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Experimental Study of Surface Roughness of AZ91 Magnesium Alloy after ENi-B-TiO_2 Electroless Nano Composite Coating

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***Abstract*—** A coating is a covering that is applied to the surface of an object, usually referred to as the substrate or specimen. The purpose of applying the coating may be either decorative, functional, or a combination of both. The magnesium (Mg) and its alloys possess low density, high specific stiffness and electromagnetic shielding property, which are attractive to use this material for the various industrial components. Surface roughness and hardness is a serious drawback of Mg alloys, restricting their practical applications. Electro-less Nano Coating is one of the effective techniques for improvement in these material properties. In this paper, experimental investigation on surface roughness of AZ91 Magnesium Alloy due to Nano composite coating processes of ENi-B-TiO_2 are investigated. The detailed investigation along with experimental analysis, of the possibility of improving the deposit efficiency and properties of the composite deposits, by developing a suitable bath composition and operating conditions, would be worthwhile attempt. It has been observed that as concentration of second-phase (titanium) particles increases, the surface roughness of coatings also increases. The optimum value of concentration of second-phase (titanium) particles and bath agitation is also investigated for obtaining better surface roughness after Nano coating.

Keywords- *Coatings; Nano Composite; Surface roughness; AZ91 Mg Alloy; Electroless*

I. Introduction

Electroless coating deposition technique is used for coating alloy or a solid work-piece, such as metal or plastic, also referred to as autocatalytic chemical deposition techniques. Because of the number of advantages, electroless coatings are mostly used in every type of industries [1]. The Figure 1 shows the usage of electroless nickel coatings. While having number of advantages, few important limitations of electroless coatings are smaller life span of chemicals and greater cost of waste treatment due to fast chemical regeneration [2-3]. Electroless nickel coatings have been used either as decorative or protective coatings in industries such as electronics, computer, aerospace, printing, automotive, textile, plastics, optics, paper and food [4-5]. Some of the exceptional characteristics of electroless nickel coatings are wear and superior corrosion resistance, excellent uniformity, large domain of thickness, good solderability, improved physical and mechanical properties [6].

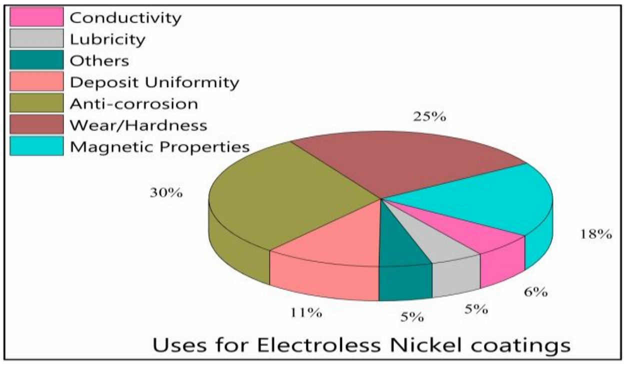

Figure 1. Use of electroless nickel coatings [2]

Most of magnesium alloys contain 8–9% aluminium with small amounts of zinc [7]. The addition of several alloying elements such as aluminium, zinc and rare earths have been reported [8-9] to improve the corrosion resistance, technologically that does not satisfy the requirement for several applications. Hence, the application of a surface engineering technique is the most appropriate method to further enhance the surface properties and corrosion resistance. Among the various surface engineering techniques that are available for this purpose, coating by electroless nickel is of special interest especially in the electronic industry, due to its conductivity and several other engineering properties Electroless nickel is well known for its corrosion resistance and hardness [10-12].

II. Bath Composition and operating conditions of ENi-B-TiO_2 Composite Coatings

Selection of an appropriate bath along with suitable operating conditions is a key to ensuring desired deposition onto the base substrate. Hence, in order to achieve the most optimum bath composition along with most suitable operating conditions, a number of experiments were undertaken. The Numerous experiments were carried out prior to selection of the most optimum bath constituents along with their quantities for ensuring successful deposition onto the substrate. The final chemical composition and operating conditions for successful deposition of ENi-B-TiO_2 Nano-composite deposition on AZ91 magnesium alloy use is summarized in table I.

