BEHAVIOR OF BLACK NICKEL TIN SOLAR ABSORBER COATING

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ABSTRACT

Electroless plating of nickel tin phosphorous on aluminum and electrodeposition of black Ni-Sn-P alloy on aluminum substrate were discussed. Electrodeposition of black nickel tin phosphorous alloy was investigated by the reflectance percent and the absorption percent for black nickel coating from the Ultra-Violet Device (UV) at different wave lengths ranging from (230-700)nm as the absorption = (1- reflectance) and the composition of black Ni-Sn-P alloy was examined by X-ray photoelectron spectroscopy (XPS). Both coats were investigated by X-ray diffraction, scanning electron microscope (SEM) and energy dispersive X-ray analyses (EDX). Corrosion resistance of both nickel tin phosphorous and black nickel tin phosphorous coats were studied by potentiodynamic polarization. The black alloy show high absorbance and can be used as solar absorbance. All coats showed good corrosion resistance.

1. Introduction

Considerable amount of work has been carried out in the development of electroless nickel poly alloys by codepositing one or more metallic or non-metallic elements in Ni–P matrix to further enhance the deposit properties[1]. Metals like cobalt, tungsten, molybdenum, rhenium, copper, zinc, tin and palladium can be codeposited in Ni–P matrix. The excellent properties of tin such as non-toxicity, good corrosion resistance and solderability have created a lot of curiosity in developing ternary Ni–Sn–P and Ni–W–P alloys [2]. Preparation and characterization of Ni–Sn–P alloys were reported by Mallory [3] and Mallory and Horn [4]. Addition of tin has improved the amorphous forming ability of Ni–P alloy compared to copper addition [5]. Ternary Ni–Sn–P alloy with low-tin content possessed a high corrosion resistance and the thermal stability was improved in comparison with Ni–P alloys having the same phosphorus content [6, 7]. Georgieva et al. reported that the distribution of tin content in low-tin (~2.0 at.%) ternary alloys was uniform, but non-uniform in high-tin (~60 at.%) ternary coatings[8]. The preparation of black coatings by electrodeposition technique has therefore aroused great attention in the world [9–12]. The electrodeposition of nickel-based black coatings was reported [9,10].

2. Experimental.

2-1. Material and chemicals

Aluminum alloy test specimens alloy composition is shown in table (1):

Table(1):Chemical composition of aluminum alloy (wt %).

Element	Si	Fe	Cu	Mn	Mg	Ni	Cr	Pd	Sn	Ti	V	Co	Al
wt%	0.327	0.582	0.00585	0.981	0.216	0.0091	0.01140	0.0107	0.00532	0.047	0.006	0.0004	97.8

The specimens of the size 20 x 40 x 8 mm were used for electroless plating of Ni-P and Ni-Sn-P alloys.

The coatings were deposited from the most stable bath with and without tin chloride. The composition and condition of the bath are shown in table (2)

Table (2): Bath composition and operating conditions of electroless Ni-P and Ni-Sn-P.

Bath constituents and parameters	Quantity
Nickel sulphate	30 g/l
Sodium hypophosphite	10 g/l
Citric acid	10 g/l
Tin chloride	0.5g/l
pH	8.5
Plating temperature(˚C)	90
Coating time	1h

2-2. Blackening of Ni-Sn-P alloy (electrodeposition).

For electrical deposition to take place, the nickel is connected to the anode from both sides and the base metal coated with bright Ni-Sn-P is connected to the cathode for the deposition of black nickel on the alloy to take place.

2-3. Characterization of Ni-Sn-P coating.

The composition of as deposited Ni-Sn-P was analyzed using X-ray diffraction. Bruker AXS, Model D8, 40 kV, 40 mA , Cu Kα ADVANCE.EDX (energy dispersive X-ray analyses). EDAX GENESIS ABEX4 (AMETET).Surface morphology is analyzed by using scanning electron microscope (SEM) Quanta 250 FEG.

2-4. Characterization of black Ni-Sn-P coating.

Besides the analysis of the composition of Ni-Sn-P by the above methods, for the black Ni-Sn-P X-ray photoelectron spectroscopy XPS is studied. Thermo SCIENTIFIC K-ALPHA. The optical properties, namely, solar absorbance and ultra violet emittance of the black samples were measured by a solar reflectometer. These instruments provide an average value of solar absorbance and emittance. A PG Instruments T80+ UV–visible double-beam spectrophotometer (PG Instruments, United Kingdom).

