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Studying the effects of the addition of TiN nanoparticles to Ni–P electroless coatings

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ABSTRACT

The effects of the addition of nano TiN on the surface morphology, deposition rate, hardness and corrosion properties of Ni–P electroless coatings were studied. Heat treatment was conducted to compare the corrosion and hardness behavior of the coatings before and after heat treatment. It was observed that the incorporation of TiN particles into the coating has an adverse effect on the corrosion properties of the specimens. The hardness of the specimens increased dramatically by adding TiN. Furthermore, the hardness of the specimens increased after conducting the heat treatment. The corrosion and hardness behavior of the Ni–P system after heat treatment largely depended on the temperature of heat treatment. The heat treatment temperatures at which the desired corrosion and hardness properties were expected were determined.

1. Introduction

Electroless nickel–phosphorous coatings are widely used in chemical, mechanical and electronic industries because of their properties such as corrosion resistance and uniformity of deposit [1–3]. In addition, it is known that the incorporation of particles onto the Ni–P matrix improves surface properties, depending on the nature of the incorporated particle [4]. Recently, the Ni–P–*X* composite coatings with better corrosion properties or higher hardness have already been deposited via the incorporation of soft particles like PTFE and graphite or hard particles like SiC and Al_2O_3 [3,5–7]. Chen et al. [8] and Gao et al. [9] studied the effects of heat treatment on coating properties of electroless Ni–P/SiC systems. Shibli et al. [10] found that the incorporation of ZnO nanoparticles in the Ni–P electroless coating improves the corrosion resistance of the coating. Shrestha et al. [11] studied the effects of addition of Al_2O_3 nanoparticles to Ni–P electroless coatings and concluded that Al_2O_3 nanoparticles improve the wear resistance of the coatings. Furthermore, Gao et al. [12] and Balaraju et al. [13] found that the hardness of the electroless Ni–P coatings was also improved by adding Al_2O_3 particles. Ni–P/TiO_2 composite coatings were also successfully obtained by Abdel Aal et al. [14] and Novakovic et al. [15]. They reported that the incorporation of TiO_2 nanoparticles in the electroless Ni–P coatings created a smoother and finer surface. Liu et al. [16] observed that the incorporation of WC nanoparticles in the electroless Ni–P coatings improved the hardness and reduced the friction coefficient of the coatings. In this paper, the effects of the addition of TiN nanoparticles to the electroless Ni–P coatings were studied. The surface morphology of the coatings before and after the addition of TiN nanoparticles was compared. In addition, heat treatment at different temperatures was conducted to compare the corrosion and hardness properties of specimens before and after heat treatment.

2. Experimental details

2.1. Coatings

2.1.1. Surface preparation

Electroless nickel composite coating was deposited on low carbon steel disks with a diameter of 20 mm and thickness of 5 mm using an acidic electroless plating bath. Each specimen was abraded to a 400 grit finish with SiC paper, degreased in acetone, washed with distilled water, and dried in dry air. Then, the specimens were subjected to ultrasonic cleaning in deionized water. Following this, the specimens were placed in an alkaline solution with an approximate temperature of 60–80 °C for 8 min. All specimens were etched in a 10% aqueous H_2SO_4 solution for 5 s and then rinsed with deionized water and acetone before plating.

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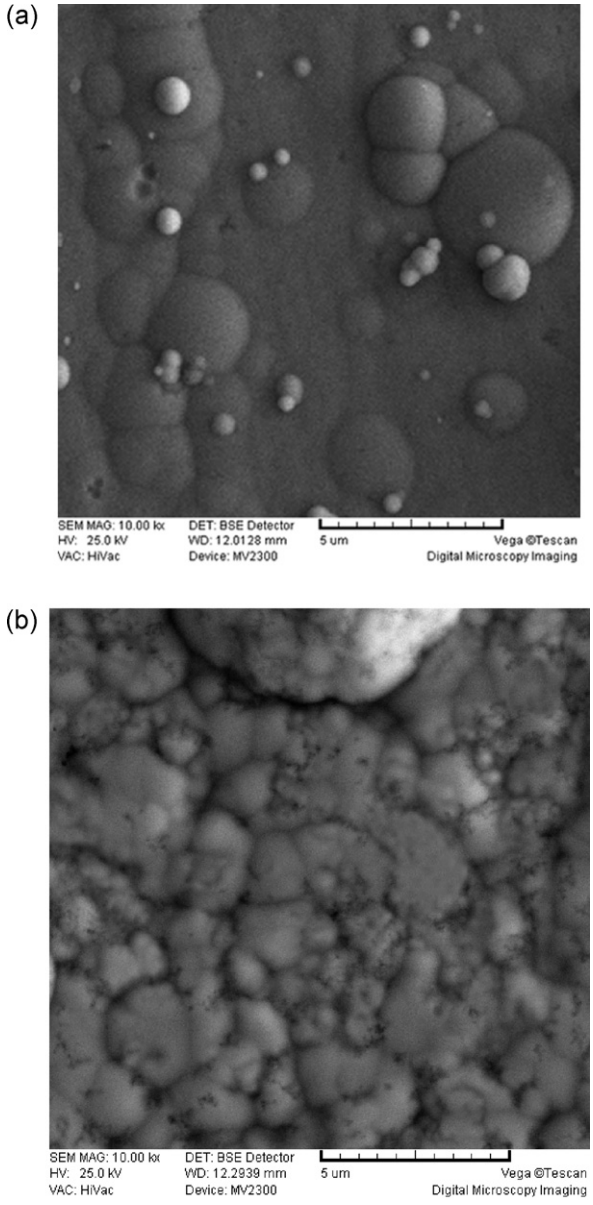

Fig. 1. Surface SEM of the microstructure of composite coatings at various plating conditions: (a) Ni–P (×25,000), (b) Ni–P/TiN (×25,000).

