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A review on Chemical Processes for Plastics substrates used in engineering industries

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Abstract : The application of chemical processess treatments over plastics based substrates have gained much importance owing to their improvement of life time , light weight after metal layers formation and suitable shapes . This article reviews the various surface modification technologies using chemical processes onplastics based substrates of engineering components. Recent work has shown that the surface finish, wear resistance, corrosion resistance, and mechanical properties of plastics can be improved selectively by using the appropriate surface treatment techniques while the desirable bulk attributes of the materials are retained. The proper surface treatment expands the use of plastics as a replacement to metals in the automotive industry. The research findings have been thoroughly investigated this review article.
Keywords: Chemical processess, surface modification, plastics,corrosion.

Introduction

Chemical Processes on plastic substrates to modify the properties

Surface Modification is considered as one of the best chemical processess on plastic substrates where the former involves the combination of physics and chemistry working together to modify materials to enhance surface properties. Surface modification is the act of modifying the surface of a material by bringing physical and chemical characteristics different from the ones originally found on the surface of a material.

Finishing or secondary operations encompasses a broad range of processes that change a manufactured part's properties. Engineers can employ finishing simply to improve a part's appearance and reshape it to meet certain dimensions, or use it to enhance functionality[40], such as increasing strength, chemical resistance, electrical conductivity and more. Secondary operations basically turn raw parts into finished goods. And this isn't limited to traditional manufactured parts. 3D printed parts can also be enhanced with secondary operations, but much like designing for additive manufacturing, different processes and best practices apply.

Determining the appropriate finishing operations depends on the additive process, material and geometry as well as the desired aesthetics and functionality.

Metallization is nothing but the process of applying metallic layers on non-conducting surfaces e.g. plastics. It is considered as an important technique in the automobile and electronics industries [25]. It is used for various purposes, such as electromagnetic shielding, weight reduction, electrical conductivity, formability enhancements, high impact resistance and weather proofing[62]. Chemical Plastics metallisation is a technology that has been attracting the interest of designers and major industry sectors for many years now. Consumer products which bear components with an attractive metallic look are fashionable and raise the perceived value of these end products.

Deposited metals onto the surfaces of non-metallic parts[18] called metallization processes such as electroless plating, physical vapor deposition and chemical vapor deposition ., the former is the most applicable for SLA plastic parts due to its possession of combined characteristics such as uniformity, simple operation, low cost and no damage to the substrate[32].

The plastic parts with critical shapes are being manufactured by melting the monomers of polymer and applying the same as individual layers that leads to a very strong formation of compounds which is known as additive manufacturing (AM) that requires post processing to improvesurface finish and mechanical properties[20,26].

A number of metallisation processes are available for coating plastics. Electroplating is the most common and provides a relatively easy, cost effective means of applying a metallic coating to plastics as well as metals. The use of toxic components such as hexavalent chromium in the process is an environmental issue[62]. Alternative technologies such as vapour deposition, thermal spray coating and chemical vapour deposition are claimed to provide solutions to the environment problems[32].

Metallization of polymers and polymer-based materials is used today in a large variety of technological applications rangingfrom the fabrication of printed circuits in microelectronics to decorative coating in general manufacturing[22].

The initial motivation for the development of processes for electroplating on to plastics came from the automotive industry. A range of components are now produced in plated plastics, including radiator grilles, window trim, name badges, front/rear lamp units, mirror housings, interior trim, and auxiliary lamp units[21].

Another finish option available for the stereolithography (SLA) process and additive manufactured processes in general is to have parts nickel plated after fabrication[22-25]. The process of adding a metal coating over an SLA model enhances the stiffness of the model. In addition, it improves the overall strength of the part. Then a coating of copper is applied via an electroplating process and finally a coating of nickel is applied via the electroplating process.

In particular, poor surface finish affects the function of additive manufacture plastic parts[21], depending on the geometry of the enclosing surface, the building strategy, layer thickness and orientation of the part; this drawback may outweigh the advantages of RP parts.

Other advantages that the process offers to additive manufacture plastic parts include resistance to moisture, temperature, humidity and corrosion[63]allowing the parts to be used in more aggressive and corrosive environments, which just would not be possible with the original plastic parts.

Weight Reduction is an exceptional attribute on many additive manufacture plastic parts, particularly within the aerospace industry[37].

