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ABSTRACTS

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ADDITIVE MANUFACTURING TECHNOLOGY FOR SMART TEXTILES

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Introduction

Additive manufacturing technology has potential in customization of large-scale protective textile material production. Fused Deposition Modelling (FDM) 3D printing technology is cost effective, material efficient, agile, several materials can be combined in one-step process and therefore can be utilized in integrating electronics into smart textiles [1]. The technique has the ability to provide complicated 3D geometries from work wear safety materials to create systems directly on fabric, which are not possible to design with traditional 2D printed methods. We have studied FDM technology for two different applications: printing of antennas and circuits using electro conductive filaments and encapsulating electronic components. FDM technology for encapsulation of electronics onto textile is fast and cost effective prototyping of the smart solutions for textile industry and also enables manufacturing of complex and conveniently customizable electronic structures as protective clothing for industrial work wear [1].

For further utilization of technology, washing resistance, wear resistance, flexibility and adhesion of the print on the textiles plays the most important role. The main goal of this work is to test properties of the prints on the textile substrate and checking physical properties of TPU encapsulated electronic system for protective clothing.

Experimental

For printing, Fused Deposition Modeling (FDM) a well-known extrusion based manufacturing 3D printing technique is involved [1]. The polymer filaments is heated and dispensed through the nozzle onto substrate. FDM parameters, including bed temperature, layer thickness, dispensing speed, etc. were investigated before the final good quality prints for further testing were obtained. For testing commercially available PLA (Polylactic Acid) based conventional, graphene filled, copper filled electro conductive, and as protective material flexible TPU (Thermoplastic Polyurethane) filaments were used for printing on textile. As protective coating on textile substrate, TPU is a well-known material which has superior physical properties of durable, flexibility, abrasion resistant, water resistant, chemical resistant, temperature resistance. Two types of textile fabrics were used: Fabric 1, 70% PE (Polyester) and 30% Cotton, and Fabric 2, 50% PA (Polyamide) and 50% cotton blends.

Abrasion resistance is tested according to Martindale, using sand paper. For peeling/adhesion tests special sample arrangements were printed and the peeling performed using tensile tester. Flex tester was used to perform flexing tests. Tests were observed using freshly printed samples and also after several washing cycles at different temperatures according to standard (ISO 15797:2004).Encapsulation of electronics was performed printing the base layer of the TPU and PLA, placing electronic components and overprinting with the same polymer layer, design of 3D print is made based on the size of the electronic components encapsulated. TPU is used here for protective clothing especially for industrial work wear. Tests and the final product were designed to fulfill the industrial protective work wear standards. For the best printing performance, the thickness of base layer of the encapsulation system was designed to make adjustment with the 0.3 mm thick RFID tag. Then, antenna was located on the TPU base layer when it reached 0.8 mm thickness. The top layer was printed up to 0.6 mm to build an encapsulation case. The top and bottom layer of TPU encapsulation provides the mechanical resistance and protective coating from the influence of environment, such as humidity, water, high temperature, chemicals etc.

Results

Tests performed using Fabric 1 and Fabric 2 have shown clear influence of textile composition on the properties of interest. Comprehensively, fabric 2 has behaved better than fabric 1.

It has been found that nonconductive PLA and Graphene PLA provides better result in terms of abrasion resistance than conductive Copper PLA on both fabrics. 3D printed Copper PLA and flexible TPU on fabric 2 (50% PA, 50% cotton) provided best outcome for peeling tests before washing. One the other hand, best result for flexing resistance was found for Copper PLA on fabric 1(70% PE and 30% Cotton).Washing was performed at 40oC and 75oC temperatures. At 40oC, washing no significant change was found on any printed materials. PLA softens easily at about 80oC temperature. Washing of PLA up to 75oC lowered in abrasion resistance. In addition, Graphene PLA showed good abrasion resistance after washing at 750C. However, Copper PLA showed less abrasion resistance than Graphene PLA in both dry and after wash condition.

The availability of flexible TPU filament has made FDM 3D printed technology a candidate for integration of electronics on textile. Figure 1 shows 3D printed samples on textile substrate. 3D printed RFID antenna with conductive copper PLA (Figure 1 a), electro conductive circuit printed on textile (Figure 1b), TPU encapsulated UHF RFID tag antenna on textile substrate by 3D printing technology (Figure 1 c). The Copper PLA printed antenna (Figure 1 a) shows maximum 5-meter reading range and encapsulated RFID tag antenna works explicitly same like the normal tag condition and maintains the reading range up to 6-8 meters. The tests for washing properties of printed TPU and tag antenna encapsulated with flexible TPU filament on textile were able to fulfill protective clothing standards.

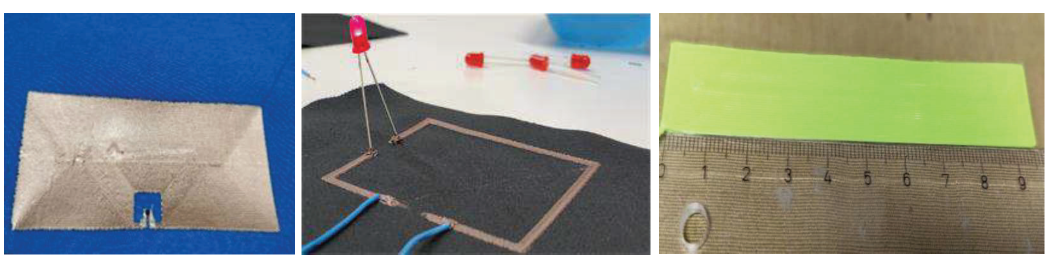

Figure 1. Different 3D printed samples on textile substrate: a) Copper PLA RFID antenna b) Copper PLA electro conductive circuit c) Encapsulated RFID tag antenna.

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Keywords: Protective clothing; 3D printing; PLA; Flexible TPU; RFID; Encapsulation.

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