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Improving the deposit efficiency of nano composite deposits on AZ91 magnesium alloy by using a suitable bath composition and operating conditions

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ABSTRACT

The purpose of applying the nano-coating may be either decorative, functional, or a combination of both. The magnesium alloys specially AZ91 possesses great specific stiffness, less density, and electromagnetic protecting characteristics, which attracts the use of this type of material for several industrial parts. But the surface roughness and hardness is a major weakness of magnesium alloys, limiting their practical uses. Electroless nano-coating is one of the useful techniques for enhancement in these material characteristics. In this research, experimental analysis of various surface properties of magnesium alloy (AZ91) due to electroless nano-composite coating is investigated. The possibility of enhancing the efficiency and the properties of the composite depository material would be a valuable attempt, by finding a suitable chemical bath compositions and operating conditions of electroless nano-coating method. It has been detected that, as the concentration of titanium particles increases, the roughness value, hardness value, and corrosion property of coatings increases. The optimal value of the concentration of titanium particles TiO_2 is also explored for gaining better surface property after coating.

1. Introduction

Electroless nickel coatings widely used for protecting coatings in industries such as computer hardware, electronic engineering, textile, optics, aerospace, automotive, printing, food, plastics, and paper [1,2]. The excellent features of electroless coatings are wear resistance and higher corrosion resistance, outstanding uniformity, good solderability, improved mechanical properties [3]. The electroless nano coating method is used for coating of an alloy or a hard workpiece, such as plastic or metal, also known as to an autocatalytic chemical deposition method [4]. While having several advantages, some important restrictions of electroless coatings are the lesser life period of chemicals and higher cost of leftover material due to chemical reinforcement [5]. Maximum magnesium alloys contain 8 to 9% aluminum with fewer amounts of zinc material [6]. Adding some alloying elements such as aluminum, zinc, and some other materials have been stated by some researchers [7,8] to increase the corrosion resistance, but sometimes they don't achieve the requirement for numerous applications. Therefore, the use of a local engineering approach is the most effective way to advance more buildings and resist corrosion. From the various engineering techniques available for this method, electroless nickel coating technique is of particular interest especially in the electronics industry, due to its performance and other engineering properties Wireless nickel is best known for its resistance to corrosion [9-11].

2. Bath properties for composite coatings

The experimental analysis on surface properties of material AZ91 Magnesium alloy is performed using an electroless nanocomposite coating method. Selecting the right bath properties and the right working conditions is the key to ensuring the desired coating deposition on the base material. Therefore, to achieve the best bath properties and most suitable working conditions, such experi-

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Table 1
Bath Material Compositions [1].

Compositions	Bath Conditions
Nickel-Sulphate Hexa-hydrate (g/l)	30.00
Sodium-Borohydride (g/l)	2.5
Ethylene-diamine (98) (ml/l)	55
Hydro-fluoric acid, (40) (ml/l)	11
Nano-Titanium Oxide (g/l)	0–15
Bath Stirrer in rpm	50–200
Temperature in °C	81–85
Immersion Time in hr	1.5

ments have been done. Several experimentations were carried out before the finalization of the most optimal bath compositions along with their amounts for confirming successful deposition onto the sample. The optimum chemical compositions and working conditions used for successful deposition of ENi-B-TiO_2 Nano-composite coating on AZ91 magnesium alloy use is brief in table 1

The experimental setup carefully prepared an electroless bath with suitable chemicals in sufficient quantities, and a hot plate used to provide suitable heat energy to chemical inside the bath, for getting the desired coating deposition. A sample of a square plate having size 20 × 20 × 1 mm of magnesium alloy (AZ91) was taken for electroless nanocomposite coating as the base material[1]. The pinhole is made at one of the corners of the substrate to hold with the help of string and stand inside the electroless bath. The diagram of a schematic and actual experimental setup is shown in Fig. 1.

3. Results and discussion

The amount of surface roughness of nano coatings is influenced by coating parameters and the quantity of second phase particles (TiO_2) integrated with the coated deposit. Therefore, to study the influence of coating parameters on the surface roughness value of ENi-B-TiO_2 composite coatings required to be examined. To observe the effect of surface roughness value after ENi–B–TiO_2 coatings on AZ91 the coated samples were properly placed in the standard Profilometer apparatus, which is used to find the amount surface roughness value of coating obtained.

Fig. 2 shows the graph of the experimental data obtained for the surface roughness value of ENi-B-TiO_2 and at 0 g/L, 5 g/L, 10 g/L, and 15 g/L amount of TiO_2 in the chemical bath. It has been detected that at a lower amount of TiO_2 composition in a chemical bath, the reaction of chemicals happens over the complete solutions instead of a well-ordered autocatalytic reaction through the sample surface. The accumulation of TiO_2 nanoparticles at greater concentration is the main cause for growth in surface roughness value. From Fig. 2 it can be perceived that, as the concentrations of titanium particles rise, the surface roughness value of coatings also rises. The optimal surface roughness of ENi-B-TiO_2 is achieved at 10 g/L.

