

# Chapter 53

## Study of Hardness and Corrosion Resistance of Electroless Ni–P–TiO<sub>2</sub> Composite Coatings

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### ABSTRACT

*Electroless nickel coatings are widely popular in various industrial sectors due to their excellent tribological properties. The present study considers optimization of coating parameters along with annealing temperature to improve microhardness and corrosion resistance of Ni-P-TiO<sub>2</sub> composite coatings. Grey relational analysis is used to find out the optimal combination of coating parameters. From the analysis, it is confirmed that annealing temperature of the coating has the most significant effect and amount of titanium particles in the coating has some significant effect on corrosion properties of the coating. The same trend is observed in case of combined study of corrosion behavior and microhardness. The surface morphology, phase transformation and the chemical composition are examined using scanning electron microscopy, X-ray diffraction analysis and energy dispersive analysis respectively. The Ni-P-TiO<sub>2</sub> composite coating revealed nodular structure with almost uniform distribution of titanium particles and it turns in to crystalline structure after heat treatment.*

### INTRODUCTION

Electroless coating is the method of plating metal by chemical method instead of electrical means. In this method specimen to be coated is immersed in the chemical bath with suitable bath temperature. Such coatings are successfully applied to both ferrous and non-ferrous surfaces of any geometry. The failure of machine components in the industries is mainly due to corrosion and wear. It increases the downtime,

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maintenance cost and the replacement cost, which ultimately affects on economy of the industries. Both corrosion and wear are surface phenomena and occur on the surface of the components. Electroless nickel (EN) coatings are best suitable to protect them against corrosion and wear. Such coatings are extensively used in industries due to their excellent mechanical, tribological, soldering and brazing properties (Sahoo and Das, 2011; Sahoo, 2008a-d). Pure nickel (black nickel), alloy and poly alloy coatings, composite coatings, and nano coatings are the basic types of electroless coatings (Sudagar et al., 2013).

Incorporation of fine inert second phase particles in the electroless coating is known as electroless composite coating. The EN composite coatings which contain soft particles such as MoS<sub>2</sub> (Mohammadi et al., 2010), PTFE (Ramalho and Miranda, 2005; Omidvar et al., 2008; Zhao and Liu, 2005a), HBN (Zhang et al., 2008), WS<sub>2</sub> (Sivandipoor and Ashrafzadeh, 2012) and graphite are known as lubricated composite coatings. Similarly, the EN composite coatings which contain hard particles such as, Al<sub>2</sub>O<sub>3</sub> (Alirezai et al., 2004; Sharma and Singh, 2011; Hamdy et al., 2007; Gadhari and Sahoo, 2014), TiO<sub>2</sub> (Wang et al., 2000; Hosseini and Bodaghi, 2013; Novakovic et al., 2006), B<sub>4</sub>C (Araghi and Paydar, 2010; Vaghefi and Saatchi, 2003), SiC (Allahkaram et al., 2011; Malfatti et al., 2005; 2009; Zarebidaki and Allahkaram, 2011), Si<sub>3</sub>N<sub>4</sub> (Balaraju et al., 2010; 1998; Ramesh et al., 2009; Krisnaveni et al., 25), ZrO<sub>2</sub> (Stankiewicz and Szczygiel, 2012; Stankiewicz et al., 2012) and diamond (Bozzini et al., 2001; Jappes et al., 2009; Xu et al., 2005; Reddy et al., 2000) are known as hard composite coatings. The as-deposited coatings with higher phosphorus content have higher corrosion resistance. In composite coatings, the phosphorus content decreases in the presence of composite particles. The EN coating with amorphous structure (as-deposited coatings) has higher corrosion resistance compared to crystalline structure (heat treated coatings) (Zarebidaki and Allahkaram, 2012). Leon et al. (2010) have observed improvement in corrosion resistance of heat treated (400°C) Ni-P- and Ni-P-Al<sub>2</sub>O<sub>3</sub> composite coatings compared to as-deposited coatings. In some cases, it is observed that corrosion resistance of composite coatings increased due to large grain size, which reduces the porosity of the coating. To get outstanding properties of the composite coatings, the second phase particles must be uniformly distributed during the deposition process otherwise several defects are formed due to agglomeration of second phase particles. In composite coatings, micro cracks are formed due to presence of second phase particles, which results in decrease in corrosion resistance.

The microhardness and corrosion resistance of almost all types of electroless composite coatings depends on structure of the coating (amorphous/crystalline/mixed), amount of phosphorus present in the coating (low/medium/high), heat treatment, coating porosity, size, shape and distribution of particles. The porous composite coating has less corrosion resistance compared to non-porous composite coating. Therefore, to avoid the porosity, second phase particles must uniformly distribute over the coated surface of the sample. Bigdeli and Allahkaram (2009) have reported that proper post heat-treatment of Ni-P-SiC composite coatings significantly improved the coating density and structure, which results in improvement in corrosion resistance and microhardness. Wetting agents play a vital role in the deposition of composite coating. In the presence of wetting agents in electroless bath, the second phase particles are uniformly distributed over the coated surface. The corrosion properties of the composite coatings significantly improved due to presence of surfactants (CTAB and PVP) in the electroless bath (Mafi and Dehghanian, 2011; Liu et al., 2009; Zhao and Liu, 2005b).

Zhao and Liu (2005a) have observed significant improvement in corrosion resistance due to increase in PTFE content from the specimen surface to the top surface of the coated layer compared to conventional PTFE composite coating. In the salty environment, Ni-P-nano SiO<sub>2</sub> composite coating shows excellent corrosion resistance (Rabizadeh and Allahkaram, 2011). Chen et al. (2010a) have reported improvement in

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