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A Review on the Electroless Coatings and Coating Processes for Improving Tribological Properties

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ABSTRACT:

The creation of composite systems, of which coated materials are one type, is frequently necessary for improvements in material performance. Protective coatings can significantly increase the abrasion and corrosion resistance of components, and this sector is expanding and has significant economic significance. In this work, the tribological properties of several electroless coatings are observed. The pre-treated substrate was plated using a bath containing different Electroless solutions such as Ni-P, Ni–P–Al_2O_3, Al–10Si–0.3Mg, Ni-p-gC_3N_4, Ni-P-Si_3N_4, Ni–P–B_4C etc. The coated samples were heated to various temperatures (400-550 C). Using the pin-on-disc approach, tribological properties were investigated. In Ni-P coatings, the mechanical properties are often improved due to alloying elements like W, B, Co, Sn, and Cu etc. The wear resistance of the coated components was increased by hard particles like diamond, SiC, Si_3N_4, TiO_2, Al_2O_3, ZrO_2 (YSZ-yttria stabilized zirconia), and others. It is found that the substrates which undergoes coating and heat treated has much improvement in hardness and wear resistance.

Keywords: Electroless Coatings, Hardness, Nano particles, Substrate, Tribology, XRD.

Introduction:

The automotive, aerospace, electrical, chemical, electronics industries frequently employ nickel-based coatings to enhance the mechanical properties and wear resistance of various components.[1]Coatings helps us in protecting the metallic surface from getting wear and corrosion.[2] The purpose of this paper is to discuss coating properties, such as wear and erosion resistance, and coating systems.in Ni-P Coatings the Phosphorus content, bath composition, temperature, and PH all have a substantial impact on structure and characteristics.[4] Recently, there has been a rise in interest in EN composite coatings employing carbon nanoparticles.[5]Higher wear resistance, a reduced coefficient of friction, and corrosion resistance are all characteristics of EN-CNT composite coatings. The mechanical and tribological characteristics of the composite, including hardness, wear, and coefficient of friction, are improved by heat treatment at the suitable conditions of temperature and atmosphere.[6] Heat treatment decreases voids, inter-nodular gaps, and other defects in addition to reshaping the microstructure. The substrates are taken for pin on disc experimentation to identify the wear and friction at different conditions by varying rotational speed, load, sliding distance, time.[1,3,8,11,13,15] Composition and surface morphology of several composite coatings were analyzed by energy-dispersive X-ray (EDX) spectroscopy and scanning electron microscopy (SEM) respectively.[9] The present work aims to study the mechanical and tribological behavior of various Ni-P composite coatings on EN8 steel with different surface patterns using electroless plating method.[10]

Objective of the review:

- To examine and understand the effect of Electroless coatings on tribological properties of various metals.
- To understand the uses of Electroless coatings in various applications.

Necessity of new material:

Why do we need to switch to Electroless coatings? Electroless coatings, also known as autocatalytic coatings, offer several advantages over traditional electroplated coatings, which require an electrical current to deposit metal onto a substrate. Here are a few benefits of switching to electroless coatings:

Better uniformity: Electroless coatings provide a more uniform and consistent thickness of the coating than electroplated coatings, which can have thickness variations due to the electrical current.

Increased corrosion resistance: Electroless coatings are more corrosion-resistant than electroplated coatings. This is because they are typically made with higher quality materials and have a more uniform surface finish.

Improved adhesion: Electroless coatings provide better adhesion to a wider range of substrates than electroplated coatings. This is because electroless coatings do not rely on an electrical charge to bond to the substrate.

Reduced waste: Electroless coatings do not generate any toxic or hazardous waste, unlike electroplated coatings, which require a lot of chemicals and create wastewater that needs to be treated before disposal.

Overall, electroless coatings can offer a more cost-effective and environmentally friendly alternative to traditional electroplated coatings.

