

THE POTENTIAL OF 3D PRINTING IN MODERN CHEMISTRY

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Northumbria University

OVERVIEW

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Additive manufacturing: A 24th century technology?

21st Century Replicators

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Iterative Development

Advancing the field to promote innovation

To take advantage of new technologies to promote sustainable chemistry

A Case Study: 3D Printed Microwave Flow Cell

Design of the flow cell

The best laid plans of mice and men..

An improved design

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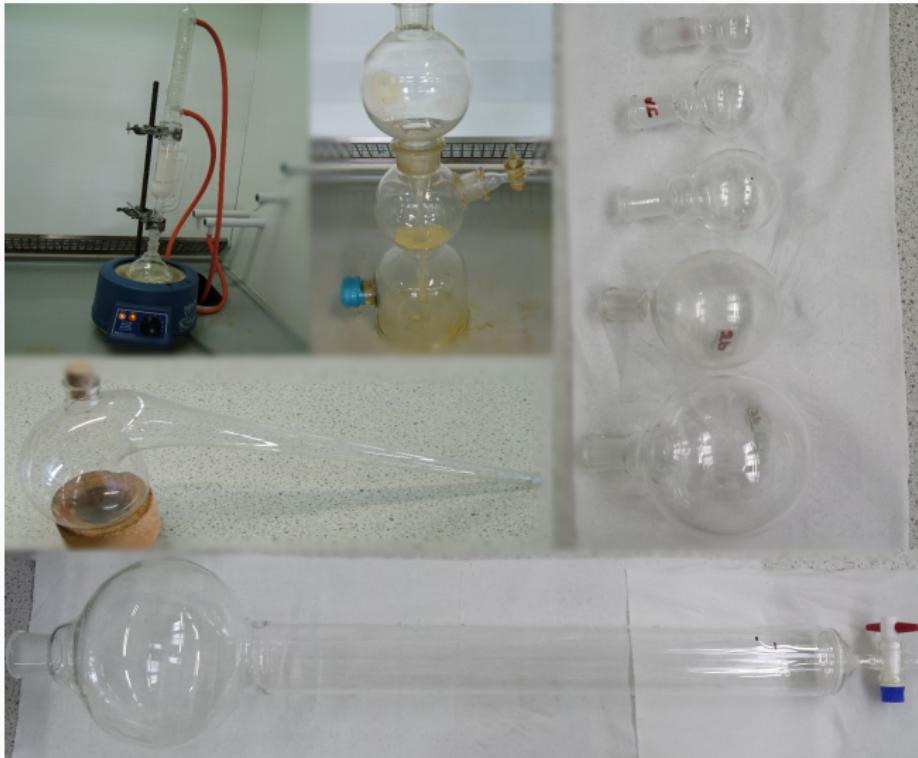
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- Most of our current glassware was developed in the 19th century and has seen little change
- Why?
 - Glass can be blown into any desired shape
 - The advent of borosilicate glass means temperature is no longer a problem
 - Transparent reaction vessels allow easy monitoring of reactions
 - However glassware production is centralized and few labs have direct access to a glassblower - increasing the difficulty of designing and obtaining bespoke glassware

ADDITIVE MANUFACTURING: A 24th CENTURY TECHNOLOGY?

