Manufacturing of polylactic acid nanocomposite 3D printer filaments for smart textile applications

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Abstract. In this paper, manufacturing of polylactic acid nanocomposite 3D printer filaments was considered for smart textile applications. 3D printing process was applied as a novel process for deposition of nanocomposites on PLA fabrics to introduce more flexible, resource-efficient and cost effective textile functionalization processes than conventional printing process like screen and inkjet printing. The aim is to develop an integrated or tailored production process for smart and functional textiles which avoid unnecessary use of water, energy, chemicals and minimize the waste to improve ecological footprint and productivity.

1. Introduction

Textiles have been part of our life for a very long time. We wear clothes all the time and they used to protect us against for example severe weather. Smart textiles are next generation of textiles which are becoming part of our life. They are intelligent materials and systems which sense and respond to their environment. Smart textiles can be used for many different applications such as medical reasons like breath and heart-rate monitoring, for protection purposes for soldier and firefighters and also for wearable electronics for high speed communications. It is believed that smart textiles will increase social welfare and they might lead to important savings on welfare budget.

The merge of textiles and electronics can be used for the development of smart materials that include a wide range of functions which is found in rigid and non-flexible electronic parts nowadays. However, there are many challenges to take up regarding flexibility, washability and integration of these materials. So, many researchers are focused on the development of flexible, stretchable and washable smart textiles with an increased comfort \cite{1–8}.

The combination of 3D printing production processes and nanomaterials have the potential to resolve this challenge and help to create an efficient production technology for smart textiles \cite{9}. This technology can be used in smart bandages, safety equipment for military use, virtual reality gloves, wearable with sensor and heat properties, medical needs, automotive and more. Based on the needs of the functional and smart textiles, printing process should be adjusted in order to print electronics and sensors as an integral part of the fabric. The printed material should have high enough functional properties including conductivity and elasticity.
3D printing is a term to define a technology applied for the rapid prototyping or rapid manufacturing of 3D objects directly from digital computer aided design (CAD) files [10]. The main differences between several 3D printing processes are in the way of layer deposition and used materials. Some methods melt or soften the material to produce the layers like fused deposition modeling (FDM), some compact and form a solid mass of powdered material by laser such as selective laser sintering (SLS), while others cure liquid materials using technologies such as stereolithography based on photo-solidification, a process by which light causes chains of molecules to link together forming polymers.

The most used technology in low-cost 3D printers is FDM. The method uses a plastic filament which is pushed the material through a heated extrusion nozzle melting. The method begins with software which processes an STL (stereolithography) or CAD (computer-aided design) file, mathematically slicing and orienting the model for the building process.

3D printing of complex geometries of nanomaterials layer by layer can lead to obtain greater control over material properties across part dimensions. So we have been trying to combine 3D printed nanocomposites with textiles to develop desired functionality in smart textiles.

In this research polyactic acid (PLA) has been selected as a matrix for nanocomposites. There are a number of reasons for increasing interest in PLA as a matrix in nanocomposites. Firstly, PLA is one of the most advanced biopolymers in terms of its commercialization. Secondly, it has high mechanical properties and can be melt processed with standard processing equipment. At the end biodegradability is an important factor that is being taken into consideration.

Present study developed method of manufacturing of conductive PLA composite 3D printer filaments for the Fused Deposition Modelling (FDM) manufacturing process. The break strength of the 3D printed material also has been investigated.

2. Materials and methods

Conductive 3D printer filaments were created using a melt mixing process from conductive polymer nanocomposites (CPC). Two different conductive fillers were applied including multi-walled carbon nanotubes (MWNT) and high-structured carbon black (HS-CB). MWNT contents between 0.5 and 5.0 wt.% and HS-CB between 1.5 and 10 wt.% was incorporated into PLA matrix. A 3D printer (WANHAO Duplicator 4/4x) with the maximum printing size of 22.5*14.5*15 with the nozzle diameter of 0.4mm was used to 3D print prepared filaments (figure 1).

![Figure 1. 3D printing of PLA nanocomposites on fabric](image)

3. Results

The resulting rods displayed sufficiently circular cross-sectional profiles (figure 2).
PLA nanocomposites for smart textile applications.

Also done to find the bending, tension and compression properties of 3D printed layers. Figure 3.

Effect of (a) filler type (b) extruder temperature on break strength of nanocomposite 3D printing of produced nanocomposites in different processing parameters such as extruder temperature. Results show that 5% CB 3D printed layer has lower break strength in compare with 2% CNT with the same conductivity (figure 3a). 3D printing of produced nanocomposites in higher extruder temperatures also brings about lower deposited layer break strength which shows higher brittleness of the 3D printed layers.

Figure 2. PLA nanocomposites 3D printer filaments

Figure 3. Effect of (a) filler type (b) extruder temperature on break strength of nanocomposite 3D printed layers

4. Future works
Different methods will be investigated for measuring electrical conductivity of produced rods to find the optimum measurement method. Dynamic mechanical analysis will be done to find the bending, tension and compression properties of 3D printed CPCs for smart textile applications.

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