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Metallization of ABS plastics prepared by FDM-RP process and evaluation of corrosion and hardness characteristics

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Abstract : An attempt has been made in this work to develop copper coatings with enhanced corrosion and hardness properties on ABS plastics prepared by FDM-RP process. The increase of corrosion resistance of copper electrodeposited coatings in sea water medium claimed that these coated plastics can find as substitute for metal parts used in automobile components. Hardness values measured by Vickers hardness tested validated the improved mechanical properties. The presence of micro roughness and improved tensile strength values signify that the coatings have firmly absorbed on ABS plastics. The morphology of copper coatings was found uniform and analyzed using SEM images.
Keywords: Corrosion resistance; FDM-RP; copper coatings; SEM; hardness.

1. Introduction

Electroplated Copper deposition is an established industrial practice as a protective and decorative coating in various industries due to its superior corrosion and wear resistance, excellent uniformity, wide range of thickness as well as mechanical and physical properties. Extensive research has been carried out on the characterization of the Electroplated Copper deposition process on non conductingsurfaces . Micro porosity, roughness and inhomogenites due to internal stress within the Electroplated Copper deposited layer are affected by the substrate pretreatment method and undercoating of metals by electroless method on plastics.

Brenner and Riddell and few investigators investigated autocatalytic nickel deposition using a sodium hypophosphite bath [1-3] and optimized the constituents of bath parameters like temperature, pH, nickel ion concentration, reducing agent concentration, the loading in the bath and agitation affect the Copper deposition rate[2-3]. Electroplated Copper deposition bath is known to have a major problem of sudden bath decomposition, which results in an increase in the operating cost of the process and the generation of environmentally hazardous waste [4]. Electroless Ni-Co-P electrolyte solution containing sodium citrate and lactic acid as complexing agents in order to obtain a relatively high deposition rate [5]. The coatings can be tailored for desired properties by selecting the composition of the coating alloy, composite and metallic to suitable specific requirements [6]. Another serious consequence of phosphite presence in the Electroplated Copper solution is its effect on the internal stress of Ni-P deposit. As the phosphite concentration increases, the internal stress becomes more tensile [7]. However, metallization of ABS plastics prepared through RP process is still at entry level. The presence of honey comb structure of ABS obtained by RP method is claiming that metallization on it will improve the mechanical properties considerably better than the injection molded plastics.

The developed coatings are found to increase hardness and tensile strength. The performance of coatings is to be screened by weight gain studies, Vickers hardness test, Tensile strength, corrosion resistant measurement by tafel polarization and AC impedance methods. The uniformity of the surface is a desirable

factor for improvement on mechanical properties for metalized ABS M30 which will be determined by micro structural analysis using FE-SEM images.

2. Experimental

The bath developed in the present study had the following ingredients.

$NiSO_4.6H_2O$ = 35 g/l ;NaH_2PO_2 = 27 g/l; Tri Potasium Citrate = 50 g/l ; Dextrin = 2 g/l
$NaNO_3$ = 1 g/l ; pH = 5.83 ; Temperature = 85±2^o C
Plating time = 10 minutes (2 microns) ;

Electrodeposition of copper

A proprietry acid copper bath was used with and furosemide drug as brightner to obtain Cu coatings on electroless Ni-P layers metalized for ABS M 30 Plastics.

Cu Coating thickness was 50-54 microns

3. Results and discussion

Weight gain studies

The results of Electroplated Copper coatings on ABS M30 plastics obtained by weight gain method and eddy current tests are placed in Table 1. It has been noticed that the incorporation improves the micro hardness values. The addition Copper coatings on fiber matrix enhanced the tensile strength because of its higher anti-galling effect than uncoated plastics. The rate of deposition for Electroplated Copper was calculated as50µm at the plating duration of 2 hours.

Table 1 The results of weight gain studies and eddy current test obtained for Electroplated Copper coated ABS M30 plastics

S.No.	Deposition timings (hrs)	Thickness (µm)		Inference
		Weight gain method	Eddy current test	
1.	2	50	49.8	Uniform coating thickness

Micro hardness measurements

The hardness of the Electroplated Copper coated ABS M30 plastics was measured by Vicker's hardness tester is given in Table 2. The higher hardness is due to the presence of non-metallic phosphorus in Ni matrix.