Types of chemical surface treatment techniques

Electroplating and Conductivizing

Electroplating, also known as electrolytic plating is a process in which an electrical current moves metal ions through an acid bath from a source metal (the anode) to the substrate (the cathode). Electroplating requires that the substrate have a conductive surface to complete the circuit[60,61]. Conductivizing is typically done with either a base coat of electroless plating (usually nickel) or conductive silver paint. Preliminary tests showed that conductive paint provided a consistent conductive layer at a lower cost than ENP [32].

Electroplating is also a geometrically dependent process (the plate is thicker the closer the feature is to the anode), however the low cost and ease of use made it worthwhile to investigate. Extensive testing with copper electroplating showed that the electroplating process is considerably too geometrically dependent to be used in this process[59].

The parts showed a considerable gradient from the exterior (closer to the anodes) to the interior. Even at high currents (which increase penetration into the part) with large entry pores, the copper did not plate all the way to the interior of the part, leaving an unplated region on the interior features of the central struts[57].

Additionally, the plating quality was so low and unpredictable that the resultant parts would be useless for most applications. Due to these issues, electroplating was eliminated as a potential solution for the metal coating sub-function.

Plating is often applied for cosmetic reasons, but also increases strength and surface durability. In tests, the tensile strength of an electroplated FDM test bar increased 10 - 12 times and the results of the flexural tests showed an increase of 21 - 24 times [38,47]. The added strength makes electroplating a good fi t for automotive applications and the decorative value benefits home fixture and appliance applications[55]. ABS-M30, ABS and ABSplus have been tested for electroplating. Electroplating can also be applied to rigid and ABS-like PolyJet materials, including Digital ABS and the Vero family of materials. In order for the metal to properly adhere to the part's surface, it must be extremely smooth. An additive manufacturing project engineer will work with you to optimize FDM build orientation to minimize layer lines.[64-66]

Electroless Plating

Electroless plating, also known as autocatalytic plating, is powered through a chemical reaction, as opposed to an electrical circuit. No anode is required as a source metal because the source metal is already present in the plating solution. This also means that the source metal in the solution must be periodically replenished as it is used. Deposition is provided by metal ions in the solution that are reduced to their metallic state in the presence of a reducing agent. ENP is most common and best understood[32]. While electroless processes are more expensive than electroplating processes, they provide two advantages that are integral to this work. First, they can plate on non-conductive surfaces with the proper pretreatment. Second, and most important, they do not depend on the geometry of the workpiece and provide an even plating coat regardless of the complexity of the part. Because of these advantages, electroless plating was selected as the solution for the metal coating sub-function.[67-69]

The surface metallization or metal plating of polymer-based substrates is widely used today in a large variety of technological applications ranging from the fabrication of printed circuits in optoelectronic devices to decorative coatings in consumer products [38]. Through the metallization of plastic substrates, which are lightweight, design-flexible, and low-cost materials, value can be added to them by inducing reflectivity, abrasion resistance, electrical conductivity, and a variety of decorative effects.[71]

Vacuum Metallization, Metal Spraying, and Cathode Sputtering

Several technologies exist for coating metals onto polymer parts. Three widely used technologies are vacuum metallization, metal spraying, and cathode sputtering. In vacuum metallization, evaporated metal is condensed on the substrate. In metal spraying, metal isatomized and propelled toward the substrate by a high velocity gas jet. In cathode sputtering, a high electrical potential disintegrate the surface of the source metal, projecting the disintegrated atoms onto the substrate. These three technologies each have high capital costs and can be very expensive for small batches of parts. Most importantly, they are each geometrically dependent, limiting their applicability for complex geometries. [72-74]

Electrochemical Polishing

Electrochemical polishing also referred to as electro polishing, is an electrochemical process that removes material from metal parts through polishing, passivation, and deburring. It is often described as the reverse of electroplating; differing from anodizing in that the purpose of anodizing is to grow a thick, protective oxide layer on the surface of a material rather than polish. The process may be used in lieu of abrasive fine polishing in micro structural preparation, and is an inexpensive option for DMLS projects that are not tolerance dependent, creating a bright uniform finish. The extent to which electro polishing is successful depends upon the degree of preparation of the treated surfaces.[75]

