ENHANCEMENT OF COATING THICKNESS AND MICROHARDNESS OF
NI-SIC NANOCOMPOSITE COATINGS FOR THE VARIATION IN BATH
PARAMETERS

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ABSTRACT

Ni-Sic nanocomposite coatings were prepared on a MS substrate by electrocodeposition process. The electro-co-deposition was carried using sulphamate bath.

In the present work the effect of electrochemical bath parameters such as bath temperature, bath loading and current density on physical and mechanical properties of Ni-based SiC composite coating on mild steel substrate was studied. SiC loading, Current density and bath temperature were varied and the coating thickness was measured using Elektro Physik thickness gauge.

The mechanical properties of the electrocodeposited Ni-SiC coatings containing ceramic particles are very much dependent on various factors like bath used, current density, duration of deposition, Thickness of the coating, bath temperature etc.

The effects of current density, bath temperature and SiC nanoparticles concentration in the plating bath on the hardness of the coatings were determined by microhardness tests using Vicker’s microhardness tester.

The Experimental results shows that, the microhardness of the codeposited coating increases with the increase in the current density and attains a maximum at the SiC concentration of 6 g/l. The decrease in the microhardness at higher concentrations may be due to agglomeration of nano sized particles in the plating bath.

Keywords: Electrocodeposition, SiC nanoparticles, Microhardness, Microstructure

I. INTRODUCTION

Ferrous materials are today of wide and varied use because of its industry friendly properties like ductility, malleability, high strength etc. But the main problem associated with ferrous materials is corrosion. To check this problem these ferrous materials are coated with several metallic non metallic additives. Protective coatings play an important role in materials science owing to the possibility to obtain modern technical design, for example, obtaining functional corrosion resistant
coating. Metal–matrix composites are materials in which the properties of a metallic host material are modified by the addition of a different type material (for example a ceramic). One type of electro-co-deposited composite coating consists of a base metal with embedded dispersed particles. These particles are insoluble in the electrolytes used for electro-co-deposition of the base metal and are mechanically dispersed to create a homogeneous medium. The second phase materials can be hard oxide (Al$_2$O$_3$, TiO$_2$, SiO$_2$), carbides particles (SiC, WC), diamond, lubricate (PTFE, graphite, MoS$_2$).

Nickel based electrochemical composite coatings have good corrosion properties and enhanced electrochemical activity for hydrogen and oxygen evolution compared to the base metal. These coatings are also used for the protection of machine parts subjected to aggressive environments.

The development of modern technology requires metallic materials with better surface properties. Coatings that consist only of nickel may not meet these requirements. As a result composite materials with new structures and special properties have become the focus of attention for the researchers. Ni based coatings are not only used for decorative purposes but also as functional coatings for resistance to corrosion, wear and refractory applications.

Ni-SiC composite coatings can be successfully employed as protective coatings in friction parts, gas engines and in creating casting moulds. It has been proved that Ni-SiC nanocomposite coatings will have improved hardness and wear resistance properties as compared to pure Ni coatings. Vaezi et al, has found that the microhardness of the nanocomposite coatings increases with the increase in the content of the SiC particles in the bath.

However most of the studies on the Ni-SiC nanocoatings have been concentrated on the optimizing certain properties such as Corrosion resistance, wear resistance, microhardness.

In this article the effects of various plating parameters like SiC loading, bath temperature and current density on coating thickness and microhardness were studied.

II. EXPERIMENTAL

In this experiment over 27 samples (3 samples size for each condition) were coated under different bath conditions such as SiC loading, current density and bath temperature and were characterized by conducting the following tests.

COMPOSITE COATING THICKNESS

To Study the effect of SiC loading, bath temperature and current density on coating thickness of Ni-SiC composites thin coatings.

The substrate Ni-SiC coating thickness was measured by using the instrument Elektro Physik thickness gauge as shown in the figure 1.
Microhardness of Composite Coating

The effect of SiC loading, bath temperature and current density on microhardness of Ni-SiC composite coatings was measured using Vickers hardness tester.

