PLA RECYCLING FOR 3D PRINTING

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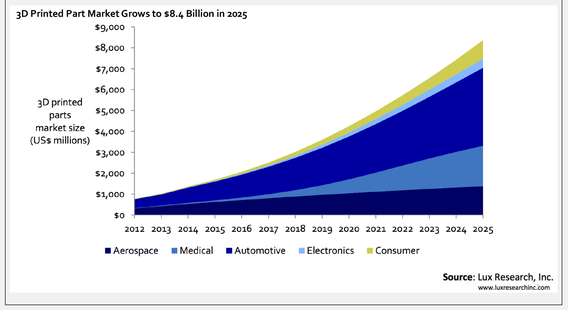
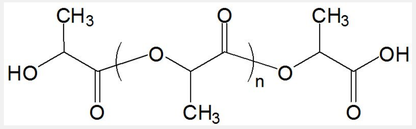
Goal: Develop a process for recycling polylactic acid (PLA) 3D prints to be reused as 3D printing filament

Purpose: Recycling will minimize waste in the growing 3D printing market



PLA Background

- Formula



- Biodegradable thermoplastic
- Glass transition temperature from 40 to 70 °C
- Melting temperature from 157 and 180 °C

Challenges:

- PLA absorbs moisture which breaks down polymer upon heating
- PLA is highly variable, depending on factors such as grade and manufacturer

Virgin PLA Pellets

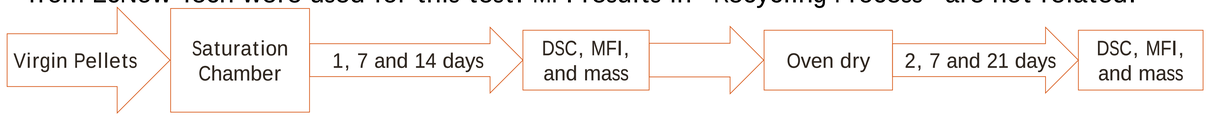
Ground Failed Prints

Terminology

- Differential Scanning Calorimetry (DSC) – Heat cycles to determine glass transition and melting temperature
- Melt Flow Index (MFI) – Forces melted polymer through a capillary to determine viscosity, which correlates to molecular weight
- Extrusion – Polymer is melted and forced through a nozzle which produces filament

Saturation Characterization

- Determine influence of high moisture content on PLA MFI and response to drying. PLA pellets from EcNow Tech were used for this test. MFI results in "Recycling Process" are not related.



Effect of Moisture on MFI

DSC Results

DSC testing showed that crystallization behavior, glass transition and melting temperatures did not change with moisture content or drying.

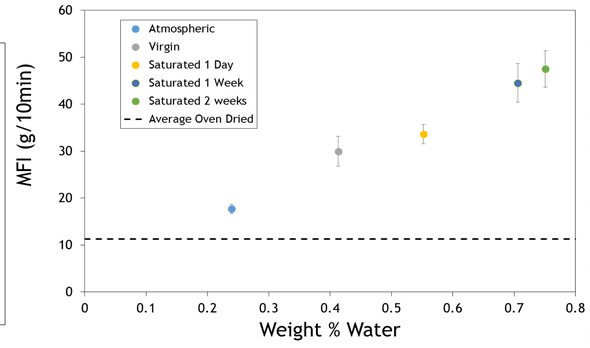


Figure 1: Figure shows weight % water vs MFI as circle markers. Dashed line shows the average value after oven drying saturated pellets. **Moisture content of less than 1% can increase MFI by over a factor of 4. Initial moisture has little affect on MFI after drying.**

Recycling Process

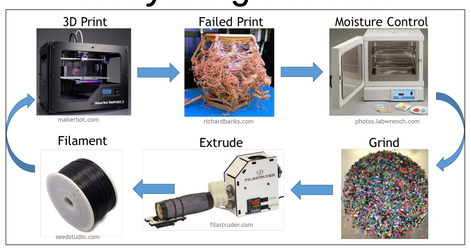


Figure 2: Shows the recycle process. Moisture control can be oven drying or humidity control.

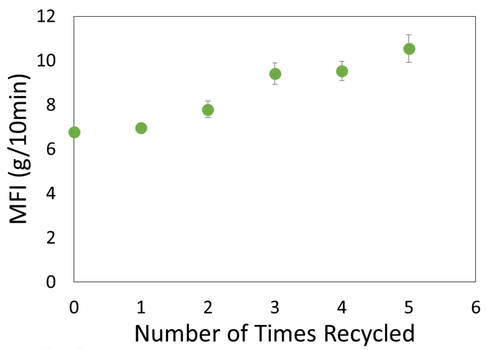
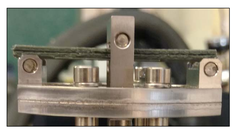


Figure 3: Shows results for multiple recycle processes (note that 3D printing step was skipped due to filament limitations).
MFI increased by an average of 9.5% per cycle corresponding to a molecular weight decrease of 2.6%.

TA Q800 DMA Testing

Dynamic Mechanical Analyzer (DMA) – A three point bend test attachment was used to obtain the elastic (storage) and viscous (loss) moduli.



3D printing succeeded using the 1st and 5th cycles. The printed rectangular bars could be tested using the DMA three point bend test

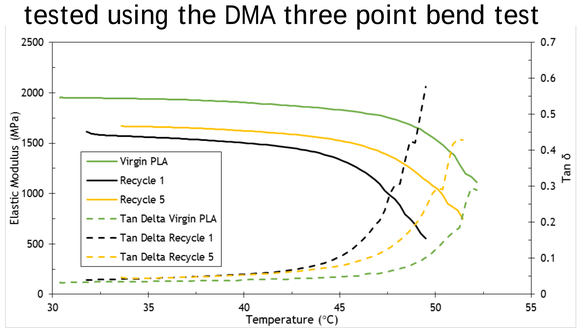
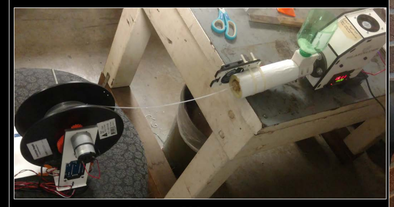


Figure 4: Figure shows temperature (°C) vs elastic modulus (MPa) and tan δ. Lines show highest quality print, 3D printing variation led to differences in results.
Recycling decreases elastic modulus. Print quality impacts elastic modulus.

Extrusion and Grinding



Extruding filament onto winder

Laboratory mill used to grind failed 3D prints

Conclusions

- Moisture content of less than 1% can increase MFI by over a factor of 4
- Moisture content above 0.4% during extrusion can lead to non-uniform filament
- MFI increased by an average of 9.5% per cycle corresponding to a molecular weight decrease of 2.6%
- Recycled filament for 3D printing is possible with minimal loss of strength

Future Work

- Characterize effect of humidity to determine drying process needed for effective filament formation
- Develop improved winding system
- Adjust printer settings for recycled filament

Acknowledgments

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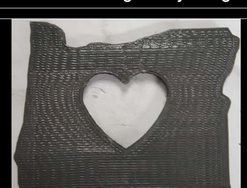
- Ehsan Taghizadeh- DMA training and assistance
- Phil Harding– Project guidance



Successful 3D print from recycled material!

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