Journal of Graphic Era University
Vol. 5, Issue 1, 45-51, 2017
ISSN: 0975-1416 (Print), 2456-4281 (Online)

Corrosion and Hardness Study of Electroless Ni-P-ZnO Nano-Composite Coatings

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(Received August 5, 2016; Accepted November 9, 2016)

Abstract
In current investigation, Ni-P-ZnO nano-composite covering has been urbanized on exterior of MS substrate by EL procedure. The next stage ZnO nano-particles were synthesized, to add in into EL Ni-P medium. 5 gpl of ZnO nano-particles were supplementary to Ni-P acidic unit for co-deposition. The heat management of as-prepared Ni-P/Ni-P-ZnO EL outside layer was conceded out at 380°C in Argon for 1h. These coatings were analysed for surface morphology, elemental composition and phase analysis by FESEM, EDAX, and XRD analysis. Corrosion resistance quality of depositions was conceded out in 5 % NaCl solution by long term immersion experiment. Hardness is measured by micro-hardness tester. A consistent allocation of ZnO nano-particles in EL Ni-P medium is long-established by FESEM/EDAX results. Corrosion and hardness examinations put forward that EL Ni-P-ZnO coatings illustrate superior performance as judge to simple Ni-P depositions.

Keywords- Electroless, Ni-P-ZnO, Nano-Coatings, Corrosion, Hardness.

1. Introduction

Electroless (EL) coating has achieve wide spread interest due to its improved corrosion and tribological properties with less complicated set-up. EL coating is forced chemical diminution method where numerous chemical effect takes set concurrently, in aqueous means devoid of the exercise of electric charge. Into EL plating method there is standardization in symphony and thickness of plating as well as convoluted fraction of substrate has identical prospect to coat (Brenner and Riddell, 1946, 1947; Agarwala and Agarwala, 2003). By EL plating method, untainted metallic Ni, two fold alloy Ni-P (Agarwala, 1987) along with Ni-B (Brenner and Riddell, 1946, Datta et al., 1991, Srivastava et al., 1992), GNM-P and Co-B (Brenner and Riddell, 1946, 1947; Agarwala and Agarwala, 2003) plus ternary alloy (Ni–P–B (Agarwala and Agarwala, 2003; Krishnan et al., 2006), Ni–W–P (Balaraju and Rajam, 2005), Ni–Co–P (Kim et al., 1995; Wang et al., 2006) etc. were plated productively furthermore considered on behalf of its mechanical qualities. In the latest decade, importance is swing towards co-deposition of next stage particles into EL Ni-P medium having countless industrial relevance. A number of particles as SiC, TiO_2, Al_2O_3 and Si_3N_4, etc., are preferred for co-deposition (Sharma, 2002; Sudagar et al., 2013; Apachitei et al., 2002; Jiaqiang et al., 2006; Huang et al., 2004; Dong et al., 2009). Additionally, particles as PTFE, BN (h), MoS_2, WS_2, carbon nano-tubes and graphite (C) provide good lubrication when incorporated into EL Ni-P matrix (Moonir et al., 1997; Ger and Hwang, 2002; Ebdon, 1988; Ramalho and Miranda, 2005; Chen et al., 2002; León et al., 1999). These soft/lubricating particles contain capability to stop linkage between two exterior beneath un-lubricated environment. In persistence our previous work (Sharma et al., 2014; Sharma et al., 2012), due to antibacterial commotion plus appropriateness below callous dispensation circumstance of ZnO nano-particles, in current study synthesized ZnO nano-particles deposited into the EL Ni-P medium on MS substrate. For prospect relevance of Ni-P-ZnO nano-composite plating like antibacterial plating, characterization, and micro-hardness as well as corrosion resistance properties have been done.

2. Experiment

2.1 Materials and Method

EL plating (Figure 1) was done on MS coupon along with chemical symphony is like tag on:

Element	C	Mn	Si	P	S	Cu	Fe
%wt	0.081	0.34	0.03	0.007	0.023	0.052	balance

The MS coupon of dimension (20 mm×20 mm× 4 mm) was selected for depositions. The bath for depositions is in accordance of (Sharma et al., 2014; Sharma et al., 2012).