Literature Survey:

[1] M. Novak (2009): Paper presented on Influence of heat treatment on tribological properties of electroless Ni–P and Ni–P–Al_2O_3 coatings on Al–Si casting alloy. In this paper Aluminum casting alloys coated with Ni-P and Ni-P-Al_2O_3 were studied for wear resistance. Both coatings considerably increase wear resistance, as was anticipated. The samples subjected to 400 °C/1 h had the best results (i.e., the lowest wear rate). Given that it results in the maximum hardness of coatings, this regime is typically regarded as ideal. Wear resistance reduces with rising temperature and annealing time when the coating is exposed to temperatures over 400 °C. From a technical perspective, it is crucial to note that even very prolonged exposure to temperatures between 400 and 450 °C does not always result in noticeable coating deterioration. Abrasion is the main mechanism for both Ni-P and Ni-P-Al_2O_3 coatings. Yet, an adhesive mechanism was also seen in the case of the Ni-P coating. Al_2O_3fiber reinforcement improves the coating's resistance to wear, as predicted.

[2] P.S. SIDKY (1999): Paper presented on Review of inorganic coatings and coating processes for reducing wear and corrosion. The development of composite systems is occasionally required by improvements in material performance; coated materials are one sort of such system. Protective coatings may greatly improve component abrasion and corrosion resistance, and this is a burgeoning business with significant economic relevance. Aqueous and high temperature applications both employ coatings. Thick coatings have proven useful in harsh settings such as coal gasification, electric power production, and waste incineration. High temperature corrosion affects diesel and gas turbine engines, and extremely helpful coatings have been produced. Coatings are also used in some nuclear power plants. Substrate compatibility, adhesion, porosity, the feasibility of repair or recoating, interdiffusion, the influence of temperature cycling, resistance to wear and corrosion, and cost are all important considerations. This comparison of various systems emphasizes the need of designing the coating and substrate as an integrated whole with all of these issues in mind.

[3] Yanwen Yuan (2015): Presented paper on High-yield Synthesis and Optical Properties of g-C_3N_4. Because of its interesting photocatalytic properties under visible light, graphitic carbon nitride (g-C_3N_4), a metal-free semiconductor with a band gap of 2.7 eV, has gained a lot of attention. Because of its high thermal and chemical stability, as well as its non-toxicity, g-C_3N_4 has been identified as the most promising photocatalyst for environmental improvement and energy conservation. As a result, it is important to get high-quality g-C_3N_4 and develop a thorough grasp of its optical characteristics. High vacuum-sealed melamine powder is heated in an ampoule at temperatures between 450 and 650°C to produce a high-yield synthesis of g-C_3N_4 compounds. The chemical composition and crystallization of the as-produced g-C_3N_4 are demonstrated using transmission electron microscopy (TEM), scanning transmission electron microscopy (STEM), electron energy loss spectroscopy (EELS), thermal gravimetric analysis (TGA), X-ray diffraction (XRD), and X-ray photoelectron spectroscopy (XPS). Many methodologies are used to conduct a systematic optical investigation of g-C_3N_4. The optical phonon behavior of g-C_3N_4 is revealed by infrared and Raman spectroscopy, and the emission property of g-C_3N_4 is researched using photoluminescence (PL) spectroscopy, while the photocatalytic property is investigated by the photodegradation experiment.

[4] M. Novak (2009): Presented paper on Influence of heat treatment on tribological properties of electroless Ni–P and Ni–P–Al_2O_3 coatings on Al–Si casting alloy. This study looks at the evolution of the tribological properties of electroless Ni-P and Ni-P-Al_2O_3 coatings on an Al-10Si-0.3Mg casting alloy under heat treatment. The pre-treated substrate was plated in a nickel hypophosphite, nickel lactate, and lactic acid bath. Al_2O_3 Saffil fibers pre-treated in demineralized water were utilized to prepare the fiber reinforced coating. The coated samples were heat treated for 8 hours at 400-550 degrees Celsius (1-8 hours). The pin-on-disc technique was employed to study tribological properties. The highest coating performance is obtained by adopting the recommended heat treatment regime (400 °C/1 h). Annealing at higher temperatures (450°C and above) causes the production of intermetallic compounds, which reduces the wear resistance of the coating. The reason for this is because the intermetallic phases have a negative impact on the coating's adhesion to the substrate. The wear track analysis shows that abrasion is the primary wear mechanism; however, due to the generated intermetallic sub-layers, partial coating delamination may occur during the pin-on-disc test on samples annealed at 450 °C and higher. Fiber reinforcement was discovered to minimize scaling and boost wear resistance of coatings when compared to non-reinforced Ni-P coatings.