Sealing

Plastic parts are naturally porous right off of the machine which presents an obstacle for containing gases and liquids. The solution is sealing the part with a water or chemical resistant epoxy coating. Vapor smoothing also seals an plastic part's surfaces, but is limited to applications with no higher than atmospheric pressure[43,45]. Two-part epoxy brushed onto the surface of a part generates an airtight seal and is resistant to many chemical agents. The other option is immersing plastic parts in epoxy resin and using a vacuum to infiltrate the epoxy to create a watertight seal and resistance to chemical agents and high temperatures.Epoxy coating and infiltration enhance plastic parts for many applications from prototype toend-use, including cooling lines for molding tools, fuel-holding, intake manifolds, ductwork and more.[73]

One of the main limitations of plastic parts is the limited strength characteristics which in turn limits their scope of application in many areas of engineering with respect to polymers. To overcome these limitations, automotive and aerospace industries have adopted electroplating procedures for creating mock-ups of modules to obtain stiffness and durability of plastic parts[35].

In the broad spectrum of additive manufacturing, a number of research works related to the topic of surfaces have been presented, but most of them have been concerned with the problem of the part itself for process optimization. That is, there have not been many approaches focusing on chemical treatment of surfaces on additive manufactured parts made of polymer. The following approaches are directly associated with chemical treatment of surfaces.

Hanus et al[1]reported the effect of modifications upon surface quality of the resulting casting.3D models made up of FDM technology for actual foundry production. The ABS model was tested with unmodified surface, chemically treated surface, blasted surface and blasted and etched surface together. The results of the experiment have confirmed it is possible to eliminate the effect of the stepped structure of the model surface on casting and surface finish. Surface quality of the castings with different stage of modification of ABS model improved from Ra 10 µm to 6.3 µm.

Daneshmand et al [2]analysed the wing and tail of a wind tunnel test model which has complicated sections, are produced by fused deposition modeling technology. In order to improve mechanical properties and surface roughness an electroplating is used on the surface of a RP model. Metal models along with fused deposition modeling models and electroplating models were tested in wind tunnels with different angels of attack. Results indicated that aerodynamic coefficients of electroplating model with a chromium coating was closer to metal model than those of AM model without electroplating. Substituting conventionally made parts with electroplating models, saves both cost and time. These models can be used in wind tunnel tests and aerodynamic data have acceptable quality. Using metal coating on AM models improved mechanical properties and surface roughness; accordingly aerodynamic coefficients are corrected regarding to AM models without coating and the results come closer to those of the real models or machined models.

Translucent plastics are commonly used in packaging for mechanical and electrical components. Although various materials are used in RP, translucent RP parts are not readily available from most RP processes

Sung et al[3]investigated by applying two post processing techniques in order to increase the optical transmissivity of the parts made of ABSi. First, elevated temperature was applied resulting in increased transmissivity while dimensional shrinkage was observed. Second, resin infiltration and surface sanding provided up to 16 percent transmissivity without shrinkage. These post-processes can be selectively applied to increase the transmissivity of ABSi parts. Thus, translucent FDM parts can be fabricated from the regular FDM process followed by the post-processes.

In this study, parts made from FDM ABSi were post-processed to increase transmissivity. Using the heating post-process, shrinkage may cause dimensional instability, and the maximum post-processing temperature was suggested to be 1800C. Using resin infiltration followed by surface sanding, transmissivity of the post-processed part increased up to 16 percent. Using this post-process, translucent FDM prototype can be made.

Shine Joseph et al[4],explored surface preparation methods for electroless plating of commercial photopolymer resins such as NanoFormTM15120 (NanoForm) and Objet FullCure®840 (Veroblue) in order to enhance the structural integrity of RP components. This study examined different surface preparation methods (chemical etching) and their effect on the surface morphology and mechanical strength of the polymers. It was observed that surface preparation of the resins significantly affected the mechanical properties and Ni plating of the substrate polymers. This is a critical step, since the Ni film takes on the surface structure of the substrate. A smooth surface with fine surface modification throughout will result in the best electroless Ni coatings with a minimum effect on mechanical properties.

Zarringhalam et al[5] investigated a series of tensile and impact test parts built using Duraform^{TM} powder (Nylon 12) on a 3DSystemsVanguard machine. The parts were subjected to various form of post-processing includingthermal treatment and infiltration with polymer infiltrants. The parts were subjected to tensileand impact tests with results showing that thermal post-processing achieved preferable resultswhen compared with infiltration. Heating above the glass transition temperature yielded superiorresults though as the melt temperature was approached issues of deformation arose.

