ECP 2024 Conference
The 3rd International Electronic Conference on Processes
29–31 May 2024 | Online

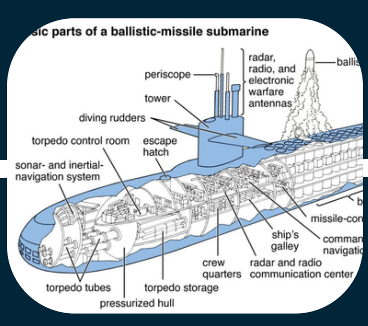
A REVIEW OF MICROREACTORS FOR PROCESS INTENSIFICATION

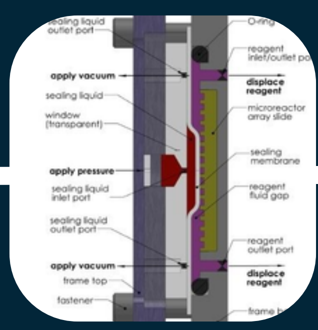
Crizha Ann Bugay, Mae Czarella Caballas, Steven Brian Mercado, Jason Franco Rubio, Patricia Kayla Serote, Patrick Norman Villarte, and Rugi Vicente Rubi
Chemical Engineering Department, College of Engineering, Pamantasan ng Lungsod ng Maynila

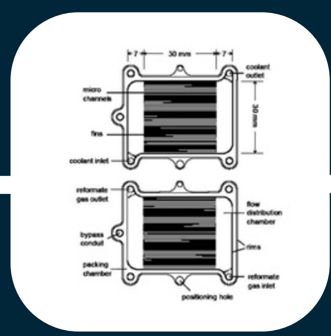
INTRODUCTION

Brief History of Microreactors


Nuclear Navy (1930s)


Nuclear Submarines (1950s)


Liquid-Based Microreactors (1990s)


Microstructured Heat Exchanger (Late 1990s)

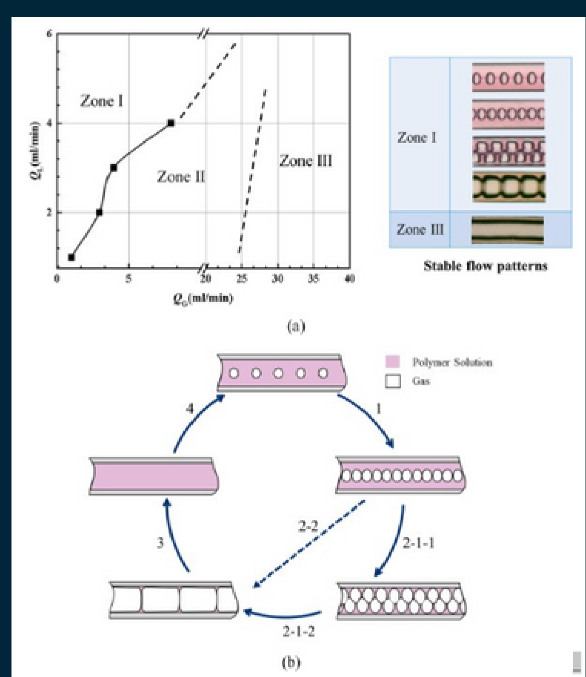

Industry Microreactors (2010s-Present)

APPLICATION OF MICROREACTORS

3.1. MIXING AND CHEMICAL MODIFICATION OF POLYMER SOLUTIONS

The study by Min et al. used microreactors in mixing and chemical modification of polymer solutions based on gas-liquid two-phase flow revealed that:

- The mode of gas introduction affects the mixing performance and the sulfonation of polystyrene in capillary microreactors.
- The sulfonation degree exhibited a significant increase from 0.42 to 0.575 with a rise in gas volume fraction, providing clear evidence of the effectiveness of this mixing intensification approach for reaction processes involving polymer solutions.



