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Coating a copper sample by Ni-Sic composite coating and studying its corrosion behaviour

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ABSTRACT

Ni-SiC composite coatings were electroplated by submerging a brass substrate in a nickel sulfate solution with a SiC suspension. The composite coatings and brass substrate were evaluated for corrosion behaviour by generating Tafel curves in a 3.5% NaCl solution at room temperature. The composite electrolyte exhibited a more significant cathodic polarization potential than the Cu substrate. The wear characteristics of the Ni coating, Cu substrate, and Ni-SiC composite coating made with an HT-8360 rotary disk were investigated in a study. Furthermore, the SiC nanoparticles co-deposited with Ni showed a homogeneous distribution within the Ni-SiC matrix. Consequently, there was a noticeable improvement in the Ni-SiC composite coating's microhardness and wear resistance.

AT The salt spray experiments were performed in a salt spray fog chamber, following the specifications outlined in ASTM-B-117. Changes in adhesion and blister formation, as well as those associated with corrosion, were examined.

Photographs of the specimens, which had been coated with a protective layer, were taken after the salt spray test. The percentage is a vital indication that precisely reflects the degree of corrosion resistance demonstrated by a coated specimen. There is no indication of corrosion.

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1. INTRODUCTION

Recent advancements in coating deposition techniques have created new multifunctional coating materials for application across several domains. These breakthroughs in coating have transformed the methodology for safeguarding material surfaces. Numerous surfaces engineering approaches, including electroplating, thermal spray, and physical vapour deposition, are used and significantly influence particle development organization and the determination of various structural, microstructural, mechanical, and electrical features. These modifications in characteristics enhance their applicability across several domains, particularly in mechanical and tribological contexts related to hardness and wear resistance. [1,2,3]. Many initiatives have been executed utilizing various deposited materials, combinations, and deposition conditions to improve the surface aesthetics and properties of metal components, thus protecting against wear and corrosion while reducing costs, as these elements critically affect the performance and degradation of industrial components.

Electrodeposition is the most straightforward and economical among the numerous deposition procedures, allowing fine control over deposition settings. The coating may be applied effortlessly to unconventional substrate geometries like wire, plate, etc. The electrodeposition technique involves flowing an appropriate amount of direct current between two electrodes immersed in an electrolyte solution, resulting in a homogeneous, dense coating with strong adhesion to a substrate.

This approach is gaining popularity due to its capacity to generate films with exceptional mechanical properties, including high resistance to wear, corrosion, and lubrication. The qualities of the composite coating are contingent upon the shape of the inert particles. In addition, the unique optical, mechanical, and magnetic properties of coatings make them excellent candidates for use in micro-devices [4,5]. Utilizing nano-composite deposition can be advantageous for conducting fundamental investigations into their nanoscale characteristics. Recently, numerous researchers have thoroughly studied the production of composite coatings using electrodeposition. Electrode coatings made using pulse current (PC) or direct current (DC) electrodeposition techniques are the primary focus of this study. [6]. By applying the right amount of heat, these coatings can have their hardness increased to between 1100 and 1200 Hv, and their resistance to wear can be strengthened. Nevertheless, the coating typically has a thickness ranging from 50 to 70 µm and has below-average wear resistance. Extensive testing led to developing a novel composite coating with increased hardness and outstanding wear resistance. This electrodeposited composite coating has an initial hardness ranging from 600 to 900 Hv.[7] One hour of heat treatment at 400 °C will raise the hardness to 1400–1700 HV. Cigarette and textile industrial components have been treated using this method. [8] Electroplating is the electrolytic technique for depositing a typically thin metal coating onto a substrate. The primary objective generally is to modify the properties of a surface to provide enhanced visual appeal (decorative finishing)—resistance to corrosive conditions and abrasion. Alter the surface characteristics, such as the ability to be soldered, the amount of light reflected, and so on. Electroplating has the potential to offer a mix of these qualities. The desired mechanical attributes of the deposits mainly determine the selection of bath composition. .[9]

2. EXPERIMENTAL WORK

This paper deals with the experimental work carried out in this study. The experimental work includes the surface pretreatment of the Cu-alloy specimen used as a substrate for the electroplating bath. The condition of the electroplating bath on the Cu-alloy specimen will be given.