2.1.2. Bath composition and alloy coating preparation

TiN nano powder obtained from Hefei Kaier Nanometer Energy & technology with an average particle size of approximately 20 nm was used for composite coating. A commercial electroless was carried out in a tube furnace with argon gas at different temperatures for 1 h. Nickel bath (SLOTONIP 70A from Schlotter) was used to obtain the coating which provided Ni–P deposit with high phosphorous content, 9–11 wt.%. The TiN nanoparticles and the surfactant were added to a separate portion of the bath and stirred by magnetic stirrer and ultrasonic mixer for 20 and 10 min, respectively. Then, the mixture was added to the main bath and the specimen was placed in the bath when the solution temperature reached 88 °C. The applied surfactant was PEG-2000 (Polyethylene glycol). The electroless plating was carried out in the electrolyte involving 1 g/l TiN in conditions with a pH of 4.5 and a temperature of 88 °C and a stirring rate of 100 rpm. The specimens were kept in the plating bath for 2 h. Heat treatment of electroless Ni–P coating and electroless Ni–P/TiN composite coating.

Table 1
Deposition composition of the specimens.

Coating	Deposit composition (wt.%)		
	Ni	P	TiN
Electroless Ni–P	90.6	9.4	0
Electroless Ni–P/TiN	88	8.9	3.1

2.1.3. Testing method

The coating thickness was determined by analyzing a cross-section of the coated plate by SEM and then the deposition rate of coatings for a given coating time was calculated. The morphology of the coating was studied by scanning electron microscopy (SEM). The weight percentage of embedded TiN particles in the deposits was determined by energy-dispersive X-ray spectroscopy (EDS). The crystal structure of the coatings was determined using X-ray diffraction (XRD, Philips, X'pert, The Netherlands), by scanning in the $2\theta = 20–100^\circ$ range. The corrosion tests were conducted using

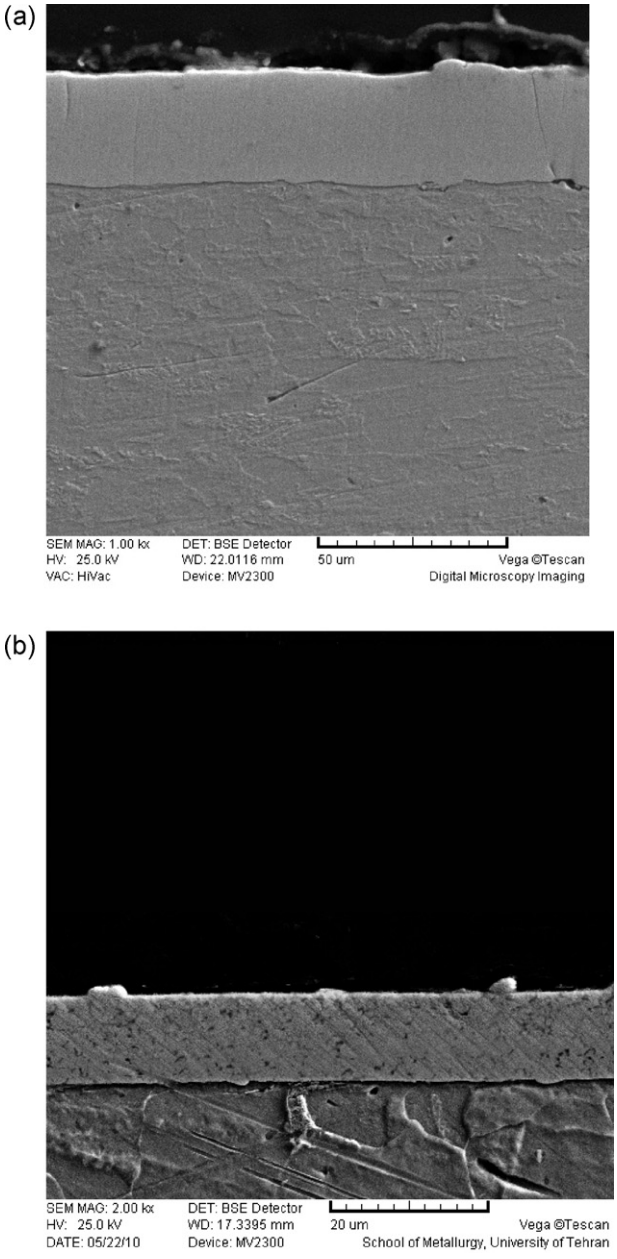

Fig. 2. Cross section SEM of the coatings: (a) Ni–P, (b) Ni–P/TiN.