TABLE I. Chemical composition of ENi-B-TiO_2 Nano-composite deposition on AZ91 magnesium alloy

Bath constituents and operating conditions	Bath Composition
Nickel Sulphate Hexahydrate (g/l)	30
Sodium Borohydride (g/l)	2
Ethylenediamine (98%) (ml/l)	50.0
Ammonium Bifluoride (g/l)	8.0
Hydrofluoric acid, HF (40% V/V) (ml/l)	12
Stabilizer (ppm)	1.0
Nano-Titanium Oxide (g/l)	5 - 15
Bath Stirrer (rpm)	0 - 200
pH (NaOH)	6.4±0.2
Temperature	80 -85ºC
Immersion Time (h)	1.5

III. Experimental Setup

The Experimental setup encompassed a carefully prepared electroless bath (chemical bath) with suitable chemicals in adequate quantities, in addition to a hotplate to provide appropriate amount of energy in the form of heat to the bath constituents, to obtain the desired composite deposit. A square plate of AZ91 magnesium alloy having dimensions 20 mm X 20 mm X 1 mm was taken as the base substrate for composite deposition. The square plate was provided with a pin hole drilled close to one of the corners / edge to enable undisturbed suspension in the chemical bath. The schematic of experimental setup is shown in Figure 2.

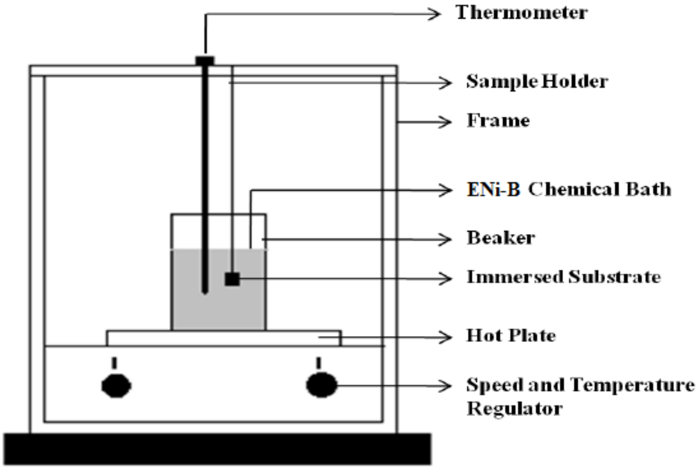

Figure 2. Schematic drawing of experimental setup

The surface morphology of the coated substrate was observed under scanning electron microscopy (SEM) to study morphological changes due to the introduction of second phase particles and at different bath agitation. The effects of bath agitation at different (0, 100 and 200 rpm) are also recognized by the different combinations of the composite shown in Figure.3. The composite samples treated at bath agitation 100 rpm is shown better or uniform deposition as compared to other samples.

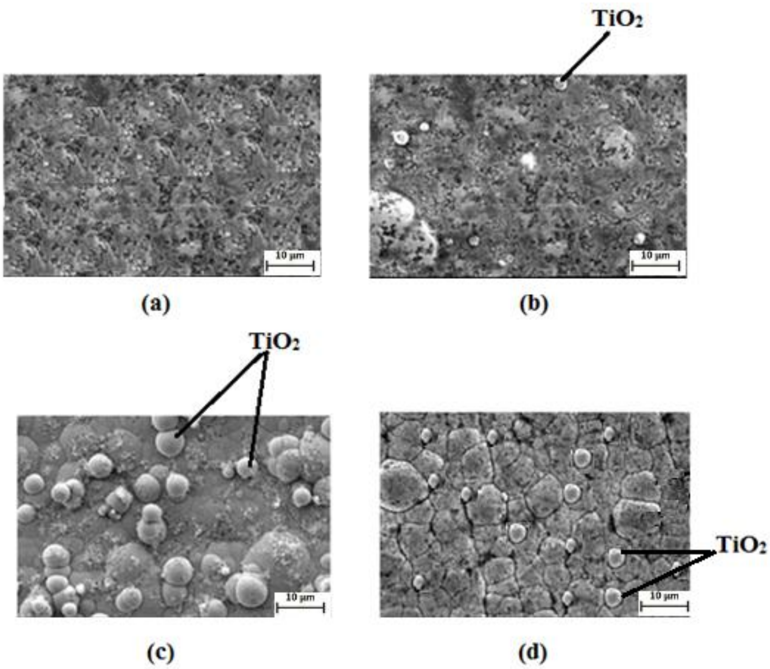

Figure 3. SEM micrographs of ENi-B-TiO_2 composite coatings: (a) Ni-B without TiO_2 (b) ENi-B-TiO_2 with no agitation, (c) ENi-B-TiO_2 with agitation at 100 rpm and (d) ENi-B-TiO_2 with agitation at 200 rpm.