The surface hardness of nano coatings also influenced by coating parameters and the quantity of second phase particles (TiO_2) integrated into the coated deposit. Therefore, to study the effect of coating parameters on the value of surface hardness of ENi-B-TiO_2 composite coatings required to be examined. Fig. 3 shows the graph of the experimental data found for the surface hardness of ENi-B-TiO_2 and at 0, 5, 10, and 15 g/L amount of TiO_2 in the chemical bath. It can be perceived that the hardness levels of ENi-B-TiO_2 deposition of the composite are seen to increase as the quantity of titanium particles increase.

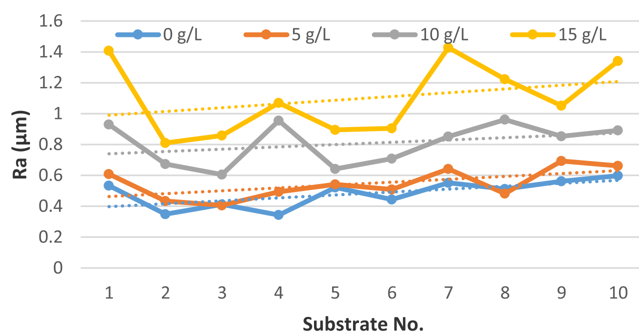

Fig. 2. Ra Value of ENi-B-TiO_2 and at 0, 5, 10, and 15 g/L amount of TiO_2.

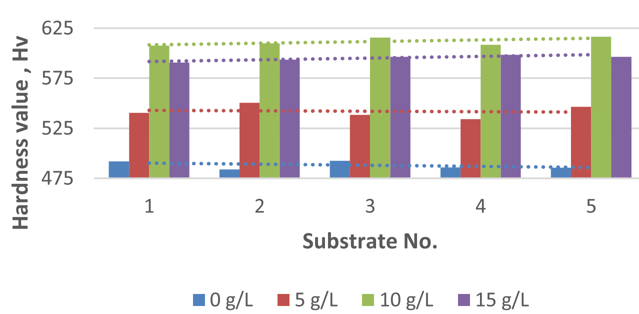

Fig. 3. Variation of hardness value for a different amount of TiO_2.

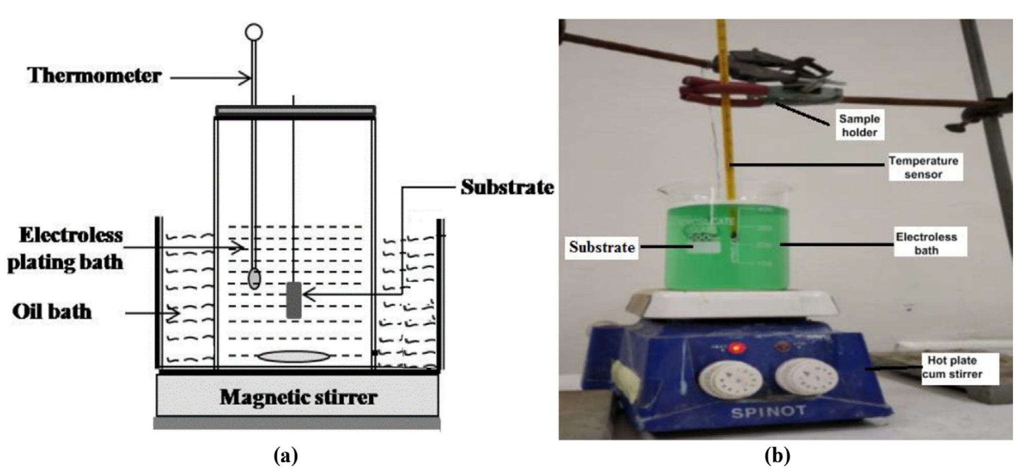

Fig. 1. (a) Schematic of an experimental set up (b) Actual experimental setup.

Table 2
Hardness levels of AZ91 without and with ENi-B-TiO_2 coatings.