3. Results and discussion.

3-1.X-Ray diffraction.

X-ray diffraction patterns of the as deposited Ni-Sn-P and black Ni-Sn-P are shown in Figs.1(a,b). from the figure , it is evident that the structure of this type of coatings are amorphous. The diffraction patterns of the as deposited Ni-Sn-P showed broad peak at 44.01, 51.00, 75.78, 91.93 and 97.85 which is attributed to amorphous nature of the as deposited Ni-Sn-P. The reflection corresponds to III plane of face centered cubic (fcc) nickel. The grain size of the as deposited Ni-Sn-P is 5.3nm. Phase identification of the blackened Ni-Sn-P samples, Fig.1(b),showed four peaks at 2ϴ equal 43.387, 51.38, 76.43 and 92.43, all corresponding to cubic nickel and the grain size is 5.2 nm.

3-2.**Microstructure.**

3.2.1- Morphology:

The surface morphology of Ni-Sn-P and black Ni-Sn-P were shown in Fig 2(a, b). It is evident from Fig 2(a, b) that all surface morphology of Ni-Sn-P and black Ni-Sn-P deposited showed the similar spherical nodule structure and one big nodule including many fine nodule. The diameter of nodule of of Ni-Sn-P and black Ni-Sn-P composition are 0.909 µm and 5.123 µm respectively.

3.2.2- Composition:

XPS spectra of the black Ni-Sn-P with 6.95%Sn was shown in Fig (4). It can be observed that Ni, Sn, P, O and C elements were contained in the black film.Carbon element may result from contact with oil and can be neglected in the following discussions. According to atomic ratio and valence of elements, The compositions of the black film should be NiO, $Ni(H_2PO_4)_2$, Ni_2O_3, SnO, metallic Ni and Sn. Nickel content in black film (80.48%) was less than that in deposit (89.11%). It can be concluded that dissolution of Ni and formation of metallic oxides are main process during blackening.

Table (3): The weight percent of the composition of Ni-Sn-P and black Ni-Sn-P.

Type of coating	Ni%	P%	O%	Sn%	C%
Ni-Sn-P	89.11	6.09	---	4.80	---
Black Ni-Sn-P	80.48	1.06	12.21	6.59	6.79

3.3- Properties of blackened Ni-Sn-P coatings with Sn at (8.11%) by weight.

3.3.1- Thickness measurement:

The cross section of Ni-Sn-P and black Ni-Sn-P showed the thickness of the layers. Fig.4(a, b) show the thickness of Ni-Sn-P and black Ni-Sn-P which is equal to 5.09 nm and 8.63nm respectively.

3.3.2- Solar properties:

The optical properties were measured via solar absorbance and ultra violet emittance of the black coating was detected. Nickel tin phosphorous with Sn content of 6.59% by weight was used for black treatment by electroplating .The rate of the reflectance of the black coating of Ni-Sn-P was 0.35 in the range of the wave length 250-550 nm. The absorption percentage range of the black Ni-W-P range was 99.65%.

The high absorption indicates that the black film can be used as an absorbing material. The black colour of Ni-Sn-P is due to the formation of the oxidized alloy at the surface of the Ni-Sn-P black layer, nickel oxides (NiO, Ni_2O_3) and nickel phosphorus Ni-P(confirmed by composition detection of black Ni-Sn-P**.**

3.3.3- Polarization.

Fig.(5). Showed the polarization curves of the substrate, as deposited Ni-Sn-P and black Ni-Sn-P in 3.5% NaCl solution. The value of the corrosion potential E_{corr} and the corrosion current density I_{corr} were calculated from the intersection of the tafel curves extrapolated from the potentiodynamic polarization curves. The value of polarization resistance R_p were calculated from the linear polarization. The calculated results were summarized in table (4).

Table (4) Corrosion potential E_{corr}, corrosion current density I_{corr} and polarization resistance R_p for as deposited Ni-Sn-P and black Ni-Sn-P.

Type of coating	E_{corr}(volt)	Log i_{corr}(μA/cm)	Polarization(mV/ mA) Rp=(βa×βc)/[2.3×Icorr(βa+βc)]
Substrate	-0.8465	-6.2672	36
Ni-Sn-P	-0.3281	-5.1125	$6.2x10^2$
Ni-Sn-P black	-0.22027	-5.8107	$1.3x10^3$

From this table, it showed the sequence of deposits with respect to less negative E_{corr} is summarized black Ni-Sn-P > as deposted Ni-Sn-P > substrate.