![Standard Specimen](image)

### III. RESULTS AND ANALYSIS

The sample results of the effect of SiC loading, bath temperature and current density on Ni-SiC composite coating thickness and microhardness are shown in table 1 below for 3 trails.

#### TABLE 1

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III. COMPOSITE COATING THICKNESS

1) The effect of bath temperature and current density on coating thickness of Ni-SiC composites coatings

Fig.3 (a-c) shows the variation in the coating thickness of the Ni-SiC composite coatings with the different current density and bath temperature at different SiC content and constant pH of 4.5. By experimental observation, it showed that, the deposit is thicker at the centre of the plate than at the corners for all the types of the coated specimens.

However, almost an uniform deposit thickness was obtained for deposition with 3 A/dm$^2$ current density, temperature of 55 °C and loading of 4 g/l. The micro structural analysis revealed a more uniform distribution of SiC particles at lower current density than at the other two current densities as shown in the figures. The cathode current efficiency increased with increasing current density. This must be related to the increase in the amount of nickel in the composite coating with increasing current density.

**Fig.3:** Effect of bath temperature and current density on coating thickness of Ni-SiC coatings for loading of a) 2 gm/l, b) 4 gm/l & c) 6 gm/l
2) The effect of SiC loading and current density on coating thickness of Ni-SiC composites coatings

Fig. 4 (a-c) shows the thickness of the composite deposited coatings formed under different current density and SiC loading. It is seen that, thickness of the composite coating increases after a peak value of current density of 4 A/dm$^2$. This may be explained according to the deposition process of Ni-SiC composites. When a negative potential is applied on the electrode, nickel ions are reduced on the cathode immediately and a thin metal film is formed. The SiC contacted to the cathode would be engulfed into the composite coating due to the reduction of nickel ions around them. As the current density increases, the reduction of nickel ions becomes faster and more SiC is is captured into the composites coatings [51, 52]. However, the diffusion rate of SiC near the cathode surface is much slower than that of nickel ions. As the electro-co-deposition current density further increases, the reduction rate of nickel ions becomes faster. This can be evidenced by the fact that the coating thickness increased obviously with the depositing current density as shown in Fig.4, while the incorporation rate of SiC into the coating remain stable because of the diffusion limitation of SiC from the solution body to the cathode surface. A peak value of coating thickness was observed from the experiment at the current density of 4 A/dm$^2$.

![Fig.4](image-url)

Fig.4: Effect of SiC loading and current density on coating thickness of Ni-SiC composites coatings for bath temperature of a) 450 C, b) 550 C and c) 650 C
3) The effect of bath temperature and SiC loading on coating thickness of Ni-SiC composites coatings

The effect of bath temperature and SiC loading on the coating at different current density of different stages of 2, 3 & 4 A/dm$^2$ is shown in Fig. 5 a, b and c respectively. Similar trends were observed with regard to the bath temperature and even weight of SiC in the deposits. The weight of deposit thickness increases with an increase in the bath temperature and loading. This was evident by metallographic observations, which revealed that a uniform distribution of the SiC in the composite was obtained at the following conditions, i.e., 4 gm/l of SiC loading, bath temperature of 55°C and current density of 4 A/dm$^2$ as shown in Fig. The coating efficiency depends on chemical kinetics and nickel ions. The concentration of nickel in the bath can be varied by an increase in electropotential and the temperature of the bath. The higher the ions, and the coating process rapid and hence thickness increases.

Fig.5: The effect of bath temperature and SiC loading on coating thickness of Ni-SiC composites coatings at a) 2A/dm2, b) 3A/dm2 and c) 4A/dm2
IV. MICROHARDNESS

4) The effect of bath temperature and current density on microhardness of Ni-SiC composites coatings

The effect of the current density and bath temperature on the microhardness of composites coatings, it is apparent that the higher HV values are those of Ni-SiC composite Fig. 6 (a-c).

It is known that, the hardness of metal matrix composites depends on the amount and the size of the dispersed phase, apart from the mechanical characteristics of the matrix, particles and interfaces. In general, several studies have shown that the microhardness of composite coating is higher than that of Ni coatings. Initially the hardness increases with increasing current density then attains a peak at 3 A/dm\(^2\) and decreases with further increasing in current density.