2.1. Substrate Materials

A brass specimen with dimensions 3.0 x 3.0 x 0.6 cm was used as substrate. A commercial brass specimen was used.

2.2 Chemicals

All chemicals were analytical grade:

Nickel sulfate (NiSO4) is a product obtained from PROLABO-France.

, sodium citrate (Na…), product by GDR Germany.

SiC powder from 600 mesh (22 µm).[10]

2.3 Preparation of the specimen

As shown in Figure 1, the cell used in electroplating consisted of the brass substrate to be plated as a cathode, and the anode was a pure nickel plate. The cell was connected to a DC power supply (MUNK-PSP-VARI-PULS, USA) between the anode and cathode. The current density was measured using a digital ammeter.

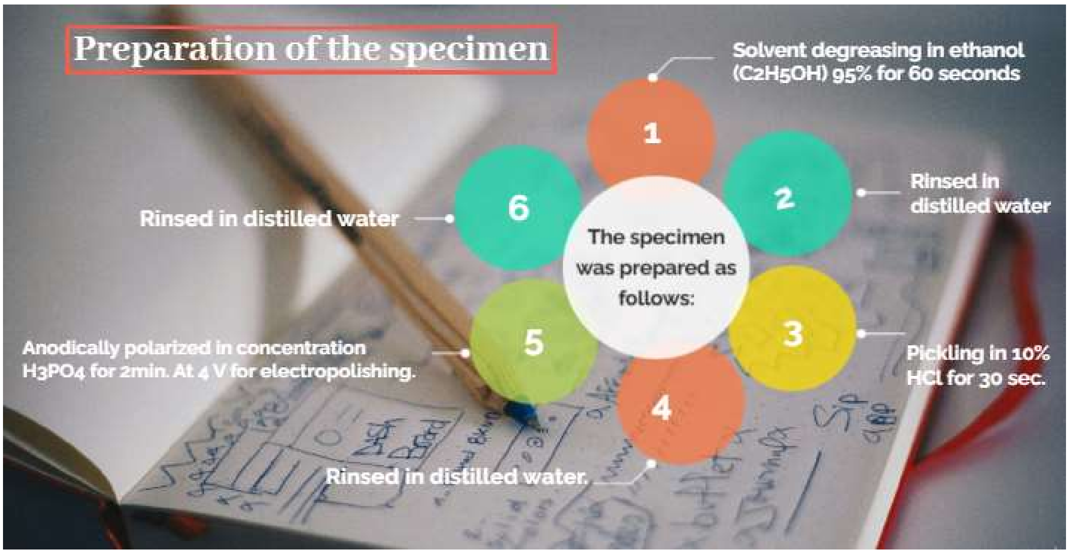

Figure 1. shows the Sample preparation steps.

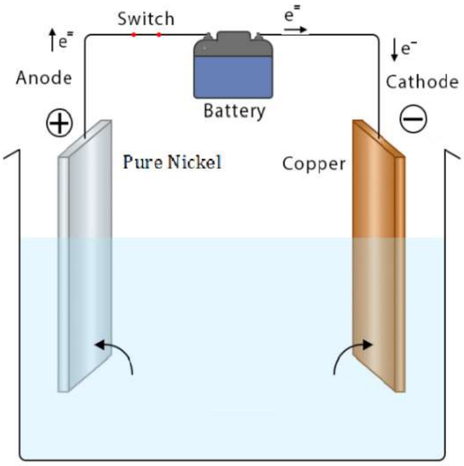

Figure 2. Electroplating cell [11]

2.4 Electroplating Bath

The plating bath consisted of nickel sulfate as the supply of nickel and sodium citrate to prevent the anode and Sic passivation. Table 1 displays the composition and variables of the bath.

Table 1. presents the bath composition and variables.

