

# Characterization of ABS for Enhancement of Mechanical Properties

Vishal Saroha, B. S. Pabla, Sukhdev Singh Bhogal

*Abstract- Polymers have been increasingly used in industry due to their light weight, lower cost, reduced secondary operations, design flexibility and ease in manufacturing. However the mechanical properties like micro hardness and wear resistance of plastic restrict their applications. In this paper an effort has been made to improve the mechanical properties of plastic by applying a coating of Ni through electrodeposition method. There has been a remarkable improvement in the wear resistance and hardness after coating. The experimental investigation, analysis of result and conclusion are presented in this paper.*

*Keywords- Metallization, Electroless plating, Surface conditioning, Micro hardness, Wear rate.*

## I. INTRODUCTION

Plastic parts have properties like light weight, corrosion resistance and flexibility constitute advantage of plastics over metal. But at some areas metallic properties are required, for this plastic part can be coated with metal by metallization. Through metallization, the specific properties of plastics are enhanced by the deposition of metallic layer. The deposition of coating on plastic parts also improves aesthetics. Coating of plastics is normally undertaken for either decorative or functional purposes. Increase in hardness, wear resistance and properties including reflectivity, abrasion resistance and electrical conductivity enhance their application range. Plating on plastics therefore has been developed and widely involved in manufacturing printed circuit boards (PCBs), automobile parts and in the electromagnetic interference (EMI) shielding applications. Acrylonitrile butadiene styrene (ABS) is an amorphous and opaque thermoplastic polymer having chemical formula  $(C_8H_8)_x \cdot (C_4H_6)_y \cdot (C_3H_3N)_z$ . Acrylonitrile and styrene are polymerized in the presence of polybutadiene and the result comes out to be an ABS polymer. ABS consists of three monomers which provide the balance of various properties. Styrene provides rigidity to the copolymer, Acrylonitrile monomer provides heat resistance and butadiene imparts good impact strength. ABS is a non-conductive polymer so for electrodeposition it should be conductive. ABS is made conductive by applying a silver ink over its surface. The properties of ABS are shown in Table 1.

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**TABLE 1 Properties of ABS**

Properties	Test Method	ABS	Unit
Yield Tensile Strength	ASTM D638	31	MPa
Ultimate Tensile Strength	ASTM D638	33	MPa
Tensile Modulus	ASTM D638	2200	MPa
Flexural Strength	ASTM D790	35-58	MPa
Flexural Modulus	ASTM D790	1650-2100	MPa

ABS, acrylonitrile-butadiene-styrene, has found the widest acceptance as compare to other polymers in plating industry due to following advantages-

- Low cost
- Low coefficient of thermal expansion
- Ease of molding
- Good metal adhesion to the substrate
- Good appearance after plate

Very few data is available concerning electrodeposition of plastic but a lot of work has been reported on metal plating of plastic through electroless method. Equbal et al. [1] comparative study has been done on ABS material for three different processes of surface preparation for electroless deposition of copper. The three processes used are coating of ABS part with Al-paste, surface preparation by chromic acid and by  $H_2SO_4/H_2O_2$  on ABS part. A uniform copper deposition and best conductivity is obtained in Al-paste sample in hydrofluoric acidic bath. The technique of direct deposition of the Nickel on the polymers and investigated the microstructure of the metallization. During metal deposition two layers primary and secondary are formed. During the first 60 seconds both layers propagate at constant rate which depend on potential. Morphology of both layer are same whereas primary layer has relatively low conductivity due to lack of electrical contact [2].

Tang et al. [3] founded a new process for activation of surface of plastic. In this a biopolymer is used in fixation of metal catalyst by the chemical sorption. Activated surface of ABS for nickel deposition was dipped in nickel plating solution. Adhesion strength between the layer and surface is improved by this method. A continuous structure of layer is obtained at low cost. The electroless plating for coating of nickel is done on multi wall carbon nanotubes. The surface was prepared by chemical vapour deposition. First nickel nanoparticles were deposited at activated surface and then the layer was thickened depending on the reaction time. It has been observed that a thin and discontinuous layer is formed in 15 minutes of reaction time and as the reaction time increases the layer grew by self-catalytic effect and thick layer was formed [4].

Metallization of copper on ABS material which

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already has deposition of PPy (polypyrrole) can be achieved directly by copper electroplating. The deposition of polypyrrole is achieved through chemical method using iron (III) chloride as oxidant. Homogeneous and compact (without cracks) coatings are obtained with controlled thickness. Thickness of coating increases as the electrolysis time increases [5].

Teixeira and Santini [6] studied the surface conditioning of acrylonitrile-butadiene-styrene (ABS) using sulphuric acid and nitric acid solution in place of chromic acid baths because it causes environmental problems. A method to convert the non-conductive materials into conductive by applying enamel pastes of aluminium-carbon black or simply aluminium is founded. The surface of the ABS is converted to Al-seeded surfaces for copper deposition. A conductive copper layer has been formed over the surface in 10 minutes deposition time. The carbon black added to paste reduces the time taken to reach maximum conductivity and improves the adhesion strength of deposited layer [7].

