Innovative 3D-Printed Catalysts for Sustainable Polymer Recycling

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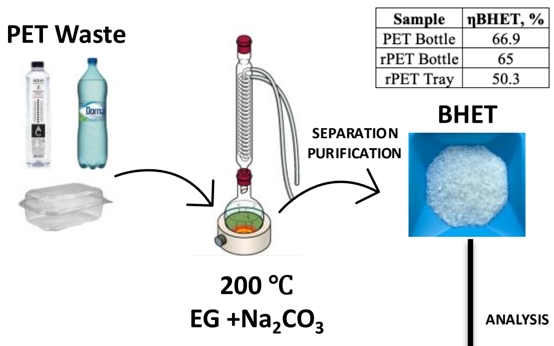
Introduction

3D printing enables the fabrication of catalysts with complex geometries such as triply periodic minimal surfaces (TPMS), which enhance surface area, mass transfer, and mechanical stability. Traditional metal-based catalysts like zinc, manganese, or titanium are effective in PET chemical recycling but raise concerns because of their toxicity and environmental impact. Sodium carbonate has emerged as a sustainable alternative. This study presents a preliminary investigation into PET glycolysis using sodium carbonate powder as a sustainable catalyst. While 3D printing has not yet been performed, the future goal is to integrate Na_2CO_3 into a UV-curable resin for SLA printing, enabling the development of eco-friendly, reusable catalytic structures.

Experimental part

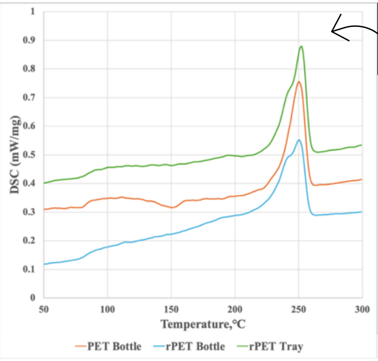
GLYCOLYSIS



Sample	ηBHET, %
PET Bottle	66.9
rPET Bottle	65
rPET Tray	50.3

PET

Differential Scanning Calorimetry



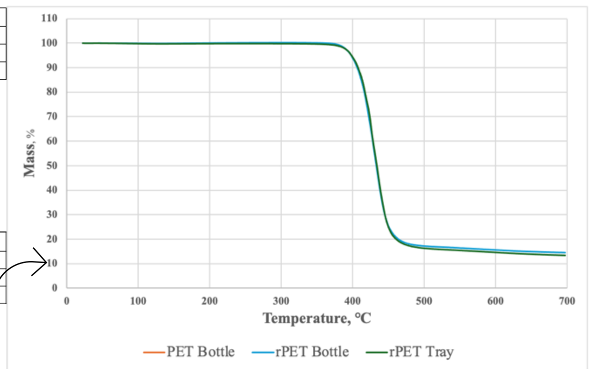
Sample	Tg, °C	Tm, °C	ΔH,m, J/g	ΔH,c, J/g	C, %
PET Bottle	79.30	249.00	32.76	19.21	9.67
rPET Bottle	76.00	248.90	34.18	33.97	0.15
rPET Tray	77.00	250.40	35.18	34.55	0.45

- Subtle T_g: Semi-crystalline PET;
- Broad T_m: Chain scission in recycled PET;
- Crystallinity: Affected by processing and degradation.

Sample	Residue 700°C, %
PET Bottle	14.86
rPET Bottle	14.64
rPET Tray	13.40

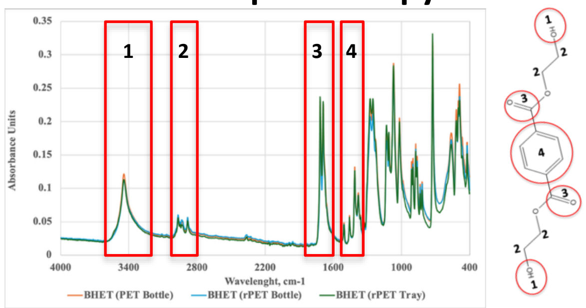
- Residue differences: possible additives or purity variations.

Thermogravimetric Analysis

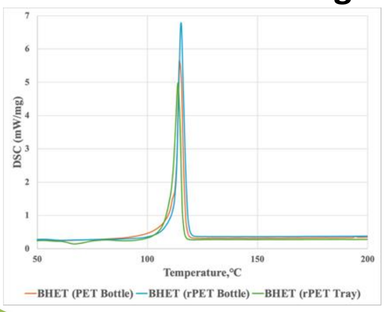


BHET

FTIR Spectroscopy



Differential Scanning Calorimetry

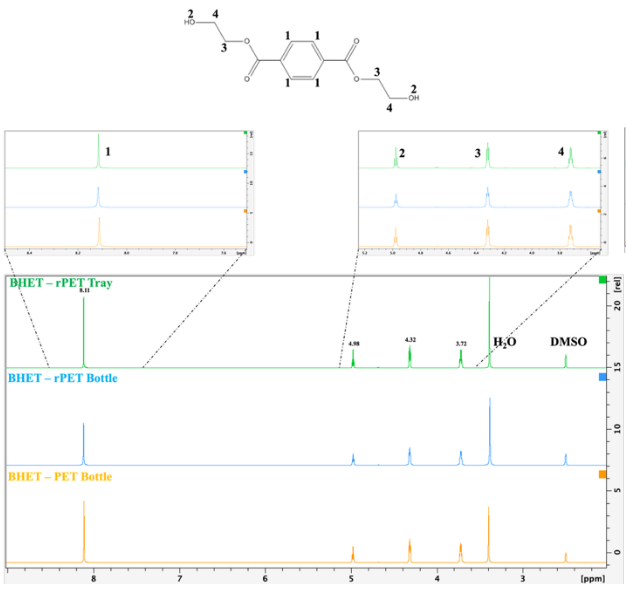


Sample	Tm, °C
BHET (PET Bottle)	114.8
BHET (rPET Bottle)	115.3
BHET (rPET Tray)	114.0