The investigation also suggested methods of increasing inter particle contact area would result in improvements and heating of the parts yielded significant increases in both impact and tensile 'strength'.

Zhou et al [6]combined a hybrid design and fabrication method based on rapid prototyping (RP) and electrochemical deposition (ED) techniques to fabricate a pressure wind-tunnel model with complex internal structure and sufficient mechanical strength.

The stereolithography (SL) prototype components were fabricated on SL apparatus and roughened by chemical treatments. And then metal-coated SL components of the airfoil model were created by ED technique. Electrodeposited nickel coating has dramatically improved the overall strength and stiffness of SL parts and the hybrid fabrication method issuitable to construct the wind-tunnel model with complex internal structure and sufficient mechanical strength, stiffness. Interface adhesion of SL-coating is poor even if chemical roughening is applied. This method enhances the versatility of using RP in the fabrication of functional models, especially when complex structure with sufficient mechanical properties is considered.

The adhesive strength of roughened SL resin-nickelinterface is higher than the original. Coatings ofelectrodeposited nickel on SL prototypes result inincreases in Young's modulus, UTS, flexural modulus andstrength. The adhesion can be explained bymechanical anchoring of the metal coating on the SL surface.For the metal coating by the conventional electrodeposition processes, it is believed that the mechanical interlocking effect is the main bonding mechanism at the interface of substrate coating rather than the chemical bonding. The pores and cavities caused by roughening can increase adhesive area and improve the adhesion between the metal deposit and SL surface. Therefore, the adhesive strength of metal coating can be enhanced with the increase in the roughness of substrate surface The adhesive strength at 0.05mm becomes lowest, 2.6 and 5.7MPa for original and roughened SL samples, respectively. The Figure 6 also shows that the adhesive strength maximum is 5.3MPa at 0.15mm coating thickness for the original untreated SL parts. Nevertheless, adhesive strength attains a maximum value 11.1MPa at a coating thickness of 0.25mm for roughening SL parts

This implies that the adhesive strength of deposited coatings will be influenced by the electroposition process conditions with temperature, PH, and current density in addition to the surface roughness of SL substance. The mechanical anchoring of the metal layer in the various micro-pores and cavities is an important precondition for good adhesion of the metal coat on a roughened SL resin surface. Therefore, an optimum pore microstructure in the roughened surface will ensure good adhesion. These optimum pores and cavitations serve as interlocking sites, thus the adhesive strength to metal coating will be increased sharply.

Galantucci et al [7]made experimental study on the FDM acrylonitrile butadiene styrene (ABS) prototypes surface finish through chemical post treatment.In this chemical treatment method Dimethylketone (Acetone)' with 90% concentrated solution and 10% water was used and parts were immersed in diluted solution for 5 minutes and has led to a significant improvement in surface finish at the expense of a negligible change in the prototype size. Chemical post-processing treatment using dimethylketone solvents has been analyzed and yields a significant improvement of the Ra of the treated specimens. The chemical treatment is economic, fast and easy to use.

Dr. U. Chandrasekhar et al [8]investigated a synergistic application of rapid prototyping and metal plating technologies for development of micro air vehicles (MAV) with high strength-to-weight characteristic. Stereolithography and fused deposition techniques are employed to fabricate complex thermoplastic MAV prototypes with significant time-compression in production cycle. Electroless and electrolytic deposition processes deposited thin metallic foils of nickel and chromium over thermoplastic MAV prototypes.

Experiments were conducted on metal plated thermoplastic test specimens for evaluating the mechanical behaviour and structural integrity properties. The thickness of the deposited layer is varied in 50 – 250 µm range. Deposition of thin metallic foil over the surface of photopolymer infuses composite like characteristic into MAV prototypes and leads to high strength-to-weight characteristic in MAV development. Based on the experimental evaluation of residual stresses it is concluded that MAV prototypes need to be built with lower levels of layer thickness in stereolithography process. Reinforcement effect in case of thin section prototypes is more pronounced than in other instances confirming that that the fabrication and deposition process suggested by this present study is a suitable fabrication option for development of MAV airframes.