STAR TREK: HARBINGER OF THE FUTURE



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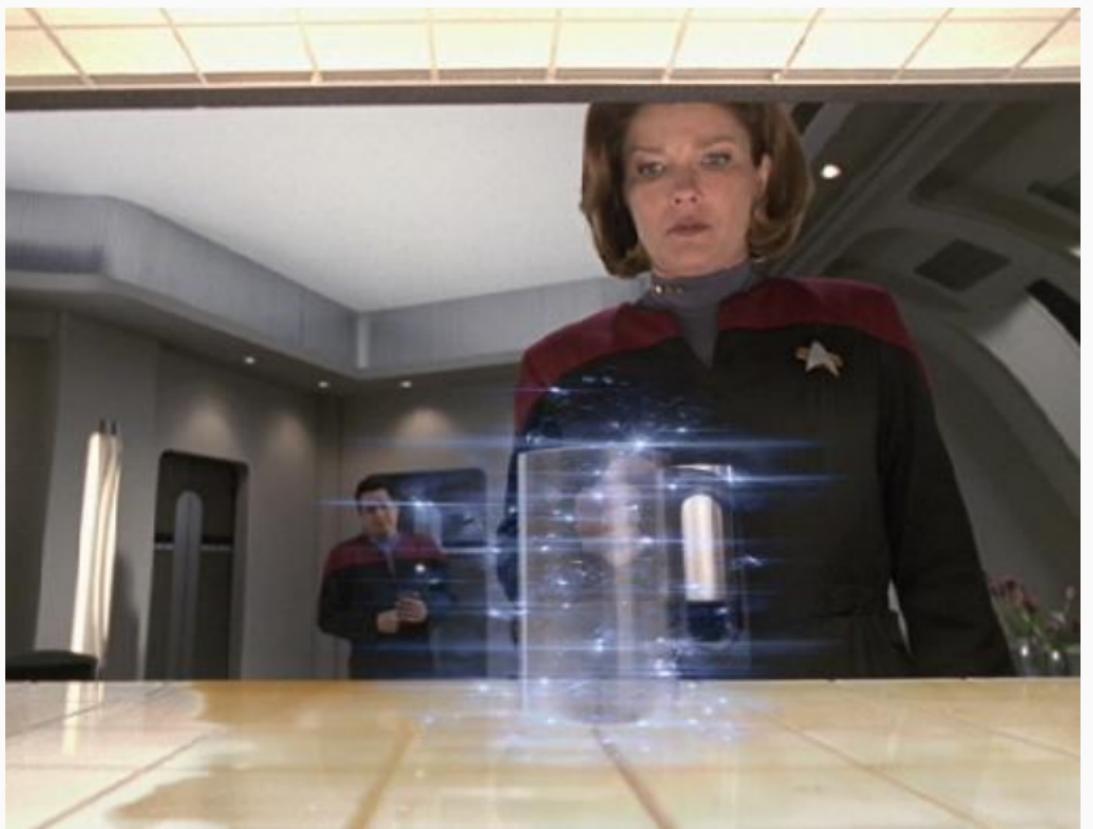
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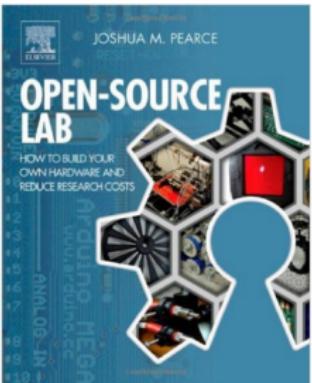
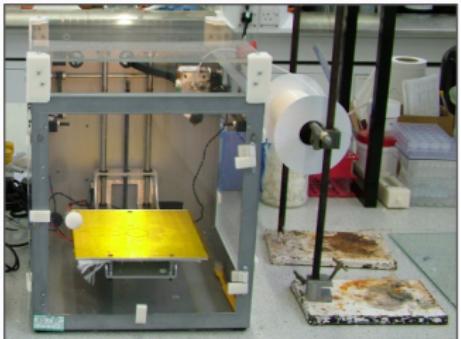
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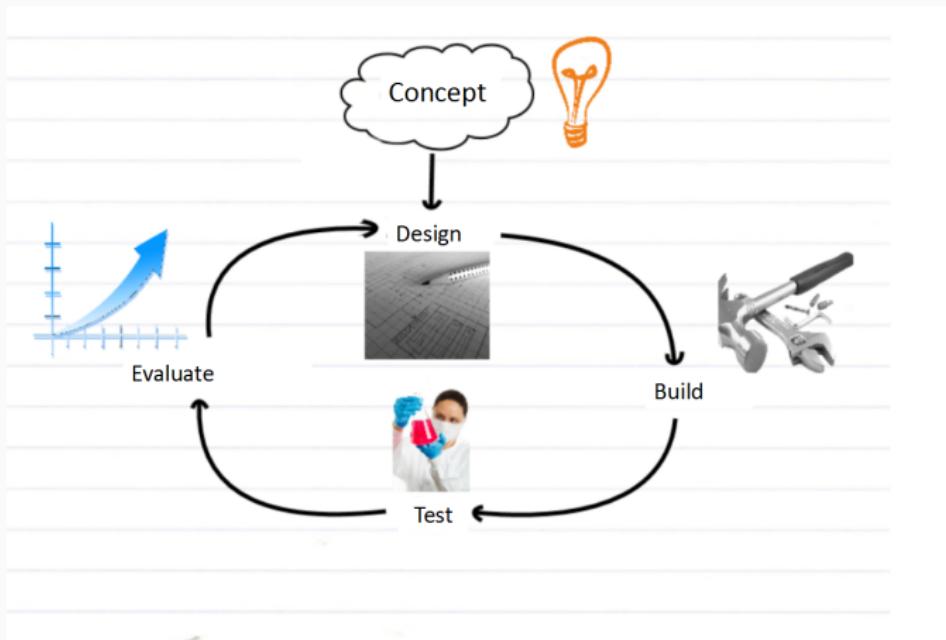
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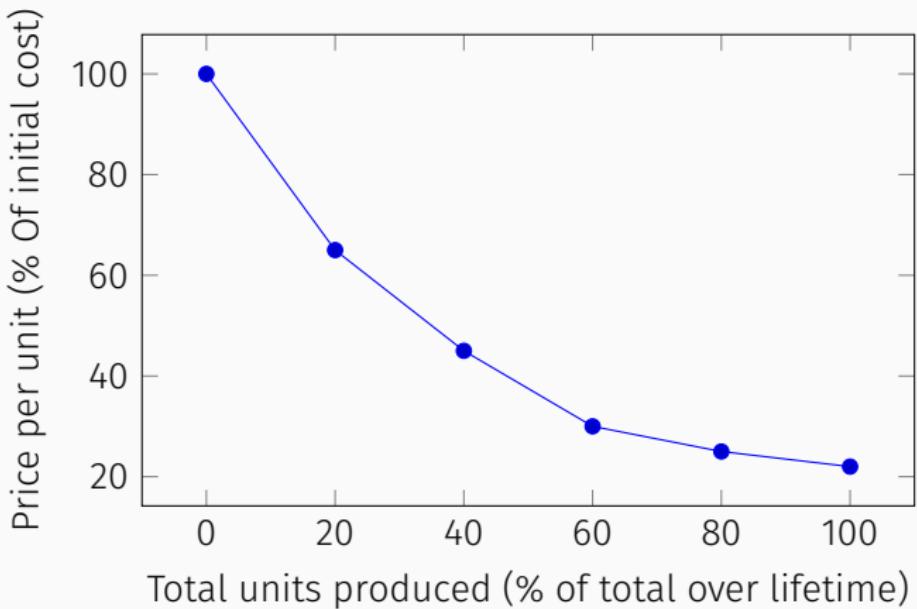
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Hypothetical experience curve, showing the typical relationship between the quantity of products produced and the cost per unit of that product.

