International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Analyzing the Properties of Electroless Ni-P Plating and its Composites for Wear & Corrosion Resistance Applications – A Review

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ABSTRACT.

Electroless coating involves coating over the surface of materials be it metallic or non-metallic without requiring any electricity for its operation. Since the deposit is independent of current distribution, uniform thickness of coating is obtained. EN coatings when nano particles are included have magnificent properties like better high wear resistance, improved hardness and corrosion resistance. This is the reason, electroless nickel has found all - around application in automobile, aerospace, electrical and chemical industries. There is vast scope of reforming the properties of electroless nickel coating by including number of nano particles and altering the process parameters. Technological advancement in today's world has demanded new type of materials which is hard, durable, wear & tear resistant and corrosion resistant. So, electroless nickel has capability to fill the void and fulfil the requirement. Therefore, it is essential to study tribological behavior of electroless nickel thoroughly. This paper aims an exhaustive study for electroless Ni-P-TiO2 nanocomposite behavior and summarize its overall properties and discuss for its future scope.

Keywords: Electroless nano-coating, Corrosion, Wear, Heat Treatment, Nanoparticle.

1.Introduction

Discovery of Ni metal extraction from hypophosphite was first accidentally done by Wurtz in 1844 and Roux in 1911, done the metal plating using both hypophosphite and orthophosphite. After that a significant development was done by Brenner and Riddell in 1946 by adding different reducing agents to an electroplating bath and they proposed the term electroless for the first time. Since then, efforts have been put for a non-traditional EN plating in which operation is easier to monitor and the quality of coating can be well – Assured [1]. Now researchers have achieved significant result by combining multiple nano-particles belonging to rare earths and rare metals etc. Here some of the research papers have been reviewed thoroughly related to EN coatings which has significantly enhanced surface properties (corrosion, wear or hardness) of steel which would help for a coherent understanding and its future aspects has also been discussed. Steel being one of most important materials used in construction industry has sought attention to save it from corrosion in respective environment. At present EN coatings has found numerous applications commercially.

Now a number of papers have been published proving the highly corrosion resistant behaviour of Ni-P coatings in addition to its hardness and wearing resistance. In general, EN coatings investigations leads to a conclusion that it possesses excellent wear and good corrosion resistance under severe environmental condition. When it's compared, EN coating having high phosphorus content shows better corrosion resistance (because of its nano-crystalline microstructure) whereas EN coating having low phosphorus content shows better wear resistance (because its hardness value is high) [2]. Experiment suggested that electroless nickel coating containing medium phosphorous content (8% P) imparts a very high degree of corrosion protection than the coating containing the higher phosphorous content (16%) [3]. It has been found that microstructure and properties of the electroless coating depends upon the main salts concentration and post heat treatment. The properties of electroless nickel coatings can also be experimented and improved through the incorporation of elements like copper, tungsten, cerium and nanoparticles like Al_2O_3, TiO_2, SiC, ZrO_2, CNTs [4]. Here it has been experimented that corrosion resistance of metal can be improved significantlywhen coating is done with Ni-P-W and Ni-P-Cu than Ni-P. In this experiment, Ni–P and Ni–Al_2O_3–WS_2 coating was successfully deposited on aluminium substrate through electroless plating technique and it was revealed in surface morphology that as the concentration of Al_2O_3 increased, uniform deposition of the powder particles having lesser bubble-like structures were observed in the coating layer. The coating layer's porosity was observed to be reducing with increase in Al_2O_3 powder concentration [5]. In an experiment co- deposition of Silicon carbide (SiC) nanoparticles were done with nickel-phosphorous (Ni-P) coatings through the process of EN deposition. The morphology of coatings gets affected due to Co-deposition of the SiC nanoparticles into the Ni-P coating and resulted in decreased size of nodules.Deposition of the SiC nanoparticles with Ni-P coating increased the Corrosion performance of resulted nano composite coating. However, corrosion resistance of the coating was found to be reducing with increasing the SiC concentration higher than 2 g/l. It was also observed that

Heat treatment enhanced the corrosion resistance of the Ni-P-SiC coating. And optimum corrosion resistance was obtained when heating was done at a temperature of 400-degree Celsius [6].

Before electroless coating pre-treatment of the substrate is done which includes-

Polishing → Degreasing → Rinsing → Activation → Rinsing → Electroless Plating

After coating its characteristics and microstructure are analysed by the test SEM (scanning electron microscopy), XRD (x ray diffraction), EDS (energy dispersive spectroscopy).

