FDM 3D printing of conductive polymer nanocomposites: A novel process for functional and smart textiles

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Abstract

The aim of this study is to get the benefit of functionalities of fused deposition modeling (FDM) 3D printed conductive polymer nanocomposites (CPC) for the development of functional and smart textiles. 3D printing holds strong potential for the formation of a new class of multifunctional nanocomposites. Therefore, development and characterization of 3D printable functional polymers and nanocomposites are needed to apply 3D printing as a novel process for the deposition of functional materials on fabrics. This method will introduce more flexible, resource-efficient and cost-effective textile functionalization processes than conventional printing process like screen and inkjet printing. The goal 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.

The contribution of this thesis is the creation and characterization of 3D printable CPC filaments, deposition of polymers and nanocomposites on fabrics, and investigation of the performance of the 3D printed CPC layers in terms of functionality. Firstly, the 3D printable CPC filaments were created including multi-walled carbon nanotubes (MWNT) and high-structured carbon black (Ketjenblack) (KB) incorporated into a biobased polymer, polylactic acid (PLA), using a melt mixing process. The morphological, electrical, thermal and mechanical properties of the 3D printer filaments and 3D printed layers were investigated. Secondly, the performance of the 3D printed CPC layers was analyzed under applied tension and compression force. The response for the corresponding resistance change versus applied load was characterized to investigate the performance of the printed layers in terms of functionality. Lastly, the polymers and nanocomposites were deposited on fabrics using 3D printing and the adhesion of the deposited layers onto the fabrics were investigated.

The results showed that PLA-based nanocomposites including MWNT and KB are 3D printable. The changes in morphological, electrical, thermal, and mechanical properties of nanocomposites before and after 3D printing give us a great understanding of the process optimization. Moreover, the results demonstrate PLA/MWNT and PLA/KB as a good piezoresistive feedstock for 3D printing with potential applications in wearable electronics, soft robotics, and prosthetics, where complex design, multi-directionality, and customizability are demanded. Finally, different variables of the 3D printing process showed a significant effect on adhesion force of deposited polymers and nanocomposites onto fabrics which has been presented by the best-fitted model for the specific polymer and fabric.

Keywords: 3D printing, Fused deposition modeling, Adhesion, Deposition, Computer-aided design modeling, Statistical design, Conductive polymer nanocomposite, Multi-walled carbon nanotube, carbon black, Piezoresistive, Pressure/Force sensors