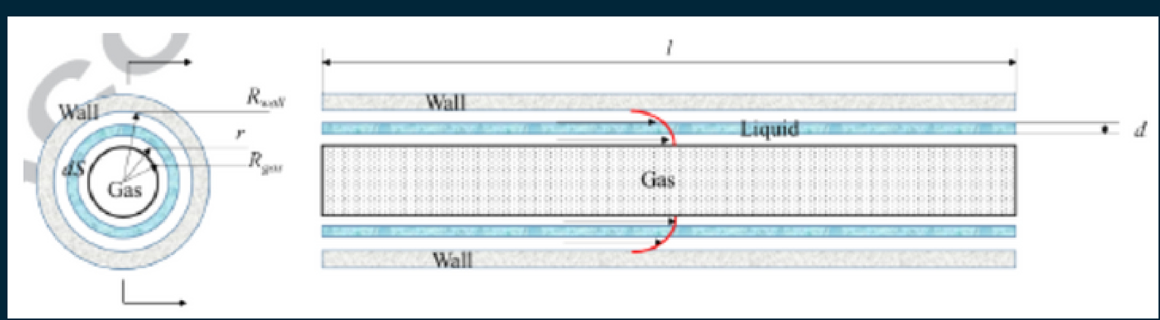
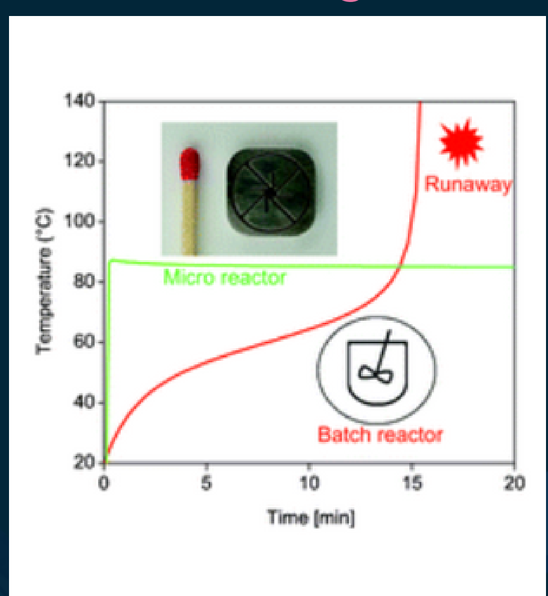


Figure 1. *Schematic diagram of a simplified coaxial flow structure proposed to describe the gas-liquid two-phase flow in the capillary microreactor.*

3.2. SYNTHESIS OF IONIC LIQUIDS

Microreactors offer an efficient synthesis of ionic liquids, as demonstrated by Waterkamp et al., achieving the following:

- The use of microreactors results in a more than twentyfold increase in space-time-yield compared to conventional batch processes.
- The synthesis of ionic liquids in microreactors can lead to a significant increase in sustainability in manufacturing processes.
- Product purity above 99% can be achieved with microreactors, although some impurities may be present at higher temperatures.



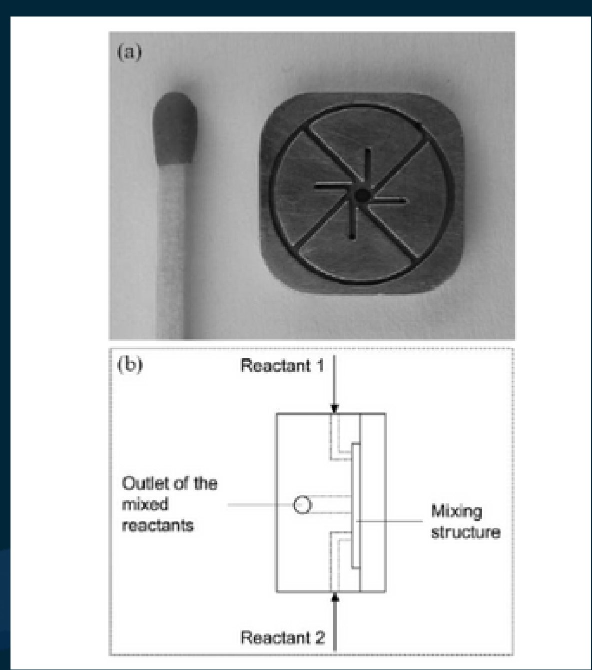


Figure 2. *Top view of the vortex-type micro-mixer (a) and side view of the working principle (b).*

3.4. SYNTHESIS OF ORGANIC NANOMATERIALS

A study by Cheng et. al., addressed the issue of poor solubility in medicinal components by creating nano-sized itraconazole (ITZ) particles using a continuous flow droplet-based microreactor.

The results indicate that:

- Improved flow rates leading smaller and more uniformly dispersed ITZ nanoparticles.
- Particle agglomeration can be regulated by amphiphilic stabilizers, longer residence times, and greater starting concentrations.
- The conversion rate was five orders of magnitude higher than of the batch reactor.
- Resistance to clogging.

