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Impact of nano zinc oxide on the friction – Wear property of electroless nickel-phosphorus sea shell composite coatings

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High friction force of NiP/SSP (Nickel-phosphorus/Sea shell particle) composite coating limits their use in low friction applications, hence to overcome this, nano ZnO is incorporated with different weight percentage. NiP with 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 were deposited on En8 steel using an alkaline electroless process. Friction – wear test was carried out on NiP/SSP/ZnO composite coatings and comparison was made with NiP and NiP/SSP composite coating using pin on disc apparatus. Wear track was characterized using SEM and non-contact surface profilometer. Hardness is measured using Vickers micro hardness tester. There is a decrease in the hardness of NiP/SSP/ZnO coating due to the incorporation of nano ZnO particles. Significant improvement in friction and wear resistance was observed for NiP/SSP/ZnO (0.25 g/l) coatings in contrast to NiP and NiP/SSP coating.

1. Introduction

Seshell is a bio-ceramic material enormously distributed as a waste on the sea shore of the world. Utilization of these wastes has been the focus [1,2], as this material tends to affects the environment badly. Generally, calcium carbonate of sea shell tends to react with oxygen in the atmosphere and release carbon dioxide. Hence, the distribution of sea shell waste generally causes carbon dioxide pollution and affects the environment. So it is important to utilize the waste sea shell in better manner to the industrial application. The utilization has been increasing in the application of automobiles, medical appliances, and food appliances for the past decades owing to their good thermal stability, biocompatibility, mechanical property [3] and corrosion resistance [4]. Recently, sea shell and calcinated sea shell is used as a reinforcement in the NiP matrix and shown an improvement in the wear resistance [5,6]. However, friction force is reported to be high for the sea shell particle reinforcement. Calcinated sea shell particle has shown the decreasing sequence of the friction force with better wear resistance. The decrease in the friction force is due to the lubricity created by the calcium and ashes of the organic residues as described in the previous article. Though the trapped organic ash produces the lubricity, it can be easily removed during the sliding condition and weakens the NiP matrix interfaces. Hence to strengthen the lubricity and interfaces of NiP matrix, hybrid particle reinforcement is preferred and reported in this article.

Extensive research has been carried out on altering the property of nickel phosphorus coating (NiP) through suitable inorganic particles such as SiC [7], Al_2O_3, CrC, SiO_2 [8], which show a drastic improvement in the tribology properties and hardness of the deposits. Some reports also show improvement in the lubrication of NiP coating after reinforcing organic fillers [9]. However, the effective combination of hybrid fillers (inorganic and organic) into NiP matrix for tribology application is still in the research arena. Surface coatings with organic and inorganic fillers have attracted much interest due to the synergistic effect from the combined properties of the inorganic (mechanical, electrical, optical and etc) and organic (lubricity, processability, flexibility and etc). The use of inorganic, particularly reinforcing ceramics particles into NiP matrix improves the hardness and wear of the coating on sliding with the other surface. Though a ceramic particle improves the hardness and wear, it certainly increases the friction force too. Hence to overcome this, organic and polymer fillers are added for decreasing friction force [10]. The selection of hybrid particles for reinforcing into NiP matrix is very important for tribology applications since the reinforced particles have a huge impact on the crystalline structure, lubricity and hardness of the interacting surface. In this work, we have taken up fabrication of a novel thin NiP films containing sea shell particles and nano zinc oxide the ability to produce better friction-wear resistance properties using electroless coating process.

Electroless deposition of NiP based alloys is a well-known coating process which is finding numerous application in various industries like electrical, aerospace, automotive, chemical, electronics, and etc., because of its excellent friction, wear, anticorrosive, magnetic property

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and ability to coat on non-conductive surfaces. Zinc oxide is an inorganic compound widely used as an additive in numerous materials such as rubbers, plastics, ceramics, glass, cement and lubricants. The advantage of zinc oxide consisting of lower cost, larger reserves, non-toxic and recyclable properties make it to the most widely employed surface protective coating [11]. ZnO is generally known for its good properties like semi conductivity, piezoelectric and biocompatibility. The high chemical reactivity of zinc oxide has also the added advantage of adhering to the NiP Matrix during the electroless coating process [12]. Nano based composite coating has found various applications in industry and engineering. Recently, zinc-fly ash [13] and NiP/carbon nanotube [14] composite coatings have also shown an improvement in the wear and corrosion resistance. On favor of that, in this work, nano zinc oxide is used as inorganic and SSP as the organic filler with the NiP matrix. The present study also demonstrates the effect of incorporated nano ZnO in NiP/SSP coatings on the hardness, morphology, structure and friction – wear property.

2. Materials and methods

2.1. Incorporated materials

The source of waste and preparation of SSP have been shown in a previous article [5]. The chemical composition of SSP is analyzed using electron diffraction spectrum and structural characterization is done using an X-ray diffractometer from angle 2θ = 8° to 80°. The nano ZnO particles were used as received without any further treatment from Qualigens fine chemicals, Navi Mumbai, India. The particle structure of the SSP was not homogenous and had a size of 0.12 to 0.19 µm. Nano ZnO particles have a homogenous spherical shape structure with an average size of 30–60 nm.