Parameter	AZ91Without Coating	AZ91 with coating at a different quantity of TiO_2 Particles (g/L)			
		0	5	10	15
Hardness, Hv	90	490	545	611	595

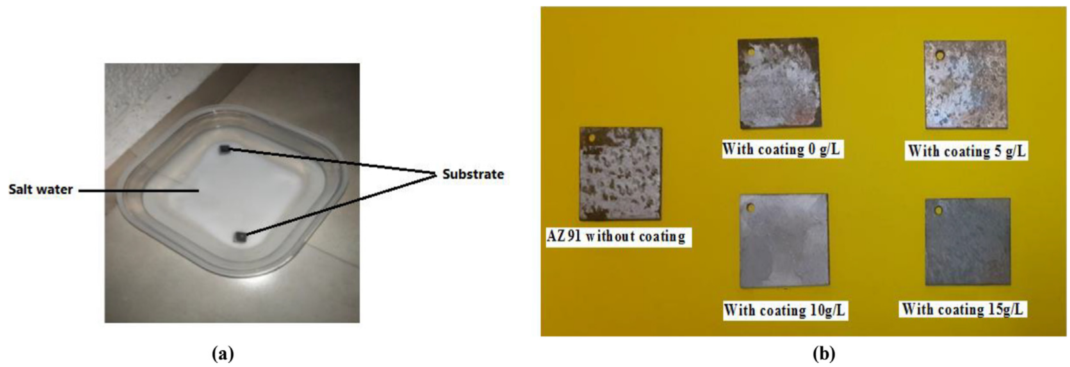

Fig. 4. (a) Salt Test Set up with Substrate (b) Substrates after corrosion test.

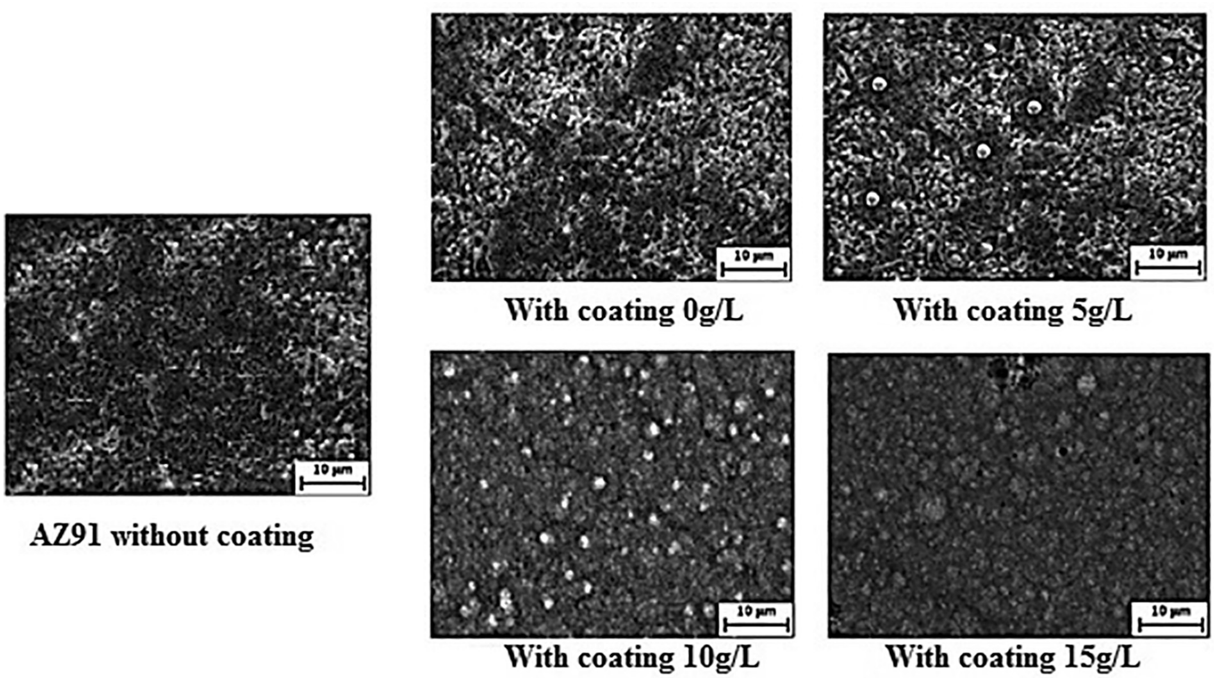

Fig. 5. SEM of corroded composite coatings of ENi-B-TiO_2.

The average value of surface hardness found for ENi-B-TiO_2 at a different quantity of TiO_2 particles is presented in table 2. It may also have observed that the hardness rate of the non-deposited on AZ91 sample is measured as 90 Hv, which is much lower than the as-deposited samples.

To find the corrosion resistance after electroless coating, the coated samples or substrate were placed in salty surroundings as per ASTM B117 standards. The chamber having saltwater is perfect for measuring the grade of corrosion resistance of samples. The specimens were kept for 240 h (10 days) in this setup which can be seen in Fig. 4. The images of both coated and non-coated AZ91 substrate were compared and was observed that ENi-B-TiO_2 coated metal was less corroded compared to that of the original AZ91 substrate.