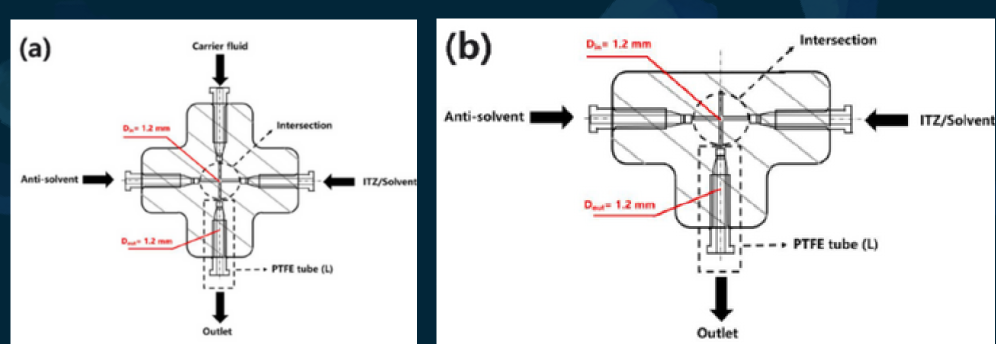
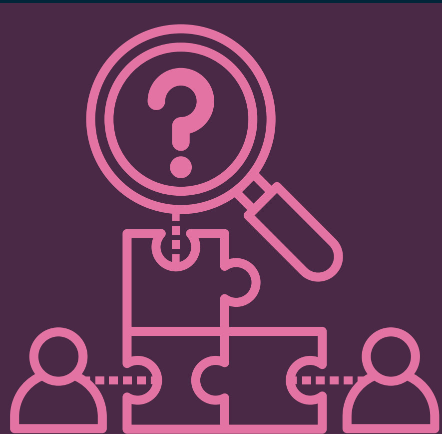


Figure 4. *Schematic of the experimental system. (a) Structure of the metal corss junction channel as the droplet-based microreactor. (b) Structure of the metal T-shaped microreactor.*

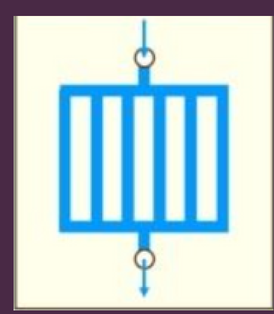
RESEARCH GAPS

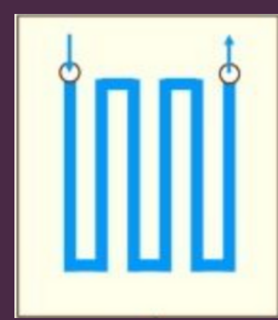
- Scaling up from the laboratory to large production facilities due to absence of universally accepted methods
- Higher costs
- A higher risk of safety, health, or environmental issues
- Compatibility of reaction mixtures