Jorge Mireles et al [9]made an attempt to use AM in more applications involving fluid pressure, parts manufactured with Fused Deposition Modeling (FDM) were sealed with a variety of sealants and tested under applied pressure. Manufacturing end-use parts using FDM has not been possible for fluid pressure applications due to part porosities, air gaps, and voids. Improving such build defects may allow FDM technology to be used for applications where fluids are applied at low pressures including hermetic housings for biomedical devices such as pacemakers and pipes/covers for thermodynamic systems such as heat exchangers

Post-processing a multi-feature, FDM test part made of ABS-M30 with industrial sealants had notable results individually, brushing and vacuum infiltration allowed the testpart to repeatedly hold a fluid pressure for at least 5 minutes at pressures of 276 kPa and 138kPa, respectively. The dimensional change can be controlled through userapplication during brushing and vacuum infiltration. Sealing method enables FDM-fabricated parts to withstand pressures up to 276 kPa (40psi) through brushing and 138 kPa (20 psi) through vacuum infiltration. Benefits of filling voids within FDM-manufactured parts enables end-use applications such as hermetic housings for biomedical devices and pipes/covers for thermodynamic systems such as heat exchangers. Precautions should be taken when using FDM manufactured parts in fluid pressure applications as voids may give rise to catastrophic failures such as exploding.

Addanki Sambasiva Rao et al[10] applied chemical treatment processes through Design of Experiments using different chemicals with variant conditions like different levels of concentration, time of exposure, temperatures and initial roughness, interaction effects of the process parameters on FDM parts (ABS). Results show satisfactory improvement in surface finish of FDM parts (ABS) with simple inexpensive and harmless chemical treatment processes.

Two different chemical were taken, i.e. Dimethyl ketone (Acetone) and Methyl ethyl ketone (MEK), in case of Acetone it was observed that the solution concentration, concentration-temperature interaction and the initial roughness are the most significant factors. For Methyl ethyl ketone chemical treatment process, it was observed that the concentration, concentration - temperature interaction and concentration-time interaction are the most important factors, surprisingly for MEK the initial roughness and time of exposure have negligible effect on the process. The process was applied for simple parts to complex free form parts. The optimum levels for the parameters for chemical treatment process are found out which shows drastic improvement in surface finish. The appearance of the finished parts is comparable to plastic moulded parts, the parts have glossy finish and the maximum curing time is about 2 to 4 hours.

The size of the specimen was measured before and after the chemical treatment process in order to account for the variation in dimensions due to chemical treatment process. The results show less than 1% deviation.

Saeed Daneshmand et al [11]attempted to improve mechanical properties and surface roughness an electroplating is used on the surface of a RP model.Metal models along with fused deposition modeling models and electroplating models were tested in wind tunnels with different angels of attack. Results indicated that aerodynamic coefficients of electroplating model with a chromium coating was closer to metal model than those of AM model without electroplating. Substituting conventionally made parts with electroplating models, saves both cost and time. These models can be used in wind tunnel tests and aerodynamicdata have acceptable quality.

Generally, the difference between aerodynamic coefficients of metal models and AM models is due to the surface roughness and generated dimension tolerance. It is thereby concluded that the FDM with chromium coating model exhibits better lift capability than the FDM model in the wind tunnel test. The study showed that between Mach numbers of 0.1 to 0.3, the longitudinal aerodynamic data showed very good agreement between the steel model and FDM model with chromium coating. The greatest difference in the aerodynamic data between the models at Mach numbers of 0.1 to 0.3 was in total axial force. The total axial force was slightly higher for the FDM model than the other models.

J.C. Rajaguru et al [12]investigated electroless nickel plating on PerFactoryTM rapid prototype model built on PerFactoryTM R05 material. PerFactoryTM R05 is acrylic based photo sensitive resin. Metallization of such a prototype can extend the application envelop of the rapid prototyping technique as they can be used in many functional applications. Unlike the electroless nickel plating on metal substrate, the process on acrylic resin substrate is not auto-catalytic. Hence, etching and activation are necessary for initiating the process. The final coating is then investigated using scanning electron microscope (SEM) together with energy dispersive spectroscopy (EDS) and x-ray diffraction (XRD) analysis to identify the morphology and structure of the coating.

The EDS analysis shows that the major chemical composition of the layer is 89% nickel and 11% phosphorous by weight for the specified electroless solution and the plating conditions. The XRD pattern of the coating shows that the layer of nickel-phosphorous alloy is in amorphous status. The morphology study using SEM investigation is performed and surface morphology shows the homogeneous layer of nickel-phosphorous coating. Furthermore, new nickel coating improves the surface hardness of PerFactoryTM model as much as 83%.

