SHAP3D

Conducting Polymer Blends for 3D Printing

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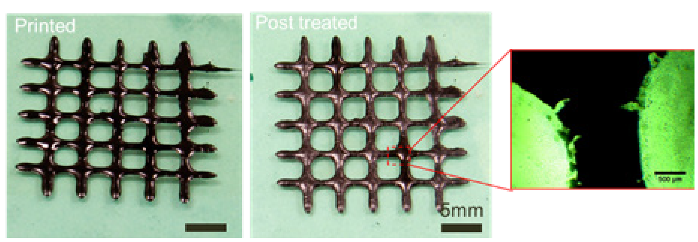
This project is directed to the incorporation of processable intrinsically conductive polymers into blends for 3-D printing. In a general sense, we aim to understand structure-processing-property relationships of multicomponent materials to develop and design new methods of additive manufacturing for composites, especially directed to the aerospace and electronics industry. Material requirements that include light-weight, mechanical flexibility, durability, and tunable conductivity are of interest. Applications include, but are not limited to, electrostatic dissipation, EMI shielding, resistive heating, flexible circuitry, and soft conducting material applications. Of special interest is the ability to form complex shapes that include grids, strain gauges, and thermocouple interfaces. In this work, we use the conducting polymer poly(aniline) (PANI) as a processable conducting polymer that can attain high transport levels. Benefits of this material include its low-cost, high conductivity, and unique redox properties. It is synthesized by chemical oxidation in the presence of an ionic dinonylnaphthalene sulfonate (DNNSA) dopant. Initial benchmarking experiments were carried out on blade coated films where we were able to demonstrate conductivities exceeding 100 S/cm. Chemical and physical characterization of the material demonstrated its high quality. Subsequently, we employed DIW printing of different blend compositions as we worked to optimize ink composition. Once a PANI:DNNSA ink was obtained with the necessary rheological properties was obtained using fumed silica nanoparticles as a rheology modifier, 3-D printed discs of the material approximately 1 $in.^2$ were printed. Single filaments were printed in order to determine the fundamental properties of the printed units, with widths on the order of 400 – 450 μm. After chemical treatment with isopropyl alcohol (IPA) we observed a decrease in width by approximately 70% and a noticeable enhancement in conductivity from less than 10-6 S/cm to 10-2 S/cm. Cracking was observed in the initial compositions. To overcome the cracking issues, high molecular weight polystyrene (Mw 20 – 30 MDa) was incorporated as a binder in the ink. Entanglements brought by the high molecular weight carrier polymer is a common strategy used in the polymer processing community to tune the mechanical properties of blend materials. We were able to determine that ink formulations with polystyrene concentrations exceeding 1.25 weight percent provided the critical level of material for the final ink composition. With this grid structures were printed with no cracking.



3D printed grid of PANI:DNNSA + fumed SiO2 + 20 million kDa polystyrene by using a premixed PS-20M/xylene solution