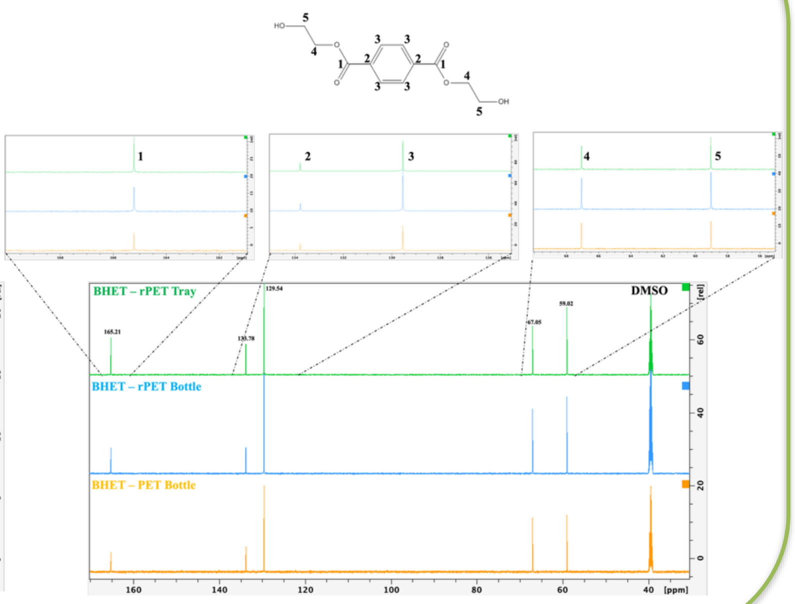
- BHET melting behaviour suggests similar purity and crystallinity for all PET sources.

Nuclear Magnetic Resonance

^{1}H



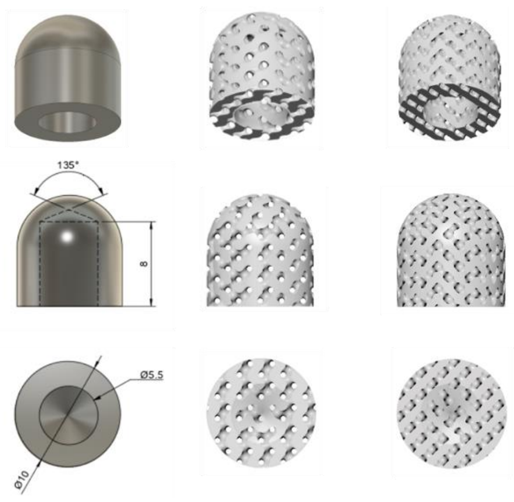
^{13}C



3D Design

- Two-part SLA-printed catalyst cover for magnetic stir bar;
- Halves bonded with resin for seamless assembly;
- Secures catalyst for optimal mixing and stability.

Solid fill | Gyroid | Schwartz D



Solid fill: maximum catalyst volume, low flow;
Gyroid TPMS cells: balanced flow & strength;
Schwarz D TPMS cells: high surface area & mass transfer.

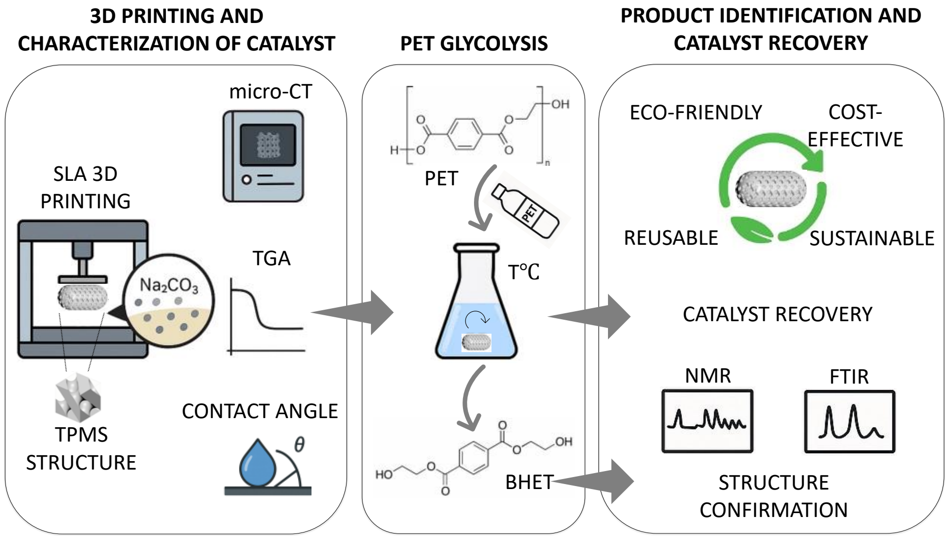
Cell size: 0.2 mm
Solidity: 0.5

Gyroid

Schwartz D

Next Steps

- Optimize sodium carbonate dispersion into SLA resin;
- Assess resin compatibility and photopolymerization with Na_2CO_3;
- Fabricate and test 3D-printed TPMS catalyst supports;
- Evaluate mechanical integrity and reusability;
- Compare catalytic efficiency of printed vs. powdered catalyst.



Preliminary data presented; 3D printing work is in progress.

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