Eric J. McCullough et al[14]attemptedanacetone-based sealing method on FDM part to improve the surface finish of the part. Treatment to seal the surface of FDM ABS devices was performed with a soak in an aqueous acetone solution which had little effect on surface roughness.

Azhar Equbal et al [15]investigated metallization of ABS (acrylonitrile-butadiene-styrene) parts on flat part surfaces. These parts are fabricated on an FDM (fused deposition modeling machine) using the layer-wise deposition principle using ABS as a part material. Electroless copper deposition on ABS parts was performed using two different surface preparation processes, namely ABS parts prepared using chromic acid for etching and ABS parts prepared using a solution mixture of sulphuric acid and hydrogen peroxide (H2SO4/H2O2) for etching. After surface preparations using these routes, copper (Cu) is deposited electrolessly using four different acidic baths. The acidic baths used are 5 wt% CuSO4 (copper sulfate) with 15 wt% of individual acids, namely HF (hydrofluoric acid), H2SO4 (sulphuric acid), H3PO4 (phosphoric acid) and CH3COOH (acetic acid). Cu deposition under different acidic baths used for both the routes is presented and compared based on their electrical performance, scanning electron microscopy (SEM) and energy dispersive X-ray spectrometry (EDS). The result shows that chromic acid etched samples show better electrical performance and Cu deposition in comparison to samples etched via H2SO4/H2O2.

S.Kannan et al [16]attempted to identify and study the influence of electroplating layer thickness on the mechanical strength of Acrylonitrile butadiene styrene (ABS) samples developed from the FDM process.The electroplated samples were also subjected to acetic acid tests and surface roughness measurements to check for proper adhesion of plating. The electroplating thickness adopted was 60, 70 and 80 μm. The electroplated tensile samples indicated an increase in the tensile strength with the corresponding increase in the plating thickness. 60 μm sample exhibited lower ductility and 70, 80 μm samples exhibited enhanced ductility.Deposition of thin metallic foil over the surface of ABS infuses composite like characteristic into FDM prototypes and may lead into the development of high strength-to-weight characteristic in functional prototypes. Based on the experimental evaluation of tensile stresses it is concluded that FDM samples need to be built with higher levels of layer thickness in FDM process. Reinforcement effect in case of thin section prototypes is less pronounced and finally ends up in brittle failure. But with the increase in thickness the prototypes may acquire the properties of ductile materials.

S.Kannan et al [17]investigated the influence of electroplating on the impact and hardness properties of ABS plastics developed by Fused Deposition Modeling (FDM). The drop weight impact tests are carried on the normal and electroplated specimens (60 μm, 70 μm and 80 μm) at different drop weights of 0.89 kg, 1.395 kg and 2.33 kgs and a drop height of 400 mm. Impact dimension under the above said conditions for the electroplated specimens (70 μm and 80 μm) indicate that the electroplating leads to a considerable improvement in the impact strength of the ABS. Coatings of copper, nickel and chrome on ABS specimens lead to the increase in Impact strength and Hardness. The improvements in impact strength and hardness by electroplating on ABS parts lead to the development of functional prototypes and end use products.The limitations faced by

FDM prototypes with respect to strength have been overcome with the usage of electroplating technique. The electroplating also tends to give smooth surface of FDM parts. The hardness of the electroplated specimens has increased by 6.3%, 7.7 % and 11.2% with 60, 70 and 80 μm specimens respectively, as compared with nonplated ABS specimens.

Luan et al [18]reported the Chemical surface preparation specifically for stereolithography _SLA. Polymers. This introduces an efficient method for metallization of SLA polymers and enhances its performance in applications. X-ray diffraction _XRD. and atomic force microscopy _AFM. image analysis were applied to understand the phase composition and the micromorphologies of the substrate. Surface profiling and optical microscopy were applied for surface analysis to understand the progression of surface modification during chemical preparation process.

Chemical etching was proved capable of significantlyimproving the hydrophilicity of the surface ofSLA parts, which is beneficial for the subsequentpretreatment for metallization. The performance ofmetallization for RP is enhanced due to the uniformityof chemical etching.The improvement to the surface hydrophilicitymay be related to the creation and formation ofgrooved micro trenches on the surface due to thephase composition and structure of the SLA part.

