DIRECT INK WRITING OF CUSTOM UV CURABLE RUBBERS WITH RADIATION ABSORBING PARTICLES AND ITS CHALLENGES

Jacob Mingear, LANL
mingear@lanl.gov
Jason Benkoski, LANL
Nick Baumann, LANL
John Bernardin, LANL

Key Words: Direct Ink Writing, UV Curable, Radiation Shielding, Elastomer, Thiol-ene reaction

Direct ink writing (DIW) is a type of extrusion-based 3D printing technique where the precursor material is typically a liquid ink that solidifies upon or after extrusion. A major benefit of this technique is that it allows for the printing of thermosetting polymeric materials, unlike the common fused deposition modeling (FDM) style printing where a polymer is melted on-demand from a filament. Further, DIW can allow for facile additions and homogenous dispersal of functional solid particles into the system. In this work, we synthesized and printed custom UV-curable thermosetting rubber structures with functional particles for radiation shielding purposes as seen in Fig. 1. Rubber blends of polyisoprene and polybutadiene utilized thiols to induce thiol-ene polymerization.

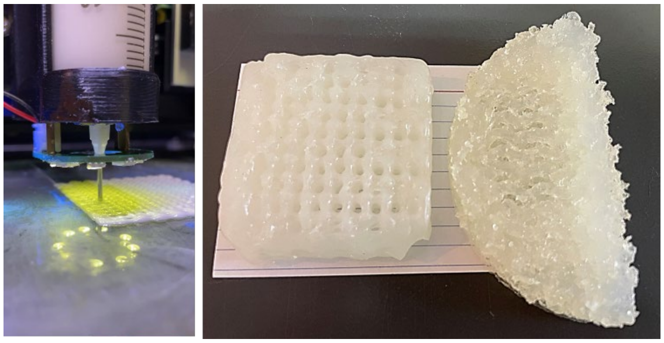

Figure 1 – (left) A syringe style print head with UV LED array curing the rubber ink as it exits the nozzle. (right) Two 3D printed rubber parts with 16 wt.% embedded boron oxide particles. The left part is composed of a grid pattern 2D lattice while the right part is composed of a gyroidal surface lattice.

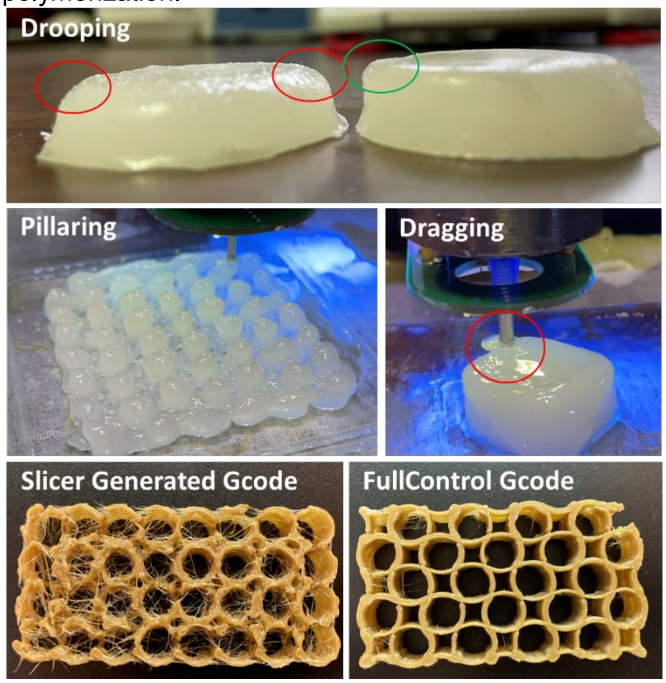

Figure 1 – Some challenges within this work associated with printing DIW UV-curable rubbers. Drooping will cause an unstable foundation. Pillaring occurs when surface tension overcomes intersections within a lattice pattern. Dragging occurs when material cures to the nozzle. The bottom figures show a 2D lattice using G-code pathing from a slicer tool versus FullControl [1].

DIW style printing issues and their mitigation is also investigated. There exists challenges in printing tall parts and fine lattice geometries as material is extruded in a partially liquid state, as shown in Fig. 2. Gravity and surface tension will cause unintended drooping or agglomeration. Drooping will easily result in failed prints without a stable foundation. When agglomeration occurs on a lattice design, the surface tension will create an array of pillars instead. The dragging issue occurs when printed material has cured to the nozzle which damages printed features and precludes future fine structures. These challenges were overcome by controlling the rheological properties and increasing rate of cure. G-code pathing can also be problematic because the material flow of a high viscosity liquid precursor cannot be easily halted. If the printer is directed to halt flow and then move its position to a distant spot, it will place material along the route to this position. G-code design must minimize abrupt position changes and favor smooth continuous pathing. FullControl G-code design software was used to facilitate smoother and more continuous printing paths [1]. Ultimately, large structural parts could be created out of DIW rubber blends of polyisoprene and polybutadiene.

[1] Gleadall, Andrew. "FullControl GCode Designer: open-source software for unconstrained design in additive manufacturing." *Additive Manufacturing* 46 (2021): 102109.