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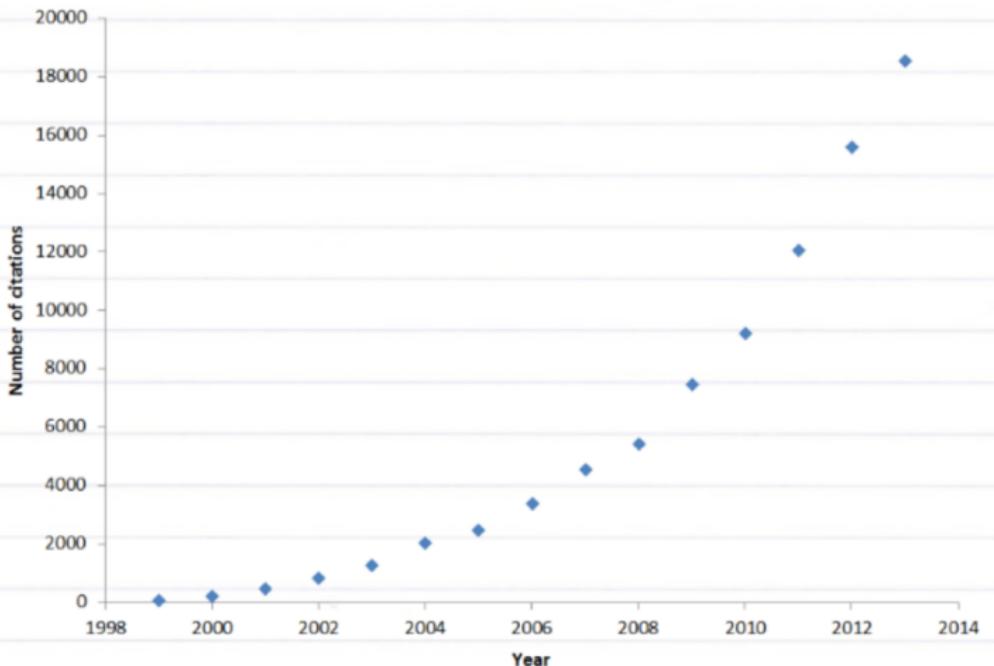
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Green Chemistry, Total citations by year