Chemicals	Composition (g/l)
Nickel sulfate	30
Sodium Citrate	84
Ammonium Chloride	10
SiC	10

Variables	
Temp.	50 – 53ºC
Current density	2-6 A/dm^2
pH	8.5
Plating time (min)	15, 30, 45, 60, 75, 90
Stirring speed (rpm)	250 - 300

The anode was a high-purity nickel material with 100 × 50 × 10 mm dimensions, providing an effective surface area. The plating bath was combined with SiC powder measuring 22 µm in size. The purpose of the agitation was to evenly distribute SiC particles throughout the electroplating bath evenly, enhancing both the particle concentration and dispersion in the resulting electroplated composite. [12,13]

Table 2. presents the bath composition and variables for Watt's bath.

Chemicals	Composition (g/l)
Nickel sulfate	30
Nickel chloride	240
Boric acid	25
SiC	10
Variables	
Temp.	60 ℃
Current density	4 A/dm^2
pH	4.5
Plating time (min)	15, 30, 45, 60, 75, 90
Stirring speed (rpm)	250 - 300

2.5 CONTROLLING THE ELECTROPLATING PROCESS

Temperature:

The temperature was adjusted using hot plate 32330; the temperature can affect the performance of the plating process and burning characteristics.

Hp

pH of the solution was controlled by adding ammonium hydroxide 25% or sulphoric acid 20%. A pH meter (Thermo Orion, U.S.A) was used to measure pH. Precision was ± 0.01. [14]

Agitation:

Magnetic stirring was used to agitate and uniformly distribute SiC particles in the plating solution. Speed was 250 – 300 rpm. [15]

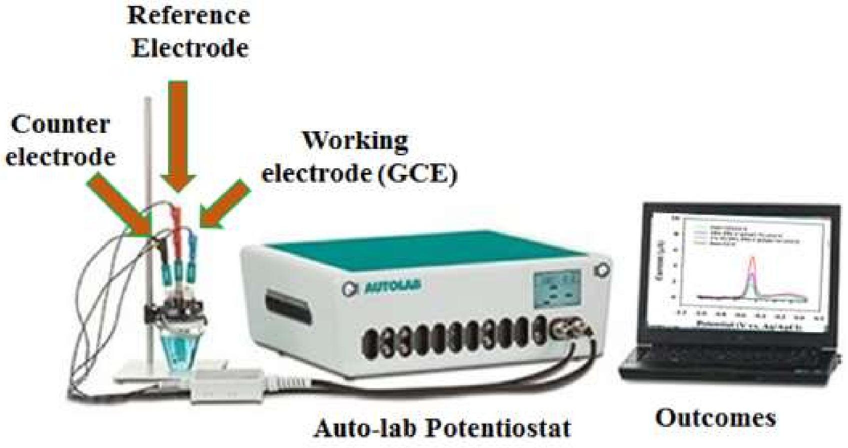

Figure 3. The Auto Lab automated Potentiostat was utilized for testing purposes.

2.5.1 Salt Spray Test

The salt spray test accelerates the corrosion process by creating a corrosive attack to determine if the coated samples are suitable for a protective finish. After a while, we look at how corrosion goods seem. The coating's corrosion resistance determines how long the test may go without corrosion symptoms. A more resistant coating will have a more extended test duration. A coating's predicted lifespan does not matter how long it takes to pass a salt spray test. In this testing setup, a nozzle is used to spray a salted solution into a sealed chamber. Although they can be built with bigger sizes, these chambers typically have 400 L [16]

Figure.4 Salt-Spray-Testing

We followed the guidelines laid out by ASTM-B 117 when we tested for salt spray. Each test panel had its visible surface slanted 15 degrees to the vertical within the chamber—the operating conditions of the salt spray test. The subsequent requirements must be followed in the salt spray test with NaCl solution by DIN EN ISO 9227: pH range of 6.5 to 7.2; Sodium chloride solution concentration of 50 ± 5 g/l. Chamber temperature: 35 °C ± 2 °C. [17]