Nigam et al. [8] studied that metallization of plastic by conventional means harms the environment and the workers due to the presence of the toxic substances such as chromium, palladium and sulphuric acid. In order to prevent this, wire arc thermal spray method is used for the deposition of copper on acrylonitrile-butadiene-styrene. It is founded that the deposition rate of this method is higher. This method is simple, non-toxic and can be used for thick coatings. An efficient process for electroless plating on ABS part which is free from chromium and palladium catalysers is developed. In this process poly acrylic acid is grafted on part. Due to the ion exchange properties of poly acrylic acid (PAA) the use of conventional surface conditioning method is eliminated. The adhesion obtained between the ABS surface and the metallic layer was good [9].

Electrodeposition is the process of formation of metallic coatings on conductive parts in a suitable solution by a charge transfer process. An external power source is required for the reduction of metal ion from the electrode. If the metal ion reduction is done by the compounds present in the solution then the process is called electroless deposition. Initially, the coating of Ag and Au was deposited only for decorative purposes. Later, this process was widely used for coating of tools and steel parts in order to increase hardness and wear resistance. The development of the electrodeposition of magnetic materials enables the compactness of magnetic recording system and development of micro fabrication techniques.

The deposition is carried out in an electrochemical cell consisting of a vessel with two or three electrodes. In two electrode cell the reactions are controlled by the current applied between a working electrode (substrate) and a counter electrode. In three electrode setup, the specimen is fixed in working electrode holder and a Pt wire is used as counter electrode. In potentiostatic electrodeposition, a reference electrode is needed to control the potential between working electrode and reference electrode. The potential of the electrode is measured and controlled by the potentiostat. This will reduce the error between the predetermined and the measured potential with the help of current flowing between counter electrode and working electrode.

## II. EXPERIMENTAL DETAILS

### A. Process Parameters

The various parameters which influence the deposition process are-

- Voltage
- Current Density
- pH of Electrolytic Bath
- Electrolyte Concentration
- Temperature
- Agitation

In the present research work, out of these parameters Voltage, pH of electrolytic bath and electrolyte concentration were selected as input parameters for the electrodeposition of Ni on the ABS substrate. The various levels of parameters selected are shown in the Table 2.

**TABLE 2. VARIOUS PARAMETERS AND THEIR LEVELS**

S.No.	Parameters	Level 1	Level 2	Level 3	Units
1	Voltage	1	1.5	2	Volt
2	pH Of Electrolyte	3.6	4.5	5.5	-
3	Titania Concentration	4	5	6	g/L

### B. Design of Experiments

In the present research work, the effect of single variable on the output of the process is examined. Three levels were selected for each of three independent parameters (voltage, pH of electrolytic bath and titania concentration).

**TABLE 3. DESIGNS FOR ELECTRODEPOSITION PROCESS**

Exp. No.	Voltage (V)	pH of Electrolyte	Titania Concentration
1	1	3.6	4
2	1	4.5	4
3	1.5	3.6	4
4	1.5	4.5	4
5	1.5	5.5	4
6	1.5	4.5	5
7	1.5	4.5	6
8	2	3.6	4

## III. RESULTS AND DISCUSSION

### A. Micro Hardness Test Analysis

Vickers micro hardness test were performed to evaluate micro hardness of coating. It was conducted on Vickers micro hardness tester. Three readings were taken at different places of coating and average of readings was considered for statistical analysis. Results for Ni coating on ABS substrate obtained after the experiment are shown in the Table 4.

**TABLE 4. MICRO HARDNESS TEST RESULTS**

S.No.	Input Parameters			Responses
	Voltage(V)	pH of Electrolyte	TiO <sub>2</sub> Concentration (g/L)	Micro Hardness (HV)
1	1	3.6	4	21.3
2	1.5	3.6	4	157.1
3	2	3.6	4	79.5
4	1	4.5	4	22.9
5	1.5	4.5	4	39.6
6	1.5	5.5	4	24.2
7	1.5	4.5	5	24.7
8	1.5	4.5	6	23

It is found that for Ni coated ABS, maximum micro hardness of 157.1 HV is obtained at input voltage of 1.5V, pH of 3.6 and TiO<sub>2</sub> concentration of 4g/L AT 50°C and minimum micro hardness of 21.5 HV obtained at input voltage of 1V, pH of 3.6 and TiO<sub>2</sub> concentration of 4g/L.

**B. Wear Test Analysis**

For wear test, cylindrical specimens of 12mm diameter and 50mm length of ABS substrate were prepared and nickel coatings were electrodeposited on ABS at designed levels of concentration of voltage, pH and TiO<sub>2</sub> in the electrolyte solution. Wear resistance was calculated for uncoated ABS substrate and coated ABS substrate by volume loss method at test load of 3kgf at 500 rpm for 3 minutes. The results of the wear test conducted on uncoated and coated ABS substrate are given in Table 5.

