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In-situ formation characteristic, tribological characterization and anti-corrosion properties of quaternary composites films

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Abstract: Improvements of wear and corrosion properties are essential characteristic in engineering application. A study was made on the structure, electro-oxidation and properties of fabricated Zn−Al−SnO_2−TiO_2 (Zn−Al−Sn−Ti) thin films using electrodeposition technique from chloride bath. The microstructural studies were performed by scanning electron microscopy with attached energy dispersive spectrometer (SEM−EDS), optical microscopy (OPM) and X-ray diffractogram (XRD). The electrochemical oxidation and erosion behavior in 3.65% NaCl medium were studied by potentiodynamic polarization technique and characterized by atomic force microscopy (AFM). The hardness and wear behavior of the electrodeposited film were performed by high diamond dura scan microhardness tester and CERT UMT-2 reciprocating sliding machine. It was found that a successful co-deposition of composite and particle were attained. Homogeneous imbedded grain structure distribution and fine refinement of crystal with improved micromechanical behavior was achieved. The corrosion resistance, hardness and wear stability resistance of the fabricated quaternary films improved significantly in all varied process parameter.
Key words: co-deposition; microstructural evolution; anti-corrosion property; composite materials

1 Introduction

Over decade, thin films electrodeposition has been widely applied in most engineering industries from automobile, photo-electronics, aerospace and marine to mention [1−6]. Much attention has been paid to binary admixed metal matrix alloy, lately especially with Zn particles [5−12]. But with higher pH value in acidic medium and high temperature range, corrosion and wear resistance properties from the binary fabricated processing are limited in service performance [1,13−20].

In view of this, codeposition reinforced metal matrix composite electrodeposition has been used to enhance and provide specific desirable properties [21−26]. Metal−ceramic matrixes, such as TiO_2 [1,16], SiO_2 [11,25], ZrO_2 [14], Cr_2O_3 [10,24], Al_2O_3 and ZnO [14,17,18], have been tested to provide enhanced strengthening properties and good surface modified behavior.

However, in an attempt to further provide continuous mechanical and morphological characteristics, replacement of binary bath formulation is necessary in relation to bath control parameters. Quaternary coatings are very limited [9−11]. The individual difference in microstructure and adhesion behavior of Al_2O_3 [9,20,21], TiO_2 [16,18,27] and SnO_2 [28,29] is known to possess high hardness, thermal stability and improved structural crystal. The quaternary fabricated formulation of this blend in single bath could guarantee a secondary phase and crystal growth. In the present study, Zn−Al−SnO_2−TiO_2 (Zn−Al−Sn−Ti) composite particulates were processed and fabricated from chloride electrolyte. The structural properties, mechanical stability and tribological characteristics of the coatings were investigated.

2 Experimental

2.1 Electrodeposition process

The chemicals used were of AR grade. Distilled water was used for the preparation of admixed bath solutions. The coating of Zn−Al−Sn−Ti in chloride bath was achieved through a designed cell consisting of two anode electrodes and a cathode electrode as described in Fig. 1.