[5] M. Hasan Sadhir (2014): Paper presented on Comparison of in situ and ex situ reduced graphene oxide reinforced electroless nickel phosphorus nanocomposite coating. Incorporation of Si_3N_4 nanoparticles into electroless nickel-phosphorus (Ni-P) plating. Matrix and post-heat treatments were performed to study the evolution of the microstructure Ni-P-Si_3N_4 composite coating. Corresponding effects on mechanical and tribology. The properties of composite coatings were systematically investigated. Improved mechanical properties of Ni-P-Si_3N_4 composite coatings after heat treatment Suggestions have been made regarding changes in the crystal structure parameters. Lattice contraction Parameters and crystallite size of Ni and Ni_3P crystals due to the presence of Si_3N_4 Nanoparticles, first observed in an electroless Ni-P plating system Involved in improving hardness and wear resistance of Ni-P-Si_3N_4 composites Coating after heat treatment. A Raman spectroscopy study of wear was also performed and identified traces of graphitic carbon and nickel oxide (NiO). By residual organic compounds and oxidation of Ni deposits under electro less coating.

[6] Dhani Ram Dhakal (2020): Paper presented on Understanding the effect of Si_3N_4 nanoparticles on wear resistance behavior of electroless Nickel-Phosphorus coating through structural investigation. To explore the microstructural evolution of the Ni-P-Si_3N_4 composite coating, Si_3N_4 nanoparticles

were added to the electroless Nickel-Phosphorous (Ni-P) coating matrix, and post-heat treatment was applied. Effects on the mechanical and tribological systems that correspond thorough investigation has been done into the composite coating's properties. It has been suggested that changes in the crystal structure parameters are the cause of the increased mechanical capabilities of Ni-P-Si_3N_4 composite coatings following heat treatment. The first-ever observation in electroless Ni-P coating systems of shrinkage in the lattice parameters and the crystallite size of Ni and Ni_3P crystals due to the presence of Si_3N_4 nanoparticles is found to be responsible for the improvement in the hardness and wear resistance of the Ni-P-Si_3N_4 composite coatings. It has been suggested that changes in the crystal structure parameters are the cause of the increased mechanical capabilities of Ni-P-Si_3N_4 composite coatings following heat treatment. The Ni-P-Si_3N_4 composite coatings' improved hardness and wear resistance are discovered to be caused by shrinkage in the lattice parameters and the crystallite size of Ni and Ni3P crystals caused by the presence of Si_3N_4 nanoparticles, a first-of-its-kind observation in electroless Ni-P coating systems. The wear debris has also been subjected to a Raman spectroscopic analysis, revealing the fingerprints of graphitic Carbon and Nickel Oxide (NiO), which are related to the oxidation of the Ni deposits in the electroless coating and the residual organic molecules, respectively.

[7] B. Bahadormanesh (2011): Paper presented on Electrodeposition and characterization of Ni–Co/SiC nanocomposite coatings. Ni-Co/SiC nanocomposite coatings were electrolytically deposited in a modified Watts Ni-Co bath containing co-evaporated 20 nm SiC particles. Ni-Co alloy and Ni-Co/SiC nanocomposite coatings are analyzed using scanning electron microscopy to determine their morphology. Distribution The state of particles in the matrix was observed with a transmission electron microscope. The application of nanomechanical testing equipment combined with atomic force microscopy, alloy and composite coatings has been studied and compared. The presence of 11% by volume SiC in the Ni-Co matrix increased the hardness by more than 60%.

[8] Ayfer Kilicarslan (2012): Presented paper on Electroless nickel–phosphorus coating on boron carbide particles. In this paper B_4C particles with average particle diameters of 93 and 32 μm are electroless coated in a sodium hypophosphite solution to produce homogeneous and continuous Ni-P layers. The surface quality of the electroless nickel coating on the coarse particles was superior to that on the fine particles. Researchers coated boron carbide particles with nickel-boron nanolayers of varying thicknesses, reporting that when the Ni-B thickness was 5 nm, the cross-section thickness was 43 nm and when the Ni-B thickness was 50 nm, the real nanolayer cross-section thickness was 90 nm. The intended nanolayer thickness was based on a computation of the pure nickel concentration, in addition to the reasons already mentioned, the scientists noted. The thickness of the Ni-B coating is increased by the oxidation of nickel and the incorporation of boron as B_2O_3 during the electroless coating process.