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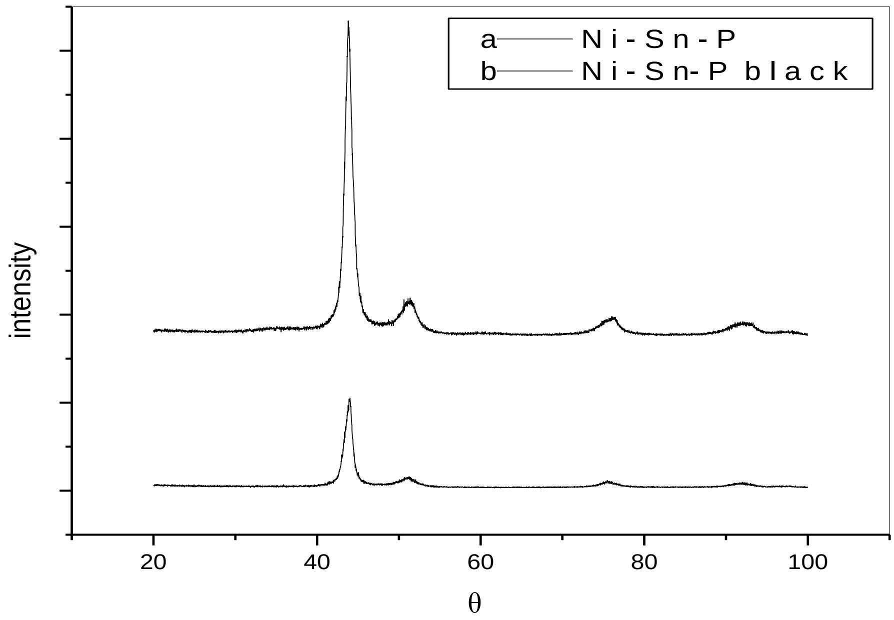

Figs.1 (a,b) show X-ray diffraction patterns of aluminum substrate, Ni-Sn-P and black Ni-Sn-P.

