You’re Printing What? Where? The material stability and safety of 3D printing thermoplastic polymers for fused filament fabrication.

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FUSED FILAMENT FABRICATION

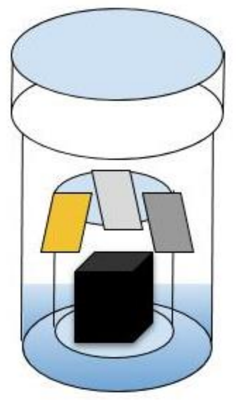
Fused filament fabrication (FFF) is the most popular method of 3-D printing. FFF printers extrude thermoplastic filament through a heated nozzle head to create a physical representation of a Stereolithography (.STL) file (created through a variety of design or scanning programs). Printers can use a variety of materials dependent upon the specifications of the printer, with most consumer-grade printers capable of handling a extrusion temperatures of 80° C to 300° C. This technology is affordable and offers new avenues in treatments, housings, and exhibition, however little testing has been undertaken to date on the suitability of the polymer filaments for heritage applications. This project sought to identify polymer filaments that may be considered for use with heritage collections by Oddy testing a set of commercially available filaments that are compatible with UF Libraries’ Fusion F400 pro-sumer model FFF printers.

ODDY TEST

This project used the Autry Museum Oddy Testing Protocols as found on the Conservation Wiki:

http://www.conservation-wiki.com/wiki/Oddy_Test_Protocols

1. Place sample into 10mL beaker
2. Hang metal coupons over edge of beaker
3. Place beaker into 45mL Kimax weighing jar
4. Pipe 0.5 mL of deionized water into bottom of jar
5. Apply light coating of Dow Corning high vacuum grease to ground glass fitting and seal lid
6. Place jars in oven set to 60° C
7. Check results after 28 days and compare to control set