2.5.2 Wear resistance measurements

The HT-8360 Taber Abrasion Tester machine was utilized to conduct the abrasion test on sheet specimens measuring 30 mm in length and 20 mm in breadth.[18]

Figure 5. Abrasion tester, HT-8360, Japan

3 RESULTS AND DISCUSSION

3.1 Corrosion Behaviour

Brass is commonly utilized in marine settings for various technical applications, particularly in cooling systems, condensers, and pipelines. This environment exhibits elevated salinity, marked by a significant concentration of chloride ions that can induce metal pitting. The corrosion of our coated samples in a 3.5% NaCl solution was assessed utilizing the potentiodynamic polarization technique. [19.20,21]

Figure 6. We analyzed the polarization curves of the composite coatings and the brass substrate in a 3.5-weight per cent NaCl solution. The figure reveals that the corrosion current, Icorr, obtained is lower for Ni-SiC than brass. Coating brass with Ni-SiC decreases its susceptibility to corrosion.

The composite coatings demonstrate significantly enhanced corrosion resistance relative to the deposit. This improved corrosion resistance is ascribed to the augmented barrier effect of incorporating SiC particles inside the Ni matrix.

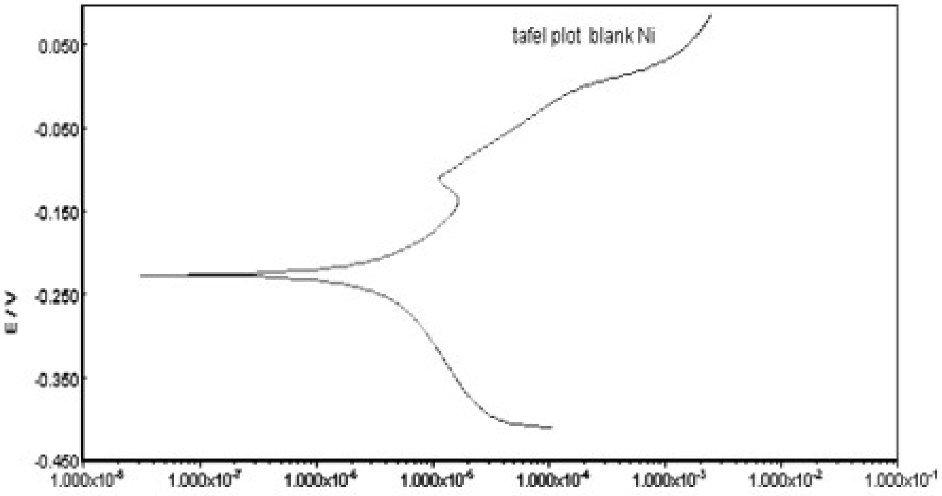

Figure 6a. Representative polarisation curves of Cu-substrate

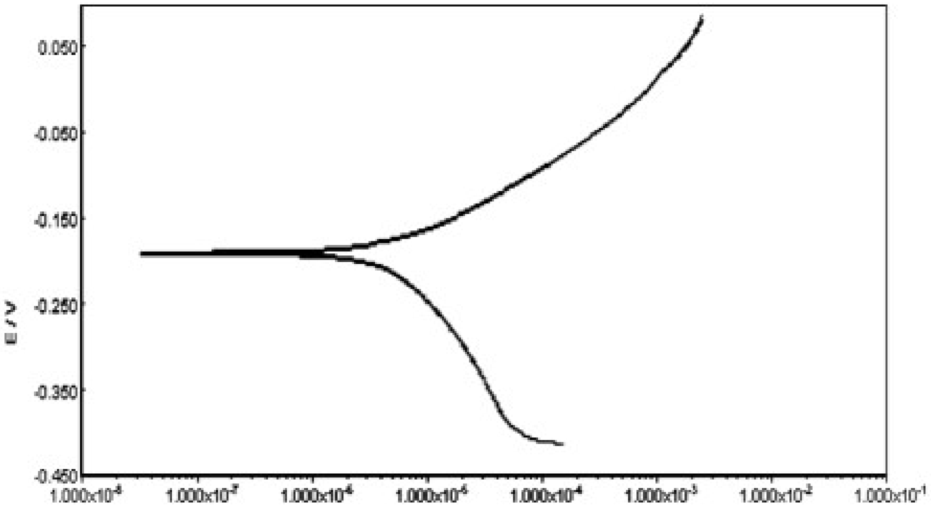

Figure 6b. Representative polarisation curves of Ni plating over Cu substrate

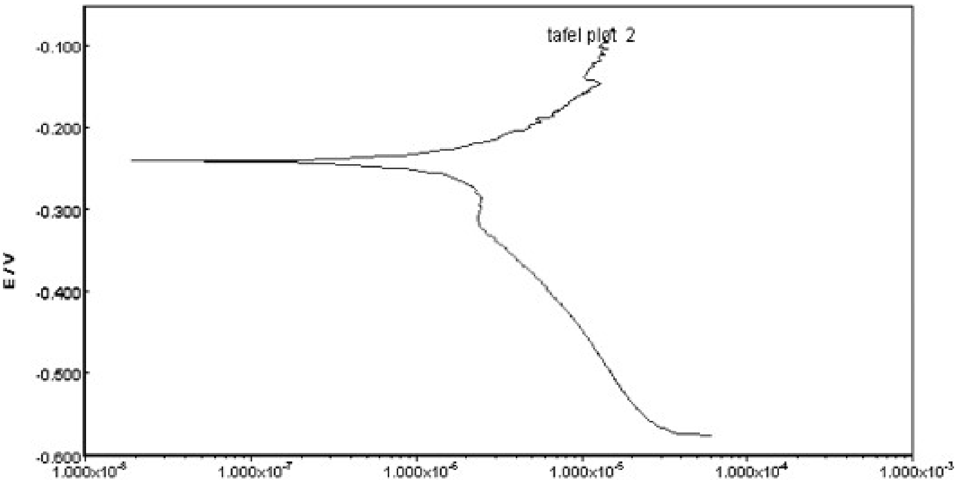

Figure 6c. Representative polarisation curves of 2 A (time I hr, pH 8.5 and temp. 53^{o}C)

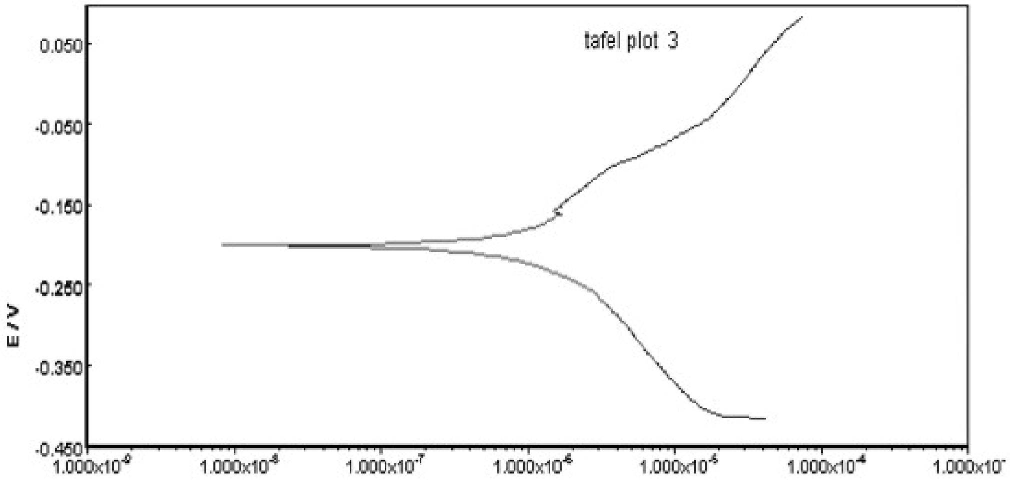

Figure 6d. Representative polarisation curves of 3 A (time I hr, pH 8.5 and temp. 53°C)

