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FEASIBILITY STUDY: INVESTIGATION OF POLYMER NANO-COMPOSITES (PNC) MATERIAL FOR BIOMEDICAL APPLICATION VIA FUSED DEPOSITION MODELLING (FDM) ROUTES

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Abstract: Polymer nano-composites (PNC) have emerged as new materials which can show significantly enhanced mechanical properties over other polymer based materials through the addition of relatively small amounts of nano-scale additives. Rapid prototyping is impacting biomedical in several important ways. This research aims to investigate the potential of using new polymer nano-composites (PNC) as a raw material for fused deposition modelling machine (FDM). Here, PNCs materials containing a polyamide (PA) and nano particles (<5wt%) will be synthesis by mechanical blending using twin extruder compounder to produce 0.85mm diameter of PNC. Dispersion analysis of the nano particles in the polymer matrix will be analyzed during the preparation and synthesis process. Futhermore, molecular binding and mixture structure will be investigated by using XPS analysis & Laser Raman Spectroscopy. Material will be characterized for their thermal properties using DSC and processed using FDM, the commercial rapid prototyping (RP) machine. The RP processing parameters will be established and used to produce test specimens to evaluate the mechanical properties of the PNC.

1.0 INTRODUCTION

The PNC will be used for the model material created using Fused Deposition Modeling (FDM) FDM is a rapid prototyping technology that can be used with wide range materials including metals, ceramics, and also composites material. This research aims to investigate the potential of using new PNC as a raw material for modeling using FDM method. The evaluation will be carried out to some extent will be able to assist in the improvement of Biomedical products mainly used as a substitute for the knee. This study will use methods Fused Deposition Modeling (FDM) and polymer Nano-composite (PNC) which by this method will be able to produce biomedical products porous. With the creation of biomedical products, the indirect positive impact on biomedical industry and improve the performance of production equipment. The cost for the production of biomedical products will be reduced by using a less expensive material. The life expectancy of the product is likely to decline but have the same preponderance and lower costs. This study is focus to investigate the optimum composition of new PNC material which can be extruded in the FDM system, to determine molecular binding mixture by using XPS analysis, to investigate molecular structure of the mixture using Laser Raman Spectroscopy and to evaluate the processing parameters of FDM and mechanical properties of PNC material. The scope of study this research is Fused Deposition Modeling (FDM) process will used for develop new metallic and ceramic materials for rapid fabrication of functional components with higher mechanical properties. Run a nano dispersion analysis on the produce Polymer nano-composites (PNC) filament to prepare the material with a good dispersion of the additive in the polymer material. Using Transmission

electron microscopy (TEM) machine for analysis that additive disperse well and not agglomerate in one area.

2.0 LITERATURE REVIEW

RP technologies may be divided broadly into those involving the addition of material and those involving its removal. According to Kruth, the material accretion technologies may be divided by the state of the prototype material before part formation [1]. The liquid-based technologies may need the solidification of a resin on contact with a laser, the solidification of an electrosetting fluid, or the melting and subsequent solidification of the prototype material. The processes using powders compound them either with a laser or by the selective application of binding agents. Those processes which use solid sheets may be classified according to whether the sheets are bonded with a laser or with an adhesive. Work has been in progress in some universities and research institutions to develop new metallic and ceramic materials for rapid fabrication of functional components by FDM with higher mechanical properties. Rutgers University in the United States have carried out considerable work in the development of fused deposition of ceramics (FDC) and metals [2]. The properties of the mixed feedstock filament meet the flexibility, stiffness, and viscosity required for successful FDM processing. But the fabricated green parts need to undergo further processing to remove the organic binder and are subjected to sintering to achieve densification. While Weihong Z, have done a research by incorporating several different property modifiers including the short glass fibre, plasticizer and compatibilizer [3]. Bellini and Bertoldi have investigated flow behavior within straight liquefier head of the FDM process in order to process ceramic prototypes through fused deposition modelling [4]. Zhang and Chou have developed a finite element analysis model using element activation method to simulate the mechanical and thermal behavior of parts built on FDM [4]. They have also studied the model for residual stress, part distortion simulation, and tool-path effects on the FDM process. Ramanath et al carried out the research in modeling of extrusion behavior of bio- polymer in fused deposition modeling [5]. They developed finite element analysis model of the melt flow channel of FDM using the ANSYS software. Then they had studied the thermal and flow behavior of biopolymer by varying input conditions and analyzing the velocity, and pressure drop profiles at various zones of extrusion liquefier. Direct rapid tooling of injection moulding dies and inserts can be conveniently performed if a strong metal based feedstock material is available for the FDM rapid prototyping systems. At Swinburne University, they have carried out work to investigate the flow for the ABS- iron composite in liquefier head [6]. They have come out with promising information in developing the melt flow modeling of metal-plastic composites and in optimizing the FDM parameters for better part quality with such composites. The FDM technology thus offers the potential to produce the functional parts with a variety of materials including composite materials. But little work seems to have been done in the development of nano-polymer composites for advance functional application using the FDM technique. Development of this FDM materials based on nano polymer based composites offers a challenging task because of the specific requirement of feed stock filament and the FDM process. So far it seems that no work have been made to develop this type of materials for the FDM process.

3.0 METHODOLOGY

For this research there will be three main stages as to comply with the previous stated objectives which is the preparation for PNC composition, checking the PNC properties, and finally conducting the fused deposition modeling (FDM) for biocompatibility.