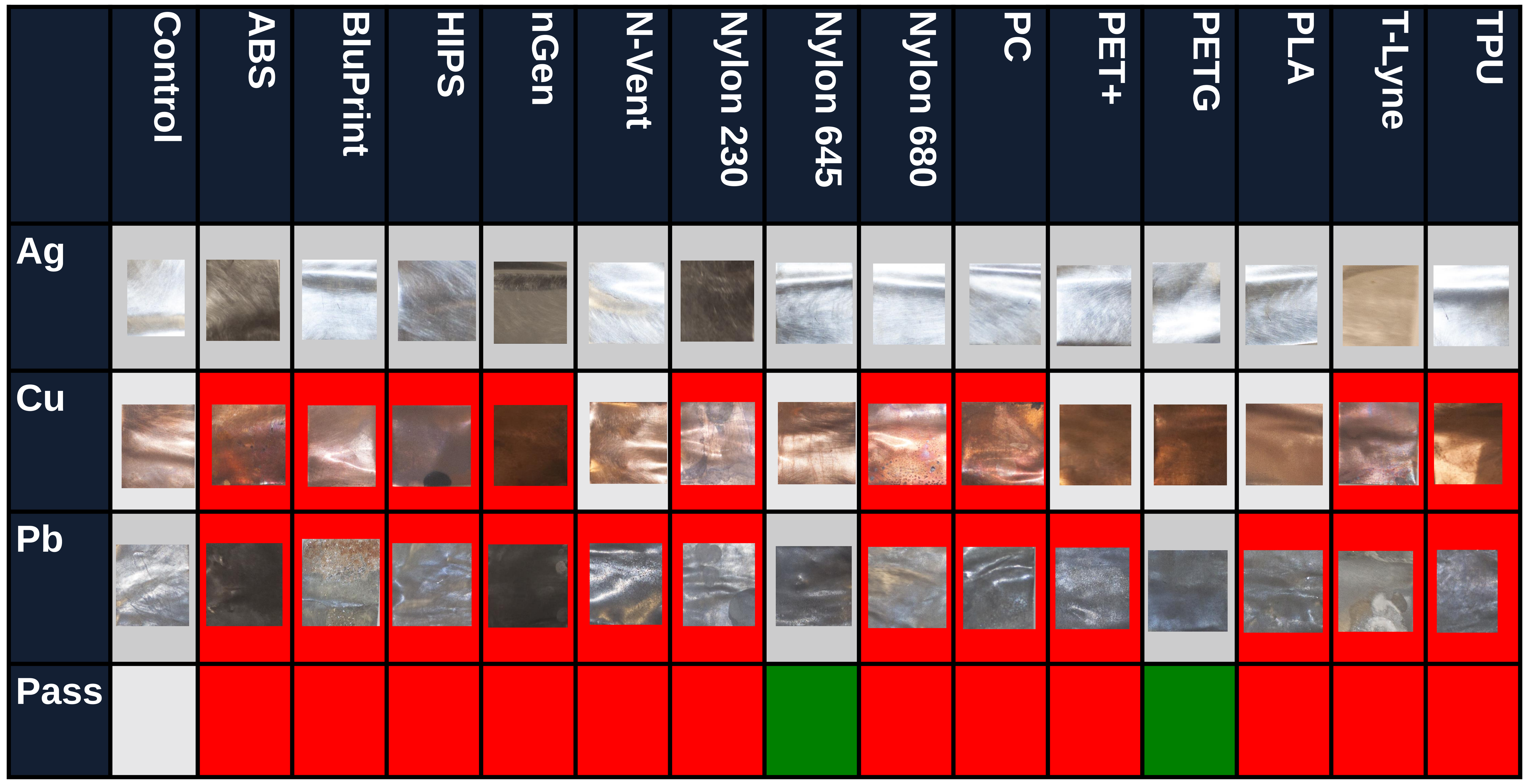
MATERIALS

All filaments were printed on a Fusion F400 3D printer in UF’s Marston Science Library’s printing facility in January and February of 2018. Samples were printed at supplier recommended temperatures onto heated beds. Samples were printed onto “rafts” to reduce the chance of contamination by the printing plate. Individual pieces were separated from the rafts and trimmed to fit in 10mL beakers.

Filament Type*	Color	Other Names
MatterHackers Natural PLA	Natural	
MatterHackers Natural ABS	Natural	
Clear PRO Series Thermoplastic Polyurethane (TPU)	Clear	
Taulman Natural 645 Nylon	Natural	
Taulman Nylon 230	Natural	
Taulman Nylon 680	Natural	
Taulman TECH-G PETG	Natural	Polyethylene Terephthalate Glycol
MadeSolid Clear PET+	Clear	Polyethylene Terephthalate
MatterHackers Polycarbonate (PC)	Natural	
Taulman BluPrint	Clear	Eastman Tritan Co-polyester
High Impact Polystyrene (HIPS) Dissolvable	Black	
Taulman T-Lyne Flexible	Natural	DuPont Surlyn (PE co-polymer)
Taulman n-vent Clear Transparent	Clear	Eastman Amphora AM1800
ColorFabb Clear nGen	Clear	Amphora AM3300

* All filament sourced from MatterHackers.com in Dec. 2017

ODDY TESTING RESULTS



CONCLUSION

The testing found that most commercially available filaments are not suitable for use with heritage materials. 12 of the 14 filaments failed the Oddy testing. All 12 showed corrosion, white accretions, or rust colored accretions on the lead coupons indicating organic acids, aldehydes, or acidic gases. 9 of the 14 filaments also had corrosion on the copper coupons indicating chloride, oxide, or sulfur compounds.

Only the Taulman Natural 645 Nylon and the Taulman TECH-G PETG filaments passed this round of Oddy tests. While many of the tested filaments were selected because their polymer base has passed Oddy testing in other formulations, these commercial filaments may contain additives. The testing had results similar to those found by Flexer, Larkin, and Carter[1] on PLA (fail) and Nylon (pass), but the qualitative amount of corrosion documented was less extensive than in those earlier tests.

Continued testing and sourcing of filament is recommended for heritage applications.

[1] G. Flexer, N. Larkin, and J. Carter, “How is the profession using new technologies, techniques and science? Current and potential uses of 3D printing in the profession: looking at the suitability of plastics” presented at ICON16, Birmingham, UK, June 17, 2016.

FURTHER RESEARCH

While the suitability of FFF polymers for use in collections was the focus of this project, there are other substantial concerns about the safety of FFF printing on human health, as the thermoplastic filament undergoes partial thermo-decomposition during printing releasing Ultra-Fine Particles (UFP) and Volatile Organic Compounds during printing. The rate of UFP emissions is related to the temperature of extrusion as found by Bharti and Singh.[2] Recent research by Wojtyla, Klama, and Baran[3] have found that ABS, PLA, and Nylon emit potentially dangerous compounds such as styrene, butanol, cyclohexanone, ethylbenzene, and other VOCs during printing. These substances raise concerns about the suitability of bringing FFF into conservation labs that may not be able to isolate or filter UFP/VOCs sufficiently to minimize risks to staff members. When printing, users should have good ventilation or wear appropriate PPE.

[2] N. Bharti, N. & Singh, S. 2017. Three-Dimensional (3D) printers in libraries: Perspective and preliminary safety analysis. Journal of Chemical Education. 94(7): 879-885. DOI: 10.1021/acs.jchemed.6b00745

[3] S. Wojtyła, P. Klama & T. Baran (2017) Is 3D printing safe? Analysis of the thermal treatment of thermoplastics: ABS, PLA, PET, and nylon, Journal of Occupational and Environmental Hygiene, 14:6, D80-D85, DOI: 10.1080/15459624.2017.1285489

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