POLYMER CHARACTERIZATION FOR ADVANCED 3D PRINTING

Installation, Characterization for Multi-Material Soft Polymer 3D Printing

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Printer Specifications

Features

- Three print nozzles for multi-material and scaffolded printing
- Ability to print soft plastics (TPU)
- Liquid-cooled print nozzles for precise temperature management
- Temperature-controlled chamber for optimum layer-by-layer adhesion
- HEPA filtration system for particle-free and odor-free production

Sample Print Materials

Body Materials:

- ABS
- ASA
- PCABS
- TPU - *soft plastic*
- PETG - *high performance*
- PPS: nPower - *high temperature, chemical resistant*

Scaffolding (Support):

- SSU00 – *not soluble*
- SSU01 – *soluble in NaOH solution*
- SSU02 – *softens in warm water*
- SSU03 – *dissolves in water*

Software

- **KISSlicer** – *open-source slicing software, converts 3D model (.stl) to layer-by-layer print instructions (.gcode).*

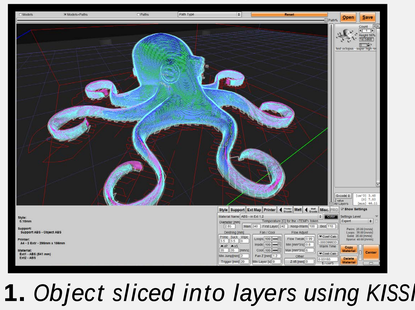

Figure 1. *Object sliced into layers using KISSlicer.*

- **Repetier Server** – *wireless printer control.*

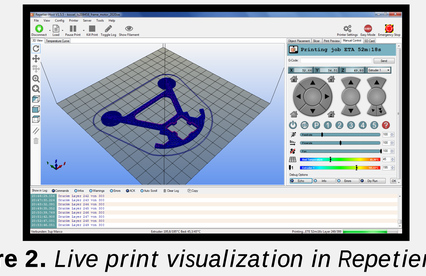

Figure 2. *Live print visualization in Repetier's UI.*

Objectives

- Install 3D printer in Gleeson 202
- Familiarize with 3D printing software
- Analyze polymers with established printing profiles to find correlations
- Tweak/Develop printer operating profiles for additional polymers
- Assist other expo teams: print bespoke, on-demand parts (hours) rather than using machine shop (weeks)

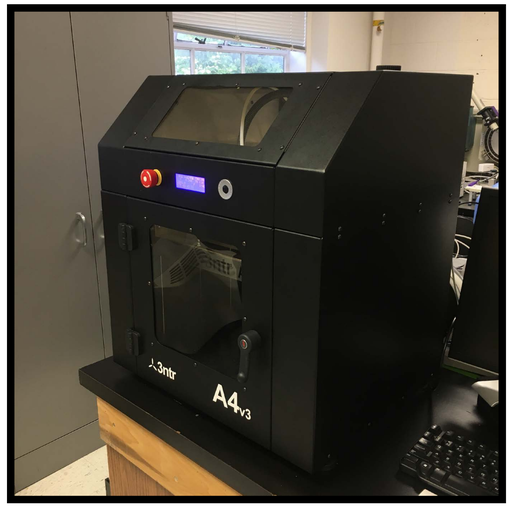

Figure 3. *3ntr model A4v3 3D Printer in Gleeson 202.*

Polymer Characterization Results

	Differential Scanning Calorimetry (DSC)			Thermogravimetric Analysis (TGA)		Melt Flow Index (MFI)			Operating Conditions		
Polymer	**Structure**	**T_g (°C)**	**T_m (°C)**	**% Polymer**	**% Filler**	**MFN**	**s.g.**	**V (mm^3/s)**	**Max OP (°C)**	**Printing Temp (°C)**	**ΔT**
ABS	amorphous	105	---	89.4	10.6	6.6	1.05	10.4	85	240	155
nPower	semi-crystalline	48	276			48.1	1.27	63.1	210	320	110
TPU	amorphous	-28	---	83.6	16.4	16.5	1.19	23.2	95	220	125
PCABS	amorphous	111, 141	---	87.5	12.5	34.1	1.13	50.3	109	260	151
PETG				93.8	6.4	20.2	1.27	26.5	75	235	160

- No correlation exists between suggested printing temperature and flow rate
- Polymer composition seems largely irrelevant
- Potential correlation: printing temperature ≥ maximum operating temperature + 110°C
- Amorphous polymers have no melting point, making correlation difficult

Acknowledgements

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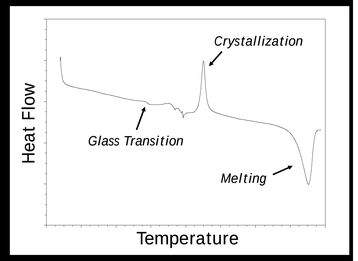
Moving Forward

- Complete polymer characterization database
- Develop operating profiles for new polymers
- Install delivery mechanism for 2nd (soft) polymer
- Establish off-campus printer access
- Develop simple SOP for future users
- Investigate mechanical effects of print density

Testing Equipment

Differential Scanning Calorimetry (DSC)

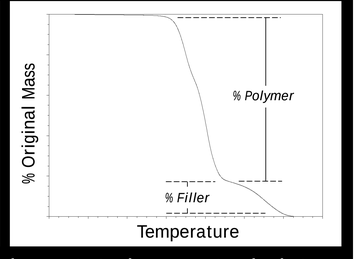
- Measures heat flow into polymer sample while ramping up temperature
- Yields melting point, glass transition temperature, relative crystallinity



Figures 4,5. *DSC and annotated conceptual plot.*

Thermogravimetric Analysis (TGA)

- Measures mass change while decomposing & combusting polymer
- Yields composition: polymer, organic filler, inorganic additives



Figures 6,7. *TGA and annotated conceptual plot.*

Melt Flow Index (MFI)

- Measures liquid polymer flow rate at a given temperature and applied force
- Yields mass flow rate (units: g/10 min)

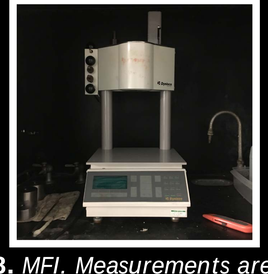


Figure 8. *MFI. Measurements are manual.*