2.2 Characterization Methods

The structure of ZnO fine particles, Ni-P as well as Ni-P-ZnO platings were calculated by XRD method. The exterior/inner morphology was scrutinized by FESEM/EDAX and SEM techniques.

Corrosion behaviour of Ni-P/Ni-P-ZnO platings was investigated by long term immersion experiment of 3-month duration in 5 % NaCl solution. Weight loss was considered by the formula.

Corrosion rate (mpy) = 534W/DAT

Where it is defined that W is weight loss in mg, D is density of steel 7.8 gm/cm^3, A area of coupons in inch square and T is time exposure in hours.

Using metallurgical microscope (Make: Reichert Jung, USA) the coupons were also analyzed for crevice and pitting corrosion attacks.

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Hardness of the coatings was calculated with micro-hardness equipment.

3. Results and Discussion

3.1 Plating of Ni-P/Ni-P-ZnO by EL Method

The plating procedure was done for 2h as by method (Rabizadeh et al., 2010, Roy, 2012, Zoikis-Karathanasis et al., 2009) furthermore get better properties with respect to as-plated coupon.

3.2 XRD/SEM/EDAX Analyses of Fine Particles ZnO, Ni-P as well as Ni-P-ZnO Platings

XRD spectrum of as-plated EL Ni-P deposits is considered by diffraction Ni (111) along with Fe peak (Table 1). The equivalent spectra of as-plated Ni-P-ZnO platings show small peaks of ZnO particles. The Heating at 380^{o}C for 1h show crystallization of Ni-P matrix i.e., Ni, Ni_3 Pin addition to ZnO stage (JCPDS Ref. No. 01-074-1384). FESEM micrographs are shown in Figure 2. Microstructure of Ni-P platings showed the typical spherical globular homogeneous. The EDAX analyses are given in Table 1.

3.3 Hardness of Ni-P/Ni-P-ZnO Platings

Micro-hardness (VHN) of Ni-P plus Ni-P-ZnO nano-composite platings in ‘as plated’ plus heat treated circumstances was dogged by means of micro-harness equipment with residence of 15 sec below 10 gf weight. Hardness of substrate, Ni-P plated coupon plus Ni-P-ZnO plated coupons are into following order Ni-P ZnO(HT)>Ni-P-ZnO (as-plated)>Ni-P>MS. The grades of micro-hardness propose addition of ZnO nano-particles into plating does not donate significantly to micro-hardness of coupon like ZnO nano subdivisions are spongy oxide of metal.

3.4 Corrosion Resistance Investigation of Ni-P/Ni-P-ZnO Platings

The amount of corrosion attack for all tested coupons has been listed in the Table 2, and it is observed that MS coupon experienced maximum (17.58 mpy) rate of general corrosion followed by Ni-P $_{Plated}$ (0.47 mpy) Ni-P-$ZnO_{380}{}^{0}C$ (0.21 mpy) and Ni-P-ZnO_{Plated} (0.13 mpy). In test solution, the better resistance against general corrosion shown by NiPZnO $_{Plated}$ coupon may be because it has an amorphous structure (SEM, XRD analysis). In other words, it does not generate inter-granular boundaries which can act as cathodic and anodic sites and will enhance general corrosion rate. The photographs of corroded coupons after removal from solution are shown in Figure 3. In the EL nano-composite coated materials, Ni-P-$ZnO_{380}{}^{0}C$ (20 µm) shows slight higher pitting corrosion attack than Ni-P-ZnO_{plated} (16 µm). The more pitting attack of Ni-P-$ZnO_{380}{}^{0}C$ than Ni-P-ZnO_{plated} can be because of transform of amorphous structure to crystalline structure after heat treatment. This can be observed by SEM/XRD microstructures also. It is well known that crystallinity creates grain restrictions plus next phases which may be vigorous location for corrosion assault.