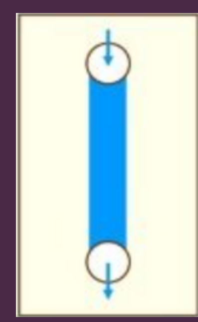


DESIGN & OPERATION

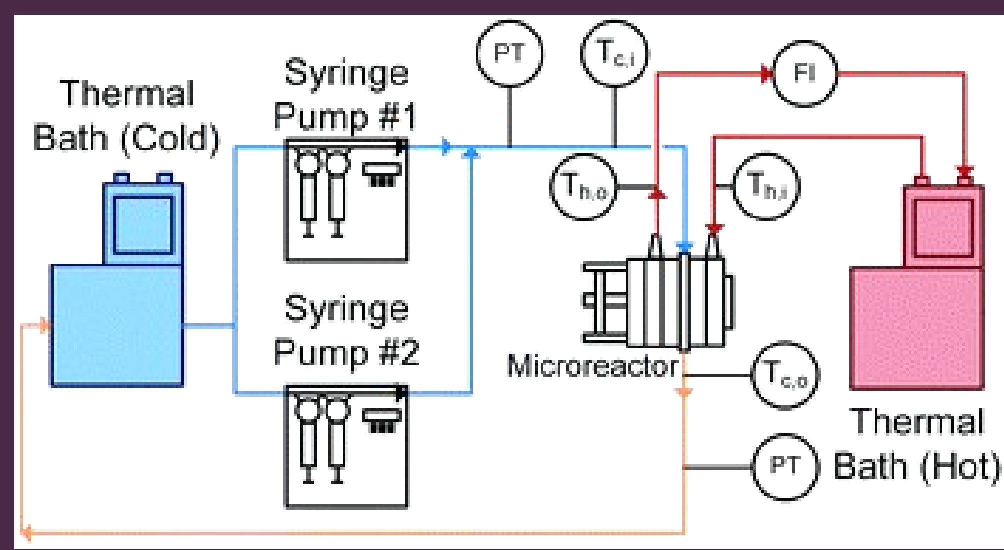
SCALING DESIGN


Numbering Up


Lengthening


Diameter Sizing Up

HEAT TRANSFER



3.3. SYNTHESIS OF INORGANIC PARTICLES

Nagasawa and Mae developed a microreactor incorporating a dual-pipe axle design, where two immiscible liquids flow into tubes of varying inner tube diameters. This resulted to sequentially connected nucleation and particle growth sections generating mono-modal spherical titania particles with precise size control, spanning from 45 nm to 121 nm, demonstrating remarkable efficiency.

Moreover, a related study by Yu et. Al, it is found out that continuous synthesis of zeolite in a one-step process within a microreactor further highlights efficiency. This method shows that:

- Lower costs of large-scale zeolite synthesis.
- Prevents variability of products.
- Enables flexible manufacturing of various zeolite varieties.
- Resistance to clogging.

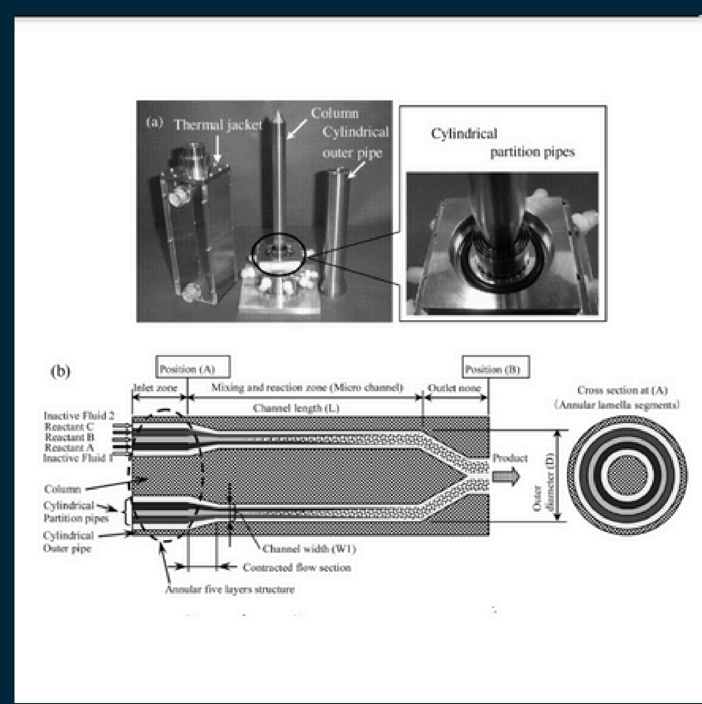


Figure 3. *Details of the microreactor: (a) internal parts and (b) schematic of flow in the microreactor.*

FUTURE OUTLOOK

Advancements in materials, manufacturing, and automation are driving the innovation of microreactor technology (MRT), positioning it as a key player in:

- Offer a potential platform for next-gen catalysts and multiphase catalytic process technologies.
- Efficient tools for rare earth extraction and separation and as catalysts for innovation by integrating microwave heating.
- Promoting green chemistry and sustainability.
- Better portability due to small size.
- More efficient power generation.
- Applications in space exploration.

REFERENCES

Nagasawa, H., & Mae, K. (2006). Development of a new microreactor based on annular microsegments for fine particle production. Industrial & Engineering Chemistry Research, 45(7), 2179–2186. https://doi.org/10.1021/ie050869w

Waterkamp, D. A., Heiland, M., Schlüter, M., Sauvageau, J. C., Beyersdorff, T., & Thöming, J. (2007, June 8). Synthesis of ionic liquids in micro-reactors-a process intensification study. Green Chemistry. https://pubs.rsc.org/en/content/articlelanding/2007/gc/b616882e/unauth

Zhang, X., Kim, S., Wang, H., Yan, L., & Cheng, Y. (2020, March 10). Continuous preparation of itraconazole nanoparticles using droplet-based microreactor. Chemical Engineering Journal. https://www.sciencedirect.com/science/article/abs/pii/S1385894720307129