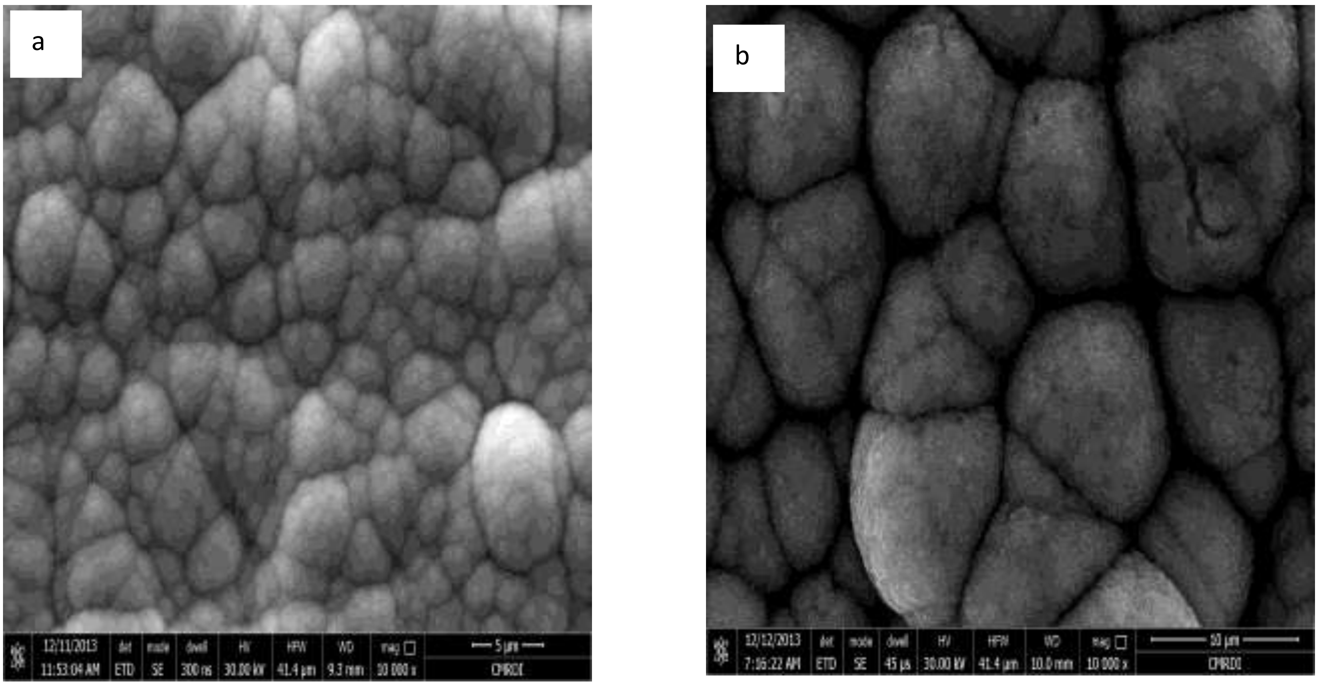

Fig.2 (a, b): Scanning electron microscope of as plated electroless (a) Ni-Sn-P and Ni-Sn-P after blackening.

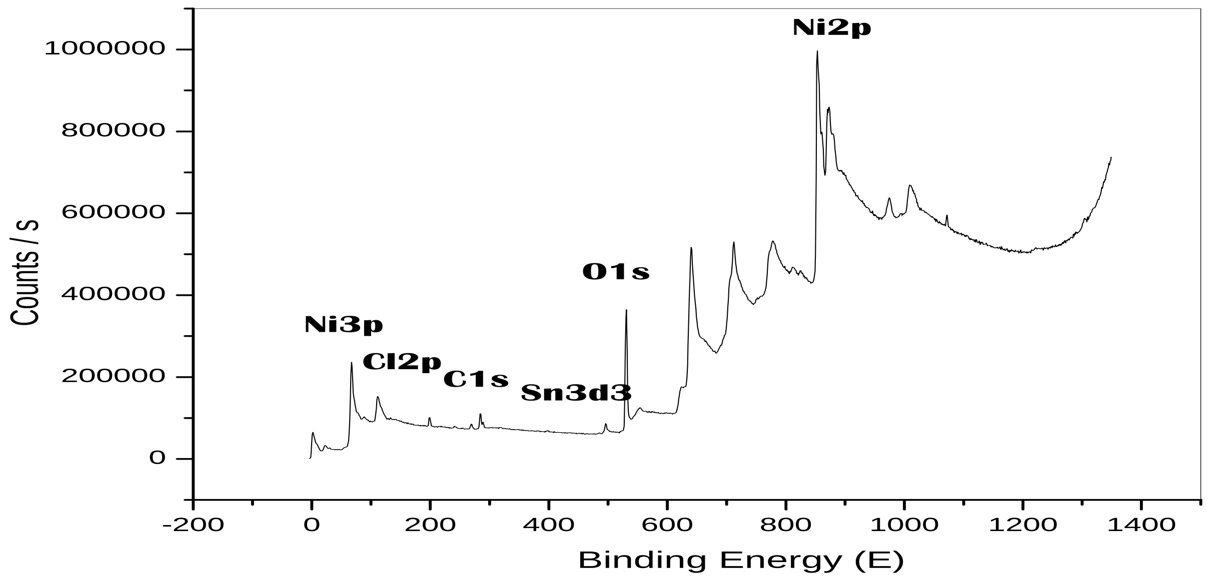

Fig.3:XPS wide scan spectrum of black Ni-Sn-P.