Chandrasekar et al [19]explored the the direct use of 3D printed parts in design and development of micro aerial vehicles (MAV). Custom developed electro-chemical and mechanical processes are used to deposit thin structural nickel coatings on 3D printed test specimens and MAVparts. Residual stress and mechanical strength of coated 3D printed specimens are evaluated through experimental methods. Considerable improvement is realized in tensile and impact performance of the coated 3D printed parts. Findings from this study enable the MAV research teams to work with multiple design options and arrive at optimal solutions without severe time and cost penalties that are typically associated with conventional manufacturing procedures.

3DP techniques of FDM and SL are successfully applied for rapid prototyping of MAV parts and airframes. In the case of SL enabled fabrication, based on the experimental evaluation of residual stresses it is concluded that, MAV prototypes need to be built with build parameter of 100μm layer thickness to minimize the residual stresses. Coating procedures for deposition of thin nickel foils on FDM specimens are established. In the case of coated FDM parts, it is observed that, deposition of 30μm nickel layers on ABS substrates leads to significant improvement in tensile and impact performance without compromising the ductility.

Schmid et al [23]explored the current finishing methods available for plastic parts. Plastic parts are often coated to fulfil the desired functional requirements during product life.This may be for decorative purposes only, but also for functions such as improved tribology, wear and humidity resistance, UV- and light stability, hygienic and biofilm resistance. Moving SLS towards Rapid Manufacturing (RM) and making those parts competitive with parts produced by other techniques (e.g. injection molding) implies the adoption of a new quality of part finishing and coating strategy for SLS. The author proposed a promising method vibratory grinding and Dip coating for finishing SLS parts with variety of selected geometries planar surfaces, parts with edges and curving geometries. The vibratory grinding experiments were performed on a rotary vibrator.

Chil – Chyuan Kuo et al [35]addressed to improve the waxinjectiontool fabricated by FDM process by filling aluminumfilledepoxyresin . Theaveragesurfaceroughnessofwaxpatternscanbedrasticallyreducedfrom1710μmto276μm.Surfaceroughnessimprovementofupto83.85%wasachieved.

Jasgurpreet et al [42]reported the benefits of vapor smoothing on ABS replicas prepared byfused deposition modeling (FDM) for rapid casting of biomedical implants. There has been significant reduction in average surfaceroughness (average 82.74 %) of ABS replicas after vaporsmoothing. The average thickness of replicas after smoothingis 6.7103 mmwhich reduced as compared to thickness beforesmoothing (average 6.8642 mm).The results also indicates the increase in smoothing time and smoothing cycles is directly proportional in improving accuracy and surface finish of replicas. Hence, the vapor smoothing of FDM based ABS replicas can be used for preparing investment castings of patient specific implants.

Erik G. Geterud et al [43]fabricated Waveguide and Antenna Components by SLA polymers and plated by autocatalytic electroless copper. The plating on plastics method is applicable for various antenna configurations such as planar arrays, slotted antennas, horns and reflectors. On conductivity and attenuation measured, the performance is approaching that of standard aluminium waveguides with 0.0375 dB/cm loss, but with reduced weight and lower cost. SLA have been identified as a suitable method of rapid and lightweight 3D-prototyping of antenna- and microwave components when metallized.

Raja et al [51]developed 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 of 36.67MPa values signify that the coatings have firmly absorbed on ABS plastics. The morphology of copper coatings was found uniform and conformedby SEM images.

Raja e al [52]attempted to develop hard coatings based on Ni-Cr on FDM rapid prototyped ABS plastics coated with copper on EN. The hard coatings exhibited excellent hardness, corrosion resistance and tensile strength. SEM images confirmed the existence of Ni-Cr in ABS polymer matrix. This investigation was found useful to develop alternate coating materials for automobile parts replacing metals.

Conclusion

In this review, an overview of chemical treatment of surfaces used to improve the physical appearance, surface finish, aesthetic, physical and corrosion resistance properties of polymers based engineering components used in chemical industries have beenthoroughly reviewed .A detailed literature discussion on chemical processess treatments over plastic substrates has been summarized in this review article as reported by several researchers. This paper has put forwarded the development of novel chemical surface treatments on plastics substrates used in chemical and automotive engineering industries.

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