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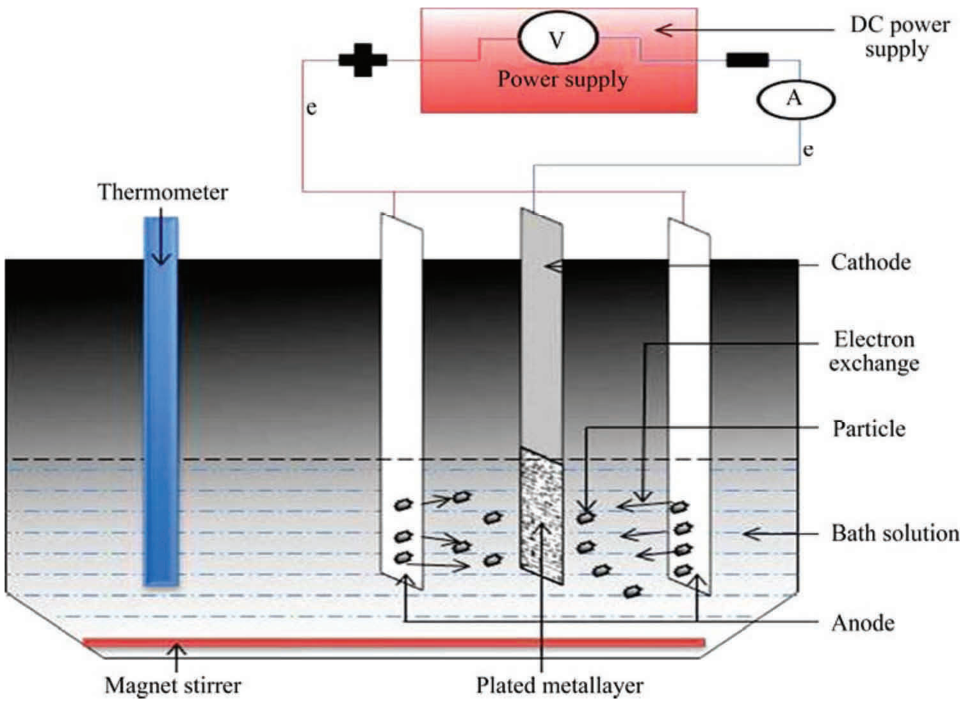

Fig. 1 Schematic diagram of electrodeposited cell

The dimensions of the mild steel sheet (substrate) used were 40 mm×20 mm×1 mm and zinc sheet of 50 mm×30 mm×3 mm was prepared as anode. The chemical composition of the mild steel substrate is shown in Table 1.

Table 1 Chemical composition of mild steel used (mass fraction, %)

C	Mn	Si	P	S	Al	Ni	Fe
0.15	0.45	0.18	0.01	0.031	0.005	0.008	Bal.

The zinc chemical composition was 99.99%. Prior to the plating, the mild steel specimens were polished mechanically, degreased and rinsed with water as described in Refs. [7,20]. In the pre-plating process, the surface preparation was done on a polishing machine with different grades of emery paper in order of 60, 120, 400, 800 and 1600 μm grades. Water was added intermittently so as to cool down the metal samples. During the grinding operation, the metal samples were rotated at an angle of 90° or 180° at intervals to erase previous marks which arose due to the initial grinding. The pickling of the samples was done in diluted HCl acid solution to remove all organic contaminants and oxides, followed by electrolytic degreasing. The prepared cathode and anodes were connected to the DC power supply through a rectifier at a varying voltage of 0.3−0.5 V with varying applied current density of 2 A/cm^2 for 20 min. The bath composition of the coated pattern is illustrated in Tables 2 and 3.

2.2 Structural characterization

The surface morphology studies of the deposits were observed by a scanning electron microscope (SEM) equipped with an energy dispersive spectroscope (EDS) (model: VEGA 3 TESCAN). Atomic force microscope was used to quantify the surface topography and morphology of the plated test specimens. The phase change of the coatings was determined by X-ray diffractogram (XRD).

Wear analysis was carried out by a CERT UMT−2 multi-functional sliding tester with design diagram shown in Fig. 2. The reciprocating sliding tests were carried out with a load of 5 N, constant speed of 5 mm/s, displacement amplitude of 2 mm in 20 min. The wear scars structural evolutions were examined with a high optic Nikon optical microscope (OPM).

The Vickers microhardness of the coating was examined by the dwell indentation technique for 15 s across the interface with a summarized average using dura scan inventor-EMCOTEST.

2.3 Electrochemical studies

The electrochemical resistance study was evaluated using linear potentiodynamic polarization test on the deposited samples. Measurements were systematically evaluated using an Autolab potentiostat (PGSTAT101 computer controlled) with the general purpose electrochemical software (NOVA) package version. Measurements were made at room temperature using 3.65% NaCl solution. The solution for this study was