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3D Printed Optics

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Recent popularization of 3D printing has transformed engineering of materials. 3D printing of optical components offers an opportunity to produce affordable and accessible optics and the possibility of manufacturing optics and lenses that were otherwise not possible using conventional manufacturing techniques. Industrial 3D printing of optical components using highly specialized equipment, such as Polyjet, is available, however, may be expensive and does not allow rapid prototyping and experimentation[1].

We describe a method by which optical parts can be printed using plastic extrusion 3D printers. 3D printers, with the current settings, are not capable of producing optically clear parts due to the inherent issues with layer deposition. Classic extrusion based 3D printers deposit molten filament one layer at a time in a pre-programmed route resulting in a 3-dimensional structure. When printing with a transparent filament, bubbles accumulate between the layers of the deposited material resulting in prints that look cloudy or white.

In this paper we describe a method that allows material deposition with minimal accumulation of bubbles. We also describe post-print processing that allows the production of optically clear parts using extrusion based 3D printers. In order to eliminate accumulation of bubbles, the rate of filament extrusion is increased to 102-107% resulting in more filament extruded per layer than needed. Also the temperature of the hot-end is raised by approximately 10 degrees Celsius above the recommended temperature for the filament. This results in a prolonged molten state and continuous "raking" of the excess molten plastic by the moving hot-end to fill in any gaps. The forceful over-extrusion allows the release air-bubbles. The prints maintain the designed shape despite over-extrusion. The excess molten plastic is raked towards one pole of the print at the end of each layer (Fig.1). This pole may be placed in a non-critical area by design and could be removed later. Other settings include, reducing the nozzle size in the slicing software by up to half the actual nozzle size, reducing the layer height to 20-35 microns and turning off retractions and layer cooling fans. Post-processing is necessary to increase clarity. Despite a print with no bubbles, the outer shell will exhibit layering, streaking and irregularities (Fig.1). Smoothing of the outer shells (horizontal or vertical) can be done with sand paper polishing followed by coating with a resin that has a similar refractive index (Fig.2). Transparent filaments successfully tested were polyethylene terephthalate and amphora based filaments. Coating XTC-3D epoxy resin was possible for prints with polyethylene terephthalate.

References:

[1] Yi J, *et al*, Scientific reports **6** (2016)

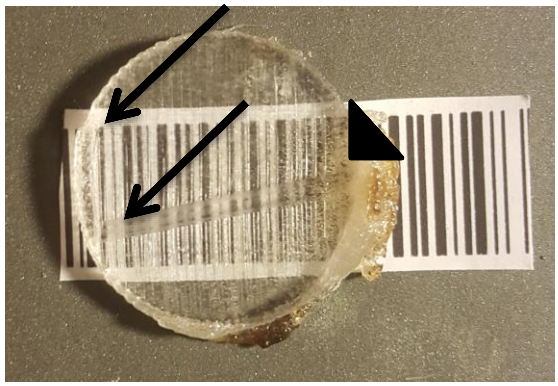

Figure 1. 3D printed clear disc showing surface irregularities (arrows). Excess extruded filament accumulates towards one pole that can be removed (arrow head)

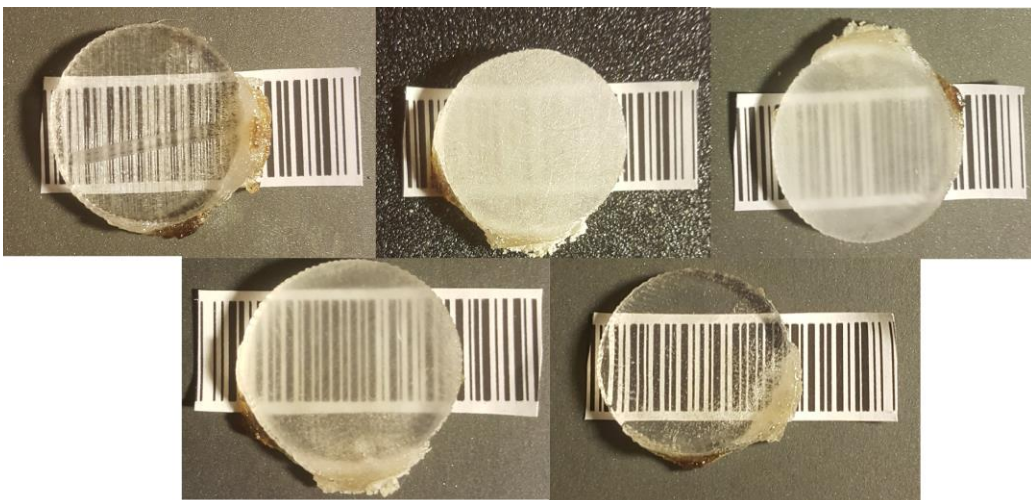

Figure 2. Progress with sanding and polishing. Epoxy coat applied (bottom right)

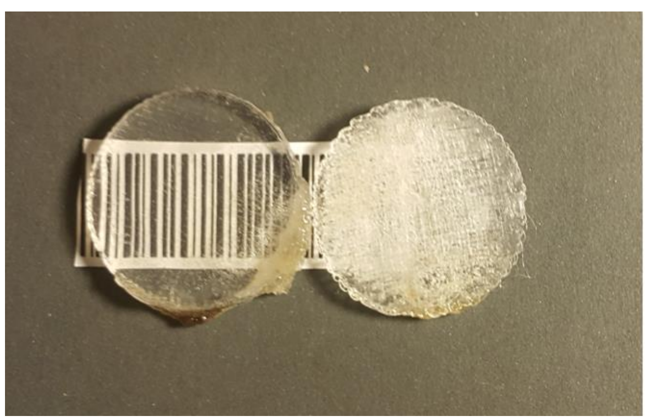

Figure 3. Comparison between forced extrusion settings (left) and standard 3d printing (right)

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