[9] D. Umapathi (2019): Paper presented on Mechanical and tribological properties of electroless nickel phosphorous and nickel Phosphorous-Titanium nitride coating. In comparison to Ni-P coatings, Ni-P-TiN coatings offer superior mechanical and tribological characteristics. The nickel phosphorous-titanium nitride coated sample has a 16% higher hardness than nickel phosphorous coated material. In comparison to coated nickel phosphorous, coated nickel phosphorous-titanium nitride has a much higher coefficient of friction. This is because nickel phosphorous-titanium nitride coatings have a higher hardness than nickel phosphorous coatings do. As compared to nickel phosphorous coating alone, nickel phosphorous-titanium nitride coatings exhibit reduced pin and disc mass loss. It is determined that a significant element influencing the mass loss of the substrate is the hardness value. In both cases, nickel phosphorous and nickel phosphorous-titanium nitride coatings, the load should be increased. It was discovered that the nickel phosphorous-titanium nitride coating had a larger wear mass loss than nickel phosphorous alone.

[10] M.S. Jagatheeshwaran (2017): Paper presented on Impact of nano zinc oxide on the friction – Wear property of electroless nickel-phosphorus sea shell composite coatings. In order to overcome the high friction force of NiP/SSP (Nickel-phosphorus/Sea shell particle) composite coatings, which prevents them from being used in low friction applications, varying weight percentages of nano ZnO are added. Using an alkaline electroless method, NiP was deposited on En8 steel with a weight fraction (3.0 g/l) of SSP and various weight fractions (0.10 g/l, 0.25 g/l, 0.50 g/l, 0.75 g/l, and 1.0 g/l) of nano ZnO particles. Using a pin-on-disc apparatus, a friction-wear test was conducted on NiP/SSP/ZnO composite coatings in order to compare them to NiP and NiP/SSP composite coatings. The non-contact surface profilometer and SEM were used to characterise the wear track. Vickers micro hardness testers are used to measure hardness. The addition of nano ZnO particles causes the NiP/SSP/ZnO coating's hardness to diminish. Compared to NiP and NiP/SSP coating, NiP/SSP/ZnO (0.25 g/l) coatings showed a significant improvement in friction and wear resistance.

[11] Fatemeh Ebrahimi (2015): Paper presented on Influence of nano porous aluminum oxide interlayer on the optical absorptance of black electroless nickel–phosphorus coating. This work describes a method for producing an ultra-black surface using an electroless deposition of nickel-phosphorus nanowires with nano porous anodized aluminium oxide as a template. Using an aluminium substrate, the optical characteristics of a nickel electro-colouring technique and a traditional black Ni-P deposition were examined. Field emission scanning electron microscopy was used to evaluate the surface morphologies of the samples, and energy dispersive spectroscopy was used to analyse the coatings' elements. By using infrared spectroscopy and spectrophotometry, optical characteristics of surfaces were identified. Also, by computing the surfaces' absorption and emission coefficients, optical properties of the coated surfaces were assessed. The findings demonstrated that compared to plain black electroless Ni-P, ultra-black duplex coating had an absorption coefficient more than 99% and an emission coefficient that was around 6% lower. A value of 5.1 in the calculation of the factor demonstrated that the optical characteristics of the sample with the duplex coating had significantly improved.

[12] Vinod Babu Chintada (2018): Paper presented on Influence of SiC Nano Particles on Microhardness and Corrosion Resistance of Electroless Ni–P Coatings. In this study the Resistance of Electroless Ni–P Coatings Using the electroless coating method, silicon carbide nanoparticles were co-deposited in a Ni-P matrix to create a Ni-P-SiC composite coating on the mild steel substrate. The effect of SiC nanoparticle concentration and heat treatment temperature on the microhardness and corrosion resistance of the Ni-P-SiC coating was investigated in this study. The experiments were used to further investigate the coating's microhardness and corrosion resistance. The phase structure, morphology, and elemental composition of the coating were studied using X-ray diffraction and a scanning electron microscope coupled with energy dispersive spectroscopy. The results show that incorporating SiC nanoparticles into the coating has a significant impact on the coating's microhardness and corrosion resistance. At 400 °C, the phase change from

amorphous Ni to crystalline nickel and nickel phosphide improves the composite coating's microhardness and corrosion resistance. Polarization investigations reveal that the Ni-P-SiC coating outperforms the mild steel substrate in terms of corrosion resistance. SiC concentrations in the electroless bath more than 2 g/L have a deleterious influence on the coating's corrosion resistance.

