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STUDY OF ELECTRO-MECHANICAL PROPERTIES OF FDM MATERIAL USING DIFFERENT COATING COMPOSITIONS

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Abstract: -Acrylonitrile Butadiene Styrene (ABS) material is engineering plastic with auniform distribution of butadiene on a matrix of acrylonitrile-styrene. ABS exhibits good toughness, better stability in dimensional field, ability to process, chemical resistance and low cost. But there are inherent flaws in terms of mechanical strength, electrical properties, upon that, the ABS is a non-conducting material. The research is to enhance the electro-mechanical properties of the Acrylonitrile Butadiene Styrene (ABS) material by developing a coating layer upon it. This paper aims to review the fabrication process, pre-treatment process, techniques of coating, enhancements in the properties are presented based on the literature published in recent years.

Keywords- Acrylonitrile Butadiene Styrene (ABS), Mechanical properties, electrical properties, techniques of coating.

I. INTRODUCTION

Plastic parts have advantages over metal because of characteristics such as less weight, better corrosion resistance and easily flexible. However, metallic properties are required in some areas, so the plastic part which is to be metallizedby plating with metal. An accumulation of the metal layer enhances the specific properties of plastics via metallization. Aesthetics can be enhanced by this coating technique. Plastic coating is typically done for decorative or functional reasons. The enhancement in the properties like reflectivity, abrasive property, conductivity followed by hardness, wear resistance can give access to wider applications. Metallised ABS has many applications like in electronics, petroleum, and national defence industries due to the combination of best engineering elastic and metal properties.Based on the pre-treatment methods, many studies have be carried out in order to investigate the effects on non-conducting objects.

An ABS material should be pre-treated which can be environment-friendly with chromium-free, palladium-free. The coating was done by electroless plating in order to have the conductivity in the ABS substrate [1]. Providing direct copper plating to the ABS by a mechanism like etching, activation, can improve the properties of the ABS material, provided slight changes is pre-treatment process [2]. The surface of ABS material can be made in the form of hydrophilicsurface with the etching process followed by providing a metal catalyst (palladium) on the ABS substrate [3].

Coatings on the ABS can be characterised based on their micro-hardness, surface roughness and current density. With the help of Taguchi method and ANOVA the most influencing parameter i.e., current density, can be determined [4].Molecular-grafting was used to achieve adhesion between the ABS substrate and the nickel coating film. With this method the corrosion resistant can be improved followed by spraying of silver films [5].With the help of Additive Manufacturing (AM) technology, the ABS material fabricated and coated with Nickel by electroplating process. Different interacting phenomena were involved and metallisation of ABS was studied thoroughly. The coating adhesiveness, coating thickness and surface roughness were enhanced by this electroplating method [6].

In order to reduce the steps and costs involved in plating the ABS by traditional method, the direct electroplating technique was implemented. Providing a nickel and copper coating to the ABS determined that thickness depends on electrolysis time, current density. Scanning Electron Microscopy (SEM) was used to investigate the layer thickness [7]. Pre-treatment on ABS can even be done with chemical roughening

and Nylon-6 with conductive paints, can be analysed based on strength like tensile and compressive strength. Having a uniform thickness of the coated layer, the mechanical performances were studied [8].

Polymerisation can be carried out on the ABS substrate with primary polyaniline thin film. Silver metal fragments were deposited on a substrate providing with increased electrical conductivity in order to have a direct electroplating of Nickel on ABS substrate [9].Selection of ABS can be based on different grades. So, ABS material selected on the bases of three different grades based on percentage of butadiene is studied. With this parameter the corrosion resistance is investigated [10].

II. METHODOLOGY

A. Fabrication of ABS

Fused Deposition Modeling (FDM) Technology uses specialised 3-D printing machines and production-grade thermoplastic to develop parts that have good strength, durable and dimensionally stable, high accuracy and repeatability of 3-D printers technology. Usually thermoplastic polymers are used as a filament form.

ABS can be fabricated by varying the machine parameter i.e., by taking different nozzle diameters, printing at higher temperatures, temperature of heated bed, speed of printing, layer thickness [18].Research can be based on the filling modes of the filament. This can be analysed for varying layer thickness corresponding to filling modes like rectilinear, grid, wiggle and honeycomb modes [22]. The previous research studies suggest that by varying the primary control parameters, the ABS can be fabricated. By varying the layer thickness along with raster angle [4].Different shapes specimen can be fabricated like dog-bone, rectangular shaped specimen. Based on one particular shape, specimen can be printed with different orientations like XY,YZ and ZX along with varying layer thickness [19]. The build direction is the important parameter in fabrication of ABS. So, setting the 3-D printer for horizontal build direction and considering the process parameters like layer thickness, infill density, raster angle, infill pattern can be fabricated [16]. As mentioned previously, the orientations can be varied. So, the material can be fabricated with X, Y or Z orientations along with different raster directions or raster angles [17].

