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Integrated Manufacture of Polymer and Conductive Tracks for Functional Objects Fabrication

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Abstract : The recent increase in the application of Additive Manufacturing (AM) of products has resulted in new demands on capability. The ability to integrate both form and function within printed objects is the next frontier in the 3D printing area. To move beyond prototyping into low volume production, we demonstrate a UK-designed and built AM hybrid system that combines polymer based structural deposition with digital deposition of electrically conductive elements. This hybrid manufacturing system is based on a multi-planar build approach to improve on many of the limitations associated with AM, such as poor surface finish, low geometric tolerance, and poor robustness. Specifically, the approach involves a multi-planar Material Extrusion (ME) process in which separated build stations with up to 5 axes of motion replace traditional horizontally-sliced layer modeling. The construction of multi-material architectures also involved using multiple print systems in order to combine both ME and digital deposition of conductive material. To demonstrate multi-material 3D printing, three thermoplastics, acrylonitrile butadiene styrene (ABS), polyamide 6,6/6 copolymers (CoPA) and polyamide 12 (PA) were used to print specimens, on top of which our high viscosity Ag-particulate ink was printed in a non-contact process, during which drop characteristics such as shape, velocity, and volume were assessed using a drop watching system. Spectroscopic analysis of these 3D printed materials in the IR region helped to determine the optimum in-situ curing system for implementation into the AM system to achieve improved adhesion and surface refinement. Thermal Analyses were performed to determine the printed materials glass transition temperature (Tg), stability and degradation behavior to find the optimum annealing conditions post printing. Electrical analysis of printed conductive tracks on polymer surfaces during mechanical testing (static tensile and 3-point bending and dynamic fatigue) was performed to assess the robustness of the electrical circuits. The tracks on CoPA, ABS, and PA exhibited low electrical resistance, and in case of PA resistance values of tracks remained unchanged across hundreds of repeated tensile cycles up to 0.5% strain amplitude. Our developed AM printer has the ability to fabricate fully functional objects in one build, including complex electronics. It enables product designers and manufacturers to produce functional saleable electronic products from a small format modular platform. It will make 3D printing better, faster and stronger.

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