A CASE STUDY: 3D PRINTED MICROWAVE FLOW CELL

BESPOKE 3D PRINTED MICROWAVE FLOW CELL

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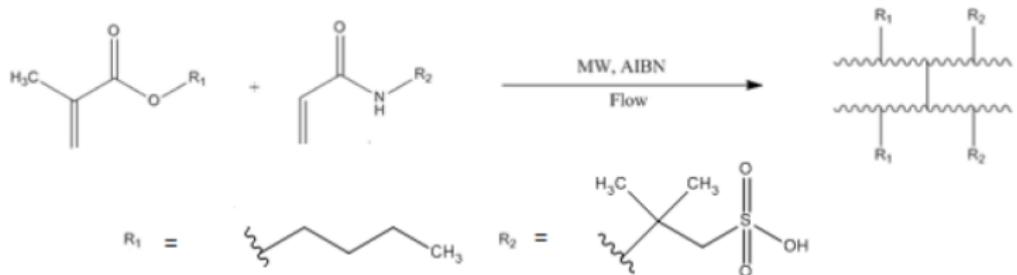
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Results and Conclusions

- We were interested in investigating the following process:



- We are not equipped to carry out flow reactions in our Microwave Reactor (CEM manufactures a flow cell for £1000)

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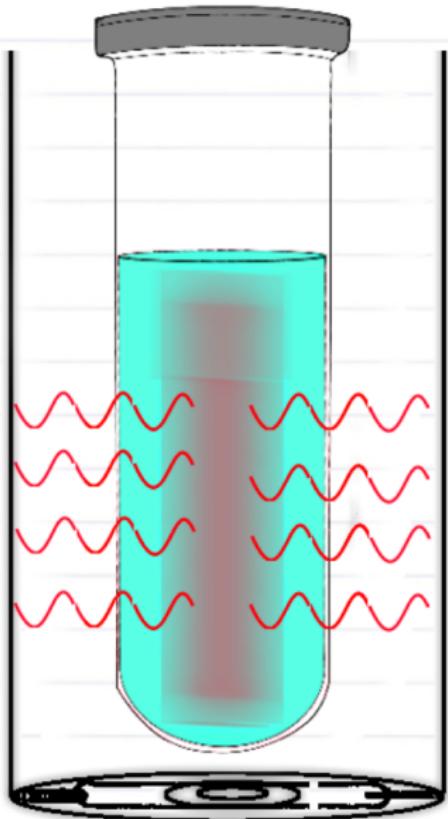
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Reactants in