For coating of substrate by electroless method electroless bath is prepared in which nanoparticles are also incorporated. The setup for the experiment is shown below-

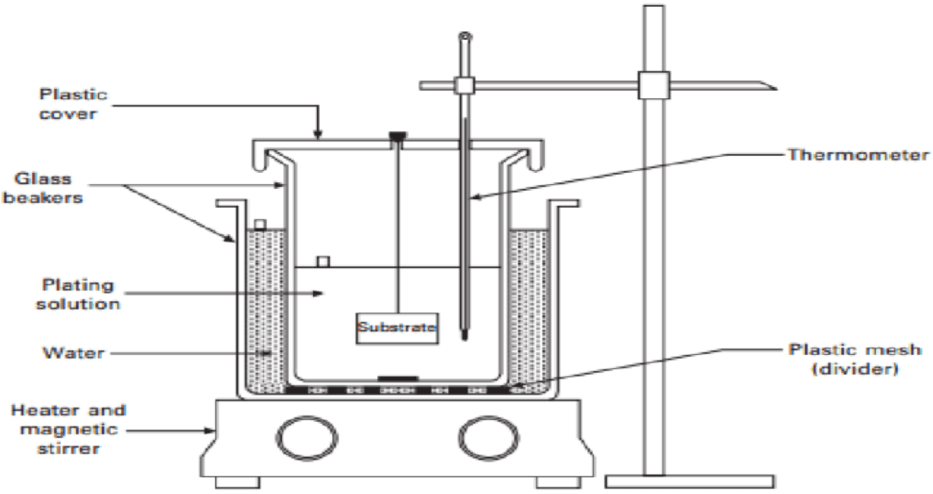

Fig. 1. Electroless Plating Setup (https://www.researchgate.net/profile/Vivek-Bharambe)

Discussing about nanoparticles, after silicon dioxide and zinc oxide nanoparticles, titanium oxide (TiO2) is most produced nanoparticles. It is used as a commodity chemical and as an additive to plastics, tiles, cements in construction industry. For its properties like blocking of ultraviolet radiation, TiO2 is also used in sunscreens [7]. In this paper the experimental results obtained when electroless nano plating was performed using TiO_2 (Titania) as nanoparticles is being reviewed thoroughly.

2. Literature Review

PreetiMakkar et. al. in [2013] investigated the properties like hardness and wear resistance of electroless Ni-P-TiO_2 composite coatings on the samples of mild steel. and compared with that of Ni–P alloy. Enhancement in hardness and wear resistance was noted in Ni–P–TiO_2 composite coatings as compared to that of Ni–P alloy layers. The improved hardness and wear resistance was 1010 VHN and 1.5e-06 mm^3/N-m respectively in the composite after the sample was heat treated in argon medium at 400 °C for 1 h [8].

Sepideh Amjad-Iranaghet. al. in [2013] experimented and found out the chemical and physical properties of electroless Ni/P/nano-composite coatings. Nano- particles TiO_2 was combined in this experiment which increased the corrosion resistance. Heat treatment also improved the corrosion resistance of the coating up to a temperature of 400 °C but heating above 400 °C caused a decrease in corrosion resistance. Besides that, Wear resistance of the samples were improved greatly in the presence of TiO_2 particles [9].

NadtinanPromphetet. al. in [2017] did research on steel sample by coating its surface with NiP-TiO_2 sol-RGO (Sol – reduced graphene oxide) nanocomposite. Coated steel samples were then examined for hydrophobicity, conductivity along with corrosion resistance. Highly homogeneous coating layer was observed with ultra-thin water-repellent RGO layer covering fully on the outer surface resulting in significant improved corrosion resistance and electrical conductivity of steel. Applications requiring for high corrosion resistance and high conductivity along with less vulnerable to humidity as in case of electrochemical sensors used in electrode and electronic parts might be useful [10].

Xiaoyan Wuet. al. in [2015] demonstrated electroless deposition by adding TiO_2 sol into conventional Ni–P electroless plating solution on 211Z Al alloy substrate and compared with the Ni–P coatings on 211Z Al alloy. It was observed that Ni–P–TiO2 coatings on 211Z Al alloy substrate exhibited higher corrosion resistance than pure 211Z Al alloy substrate in the salty environment. The microhardness was found to be 608 HV and 685 HV for Ni-P and Ni-P-TiO_2 coated samples respectively. After heat treatment at 400 °C for 1 h, microhardness improved considerably to 929 HV and 1325 HV for Ni-P and Ni-P-TiO_2 coated samples respectively [11].

M. Momenzadehet. al. in [2011] inspected the properties like hardness and corrosion resistance of nanocomposite coatings by varying the contents of TiO_2 nanoparticles in Ni–P electroless plating solution. The corrosion resistance of Ni–P–TiO_2 nanocomposite coating was significantly improved compared to Ni–P coatings by incorporation of TiO_2 nanoparticle. It was also observed to have great improvement in hardness especially after heat treatment [12].

Weiwei Chenet. al. in [2010] inspected a nano composite coating produced through a new processing technique. This technique involves combining of sol-gel with electroless plating process to prepare a coating which is nano-particle reinforced extremely dispersive oxide. Here Mg alloys were coated by adding transparent TiO_2 sol into the conventional Ni–P electroless bath at a supervised rate to generate Ni–P–TiO_2 nano-composite coatings. The microhardness and wear resistance were observed to have improved significantly by this new technique compare to the conventional method (solid particle Mixing methods) [13].