B. Pre-treatment with ABS substrate

In the early 1960s, plating on plastics (POP) was the best substitute for metal finishing. POP, which was first established in Europe and North America, was a commercial success due to advances in chemical processing of ABS plastics.By first chemically etching the ABS surface with chromic acid-based mixtures, it was able to develop a highly decorative and well-plated ABS parts.

As we know that 3-D printed materials are mostly of cheaper cost with maximum speed printing capacity. Some common factors of 3-D printing parts is its lose adherence of the layers and irregular surface finish, so, the post processing is the necessity to enhance them. Post processing techniques such as heat treatment and vapor-polishing are used to address 3D printed materials for enhancement with poor layer adhesion and rough surface finish, respectively [23]. Some studies are based on properties development only with pre-treatment process. By having a silver (Ag) coated on ABS by Layer by Layer process (LbL) the Atomic Force Microscopy (AFM), X-ray Photoelectron Spectroscopy (XPS), Scanning Electron Microscopy (SEM) can be analysed [11]. After the fabrication of ABS material, it can be analysed based on Contact Angle (CA) computation by considering three different test liquids like deionized water, diiodomethane, and formamide followed by analysis of non-sanded and sanded 3-D printed parts.

C. Electroplating on ABS

By applying a thin, durable metal coating to an ABS surface, the electroplating provides a protective layer which in-turn helps in friction reduction and avoids tarnishingwhile also protecting the surface from wear and tear. Electroplating can make low-cost metals appear to be of higher quality. ABS plastic cannot be directly electroplated with metal/alloy on its surface because it is not conductive. As a result, electroless plating is required prior to electroplating. After roughening, sensitising, reducing, and accelerating degelling, ABS plastic will form a thin noble metal film on the object's surface.

So, having a copper coating and copper-GNS (Graphene Nano Sheet) coating by electroplating on ABS material can improve the conductivity property at different current densities. The effects of electroplating were also studied[1]. Corrosion is an important parameter and a natural process that convert metals into chemical stable forms like oxide, sulphide that has to be studied. The most important partcoated ABS material is the corrosion property of the material since it is to be coated with metallic substance. Sometimes, double-metal electroplating can be developed to study the changes in corrosion resistance property[5].Every time, an electroless pre-treatment is not required for ABS substrate. Instead, a conductive polymer-metal surface can be developed on the surface of the ABS substrate, such as primary polyaniline, which can be used to form a thin film on the ABS material via polymerization, followed by anaccommodation of silver particles using a reducing agent to achieve the highest possible conductivity. Furthermore, direct nickel electroplating is possible to gain an understanding of morphology and adhesive strength[9].

D. Spraying technique on ABS

Metallization is one of the techniques to coat the ABS. But this metallisation can be sometimes chemically hazardous to the material.So, novel metallization technique for accommodation of copper powders on ABS is developed which is free from hazards and provides higher deposition rate. ABS is one of the toughest plastics in market and the presence of lamellar-like structures in the coating was brought to light by SEM [4].

E. Electroless plating on ABS

In order to havethe use of a catalyst metal on the substrate for chemical sorption of a type of biopolymer resulted in a low-cost and environment friendly method for surface activation on ABS plastic.. XPS is used to investigate the reaction mechanisms for each step of pre-treatment for the ABS foils. This new method led to an enhancement wherechemical sorption provides the same adhesive strength to the plating surface and substrate as physical one does in the traditional sensitising activation process. So, once an activated ABS substrate prepared, it was further treated with electroless nickel plating solution by a dip process, which led to a nickel deposition.

Unlike the traditional sensitizing-activation method, this new method led to an enhancement wherechemical sorption has the same adhesive strength as physical one on the plating surface and substrate.A hydrophilic surface by developed by treating the substrate with the faintly etching solution devoid of chromium in it. With this activation method, the electroless nickel plating method yielded a tight, dense, and continuous structure of the Ni-P plating surface. [3]. There are techniques where a coating is done as Layer by Layer (LbL) process. To study,a spray assisted LbL process was designed as a series of spray passes in air or nitrogen atmosphere, with angle resolved XPS analysis of the component structure of Ag coatings.Some common tests like cross cut tests and 90^0 peel tests were conducted for the confirmation of the high adhesion at the interface coating surface and the ABS substrate, furthermore, because of chemical covalent bonding, which was introduced for other plating purposes on various types of materials were also studied.