[13] S. Karthikeyan & L. Vijayaraghavan (2016): Paper presented on Investigation of the surface properties of heat treated electroless Ni–P coating. In this study, the manufacture of electroless nickel phosphorus (Ni-P) coatings used an acid chloride electrolyte. SEM and X-ray diffraction were used to characterize the surfaces of the heat-treated coatings after the synthetic coatings were heat-treated at various temperatures. The measured coatings' adhesion, wettability, hardness, and corrosion behavior. Under heat-treated conditions, the surface morphology demonstrated the creation of a nanocrystalline nickel matrix. The recrystallization of nickel and creation of the Ni3P phase in the coatings were discovered through X-ray diffraction examination of the heat-treated samples. The wettability analysis revealed that the Ni-P coating is hydrophobic when it is being applied, and that due to the development of nano crystals at 400°C during heat treatment, wettability increases to a maximum of 70.8° contact angle, With an increase in heat treatment temperature, the Rockwell C adhesion test showed the presence of microcracks, but the failure is within the acceptable range. As the heat treatment temperature increased, the micro hardness of the Ni-P coating also increased. Due to the oxidation and precipitation of the Ni_3P phase during heat treatment, the Ni-P coating's corrosion potential changed to a positive potential. Heat treatment at 400° is responsible for reduced corrosion rate and corrosion current density (7.37- 0.21 A cm2).

[14] Shaowen Cao (2014): Paper presented on g-C_3N_4-Based Photocatalysts for Hydrogen Generation. In this paper, the semiconductor-based photo catholic hydrogen production from water splitting is now considered as a potential and promising strategy to obtain clean and renewable energy as a result of this kind of strategy only uses sunlight and water as sources. And graphitic carbon nitride, a semiconductor photocatalyst, is a good optional semi-conductor because it is only composed of the earth's abandoned elements carbon and nitrite and can absorb visible light to drive the overall volatility. It is simple to prepare and has excellent thermal and chemical stability.

The photocatalytic performance is improved by using rational methods such as nanostructure design, band gap engineering, dye sensitization, and heterojunction construction. Along with photocatalytic hydrogen evolution, the use of g-C_3N_4 in many photoelectronic devices such as solar cells and fuel cells has gained popularity.

[15] Kezhen Qi (2018): Paper presented on Electroless plating Ni-P cocatalyst decorated g-C_3N_4 with enhanced photocatalytic water splitting for H_2 generation. This study describes the photocatalytic water splitting to H_2 production using a nickel-phosphorus (Ni-P) cocatalyst coated graphitic C_3N_4 (g-C_3N_4/Ni-P). The g-C_3N_4/Ni-P composite is made in two steps: the first is thermal breakdown of urea to form g-C_3N_4, and the second is electroless plating to coat Ni-P on the g-C3N4 surface, resulting in a significant increase in g-C_3N_4 photocatalytic activity. Among the as-prepared samples described in this work, 3 wt% (g-C_3N_4/Ni-P-3%) had the greatest photocatalytic activity, with an H_2 generation rate of 1051 mol g^{-1} h^{-1}. However, g-C_3N_4 modified with more than 3 wt% Pt creates only 841 mol g^{-1} h^{-1} of H_2, and nearly no H_2 production by pure g-C_3N_4 has been determined. A photocatalytic mechanism for pure g-C_3N_4 and g-C_3N_4/Ni-P-3% has been proposed based on measurements of photoluminescence and photocurrent. This study presents a straightforward procedure for making high activity Ni-P/g-C_3N_4 photocatalysts, with the goal of creating high activity photocatalysts for the production of hydrogen.