BurcuDidemÇorbacıoğlu in [2018] investigated andstudied the electroless Ni-P-acetylacetonate-TiO_2 coated nanocomposites on steel samples. The effects of parameters like TiO_2 concentration, process time, temperature, and pH of the plating materials were examined to get optimal values. The corrosion resistance of nano composited samples was then compared to Ni plating layer and the Ni-P plating layer and was found to be superior than both of them in a 3.5% NaCl salt spray, as well as in 15% H_2SO_4 and 20% HCl solutions [14].

Komal Yadav et. al. in [2016] did a research work in which the behavior of Ni–P–TiO_2 nanocomposite coatings on mild steel was studied. The inclusion of TiO_2 nanoparticles into Ni-P matrix enhanced their hardness considerably. Also, there was improvement in the corrosion resistance of nanocomposite coated steel samples when compared with the pure mild steel and Ni-P coating. The enhancement in anticorrosive property was due to amorphous nature of nano –composite [15].

Sepideh Amjad-Iranagh et. al. in [2020] performed an experiment in which electroless Ni/P/ nano-composite coatings was obtained by using TiO_2 in electroless plating bath as nano-particles. The coatings were heat treated at different temperature and their physical and chemical properties were investigated. The result showed that optimum temperature for the heat treatment of the composite coatings was 400 ^oC. Corrosion resistance obtained for nanocomposite coating was found to be higher than Ni-P coating. Also, heat treatment improved the corrosion resistance of the nanocomposite coating up to a temperature of 400 ^oC. However, heating further resulted in decrease in corrosion resistance [16].

Li Yongfeng et. al. in [2017] studied about the different factors which influence the rate of deposition of Ni-P-TiO_2 nanoparticle composite layers over the surface of Q235 cold-rolled steel sample. These factors were amount of TiO_2 added, plating time, temperature and pH. By optimizing mentioned factors electroless composite coating was done onto a sample. The result showed that corrosion resistance of the Ni-P-TiO_2 nanoparticle composite plated layer was better than that of the Ni-P plated layer tested in the 3.5% NaCl solution. However, Ni-P-TiO2 nanoparticle composite plating layer was found to be slightly less corrosion resistant in in the 10% H_2SO_4 and 15% HCl solution. Furthermore, bare steel sample's corrosion resistance was enhanced by both the coating layers be it Ni-P or Ni-P-TiO_2 [17].

Weidong Gao et. al. in [2017] experimented the behavior of Cu-Sn-Zn-TiO_2 nano-composite coating by incorporating TiO_2 nanoparticle. As Cu-Sn-Zn coating have widely been used in the electronics industry and precision instrument manufacturing for their unique properties, such as good conductivity, better corrosion resistance and exceptional solderability, it is important to search for its applicability in electroless plating. The microstructure of coatings was examined by X-ray diffraction (XRD) and Scanning Electron Microscopy (SEM). The results obtained when tested for microhardness and wear resistance, indicated that inclusion of TiO_2 nano particles can influence the properties of Cu-Sn-Zn coatings significantly. When TiO_2 nanoparticle incorporated, the corrosion resistance was enhanced and wear resistance was also improved from 330 HV to 383 HV with 1g/L of TiO_2 addition [18].

C.K. Lee in (2008) investigated the properties like wear and corrosion resistance of electroless nickel–phosphorus (ENP) coatings over the surface of glass fiber-reinforced plastic (GFRP) composites that are often used for the blades of wind turbine. As the P- content increased, higher thickness of coating, higher hardness and roughness of substrate was observed. Also, the corrosion and wear-corrosion resistance of ENP coated GFRP was improved [19].

Xiou- Jia Liu et. Al. in (2019)observed the Microstructure and corrosion resistance of Ni–P gradient coating/stannate conversion layer on magnesium alloy (AZ91D, 25×15×10 mm). The corrosion resistance of substrate was significantly improved by the stannate conversion layer and the Ni-P gradient coating. When compared, Ni-P gradient coating had better corrosion resistance than stannate conversion layer and found to be improving further when P content was increased. Scanning electron microscopy (SEM) and X-ray diffraction (XRD) of deposits showed that structures transformed from crystalline to microcrystalline and eventually became amorphous, as P content was increased to 12.58 wt%from 3.31wt% [20].

3.Conclusion

The process of electroless plating onto a substrate be it conducting or non-conducting is an autocatalytic reaction. Instead of using outside source of electricity as in case of electrodeposition, here we use chemical bath to deposit a nickel / phosphorous layer. In this paper, the second phase particles

(TiO_2) are included for nanocomposite coating and the various properties like hardness, wear & tear resistance, corrosion resistance is analysed. These Properties which is required in a material to be used indifferent industries like in engineering, aerospace, oil and gas, construction, electronics and several others is improved significantly. Also, heat treatment to the nano-coating is observed to improve the above-mentioned properties further. So, it can be concluded here that by including different nano particles, surface treatments (heat treatment, laser treatment etc.) and altering the process parameters can offer suitable coatings which would fulfil the different industries requirement. Its future scope may be to reach a point by more experimentation where the obtained results are what is directly required in industries.

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