IV. MEASUREMENT OF SURFACE ROUGHNESS OF COATINGS

One of the purposes of using a electroless coating for a surface of the AZ91 for any application has to do with providing smoothness and extending surface roughness properties. The surface roughness of coatings depends on coating parameters and the amount of second phase particles incorporated in the coated layer. For this purpose, effect of coating parameters on surface roughness ENi-B-TiO_2 composite coatings needs to be investigated. In order to study the surface roughness of substrate after ENi-B-TiO_2 composite coatings, the coated specimens were suitably placed in Profilometer equipment which is used to measure the surface roughness of the composite coating obtained. The table 2 shows results obtained from Profilometer equipment for ENi-B-TiO_2 composite coatings with different concentration of second-phase (titanium) particles.

TABLE II. EXPERIMENTAL DATA OF CENTERLINE AVERAGE ROUGHNESS (RA) AT DIFFERENT CONCENTRATION OF TIO2

Substrate No.	**Roughness value R_a (μm)**			
	0 g/L	**5 g/L**	**10 g/L**	**15 g/L**
1	0.533	0.609	0.929	1.408
2	0.349	0.433	0.673	0.81
3	0.412	0.406	0.605	0.858
4	0.343	0.493	0.954	1.07
5	0.521	0.541	0.642	0.895
6	0.443	0.508	0.709	0.904
7	0.552	0.642	0.852	1.428
8	0.512	0.481	0.961	1.223
9	0.562	0.693	0.853	1.052
10	0.598	0.661	0.891	1.341
11	0.389	0.453	0.793	0.823
12	0.561	0.515	0.655	0.878
13	0.456	0.495	0.695	1.134
14	0.618	0.773	0.873	1.085
15	0.397	0.496	0.845	1.165

V. RESULTS AND DISCUSSION

Figure 4 shows the graphical representation of the experimental data of the surface roughness of ENi-B-TiO2 and at 0g/L, 5g/L, 10g/L and 15g/L concentration of TiO2. From the Figure 4 it can be observed that, as concentration of second-phase (titanium) particles increases, the surface roughness of coatings also increases. The average surface roughness obtained for ENi-B-TiO_2 at different concentration of TiO_2 is shown in table III

Figure 5 shows bar chart of average surface roughness of ENi-B-TiO2 composite coatings for various concentration of TiO2 particles at bath agitation 100rpm. From Figure 5 it can be observed that, as concentration of second-phase (titanium) particles increases, the surface roughness of coatings also increases. The optimum surface roughness of ENi-B-TiO_2 is obtained at 10g/L, the reason behind of this is the uniformly distributed composite coatings on a sample at 10g/L.

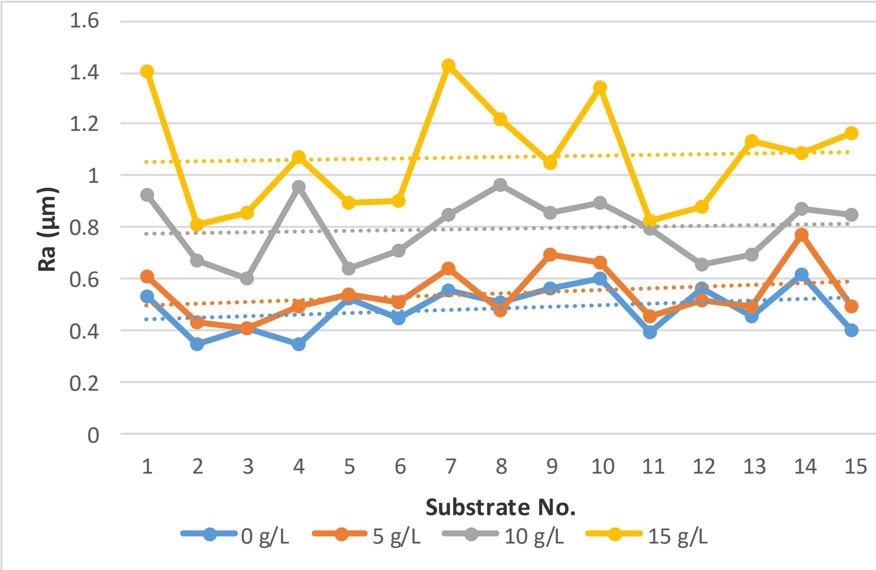

Figure 4. Variation of center line average (R_a) for different concentration of TiO_2