Microhardness of Ni–SiC matrix was observed to be 650 kg/mm\(^2\). The hardness values of Ni-SiC composite coatings ranged from a minimum of 550 Hv to a maximum of 1244 Hv.

![Fig.6: Effect of bath temperature and current density on Microhardness for Ni-SiC coatings for loading of a) 2 gm/l, b) 4 gm/l & c) 6 gm/l](image-url)
5) The effect of SiC loading and current density on microhardness of Ni-SiC composites coatings.

Here the effect of the SiC particle content on the microhardness values is studied. It is apparent that the higher HV values are obtained for higher percentage SiC in Ni-SiC composite which is shown in Fig. 7. It is known that, the hardness of metal matrix composites depend on the amount of the dispersed phase, apart from the mechanical characteristics of the matrix, particles and interfaces. The Vickers hardness increases with increasing amount of SiC particles in Ni–SiC coatings. Microhardness of Ni–SiC matrix was observed to be 1244 kg/mm². The Vickers hardness of SiC is very high as compared to Ni–SiC plating. The Vickers hardness of all Ni–SiC coatings investigated is higher than the pure Ni-electroplating. Lower hardness value is obtained at a lower volume percentage of SiC particles. It is known that the hardness and other mechanical properties of the metal matrix composites depend in general on the amount of the dispersed phase, apart from the mechanical characteristics of the matrix, particles and interfaces. The grain refining as observed by XRD and dispersive strengthening effects become stronger with increasing SiC content.

Fig.7: The effect of SiC loading and current density on microhardness of Ni-SiC composites coatings for bath temperature of a) 450 C, b) 550 C and c) 650 C
6) The effect of SiC loading and bath temperature on microhardness of Ni-SiC composites coatings.

Fig 8(a-c) shows the hardness Ni-SiC composite coatings as a function of the bath temperature. The hardness of the as-deposited Ni-SiC coating was approximately 1244 kg/mm², which is approximately 50% larger than that of the pure nickel coating. Furthermore, the hardness of the Ni-SiC coating decreased continuously with increase in current density, bath temperature and SiC-loading. The current density increased whereas the microhardness of the coating showed mixed trends. Initially it increases and then decreases with bath temperature and loading irrespective of the current density In the first stage, the hardness increases with increasing temperature due the higher concentration of Ni ions. Although the concentration of Ni ions is more, the high porosity results in a drop of Microhardness after 55 °C of bath temperature. Hydrogen bubbles physically push the electrolyte away from the deposition zone, possibly stopping electroplating and hindering the electrolytic processes. This makes it more prone to porosity.

![Graph showing the effect of SiC loading and bath temperature on microhardness of Ni-SiC composites coatings for current density of 2A/dm², 3A/dm², and 4A/dm².](image)

**Fig.8:** The effect of SiC loading and bath temperature on microhardness of Ni-SiC composites coatings for current density of a) 2A/dm², b) 3A/dm², and c) 4A/dm²
CONCLUSIONS

- A uniform deposit thickness was obtained for deposition with 3 A/dm$^2$ current density, temperature of 55 °C and loading of 4 g/l. The micro structural analysis revealed a more uniform distribution of SiC particles at lower current density than at the other two current densities as shown in the figures (ie at 55 °C and 65 °C).
- A peak value of coating thickness was observed from the experiment at the current density of 4 A/dm$^2$.
- A uniform distribution of the SiC in the composite was obtained at the following conditions, ie 4 gm/l SiC loading, bath temperature 55 °C and current density of 4 A/dm$^2$.
- The hardness increases with increasing current density then attains a peak at 3 A/dm$^2$ and decreases with further increasing in current density. The Vickers hardness increases with increasing amount of SiC particles in Ni–SiC coatings.
- The hardness of the Ni-SiC coating decreased continuously with increase in current density, bath temperature and SiC-loading. The current density increased whereas the microhardness of the coating showed mixed trends.

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