In all corroded coupons MS shows the highest crevice type attack (53 µm) followed by Ni-P-$ZnO_{380}{}^{0}{}_{C}$ (27 µm), NiP_{Plated} (24 µm) and Ni-P-ZnO_{Plated} (21 µm). The depth of attack under crevice is slight higher in comparison to pitting attack on open surface on all coupons. The crevice type attack can be due to higher concentration of oxidized chemical (NaCl) under crevice former than open surface.

4. Conclusion

A dazzling greyish along with consistent nano-composite covering of Ni-P-ZnO on MS coupon is observed. The coated substrate was heat treated to attain crystalline nature of plating. The EL Ni-P-ZnO depositions exhibit high-quality observance on MS coupons. In favour of 'as-plated' Ni-P-ZnO plating grades, micrographs and line spectrum of compound symphony get hold of by FESEM-EDAX put forward that ZnO particles are consistently co-plated into EL Ni–P medium on exterior by means of a little extreme evidence of ZnO particles in plating. A trivial upgrading in micro-hardness for Ni-P-ZnO platings is experienced. The micro-hardness result for Ni-P-$ZnO_{nanosize}$ (HT) is 589.8 along with for Ni-P-$ZnO_{microsize}$ (HT) is 410 as dogged by earlier study (Sharma et al., 2012). In 5 wt. % NaCl, resistance against corrosion of EL Ni–P plating is enhanced by assimilation of ZnO nano-elements.

Acknowledgement

Authors recognize for different GEU labs providing experimental assistance in completion of this experimental research work.