2.2. Electroless coating process

En8 steel with chemical composition of C – 0.45%, Mn – 1.0%, Si – 0.35%, S – 0.06% and P – 0.06 wt% was used as a substrate material for the coating process. The samples with dimension of 55 mm diameter and 10 mm thickness were mechanically polished to a R_a (average roughness) value of 0.3 µm. The pretreatment procedure is shown as a flow chart in Fig. 1. After pretreatment process, the samples were quickly transferred to an electrolyte bath (volume: 1litre) containing composition in Table 1. Baths were prepared exclusively in the NiP, NiP/SSP and NiP/SSP/ZnO composite coatings. The schematic representation of electroless bath and coating process is shown in the Fig. 2. After the coating process, the coated samples were post-annealed at 400 °C for an hour in a muffle furnace for improving the surface properties.

2.3. Structural characterizations of composite coating

X-ray diffraction pattern was obtained to find out the structural changes in the coating using an X-ray diffractometer with Cu-K alpha radiation from angle 2θ = 25° to 85° with step size of 0.02029. The X-ray wavelength used was 1.54 Å.

2.4. Surface property study of composite coatings

Surface hardness, roughness and morphology of the composite coating were carried out in this work for justifying the wear behavior of the coating. Surface hardness was measured using a Vickers hardness tester at a load of 50 g. Surface roughness is calculated using the arithmetical mean deviation of peaks and valleys measured in the non-contact surface profilometer. The surface area used to measure the roughness of the surface is 333 µm × 333 µm.

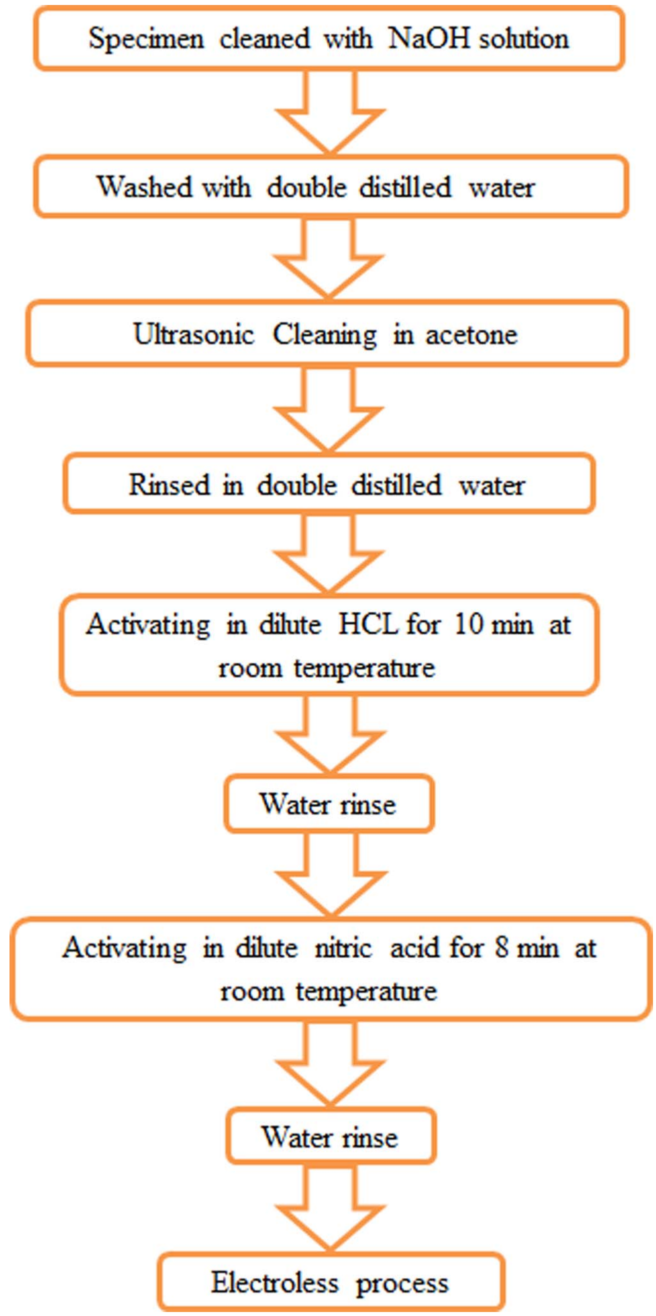

Fig. 1. Pretreatment procedure flowchart of the coating process.

Table 1
Bath composition of electroless coating.

Component	Concentration
Nickel sulphate,	18 g/l
Sodium hypophosphite	23 g/l
Sodium citrate	13 g/l
lead acetate	0.001 g/l
Acetic acid	6–7 ml
SSP	3.0 g/l
Nano ZnO	0.10 g/l, 0.25 g/l, 0.50 g/l, 0.75 g/l and 1.0 g/l

2.5. Wear test

The friction force and wear depth of the uncoated, NiP/SSP and NiP/SSP/ZnO (0.10 g/l, 0.25 g/l, 0.50 g/l, 0.75 g/l and 1.0 g/l)