**TABLE 5. RESULTS FOR WEAR TEST**

S.No.	Parameters	Units	Uncoated	Coated
1	Cross Sectional Area (A)	mm <sup>2</sup>	113.09	113.09
	Initial Length (L1)	mm	50.4	50.5
	Final Length (L2)	mm	39.5	50.02
	Decrease in Length (L)=L1-L2	mm	3.63	0.16
	Volume Loss= AxL	mm <sup>3</sup>	410.5	18.09
2	Initial Mass	gm	3.6249	4.6480
	Final Mass	gm	3.6188	4.6531
	Mass Loss	gm	.0061	0.0051
3	Volume Loss (V)	mm <sup>3</sup>	410.5	18.09

S.No.	Parameters	Units	Uncoated	Coated
	Sliding Distance (D)	m	471.23	471.23
	Wear Rate =V\D	mm <sup>3</sup> /m	0.871	0.039

It has been observed that wear rate of coated substrate was 0.039mm<sup>3</sup>/m. Maximum wear resistance of 25.64 m/mm<sup>3</sup> on coated substrate was obtained. Wear rate of 0.871 mm<sup>3</sup>/m and wear resistance of 1.14 m/mm<sup>3</sup> of uncoated substrate was obtained.

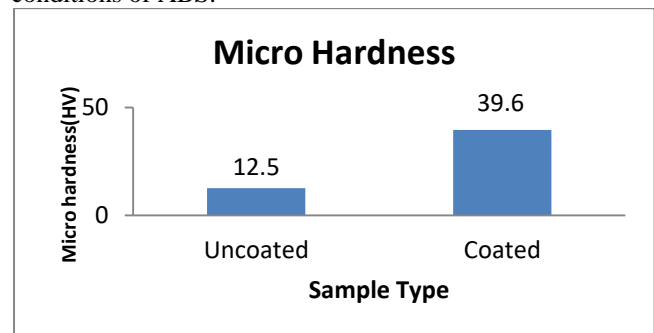
**C. Comparison of Micro Hardness**

Micro hardness of the coating is the important mechanical properties, which directly relates to the wear resistant of the coatings. Increase in micro hardness of the coatings can lead to better life of the part. Nickel coating increases the micro hardness of the ABS. Table 6 represents comparison of micro hardness for different substrate conditions.

**TABLE 6. MICRO HARDNESS OF UNCOATED AND COATED SUBSTRATE**

Response	Different Conditions of Substrate	
Micro Hardness(HV)	Uncoated	Coated
	ABS sample	ABS sample
	12.5	39.6

Figure 1 shows micro hardness obtained for different conditions of ABS.



**FIGURE 1. COMPARISON OF MICRO HARDNESS**  
Micro Hardness of uncoated ABS part was 12.5 HV, whereas nickel coated ABS was 39.6HV. It was observed that the micro hardness of the coated substrate becomes 316.8% of the uncoated substrate after the nickel deposition.

**D. Comparison of Wear Rate**

The wear rate of coating on substrate was measured in following conditions:-

- (i) Uncoated ABS substrate
- (ii) Coated ABS substrate

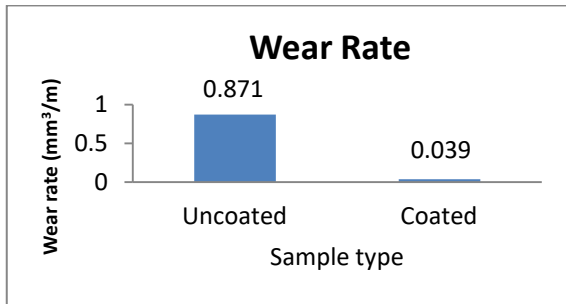
The comparisons of result of wear rate of coatings in above conditions are given in Table 7.

**TABLE 7. WEAR RATES OF COATING ON DIFFERENT CONDITIONS OF SUBSTRATES**

Response	Different Conditions of Substrate	
Wear Rate(mm <sup>3</sup> /m)	Uncoated	Coated
	ABS substrate	ABS substrate
	0.871	0.039

Decrease in wear rate was observed due to nickel coating on substrate. Figure 2 represents comparison of wear rate in different conditions of substrate in the graphical form.





**FIGURE 2. COMPARISON OF WEAR RATE**

Reduced wear of  $0.039\text{mm}^3/\text{m}$  observed on coated substrate and wear of  $0.864\text{mm}^3/\text{m}$  was observed on uncoated substrate. Decrease in wear of coated substrate was due to increased hardness of coating. There is 95.5% decrease in wear rate of ABS after nickel coating than the uncoated substrate.

#### IV. CONCLUSION

Polymers coated with metallic layer have many applications as compared to non-coated plastics. Most of the metal coating processes uses electroless deposition method in which the surface is prepared by the chemicals like chromium, palladium and sulphuric acid which are environment unfriendly. However, coating on polymer can be done by some methods which are simple and free from chromium and palladium catalysers.

Demand of ABS in industries has been increasing due to its less weight, flexibility and low cost. For wide applications of ABS Ni coating is deposited to make its surface hard and wear resistant. From the results, it is observed that micro hardness of the coated substrate becomes 316.8% of the uncoated substrate after the nickel deposition and there is 95.5% decrease in wear rate of ABS after nickel coating than the uncoated substrate.

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