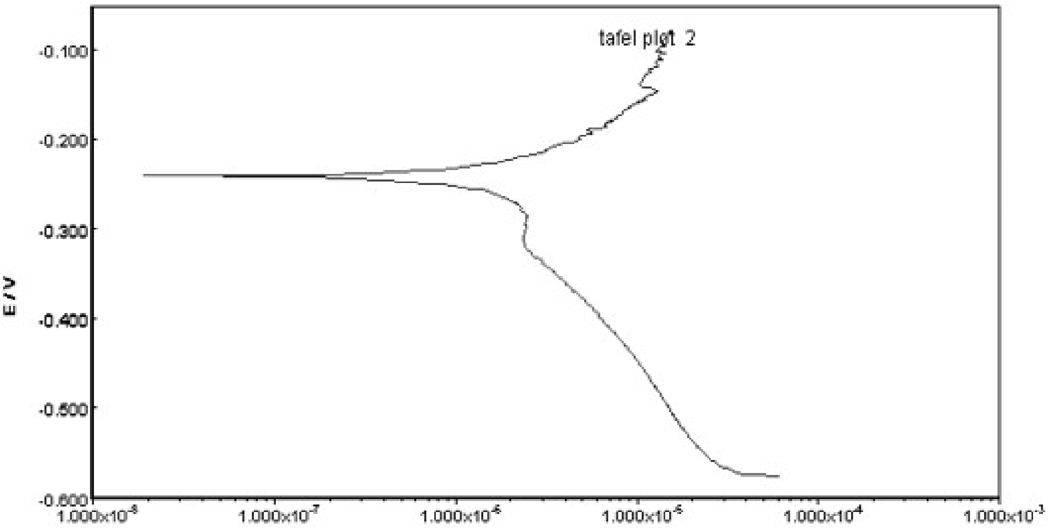

Figure 6e. Representative polarisation curves of 4 A (time I hr, pH 8.5 and temp. 53°C)

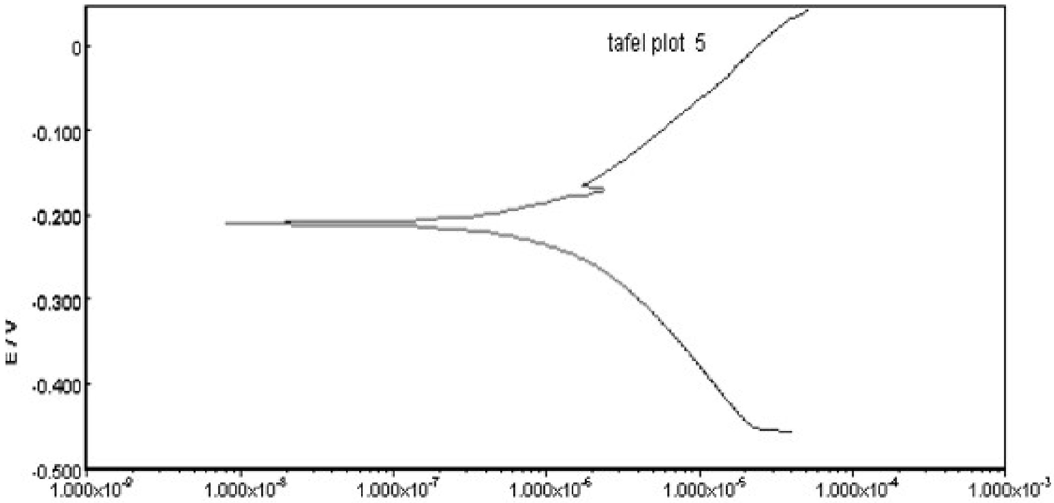

Figure 6f. Representative polarisation curves of 5 A (time I hr, pH 8.5 and temp. 53°C),