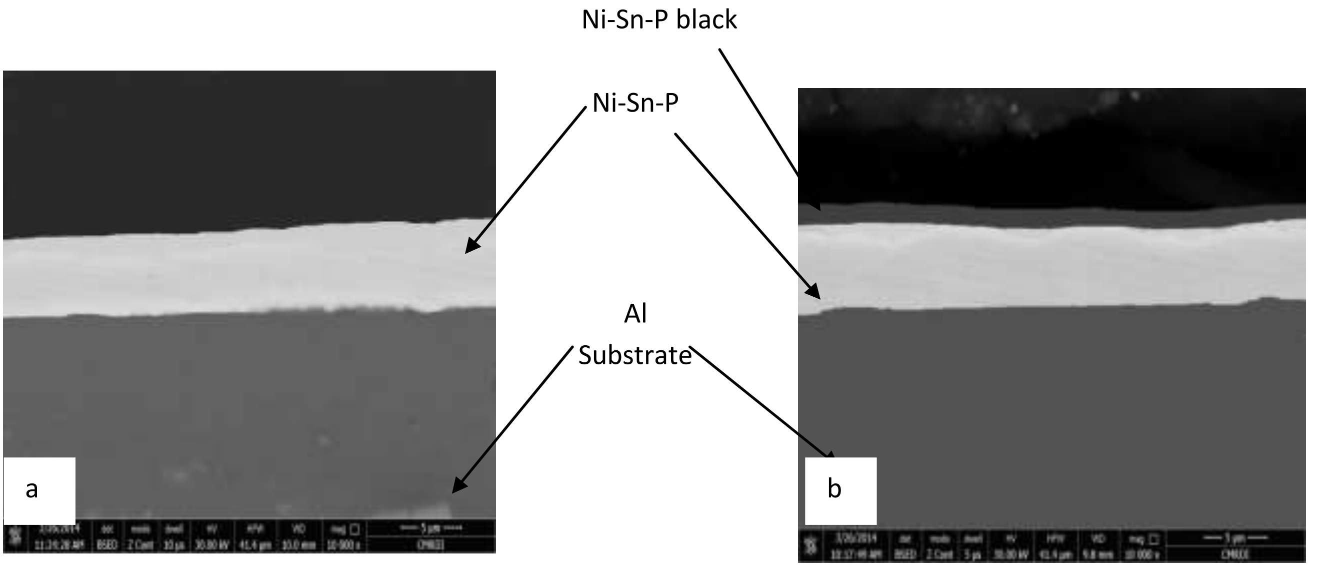

Fig.4 (a, b) Cross section of Ni-Sn-P and Ni-Sn-P black layers.

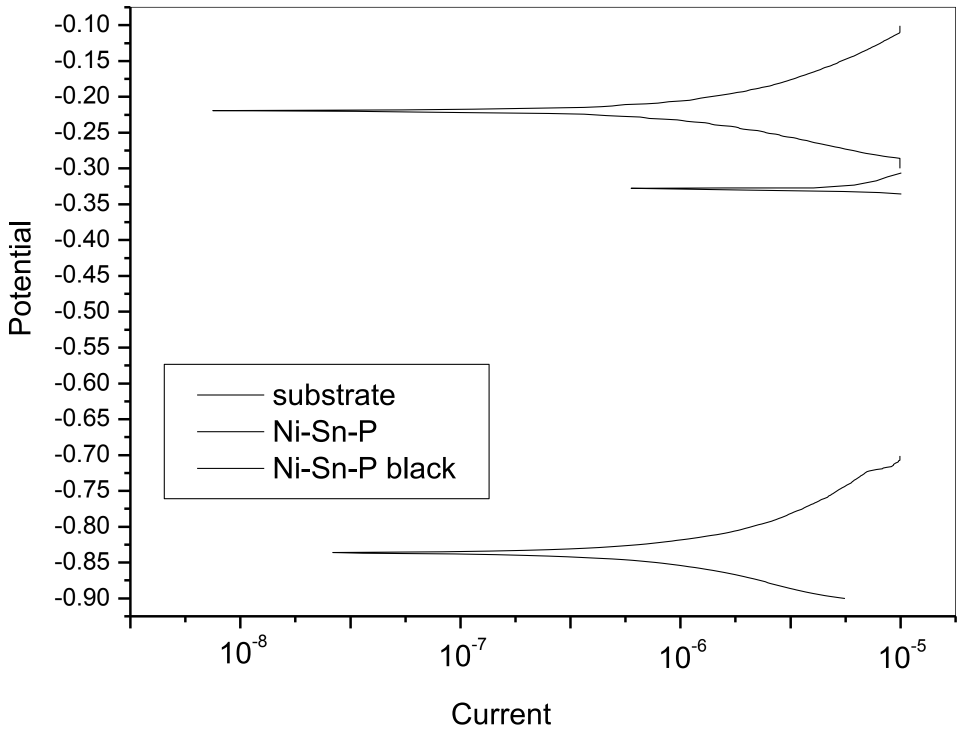

Fig.(5) shows potentiodynamic curves of (a) the substrate , (b) as deposited electroless Ni-Sn-P coat and (c) black coat Ni-Sn-P in 3.5% sodium chloride solution.