

Tables 3 and 4 show the outcome for the uncoated and the developed coated composite of the potentiodynamic polarization data in 1 mol H_2S0_4 & NaCl solutions respectively. From the tables, all the developed coated composites proved to have lower corrosion rate values as compared to that of the uncoated mild steel. An increase in nanoparticles magnificently reduces the corrosion value. Ni coating displays the rate of corrosion of 0.0217 and 0.00434 mm/year in H_2S0_4 and NaCl respectively. This was followed closely by Ni-Cr_2O_3-SnO_2 synthesized coating with rate of corrosion of 0.0112 mm/year in an acidic environment. Presently, among the coating developed, Ni-Cr_2O_3 gave the most noteworthy rate of corrosion of 0.0417 mm/year in the NaCl simulated environment. The control sample was identified with high rate of corrosion of 4.09 mm/year in NaCl and 0.7800 mm/yr in H_2S0_4. Additionally, the potentiodynamic data illustrate the offered enhanced corrosion resistance of the developed coatings as compared to pure mild steel substrate which can be confirmed for all samples in H_2S0_4 and NaCl solutions in the potentiodynamic polarization curve (Figure 3 and 4). All the developed coatings proved to have high corrosion resistance potential value than that of the substrate. Also, the corrosion current (icorr) values are more negative for all developed coatings as compared to the uncoated mild steel. Hence, the protective nature of the nano-coating materials can be attributed to their affinity for oxide regeneration and the ability to form passive thin film layers on the prone metal surface.

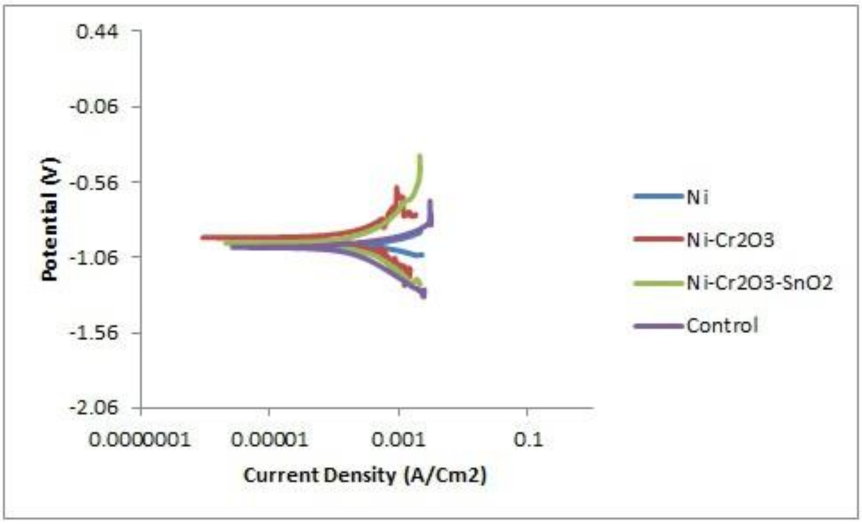

Figure 2: Potentio-dynamic Polarization Curves for all Samples in H_2S0_4 Solution.

Table 3: Potentio-dynamic Polarization Data and Sample Labelling in an H_2S0_4 Solution

Sample	jcorr (A/cm2)	Corrosion rate (mm/year)	Polarization resistance (Q)
Control sample	0,00037743	0.7800	46,910
Ni	0,00028192	0.0217	181,734
Ni-Cr_2O_3	0,00027343	0.0417	149,268

Ni-Cr_2O_3- SnO_2	0,0004022	0.0112	217,260

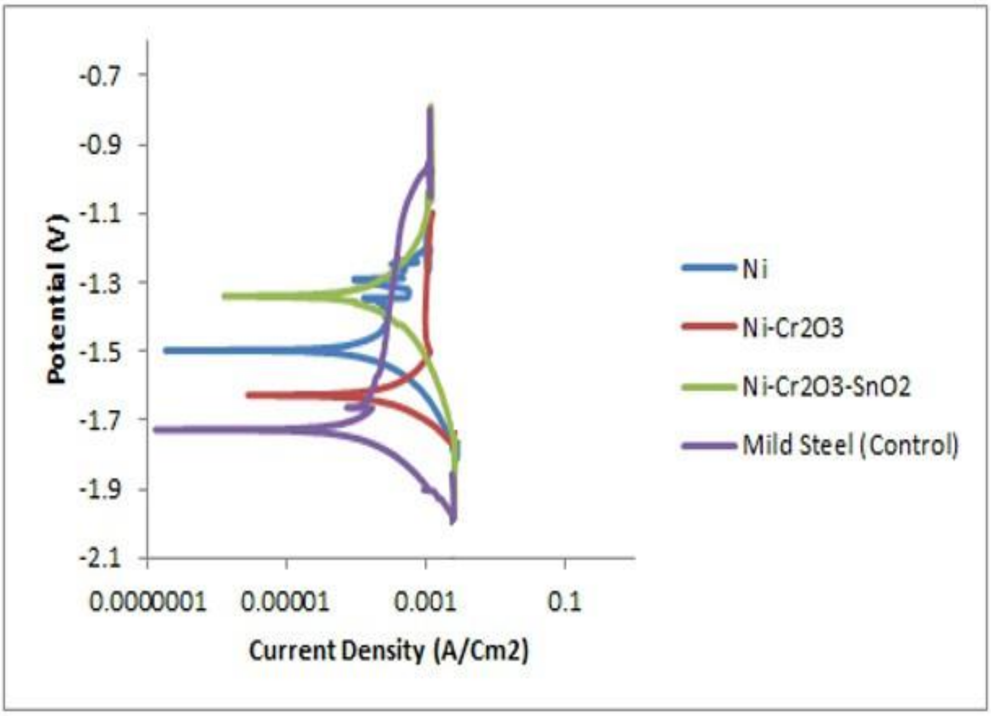

Figure 3: Potentio-dynamic Polarization Curves for Coatings in NaCl Solution.

Table4:Potentio-dynamicpolarizationdataandsamplelabellinginaNaClsolutiion

Sample	jcorr (A/cm2)	Corrosion rate (mm/year)	Polarization resistance (Q)
Control sample	0,0003264	4.09	27,91
Ni	0,0008219	0.00434	184,31
Ni-Cr_2O_3	0,0006042	0.00367	182,76
Ni-Cr_2O_3-$Sn0_2$	0,0004204	0.00288	199,24

Conclusion

It can be concluded that:

- Ni-Cr_2O_3/$Sn0_2$ was successfully electro-deposited on mild steel
- Ni-Cr_2O_3/$Sn0_2$ composite coatings revealed more corrosion resistance prowess in the saline environment than in an acidic condition.

- Ni-Cr_2O_3 retard corrosion attack on the mild steel surface mostly in a corrosive acidic environment.
- A more enhanced hardness was obtained for Ni-Cr_2O_3 coating.
- In all, the developed coated composites were observed wih enhanced material properties compared to the uncoated mild steel.

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