[16] M.R. Vaezi (2007): Paper presented on Electrodeposition of Ni–SiC nano-composite coatings and evaluation of wear and corrosion resistance and electroplating characteristics. In this study, Ni–SiC nano-composite coatings with different contents of SiC nano-particulates were prepared by means of the conventional electrodeposition in a nickel-plating bath containing SiC nano-particulates to be co-deposited. The dependence of SiC nano-particulates amount in the nano-composite coatings was investigated in relation to the SiC concentration in bath, cathode current density, stir rate and temperature of plating bath and it is shown that these parameters strongly affected the volume percentage of SiC nano-particulates. The deposition efficiency with and without SiC nano-particulate in bath was studied. The morphology and phases of the electrodeposited nano-composite were studied. The wear behavior of the nano-composite coatings was evaluated on a ball-on-disk test. The corrosion behavior of the nano-composite coatings was evaluated in the solution of 0.5 M NaCl at room temperature. It was found that the cathodic polarization potential increased with increasing the SiC concentration in the bath.

The microhardness and wear and corrosion resistance of the nano-composite coatings also increased with increasing content of the SiC nano-particulate in bath. The SiC distribution in the nano-composite coatings at low concentrations of SiC in bath was uniform across the coatings, but at high concentrations, SiC nano-particulates on the surface were agglomerated.

[17] Mostafa Alishahi (2011): Paper presented on the effect of carbon nanotubes on the corrosion and tribological behavior of electroless Ni–P–CNT composite coating. In this study, Electroless plating was used to successfully deposit a Ni-P-CNT composite coating on copper's surface. The coatings were characterized using X-ray diffraction (XRD) analysis and scanning electron microscopy (SEM). Using a pin-on-disk test rig, the wear behavior of the coatings was examined, and the results were presented together with data on the friction coefficient. Polarization curves and electrochemical impedance spectroscopy (EIS) in 3.5 wt% NaCl aqueous solution at room temperature were used to assess the corrosion behavior of the Ni-P and Ni-P-CNT coated specimens. The outcomes showed that adding carbon nanotubes (CNTs) to the coating enhanced tribological behavior as well as corrosion resistance. These advancements are ascribed to nanotubes' exceptional mechanical capabilities, distinctive topological structure, and excellent chemical stability.

[18] Ali Rasooli (2018): Paper presented on Cr2O3 nanoparticles: A promising candidate to improve the mechanical properties and corrosion resistance of Ni-Co alloy coatings. The purpose of this research was to evaluate the impacts of reinforcing nanoparticle content on the microstructure, mechanical characteristics, and corrosion-related parameters of Ni-Co-Cr_2O_3 nanocomposite coatings. The microstructural characteristics and chemical content of the nanocomposites were evaluated using a scanning electron microscope (SEM), an energy dispersive X-ray spectrometer (EDS), and X-ray diffraction

(XRD). Furthermore, the mechanical and corrosion-related characteristics were investigated using the microhardness tester and electrochemical impedance spectra (EIS) tests in conjunction with potentiodynamic polarization studies. Although the volume percentage of cobalt in coating, average particle size, Cr_2O_3 nanoparticle concentration in coating, and microstructural characteristics are all relevant in influencing the attributes of the nanocomposite coatings, the results show that Co content is more important. Actually, Cr_2O_3 nanoparticles serve as good nucleation sites for the deposition of Co particles throughout the microstructure. Thus, the combined actions of Cr_2O_3 nanoparticle inclusion and their appropriate content promote the nucleation of a substantial population of Co particles, which considerably improves the characteristics. The mechanical and corrosion-related features of the Ni-Co8.9 wt%Cr_2O_3 nanocomposite coating are excellent.

[19] Aiwu Wang (2017): Paper presented on Recent Advances of Graphitic Carbon Nitride-Based Structures and Applications in Catalyst, Sensing, Imaging, and LEDs. In the field of environmental remediation, the two-dimensional conjugated polymer graphitic carbon nitride (g-C_3N_4) has attracted considerable interdisciplinary interest as a cheap, metal-free, and visible-light sensitive photocatalyst. The g-C_3N_4-based materials are "earth-abundant," have high physicochemical stabilities, outstanding electronic band structures, electron-rich characteristics, and basic surface functions. The most recent developments in the design and manufacture of g-C_3N_4-based materials, as well as their uses in white-light emitting diodes, sensing, imaging, and catalysis, are summarized in this study. There is also a forecast for potential future advancements in g-C_3N_4-based research for novel applications and features.