Table 2 Micro hardness values for Electroplated Copper coatings on ABS M30 plastics

S.No.	Coatings	Hardness (V.H.N) Load:100g
1	Electroplated Copper coated ABS M30	255

Corrosion resistance studies

Tafel polarization studies

The corrosion resistance experiments were carried out for Electroplated Copper coatings on ABSM30 plastics has been done by employing current-voltage measurements using polarization studies. The shift of Potential to less negative direction by coating indicated the corrosion protection nature of the surface. Also I_{corr} values have reduced to a greater extent by Electroplated Copper coatings and the results are presented in table 3.

Table 3 Current-Potential results for the rapid prototyped ABS M30 in sea water medium

Nature of substrate	Corrosion kinetic factors		Tafel slopes ($mV.dec^{-1}$)
	E_{corr} (mV)	I_{corr} (µA)	b_a
Copper Coated ABS M30	-560	1.82	82

Electrochemical Impedance Spectroscopy (EIS) studies

The calculated impedance values of Electroplated Copper coated ABS M30 plastics in 3.5% sea water medium are indicated in the table 4. It is cleared that R_t values are increased at the expense of double layer capacitance. The reduction in C_{dl} values have been accounted for the system following Warburg's impedance. It is evident that Electroplated Copper coatings on ABS M30 plastics prepared by FDM RP method can be useful for electronic circuits as this coatings exhibit EMI shielding effect due to the presence of phosphorus in Ni matrix.

Table 4 Impedance values of Electroplated Copper coatings ABS M30 plastics

Nature of deposit	R_t(Ohm.cm^2)	C_{dl}(µF. cm^{-2})
Copper coatings on ABS	800	1.28

Tensile strength measurements

The table 5 indicates that at strain rate of 2.48 in the case uncoated plastics resulted maximum stress at 27.78 MPa. For Electroplated Copper coated plastics, the rate of strain started at 2.48% and at 1.67 %, the ultimate tensile strength of 36.67 Mpa was achieved due to presence of Electroplated Copper coatings on ABS M30 Rapid prototypes. Hence it is understood that Electroplated Copper coated surfaces can be used as intermittent layers for developing surface finishing for automobile components.

Table 5 The results of tensile test obtained for Electroplated Copper coated ABS M30 plastics

S.No.	Nature of substrate	Tensile strain at Maximum Load (%)	Tensile stress at Break (Standard) (MPa)
1.	Uncoated	2.48	27.78
2.	Coated	1.62	36.67

Scanning Electron Microscopic studies

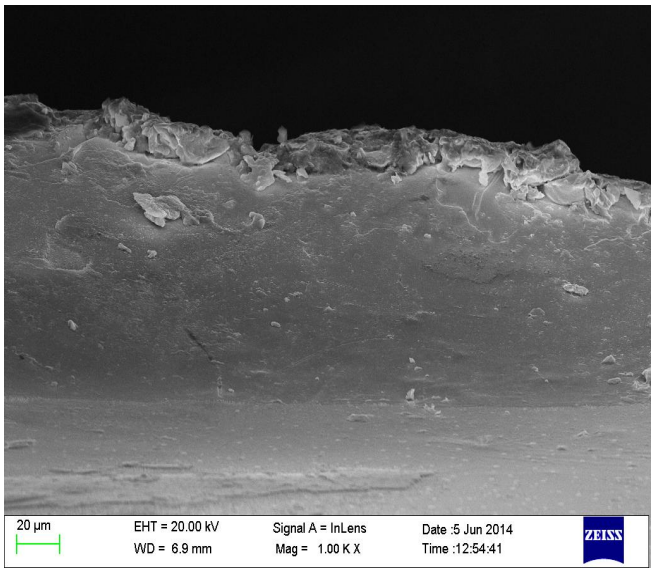

Figure 1.FE-SEM image of Electroplated Copper coated rapid prototyped ABS M30

Figure 1 indicates the cross-sectional SEM images of Electroplated Copper coatings obtained from citrate based bath. The appearance of layered structures with hanging of spherical particles aggregation indicating that the presence of Copper in the coatings.This entire coatings micro structures seem to be a caterpillar resting on a leaf. The black images are the conductive gold coatings on ABS M30 plastics. The top layer in the image is the indicative of reflected X-rays in SEM instrument and not on the coating systems.

4. Conclusion

An attempt has been made successfully to develop non magnetic coatings based on Electroplated Copper on ABS M30 plastics. The Electroplated Copper coatings improved hardness, corrosion resistance and tensile strength of ABS plastics. SEM images confirmed the existence of **Copper** in ABS polymer matrix. This investigation was found useful to develop an EMI shielding coatings for and PCB.

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