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III. Results and discussion

Table 3.1 Properties and parameters of FDM materials

Author	Material	Coating material	Pre-treatment	Coating process	Mechanical properties	Electrical properties	Other developments
Songtan Yang et al. [1]	ABS	Copper and Copper-Graphene Nano Sheet (Cu- GNS)	Preparation of silver (Ag) film on ABS material.	Copper (Cu) and Cu-GNS electroplating solutions were prepared, and based on different current densities, substrate was coated.	-	Resistivity of the Cu-GNS was reduced to 40% as compared to Cu coatings.	Homog-eneous single silver film provided good conditio-ns for next step of eletcrop-lating.
Li Ning et al. [2]	ABS	Copper	ABS was subjected to etching process using the solution of CrO_3/H_2SO_4 and Pd^{2+} ions that is in-turn catalysed by Pd/Sn colloid solutions followed by dipping operation in accelerating solution.	An acid copper sulphate solution was used to coat the substrate.	-	Cu^{2+} ions is important to form a conductive layer which plays important role in determinin g uniformity of Cu-plating.	The Pd/Sn colloid catalyst has good dispersibility and a narrow particle size distribution.
Shrutee Nigam et al. [4]	ABS	Copper	Sand blasting technique.	Thermal spraying technique was implemented.	Hardness value got enhanced after coating. Higher the current density, stronger was the coating layer.	-	-
Meng Cao et al. [3]	ABS	Nickel	Etching process was carried out followed by dipping in acetic acid solution.	Nickel coating obtained by dipping substrate in electroless nickel plating solution.	Adhesive strength was enhaced on the pating layer	-	Ni-P was found to have a tight, dense, and continuous structure.
M. S. Khan et al. [6]	ABS PLA	Nickel	Etching or conditioning process followed by graphite	Activated ABS material was dipped in the electrolytic			Increase in raster angle, increases the surface

			coating.	solution.		-	roughness and plating thickness. Increase in air gap, decreases the surface roughness.
P. Sukwisute et al. [14]	ABS	CrN	ABS was rubbed by sand paper and rinsed followed by ultrasonic bathing	Pre-treated ABS substrate was coated with CrN using DC magnetron sputtering technique.	The coating's hardness ranged from 6.65 to 9.5 GPa. The Young's modulus increased from 30.87GPa to 44.25GPa.	-	-
Dong Zhang et al. [15]	ABS	CrN	Plating the ABS substrate by UV paint with spraying technique followed by curing process to avoid surface defects	CrN coatings were applied to ABS using the DCMS and HiPIMS techniques.	HiPIMS has superior corrosion resistance as compared to DCMS.	-	HiPIMS outperforms DCMS in terms of target ionisation rate.
I˙lyas Kartal [12]	ABS PMMA	Fluorinated organic–inorganic hybrid coating that is UV-curable.	After removing the protective foil, PMMA and ABS was washed using 2-propanol.	A developed formulations are applied on PMMA and ABS panels. Then polymerized by UV-curing	The addition of sol–gel precursors and perfluorinated urethane modified alkoxy-silane to pure epoxy acrylate resins improved their pendulum hardness, solvent resistance, and mechanical properties.		The surface became more hydrophobic after coating, and the contact angle increased dramatically from 660°C to 1060°C.

CONCLUSION

Plastic electroplating is one of the examples of the modern processing technology that work with new materials.These electroplated plastic products can achieve a better metal texture along with reduced weight, followed by improvement in its appearance and decorative purpose also, enhancement in the mechanical strength and show good performance in the field of electricity, heat, corrosion and many more. The main aspect is the choosing of a route which involves all the concepts like material properties, mechanical properties, costs of the materials, coating materials, electroplating techniques and dimensional accuracy, among other constituents.

Coating ABS with copper, chromium, or nickel improves its mechanical and electrical properties.Pre-treatment has the major effect on the metallization technique. With the help of metallization, the plastic gains sufficient hardness. The effects on ABS material can be studied depending on the coating techniques used. The coated ABS substrate can be used in different fields like automotive parts, aerospace applications and medical fields also.

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