Table 3. Corrosion resistance data

Sample No	I corr.	Corrosion rate (mpy)
Cu-substrate	0.000025573	15.125
Ni plating over Cu substrate	0.000005587	4.856
2 A (time I hr, pH 8.5 and temp. 53ºC)	0.000002914	1.723
3 A (time I hr, pH 8.5 and temp. 53ºC)	0.000000936	0.55
4 A (time I hr, pH 8.5 and temp. 53ºC)	0.000005026	2.97
5 A (time I hr, pH 8.5 and temp. 53ºC)	0.000001989	1.176

3.2 Wear behaviour

The HT-8360 Taber Abrasion Tester machine was used to conduct the abrasion test on sheet specimens measuring 30 mm in length and 20 mm in breadth. The testing piece was fastened to the rotary disk fixture, and controlled pressure was applied to the movable arm to bring the testing piece close to the grinding wheel during the wear test. The testing component will gradually lose weight due to the grinding wheel's abrasion. We measured the amount of weight lost from the samples due to abrasion. The abrasion test was conducted with a rotational speed of 60 rpm, an applied weight of 250 g, and a testing duration ranging from 1 to 5 hours. Fig 7 shows the wear rates (wear mass loss) of brass, Ni coating on the brass substrate, and Ni-SiC on the brass substrate. Brass ages more quickly than nickel deposits on a brass substrate and wears out more noticeably than nickel-silicon carbide composite coatings.

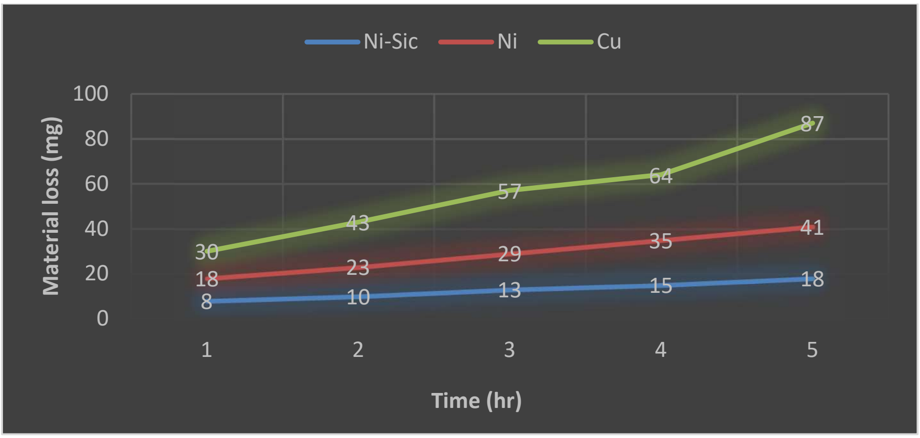

Figure 7. Indicates the comparative total wear loss of Cu substrate, Ni coating on Cu substrate, and Ni-Sic composite coating on Cu substrate subjected to dry sliding wear test.

3. 3 Evaluation of Corrosion Performance

ASTM-B-117 was evaluated in a salt spray fog chamber regulated at 35 degrees Celsius. The salt fog test is a quick corrosion assessment that enables the comparison of samples subjected to consistent conditions.

In the B117 test, samples were exposed to a salt fog produced from a 5% sodium chloride solution with a pH of 6.5 to 8.5. All samples were exposed to the salt fog chamber for 24 to 72 hours. During this time, before- and after-exposure photographs were taken to document surface conditions.

The initial mass and measurements were documented. After exposure, all samples were rinsed with water to remove salt deposits from the surface and then quickly dried with compressed air. Figure 8 shows the overall morphologies of the uncoated and coated Ni-SiC superfine alloys after 1, 2 and 3 days of salt testing.

Corrosion-induced alterations in adhesion and blistering were evaluated in specimens subjected to salt fog without scribes. Images of the concealed specimens were obtained. We obtained the fraction of the corded region, not the corded area of the specimens. The % is crucial for evaluating a coated specimen's corrosion resistance.

