Designing a 3D Printed Catalyst Carrier That Maximized Reaction Yield

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Problem Description

- A catalyst is a substance that increases the rate of a chemical reaction without itself undergoing permanent chemical change
- Test of basic household Amberlyst catalyst against specially made catalyst carrier
- Certain parameters of catalyst carrier affect the reaction yield
- How will differentiating parameters effect reaction yield?

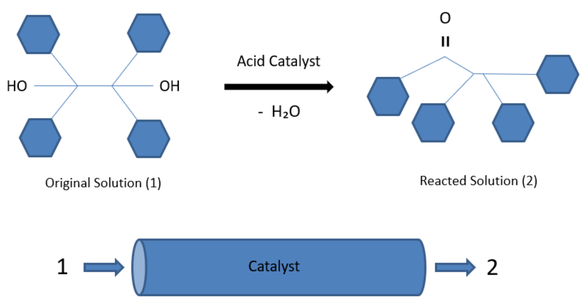

Figure 1: Visual of Pinacol Rearrangement Catalytic Reaction

Objective

- Design and develop a catalyst carrier that maximizes reaction yield
  - Increase fluid resistance so reaction will take place over a longer timespan
  - Maximize interior surface area by using a lattice design so reaction will happen quicker

Design Method

- Team will use CAD software to design interior mesh of catalyst carrier
- Catalyst carrier has set parameters that must be followed
- Each catalyst carrier will have a unique interior mesh following a lattice structure design
- CAD file is imported into CAM software to generate 3D printer toolpath
- Catalyst carriers are 3D printed using method of Fused Deposition Modeling
- Printed using Acrylonitrile Butadiene Styrene (ABS) material

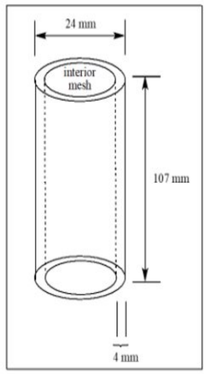

Figure 2: Catalyst Carrier Set Parameters

Catalyst Conversion Process

- After catalyst carriers are printed, chemistry department pours an acid solution through carriers
- Acrylonitrile butadiene styrene material reacts with solution to create acid groups, allowing catalytic reaction

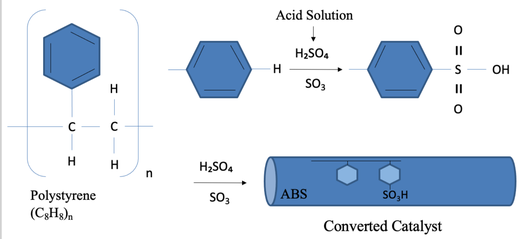

Figure 2: Visual of Catalyst Conversion Process

Iteration 1

Issues

- Geometries were too small to print
- Solution could not easily flow through
- Acid solution causes thermal expansion
- Acid solution leaks and disfigures part
- Over emphasis on increased surface area

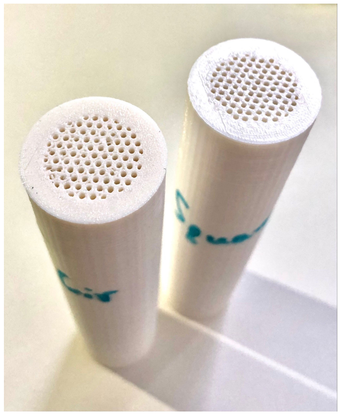

Figure 3: Final Printed Circle and Square Lattice Designs

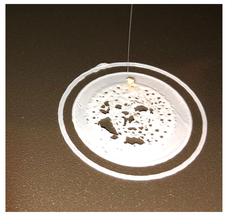

Figure 4: Failed Print

Expansion Ratio Testing

Our solution to the issues faced in iteration 1 was to develop small coupons. Coupons are measured before and after being treated with chemical solutions. Expansion ratio testing was conducted to account for the swelling of future parts.

Expansion Ratio Testing Results

- Coupon diameter and side lengths expanded 1.66% while wall thickness shrunk 6.1% after being printed and treated with acid
- Coupons expanded 2.22% after being treated with second solution, chloroform, while wall thickness shrunk 10.1%

Figure 5: Coupons Developed After Acid and Chloroform Treatment

Iteration 2

- Second iteration of parts are updated to account for swelling during catalyst conversion and catalytic reaction processes using the expansion ratio from the coupon testing
- A lip was added onto new parts to account for solution leakage and easier handling by chemistry department

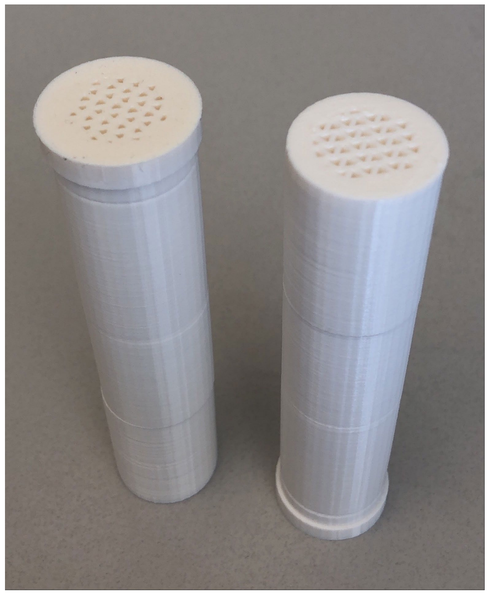

Figure 6: Final Printed Parts for Second Iteration

Conclusions

- Only maximizing surface area is not an effective approach
- Sacrificing some surface area to account for printability and proper liquid flow is essential
- None of our original assumptions held true
- When treated with acid and chloroform solution, the walls of the catalyst carrier tend to decrease while the outer edges tend to expand
  - Possibly due to thermal expansion and/or printer error

Future Work

- Experimentation is ongoing
- Chemistry department does not expect to be done with experimentation until the end of May
- Multiple iterations are needed to finalize a design

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