Fig. 5 shows SEM micrographs of corroded ENi-B- TiO_2 composite coatings. In these coated substrates, black spots and limited cracks are observed on the coated surface after corrosion. It indicates that all the coatings are affected by corrosion in the salty environment. The corrosion rate of ENi-B-TiO_2 composite coating deposits is detected to decrease as the amount of titanium particles increase.

The corroded ENi-B-TiO_2 composite samples for different concentration of TiO_2 particles make known that the substrate from bath 10 g/L has higher corrosion resistance, then the substrate obtained from bath 0, 5 and 15 g/L respectively and this can be observed in different SEM micrographs in Fig. 5. The corrosion resistance for the non-deposited AZ91 substrate, on the other hand, had less than that of the substrate subjected to ENi-B-TiO_2 composite deposition. This is indicative of the fact that the suitable control of the concentration of titanium particles can cause an increase in the corrosion resistance of the AZ91 material, therefore improving the surface property after coating.

4. Conclusion

In this research paper, the possibility of enhancing the efficiency and the properties of the composite depository material, by developing an optimal bath chemical compositions and its optimum operating conditions of ENi-B-TiO_2 coatings has been developed. The research confirms that the use of TiO_2 particles has a more impact on the value of surface roughness of the coatings. An increase in the quantity of TiO_2 particles rises the surface roughness value of the nano composite coating. The ENi-B-TiO_2 composite coatings deposited using an optimal combination of parameters have a smoother surface as compared to the coatings developed using the initial condition. The optimal surface roughness value of ENi-B-TiO_2 is achieved at 10 g/L titanium particles. Also, the research shows that the rise in the amount of TiO_2 particles rises the hardness value of the composite coating surface. The corrosion rate of ENi-B-TiO_2 composite coating deposits is seen to decrease as the amount of titanium particles increase. The corrosion rate of as-deposited ENi-B-TiO_2 composite coating gained from 10 g/L is minimum than other bath conditions. The appropriate control of the concentration of second phase titanium particles can cause a reduction in the corrosion rate of the AZ91 material.

CRediT authorship contribution statement

Farook Sayyad: Conceptualization, Methodology, Data curation, Writing - original draft, Investigation, Validation. **Rohan Senanayake:** Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] M.I. Ansari, D.G. Thakur, Effect of bath agitation on surface properties and corrosion behaviour of ENi–P coatings along with annealing temperature, Eng. Sci. Technol. 19 (4) (2016) 2094–2099.

[2] W.J. Cheong, B.L. Luan, D.W. Shoesmith, The effects of stabilizers on the bath stability of electroless Ni deposition and the deposit, Appl. Surf. Sci. 229 (1-4) (2004) 282–300.

[3] A. Brenner, G. Riddell, Deposition of nickel and cobalt by chemical reduction, J. Res. Nat. Bur. Stand. 39 (5) (1947) 385, https://doi.org/10.6028/jres.039.024.

[4] M.I. Ansari, D.G. Thakur, Influence of surfactant using electroless ternary nanocomposite coatings to enhance the surface properties of AZ91 magnesium alloy, Surf. Interfaces. 7 (2017) 20–28.

[5] A. Wurtz, Formation of a cuprous hydride, by the action of hypophosphorous acid on a cupric salt solution, Ann. Chim. Phys. 11 (1844) 250–252.

[6] N. Feldstein, T. Lancsek, D. Lindsay, L. Salerno, Electroless composite plating, Metals Finishing 81 (1983) 35–41.

[7] J. Balaraju, T. Sankara Narayanan, S. Seshadri, Electroless Ni-P composite coatings, J. Appl. Electrochem. 33 (2003) 807–816.

[8] P. Sahoo, S.K. Das, Tribology of electroless nickel coatings-a review, Mater. Des. 32 (4) (2011) 1760–1775.

[9] R.C. Agarwala, V. Agarwala, Electroless alloy/composite coatings: a review, Sadhana 28 (3-4) (2003) 475–493.

[10] L. Li, M. An, G. Wu, A new electroless nickel deposition technique to metallise SiCp/Al composites, Surf. Coat. Technol. 200 (16-17) (2006) 5102–5112.

[11] M.I. Ansari, D.G. Thakur; Influence of electroless nickel-phosphorus deposition on hardness of mild steel and Az91 magnesium alloy, International Journal of Pure and Applied Research in Engineering and Technology. 2015, Vol 3(9), 264-271.

Further Reading

[1] F. Sayyad, R. Senanayake; Experimental investigation of surface roughness of electroless Ni–B–TiO2 nanocomposite coatings, Sadhana, 2021, Vol 46:61, p 1-5.