[20] C. U. Atuanya (2016): Paper presented on Experimental correlation between varying processing properties and wear behavior of ternary Ni-Co-SiO_2 composites coating of mild steel. This paper discuss about the association between different processing and wear behavior of ternary Ni-Co-SiO_2 composites coating was explored experimentally. The following parameters were employed in this study: SiO_2 (5-25 wt%), thermal treatment (100-300 °C), and applied load (5–15 N). The results reveal that a unique ternary NiCo-SiO_2 nanoparticle composite coating applied to mild steel was effective. The presence of SiO_2 nanoparticles in the coating Ni-Co bath results in a homogeneous microstructure. Thermal treatment of the coating at 300 °C reduced the wear rate by (0.031), increasing the wt% of SiO_2 from 0 to 25 reduced the wear rate by 0.018, and raising the applied load from 5 to 15 N increased the wear rate (0.0097), Lower wear rates were obtained with 25 wt% SiO_2, 5 N applied load, and 300 °C thermal treatment. Validation of the pin on disc test findings using an electro-hydraulic servo PV friction testing equipment reveals the same wear pattern. This study concludes that the wear rate of coated materials is determined by the coating's composition rather than the kind of wear mechanism. This study established that heat treatment and SiO_2 nanoparticles may be employed to improve the wear behavior of a Ni-Co coating on mild steel.

[21] Mohammad Farhan (2022): Paper presented on Synthesis and properties of electroless Ni–P-HfC nanocomposite coatings. This research describes the creation and characterization of Ni-P coatings with various hafnium carbide nanoparticle concentrations (HCNPs). By using an electroless deposition process, new Ni-P-HCNPs nanocomposite coatings were produced and applied to A36 carbon steel. Investigated were the effects of increasing HCNP concentrations on the structural, compositional, microstructural, topographical, electrochemical, and mechanical characteristics of Ni-P coatings (0.25 g/L, 0.50 g/L, 0.75 g/L, and 1.00 g/L). The effective integration of HCNPs into the Ni-P matrix is confirmed by the structural (XRD, FE-SEM) and compositional (EDX, XPS) investigations. Further observation reveals that the amount of HCNPs significantly affects how Ni-P-HCNPs nanocomposite coatings are modified in terms of their microstructural, surface, mechanical, and corrosion resistance capabilities. Comparative investigation of the coatings' attributes reveals that when compared to Ni-P coatings, nanocomposite coatings containing 0.75 g/L HCNPs exhibit the best improvements in hardness (40%) and corrosion resistance (95%). Dispersion hardening, which is a result of the existence of HCNPs, is what is responsible for the increase in hardness. Because there are less active sites in the Ni-P matrix and more HCNPs are used to fill the micropores, the corrosion resistance qualities have improved. The enticing qualities of HCNPs nanocomposite coatings make them an intriguing option for use in a variety of industries, including the oil and gas, automotive, electronic, and aerospace sectors.

Results and discussions from the review:

M. Novak (1) Abrasion is the main mechanism for both Ni-P and Ni-P-Al_2O_3 coatings. Yet, an adhesive mechanism was also seen in the case of the Ni-P coating. Al_2O_3fiber reinforcement improves the coating's resistance to wear, as predicted. P.S.SIDKY (2) In this study, It is necessary to use coatings that create dense glasses, complicated oxides, or spinels, especially self-healing coatings for long life. Yanwen Yuan (3) We investigated the g-C_3N_4 products' photocatalytic degradation properties and found that the highest photocatalytic efficiency was attained at a growth temperature of around 550°C.

M. Novak (4), M. Hasan Sadhir (5) In his study, Lattice contraction Parameters and crystallite size of Ni and Ni_3P crystals due to the presence of Si_3N_4 Nanoparticles, first observed in an electroless Ni-P plating system Involved in improving hardness and wear resistance of Ni-P-Si_3N_4 composites Coating after heat treatment. A Raman spectroscopy study of wear was also performed and identified traces of graphitic carbon and nickel oxide (NiO). Dhani Ram Dhakal (6) It has been suggested that changes in the crystal structure parameters are the cause of the increased mechanical capabilities of Ni-P-Si_3N_4 composite coatings following heat treatment. The Ni-P-Si_3N_4 composite coatings' improved hardness and wear resistance are discovered to be caused by shrinkage in the lattice parameters and the crystallite size of Ni and Ni_3P crystals caused by the presence of Si_3N_4 nanoparticles, a first-of-its-kind observation in electroless Ni-P coating systems. B. Bahadormanesh (7) In this study it was discovered that the nickel phosphorous-titanium nitride coating had a larger wear mass loss than nickel phosphorous alone.