TABLE III. AVERAGE ROUGHNESS VALUE OF AZ91 WITHOUT AND WITH ENI-B-TIO_2 COMPOSITE COATINGS AT AGITATION 100RPM

Parameter	**AZ91Without Coating**	**AZ91 With ENi-B-TiO_2 Coating at different Concentration of TiO_2 Particles**			
		0 g/L	**5 g/L**	**10 g/L**	**15g/L**
Roughness R_a (µm)	**0.42**	**0.48**	**0.54**	**0.79**	**1.07**

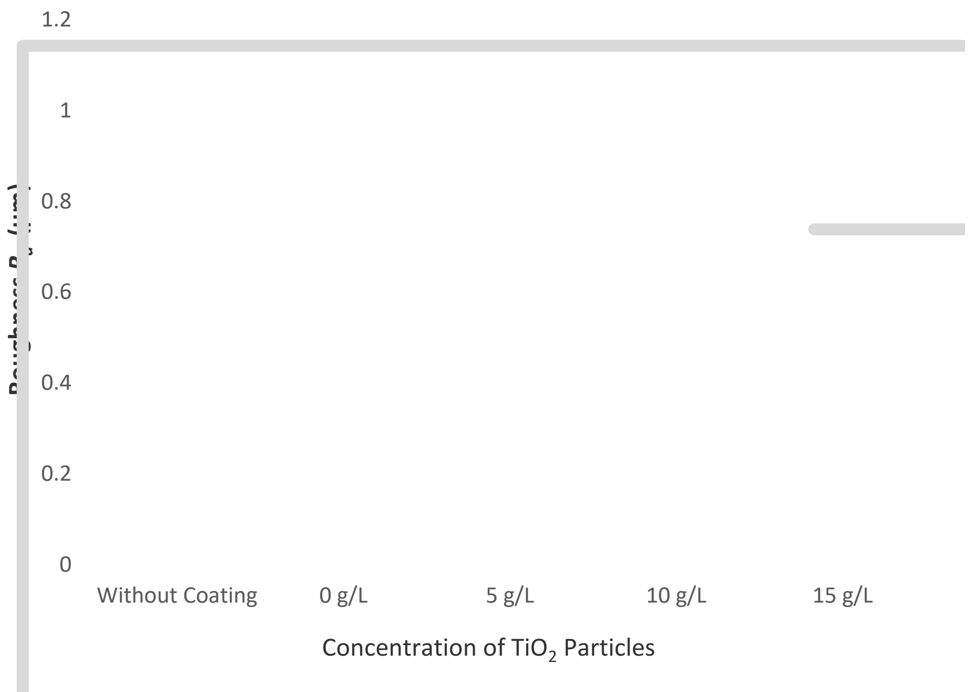

Figure 5. Roughness Value of ENi-B-TiO_2 composite coatings for different concentration of TiO_2 at bath agitation 100rpm

VI. CONCLUSION

In this paper, the effect of coating process parameters on the surface roughness of ENi-B-TiO_2 composite coatings has been investigated. The investigation shows that the incorporation of TiO_2 particles has greater impact on the surface roughness of the composite coatings. Increase in amount of these particles increases the roughness of the composite coatings. From the analysis of multiple response parameters, optimal combination of coating parameters for minimum roughness is obtained as middle level of nickel source, higher level of reducing agent, and higher level of nickel sulphate and sodium hypophosphite and middle level of titania particle concentration for ENi-B-TiO_2 composite coatings. The ENi-B-TiO_2 composite coatings deposited using optimal combination of parameters have smoother surface as compared to the coatings developed using the initial condition. The optimum surface roughness of ENi-B-TiO_2 is obtained at 10g/L titanium particles.

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