Polymer-Carbon Nanotube Composites for Electrospinning and Photovoltaic Applications

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As well as being bendable and lightweight, flexible electronics and organic photovoltaic devices are highly attractive due to the ability to conform to unconventional locations for applications that range from medical devices to wearable technologies. Electrospinning (ES) provides an attractive platform for fabricating flexible devices due to producing fibrous materials with high surface area, low fabrication cost, and customizable mechanical properties.[1] For instance, a conductive electrospun mat can be produced by using a feed polymer composite doped with conductive nanomaterials. Conductivity in polymeric composites has been achieved though the addition of carbon nanotubes.[2] In this work, we utilized single-walled metallic carbon nanotubes (SWMCNTs) and polycaprolactone (PCL) to prepare a conductive polymer composite that will be used to produce low-cost electrodes for flexible electronics and an electrospun photovoltaic cell.

In our preliminary studies, conductive polymer composite films (*Figure 1*) and conductive ES fibers (*Figure 2*) containing PCL and multiwall carbon nanotubes (MWCNTs) combined with hydroxyl functionalized multiwall carbon nanotubes (OHMWCNTs) were prepared. The composite was used to fabricate two photoactive perovskite cells utilizing the PCL/MWCNTs/OHMWCNTs composite as an electrode. In this work, we prepared a SWMCNTs and hydroxyl functionalized single-walled metallic carbon nanotube (OHSWMCNTs) composite to lower the percolation threshold for conductivity and increase the maximum conductivity of the composite.

Presented work will include a design of experiments and conductivity optimization for a new PCL/SWMCNTs/OHSWMCNTs composite, computer aided equivalent circuit modeling, and fabrication and evaluation of reference perovskite solar cells and cells utilizing the fabricated composite as an electrode (*Figure 3*). Solar cells will be analyzed layer-by-layer utilizing atomic force microscopy, four-point probe, solar I-V scan, light spectroscopy, and scanning electron microscopy. In future work, we intend to use the designed composite to fabricate a triaxial ES perovskite solar cell consisting of the conductive polymer composite, a hybrid perovskite active layer, and a polymeric hole transport layer (*Figure 4*).[3]

[1] X.X. Wang, G.F. Yu, J. Zhang, M. Yu, S. Ramakrishna, and Y.Z. Long, Prog Mater Sci **115**, (2021).
[2] G. O'Bryan, E.L. Yang, T. Zifer, K. Wally, J.L. Skinner, and A.L. Vance, J Appl Polym Sci **120**, 1379 (2011).
[3] D. Liu, J. Yang, and T.L. Kelly, J. Am. Chem. Soc **136**, 17116 (2014).

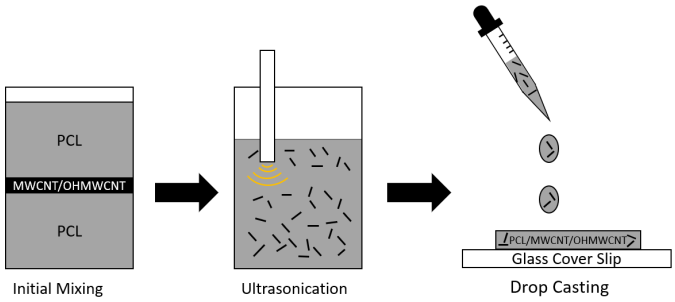

Figure 1. Process flow for the fabrication of PCL/MWCNTs/OHMWCNTs films. Current fabrication process yields composite films of 240 µm. Varied ultrasonication times and composite compositions affect final conductivity of the films.

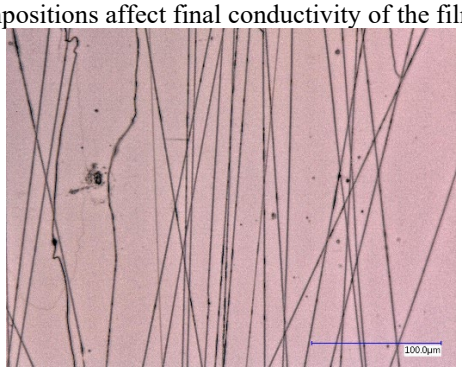

Figure 2. Optical micrograph of conductive electrospun fibers fabricated with the PCL/SWMCTs conductive composite.

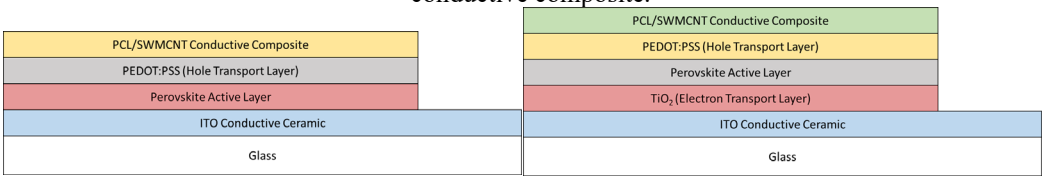

Figure 3: Visual representation of the three-layer and four-layer solar cells that will be modeled, fabricated, and analyzed throughout this work. Each of the cells will have reference cells (in which the PCL/SWMCNTs conductive composite electrode layer will be replaced with sputter deposited metallic electrode.

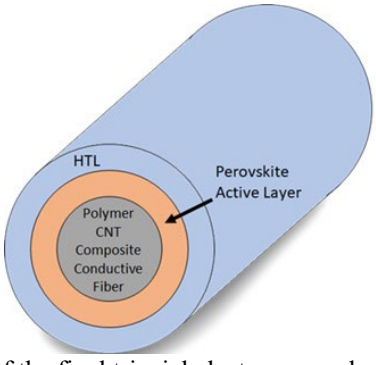

Figure 4: Visualization of the final triaxial electrospun solar cell configuration. The fiber configuration will be placed on a metallic electrode, and the polymer/CNTs conductive composite fiber will be used as the secondary electrode to complete the electrical circuit. We anticipate electrons being generated in the perovskite active layer and transported to the metallic electrode via the hole transport layer.