

“Research Note”

INFLUENCE OF PARTICLE SIZE ON CORROSION RESISTANCE OF ELECTROLESS Ni-P-SiC COMPOSITE COATINGS*

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Abstract– High phosphorus electroless nickel bath has been used to prepare composite coatings containing SiC particles (40 nm, 3 μm and 7 μm). The coated samples were subjected to heat treatment at 400 °C for 1h. The effect of heat treatment on the microstructure of Ni-P-SiC composite coatings was investigated by X-ray diffraction. Potentiodynamic polarization measurements made on these deposits in 3% sodium chloride solution showed that corrosion resistance in nano-composite coatings was much higher than micro-composite coatings. The corrosion rate results for nano-composite coatings showed a 6 fold improvement as compared to the micro-composite coatings.

Keywords– Particle size, Ni-P-SiC, electroless, corrosion resistance

1. INTRODUCTION

The autocatalytic (electroless) deposition of Ni-P based alloys is now a well-known commercial process that has found numerous applications in the production of, for example, corrosion-resistant coatings [1]. Co-deposition of the particles depends on the size, shape, density, concentration and method of suspension in the bath. In addition, it is dependent on the charge present on the particle [2].

The properties and microstructures of EN coatings depend on the amount of phosphorus alloyed in the deposit and post-deposition heat treatment. The structure of the as-plated EN coatings has been reported to be either crystalline, amorphous, or a mixture of both [3-5]. In general, low phosphorus (1-5% P) EN deposits are microcrystalline, and medium phosphorus (6-9%P) coatings have mixed crystalline and amorphous microstructures, high phosphorus (10-13% P) EN alloys are amorphous. High phosphorus amorphous EN have coatings outstanding corrosion resistance, but their hardness and wear resistance are lower than their low phosphorus counterparts [6].

An advance in electroless Ni-P deposition is the co-deposition of solid particles into coatings to further improve certain properties [3]. Among the solid particles used for reinforcement, SiC is the most frequently studied and applied particle [7, 8].

The anti-corrosion performance of electroless plating Ni-P coatings have been investigated extensively [9]. However, few corrosion data for the Ni-P based composite coatings are available. The aim of this study is to obtain electroless Ni-P composite coatings using three sizes of silicon carbide particles, so as to investigate the influence of particle size on corrosion resistance of coatings.

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2. EXPERIMENTAL

EN and EN composite coatings were obtained on St37 steel substrates of 40×40×3.0 mm vertically positioned in a 250 ml bath. A commercial electroless nickel bath (SLOTONIP 70 A from Schlotter) with sodium hypophosphite as the reducing agent was used to obtain the coatings. This bath provided NiP deposits with a high phosphorous content, 9-10% P. Temperature changed within 88-93°C and pH changed within a 4.5-4.7 range during the coating process. SiC powders used were of the sizes 40 nm, 3 μm and 7 μm. Hexadecyltrimethyl ammonium bromide (HTAB) was employed for particles dispersion and surface charge adjustment, and magnetic stirring was used to keep particles from sediment. Powders were used as received and ultrasonically dispersed in the bath for 15 min before the deposition. The thickness of all coatings for evaluating the corrosion resistance was chosen as 20±1 μm.

The coated samples were subjected to heat treatment at 400 °C for 1h. The structures of the EN and EN composite coatings were analyzed by X-ray diffraction (XRD), and X-ray diffraction phase analysis was performed on a PHILIPS X' Pert Pro. diffractometer, using CoK_α radiation. The morphologies of Ni-P and Ni-P composite coatings were examined using an Oxford Cam Scan MV 2300 scanning electron microscope (SEM).

The corrosion resistance of coatings in 3% sodium chloride solution was assessed by potentiodynamic polarization. The corrosion tests were conducted using an EG&G Potentiostat/Galvanostat Model 273A. A standard three-electrode configuration consisting of the sample as the working electrode, a conventional saturated calomel electrode (SCE) and a platinum counter electrode were used to estimate the polarization behaviors.