Reaction occurs
In flow

Products out

INITIAL DESIGNS

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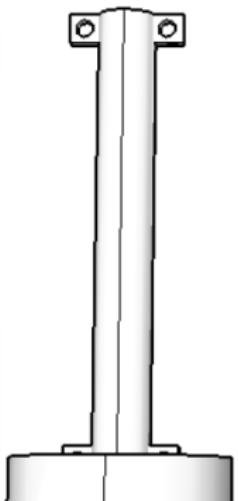
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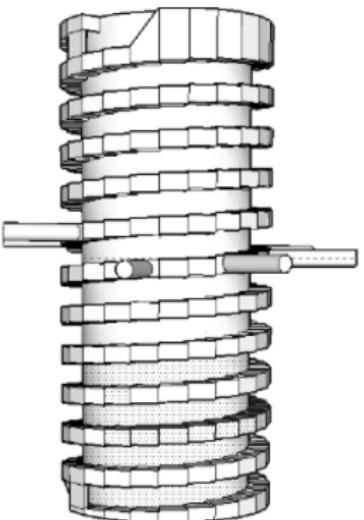
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Version 1



Version 2



Version 3

THE FIRST TEST OF THE FLOW CELL...



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..UNANTICIPATED INTERNAL COMBUSTION

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FAILURE ANALYSIS

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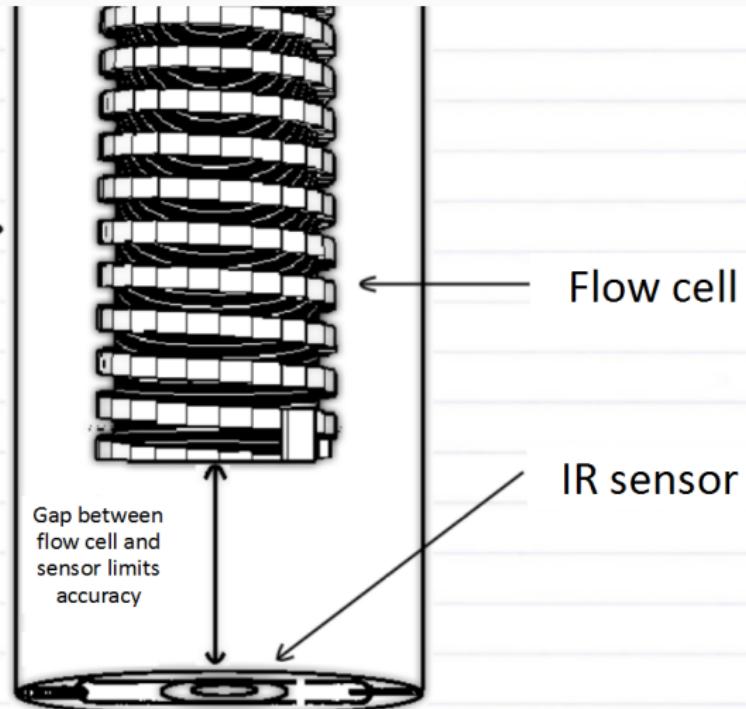
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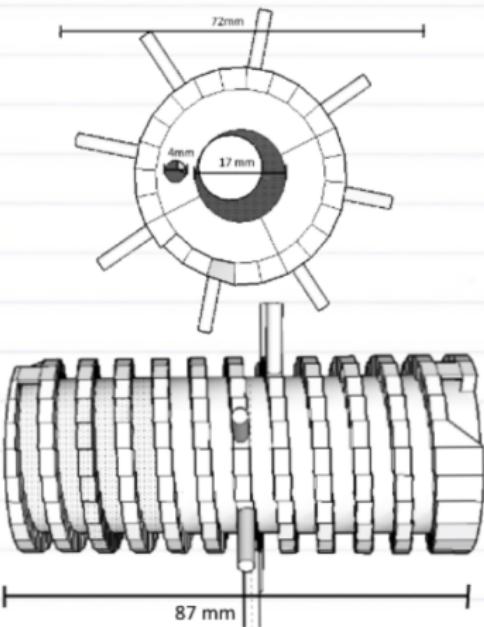
Microwave Cavity