Ayfer Kilicarslan (8) The intended nanolayer thickness was based on a computation of the pure nickel concentration. The thickness of the Ni-B coating is increased by the oxidation of nickel and the incorporation of boron as B_2O_3 during the electroless coating process. D. Umapathi (9) In this work, nickel phosphorous and nickel phosphoroustitanium nitride have successfully coated on EN8 steel using the electroless plating method. When compared to Ni-P coatings, NiP-Ti coatings offer superior mechanical and tribological characteristics. The nickel phosphorous-titanium nitride coating on the sample increases hardness above nickel phosphorous coating by 16%. M.S. Jagatheeshwaran (10) In this study, Alkaline baths were used to create electroless NiP, NiP/SSP, and NiP/SSP/ZnO composite coatings. SSP and ZnO particles have been used to strengthen electroless NiP coatings, changing their mechanical and wear properties. Fatemeh Ebrahimi (11) Compared to electro-colored and black electroless surfaces, which have absorption coefficients of 0.965 and 0.985, respectively, duplex coating has a higher absorption coefficient of 0.992. Also, the results demonstrate that the duplex sample had a lower emission coefficient than the electro-colored and black electroless samples, at 0.193. (0.254 and 0.268, respectively). Vinod Babu Chintada (12) In this study, the Ni-P-SiC coating's microhardness was increased by raising the concentration of SiC nanoparticles in the electroless bath. To achieve the highest microhardness, the 2 g/L bath's ideal concentration of SiC nanoparticles was discovered. S. Karthikeyan & L. Vijayaraghavan (13) For the Ni-P coating, the surface morphology was fine and smooth, but when the coatings were heated, nodular structures began to form and grow. Heat treatment caused the production of an oxide layer, but no oxygen diffusion with the nickel matrix was noticed. Shaowen Cao (14), Kezhen Qi (15) As a result of the two-step pyrolysis and electroless plating approach, g-C_3N_4/Ni-P composites with various Ni-P loading amounts were effectively created. These composites exhibit significant photocatalytic H_2 evolution activity. M.R. Vaezi (16) In this study, compared to nickel, the Ni-SiC nanocomposite covering is more corrosion resistant. Mostafa Alishahi (17) The addition of CNTs to the coating resulted in a decrease in the coating's phosphorus content, which in turn increased the coating's percentage of the nanocrystalline phase. Ali Rasooli (18) In this study, %Ni-Co-8.9 wt% the maximum microhardness value is found in Cr_2O_3 nanocomposite coatings electrodeposited at a current density of 6 A dm^2 and the addition of Cr_2O_3 nanoparticles to the Ni-Co alloy matrix has little impact on the shape of the individual particles, but it may improve the homogeneity of the microstructure. Aiwu Wang (19) This study provides an overview of current developments in g-C_3N_4-based structures and their uses in LEDs, chemical and biosensing, imaging, and catalytic applications. The surface state (defects, function groups, and doping) and structures of g-C_3N_4 are the major factors that determine how well it performs (porosity, thickness, and morphology). C. U. Atuanya (20) A homogeneous microstructure is produced by adding SiO_2 nanoparticles to the coating Ni-Co bath. Mohammad Farhan (21) It has been found that changing the microstructural surface properties significantly depends on the amount of HCNPs present. Due to effective micropore blocking and the dispersion hardening effect, Ni-P-HCNPs nanocomposite coatings have improved mechanical and corrosion resistance capabilities.

Conclusion:

In this review, by going through all the papers we found that Electroless coatings are the most used coating techniques in many applications and industries in the recent years because of their exclusive properties like superior Hardness, mechanical resistance, Wear resistance besides those these having corrosion resistance too. In the meanwhile, for the contact pairs, we need to provide special lubrication arrangements because without lubrication the friction generation, wear and tear will be extremely high we will not get any such problems with these coatings because these are having lubrication properties in it. Analysis was done with different Electroless coatings on different substrates, all among them have great impact due to heat treatment after coatings. As these coatings provides best wear resistance, corrosion resistance and good mechanical properties these are used in automotive, aerospace, electrical, chemical, electronics industries. The elemental compositions and surface morphologies are studied in detail using XRD, SEM and TEM respectively.

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