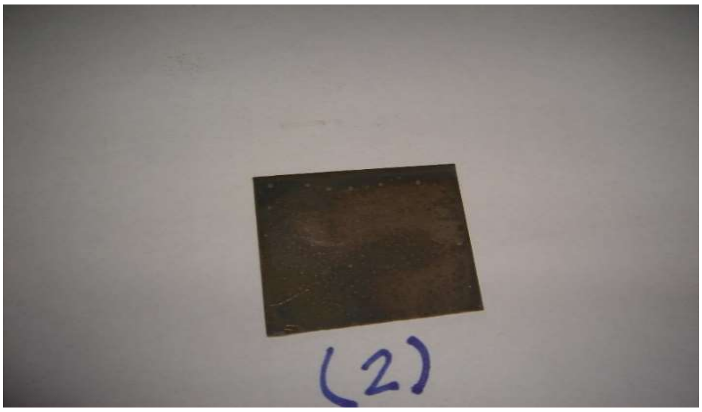

Figure 8a. Sample 2 showed no signs of degradation after the salt spray test.

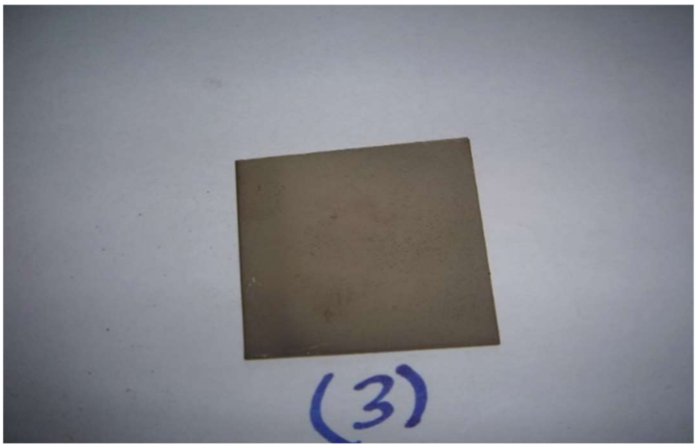

Figure 8b. Sample 3, after the salt spray test, showed no deterioration.

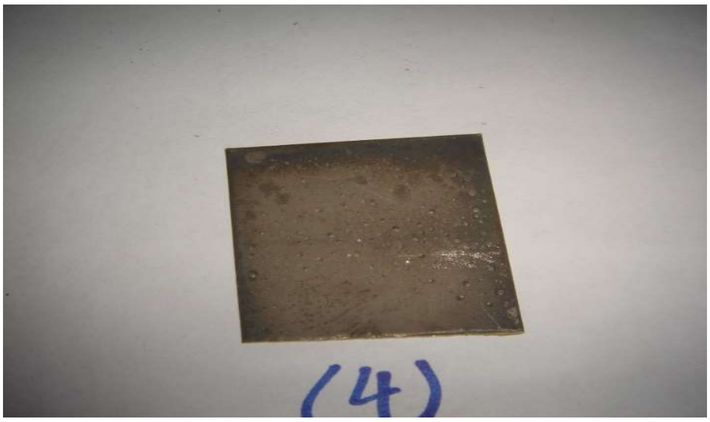

Figure 8c. Sample 4 showed no degradation after the salt spray test.

4. CONCLUSIONS

1. The Ni-SiC composite coating creates a protective layer with superior mechanical characteristics and corrosion resistance.
2. The Ni coating is less corrosion-resistant than the Ni-SiC composite coating. Because of its exceptional corrosion resistance, it is an excellent choice for marine conditions. Future studies may investigate further optimization of this coating, which could increase the range of industrial areas in which it can be used.
3. When compared to Ni plating, the wear resistance of the Ni/SiC composite coating on the brass substrate is much higher.

4. Copper exhibits a higher corrosion rate than nickel deposits on a copper substrate and a nickel-silicon carbide composite coating applied to a copper base material. Proper concentration and coating condition selection can produce composite deposits that enhance hardness and corrosion resistance.
5. The Ni/SiC composite coating demonstrated exceptional corrosion resistance in a salt spray test; no corrosion was seen in uncoated or coated Superfer superalloys exposed to salt fog tests for various periods. The external appearance of all samples stays unaltered.

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