AN IMPROVED DESIGN

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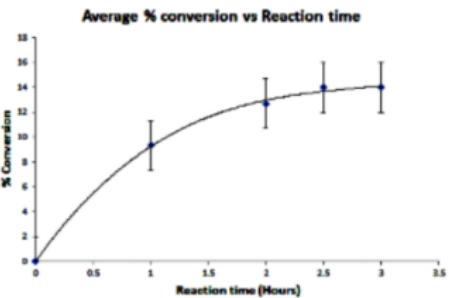
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- Flow Rate: 0.036-0.2ml per minute
- Programme Type: Solid Phase Synthesis
- Max Temperature: 45°C
- Solvent: DMF
- Power: 100W

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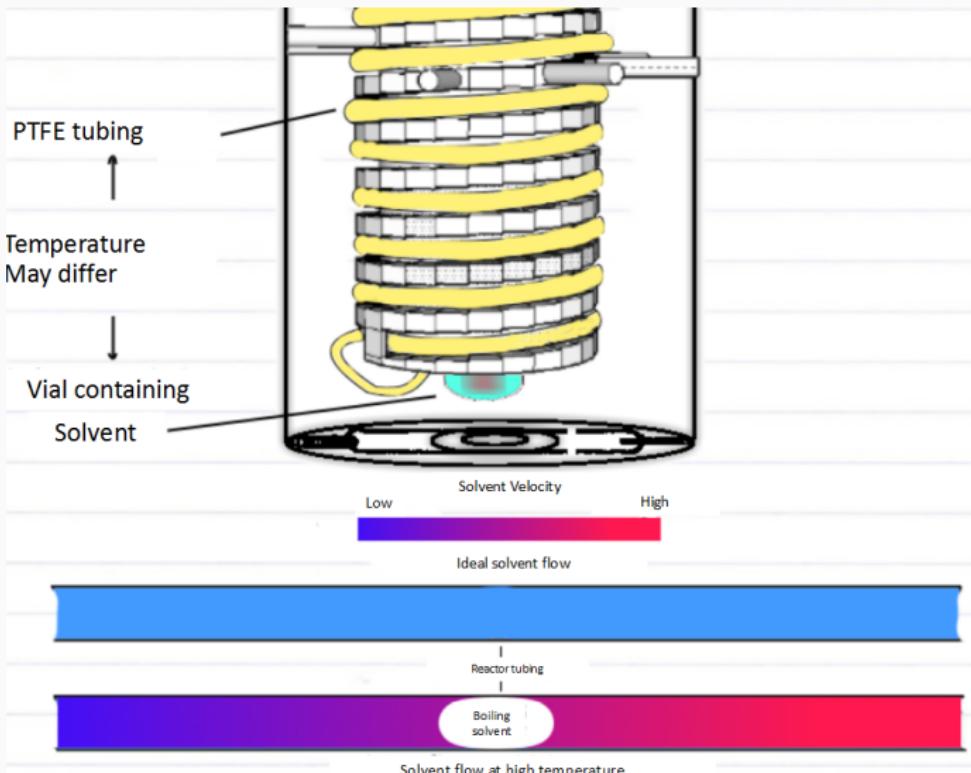
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- Reached an average of 14% conversion of material passed through the apparatus after 3 hours
- No Auto polymerization at room temperature was detectable over this time period in monomer solution kept at room temperature
- $20 \pm 4\%$ after 80 hours at room temperature
- Considerable control and instrumentation problems to overcome
- Pressure issues need to be considered