3. RESULTS

Figure 1 shows the surface morphology of Ni-P composite coatings. A uniform distribution of particles on coating surfaces was observed. SiC particles were successfully co-deposited in Ni-P alloy matrix by electroless plating. With the increase of SiC concentration in the bath, the content of particles in the composite coating increased, but the plating rate decreased.

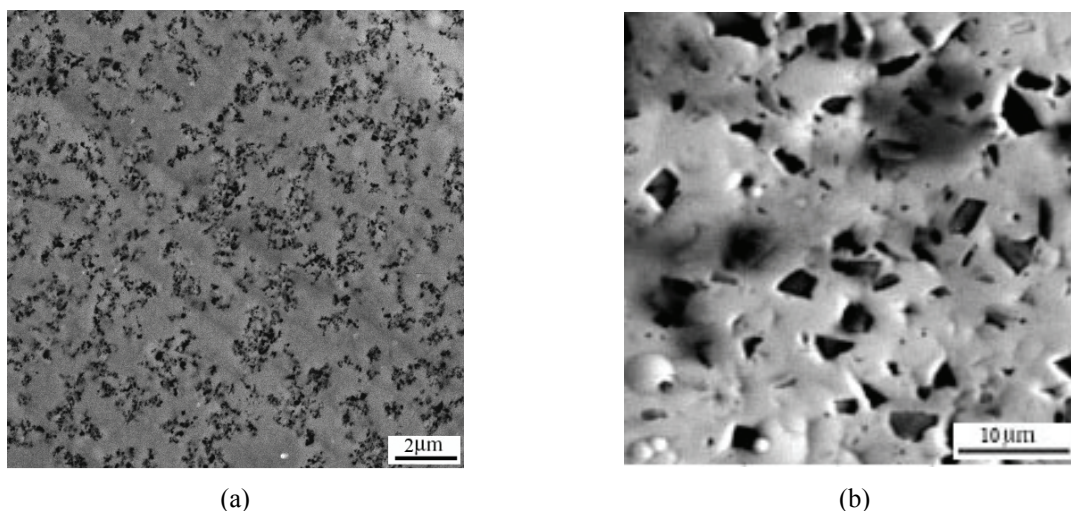


Fig. 1. Surface morphology of a) nano- composite and b) micro-composite Ni-P-SiC coatings

Figure 2 shows the XRD patterns of EN and EN composite coatings. All of the coatings were amorphous as deposited. As shown in Fig. 2, the EN and EN composite coatings crystallized into nickel crystal and nickel phosphide after being heat treated at 400 °C for 1 h.

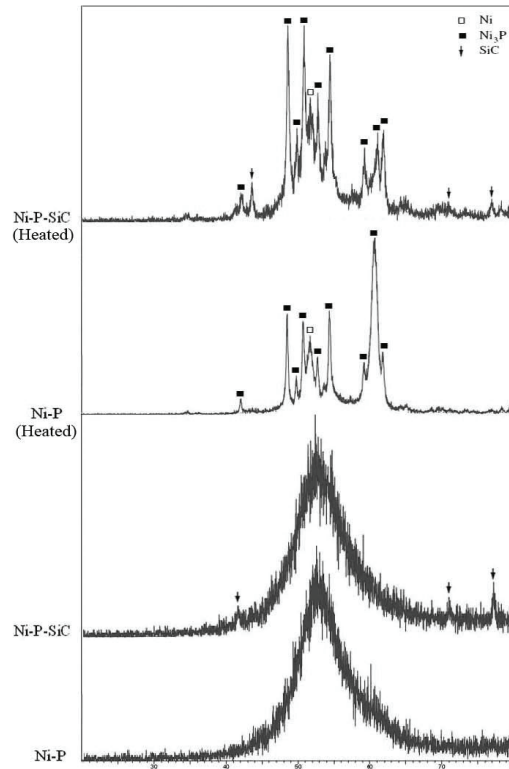


Fig. 2. XRD patterns of EN and EN composite coatings

Figure 3 shows the polarization curves of micro-composite and nano-composite Ni-P-SiC coatings.

