Transforming the inferior metal alloy by electroless Ni-P/SiC deposit

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Transforming the inferior metal alloy by electroless Ni/P/SiC deposit

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1. Introduction

Surface modification by metal deposition onto inferior material is of paramount importance for many engineering applications. A type of metal coating by electroless technique is versatile owing to its promising material properties and characteristics. Heat treatment of electroless nickel coating is important owing to the properties enhancement such as increase in microhardness, tribology and phase transformation [1].

1.1 What is the purpose?

For automotive and aerospace industries lightweight aluminum alloy are the back bone for any design and structure. But these alloys are vulnerable to wear, erosion, corrosion etc. Electroless nickel coating reinforced with hard particles can transform the surface behaviour of the substrate. With optimal heat treatment the coating properties can further be enhanced.

1.2 Research aims

The present work aims to develop and understand the composite coating Ni-P/SiC by electroless technique. The characterisation such as phase structure, morphology and properties like microhardness, friction and wear are investigated systematically.

Aluminum alloy LMD5 (Al90Si5Fe5Co5 alloy) was used as substrate. It underwent pretreatment as shown in Table 1. Each step was followed by tap water washing and distilled water rinsing. The composite coating process parameters are shown in Table 2. The hard particles were introduced and stirred for 30 minutes prior to the plating process started. Upward and downward of the pH adjustment was done using 50% NH3·H2O and 10% H2O2, respectively.

Table 1: Pretreatment conditions and parameters

<table>
<thead>
<tr>
<th>Process</th>
<th>Chemicals</th>
<th>Temperature °C</th>
<th>Time</th>
<th>Solution Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degreasing</td>
<td>CaO+Na2CO3</td>
<td>Room</td>
<td>None</td>
<td>5-6 %</td>
</tr>
<tr>
<td>Chelating</td>
<td>Na2HPO4</td>
<td>60-65</td>
<td>~5</td>
<td>%</td>
</tr>
<tr>
<td>Calcifying</td>
<td>(NH4)2SO4</td>
<td>Room</td>
<td>~20</td>
<td>%</td>
</tr>
<tr>
<td>Activating</td>
<td>100 g/l HCl, 50 g/l Na2S</td>
<td>Room</td>
<td>~20</td>
<td>%</td>
</tr>
</tbody>
</table>

Heat treatment was done in furnace and for vacuum all the samples were sealed in glass before placing in the furnace. XRD analysis on coated samples was carried out at room temperature using PANalytical X-ray diffractometer applying CuKα radiation. The step size of scans was 0.02°. Energy dispersive X-ray (EDX) test by Animex version 2.0 software was used for chemical composition analysis. Microhardness by microhardness tester using load of 100 gf. Tribology behavior was tested using wear tester with load of 30 N rotating in a circular track of 8 mm diameter at a rotational speed of 200 rpm with the ball diameter of 7 mm. And also in-air (200°C) monitoring using 2.9 load with ball diameter of 6 mm and track diameter of 15 mm was performed using different pin-on-disc wear tester.

2. Results and discussion

The coating uniformity and the distribution of the reinforcing particles are shown in Fig. 1. The particles are evenly distributed in the coating which also follows the contour of the substrate [3].

Fig. 1: Cross section of the coatings of different SiC concentrations A, B (p 12 g/l), C (p 6 g/l) and D (1 g/l)

1.3.1 Phase structure

The fractal peak for the as-deposited state (AD) of the coating shows the amorphous structure for all the samples. The heat-treated state in both an atmospheric (AHF) and vacuum (VHT) conditions show well defined sharp peaks mainly from the crystallites Ni and SiO2 with SiC peak for composite coatings. Oxide peaks are not observed for the two types of heat treated samples.

Fig. 2: XRD patterns for samples A, B, C and F

1.3.2 Microhardness

Significant increase in microhardness post coating as compared to the bare Al substrate (Fig. 3) is observed. Upon heat treatment the microhardness further increases. Reference grey cast iron was taken as it is the conventional material for cylinder liner in engine systems.

Fig. 3: Microhardness for bare aluminium, grey cast iron and coated samples (heat treated in light grey colour)

1.3.3 Friction

There are substantial fluctuations in the friction graph especially in the early stage of the wearing time and then the friction becomes stable and smooth after this period of wearing time for atmospheric conditions. Large significant difference is observed before and after a threshold. Such observation does not occur in the friction graph for the sample heat treated in vacuum condition (Fig. 4). However, some irregularities of friction are seen which gradually fade away as the wearing proceeds. The main differences in the friction behaviour obtained with different heat treatment conditions could be due to the considerable layer of oxide formation. The blush appearance (visual inspection) on the surface of sample heat treated in atmospheric condition which is not seen for vacuum heat treated samples is the indication of the oxide formation. In-situ engine simulation (283°C) friction response suggest the coated samples exhibit lower friction as compared to grey cast iron as shown in Fig. 5.

Fig. 4: Friction responses over sliding time

1.3.4 Wear

Wear characteristics of the bare aluminum and the coatings in terms of wear rate is tabulated in Table 3. Wear rate is lower after the coating. Wear resistance is improved on heat treatment as compared to as-deposited state.

Fig. 5: In-situ friction responses at high temperatures

1.4. Concluding remarks

- Deposition of composite Ni-P/SiC onto aluminum alloy shows uniform coating and even distribution of reinforcing particles. SiC content increases on increasing SiC concentrations in the plating solution.
- XRD profile shows crystalline peaks from Ni and SiO2 and SiC peaks for composite samples in heat treated conditions and amorphous phases in as-deposited state.
- Microhardness increase after coating as compared to uncoated aluminum. Heat treatment further enhances the microhardness.
- Instability of the friction during the early stage of sliding is noticeable for atmospheric environment environmental samples of electroless nickel coated. No abrupt changes in the friction are found for vacuum heat treated samples.
- High temperature friction of near engine environment shows lower friction for coated samples as compared to grey cast iron.
- Wear performance is better for coated samples in terms of lower wear rate. Heat treated samples exhibit better wear resistance as compared to as-deposited state.

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References