FUTURE PROPOSALS

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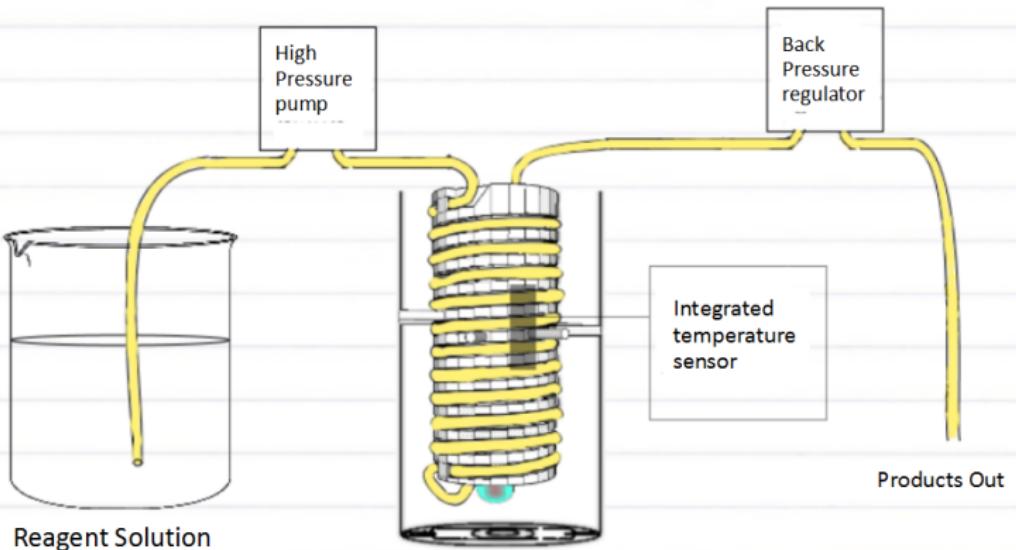
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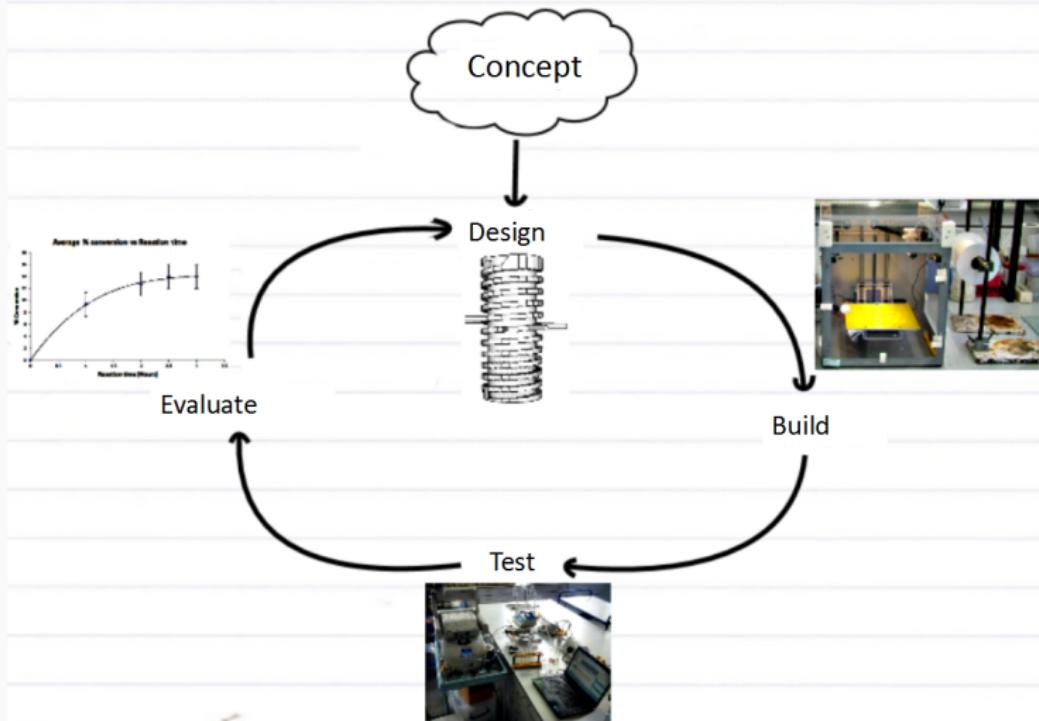
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- 3D printing offers considerable opportunity for making bespoke equipment with non-conventional geometries
- Ease of design and use permits rapid feedback between users and manufacturers of equipment
- Cheaper plastics have properties which limit the range of applications they can be used in - not ready to completely replace glassware yet