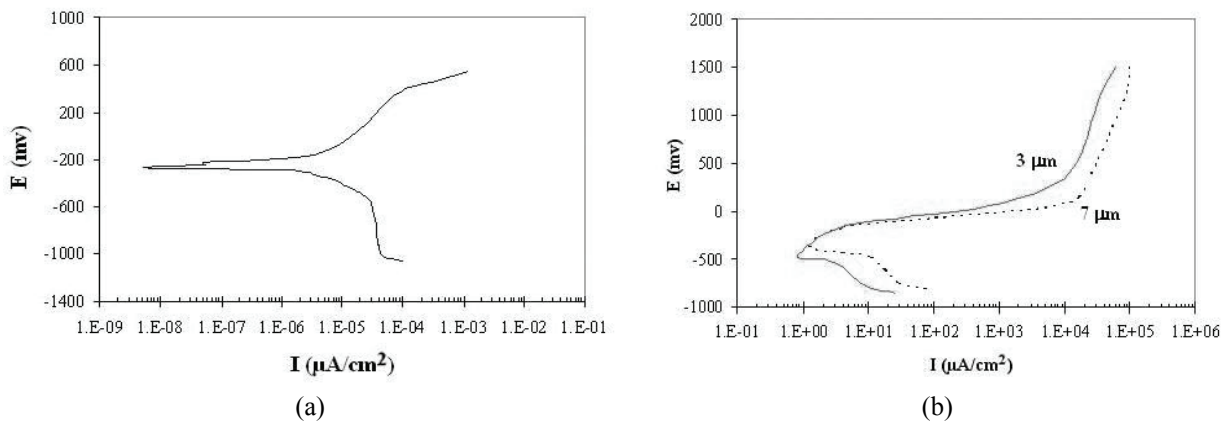


Fig. 3. The polarization curves of a) nano-composite and b) micro-composite Ni-P-SiC coatings in 3% NaCl electrolyte

Table 1 shows the values of E_{corr} and I_{corr} for EN composite coatings after heat treatment. Concentration of particles in the bath for all of these coatings was 5g/l. The corrosion current (I_{corr}) of micro-composite coating was much more than nano-composite coating.

Table 1. E_{corr} and I_{corr} of EN composite coating in 3% NaCl Electrolyte

Coating	E_{corr} (mV)	I_{corr} (μA)
Ni-P-SiC (40 nm)	-242	2.18×10^{-6}
Ni-P-SiC (3 μm)	-378	2.24
Ni-P-SiC (7 μm)	-326	2.15

4. DISCUSSION

In as-plated condition, the electroless Ni-P-SiC coatings were amorphous. After heating to 400 °C for 1 h, the nickel phosphide (Ni₃P) phase precipitates in the matrix and diffractograms showed well-defined peaks corresponding to crystalline Ni, Ni₃P and embedded particles.

According to the corrosion results, among the electroless coatings, the one containing nano-particles had a better corrosion resistance as compared to the others. From the aspect of corrosion, it was believed that corrosion resistance decreased as the grain size decreased because of an increment of grain boundary. Although this fact is generally acceptable, when nano-particles were used due to their homogen distribution on the surface of the coating, uniform-not localized- corrosion would occur. On the other hand, these nano-particles could cover the defects of coating which would result in a reduction of localized corrosion and improvement of coating quality. It seemed that the same phenomenon occurred for Ni-P-nanoSiC coatings, which could result in the improvement of the corrosion resistance of coatings.

5. CONCLUSION

The results showed that NiP and Ni-P-SiC composite coatings were amorphous as deposited. The nano and micro-particles did not change the structure of the Ni-P alloy during electroless plating. However, the amorphous alloy of electroless Ni-P and Ni-P-SiC composite coatings was crystallized upon heating, resulting in the production of Ni and Ni₃P phases. Corrosion tests showed that electroless Ni-P-SiC nano-composite coatings demonstrated better corrosion resistance than electroless Ni-P-SiC micro-composite coatings.

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