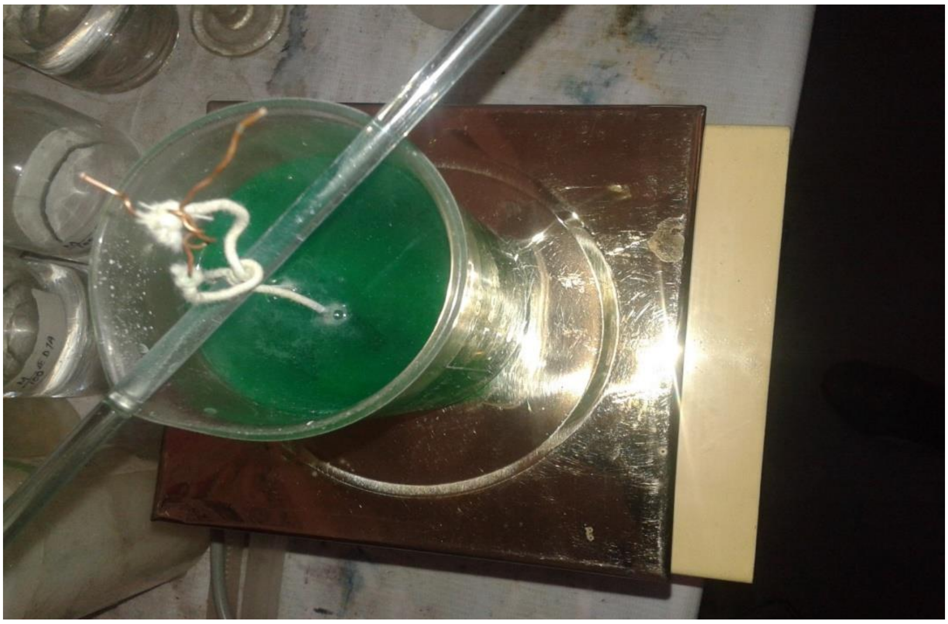

Figure 1. Deposition of ZnO nano-particles introduced into the EL Ni-P matrix

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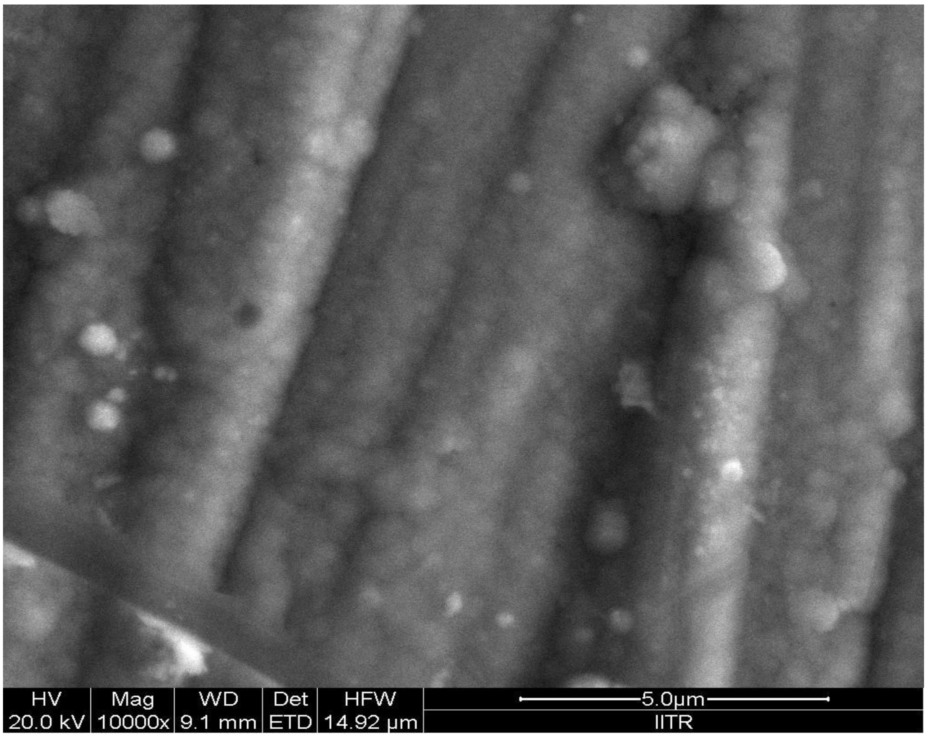
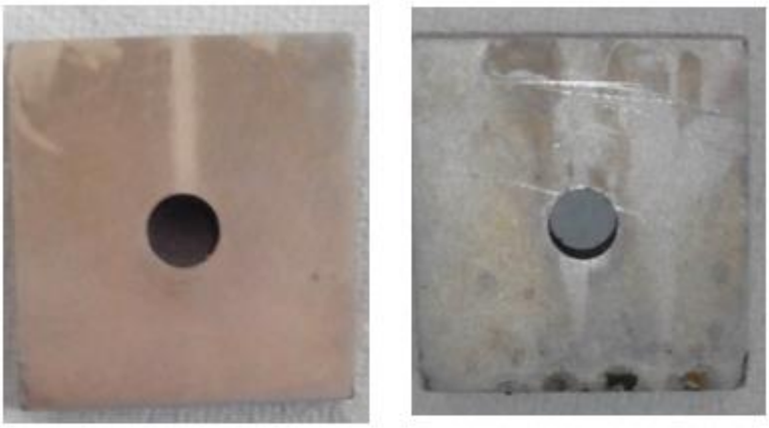


Figure 2. FESEM micrographs of heat treated Ni-P-ZnO coating



(a) Ni-P-ZnO As-plated **(b) Ni-P-ZnO Heat Treated**

Figure 3. The photographs of corroded coupons after removal from solution

Elements	% Weight As-Plated	% Weight Heat Treated
Ni	78.10	77.50
P	10.53	10.12
Zn	2.12	1.87
O	3.54	4.23
Fe	5.71	6.28
Total	100	100

Table 1. EDAX values of EL Ni-P-ZnO as-plated and heat treated samples

Grade	Corrosion Rate (mils per year, mpy)	Localized Corrosion Maximum Pit Depth (mm)	Crevice Corrosion Maximum Pit Depth (mm)
MS	17.58	0.023	0.053
Ni-P $_{Plated}$	0.47	0.021	0.024
Ni-P-ZnO$_{Plated}$	0.13	0.016	0.021
Ni-P-ZnO$_{380}{}^{0}{}_{C}$	0.21	0.020	0.027

Table 2. Corrosion attack on coupons exposed in 5 wt % NaCl solution

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