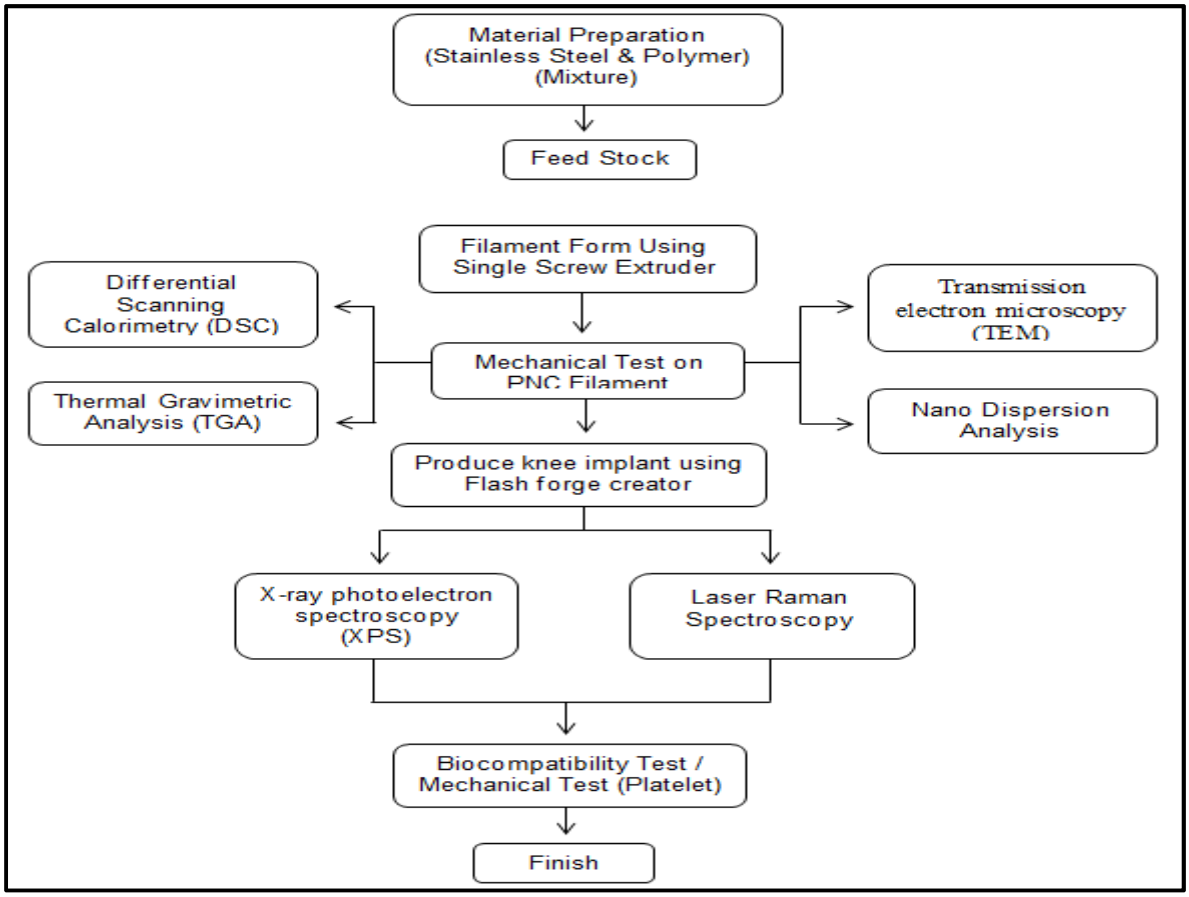

Figure 1: Flow Chart For This Experiment

3.1 Preparation for PNC composition

Several compositions of certain percentage of polymer and the additives will be design. This is to find the optimum composition between the polymer and additives which will produce the best PNC material. Then, the mixture will be synthesis using a single screw extruder to produce it into a filament form so it is compatible with the FDM device.

3.2 Checking the PNC properties

Molecular linkage and binding of the PNC will be determine using Transmission electron microscopy (TEM) machine and also by using XPS and Laser Raman Spectroscopy. This is to check whether there might be imperfection such as void or crack that occurs on the filament. This makes sure to get the full performance of the material.

3.3 Fused Deposition Modeling (FDM)

The PNC then is tested for processing behavior by using commercial FDM machine. After the machine ready, experiment will be start by processing single layer and then continues with multiple layers. However if there is error occurs during the analysis, certain modification will be conduct on the liquefier head and also the nozzle of the FDM machine [8].

3.4 Stainless Steel & ABS Polymer

3.4.1 Stainless Steel

Stainless steel 316L (SS316L) has been widely used in manufacture of vascular stents, artificial joints and other orthopedic implants due to its good mechanical properties and biocompatibility. However, the concern about the long-term use of SS316L implants in vivo has been brought up because the corrosion of stainless steel in the body can cause mechanical failure of implants. The surface property of SS316L will determine whether SS316L implants could function well for long-term use since the corrosion always starts from the surface.

3.4.2 ABS polymer

In this research acrylonitrile–butadiene–styrene (ABS) is selected as the material of experiment. ABS is one of the industrial polymers and among the five most highly consumed polymers in the word. High level of strength, rigidity, toughness and impact strength of ABS has led to its good mechanical properties. Its low shrinkage has made it to be used for producing parts with high accuracy and products of exceptional dimensional stability [11]. Shrinkage is an unwanted phenomenon in injection molding process which leads to changes in dimension and low part quality.

4.0 EXPECTED OUTCOMES

This research embarks new materials which are Polymer Nano-Composite will be produced. This material will exhibits great strength, good flexibility elongation and stiffness and also will be able to use in FDM machine without causing any problem. Potential applications of this material and rapid prototyping technique mainly manufacturing a customized product such as medical part (implants) which need require accuracy and properties excellency and also special design (custom made).

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