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Microfluidic Application in Carbon Capture

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Introduction

Excessive concentration of atmospheric CO₂ has significantly contributed to global warming. Carbon capture and storage is the most viable approach for decreasing the amount of CO₂ released into the atmosphere. Monoethanolamine (MEA) scrubbing is the most commercially proven approach for CO₂ capture. However, MEA is corrosive and degrades during repeated regeneration cycles at elevated temperatures into the products that pose a hazard to human health and the environment. Encapsulating CO₂ solvents (such as MEA within carbonates) within CO₂ permeable shell is a novel technique that prevents evaporation of solvent and its direct contact with the capture system, and provides much higher surface area-to-volume ratio, in comparison to typical packed towers [1].

Methodology

Numerical modelling

A two-dimensional incompressible axisymmetric numerical model based on volume of fluid - continuum surface force (VOF-CSF) approach was developed to study the hydrodynamics of double emulsion formation.

\[
\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{U}_1) = 0
\]
\[
\frac{\partial (\rho \mathbf{U}_1)}{\partial t} + \nabla \cdot (\rho \mathbf{U}_1 \mathbf{U}_1) = -\nabla p + \nabla \cdot (\mu \nabla \mathbf{U}_1) + F_r
\]
\[
\frac{\partial \mathbf{U}_1}{\partial t} + \nabla \cdot (\mathbf{U}_1 \mathbf{U}_1) = \nabla \cdot \mathbf{U}_1 = \mathbf{0}
\]

Experimental results

(a & b) SEM images of micrometre cross-sectioned capsules; (c) collapsed capsules synthesised without DC 749 in the middle phase; (d) dehydrated buckled capsules with 15 wt% K₂CO₃ in the core after 6 h of exposure to ambient air; (e) 15 wt% K₂CO₃ capsules before capillary-induced cavitation; (f) 15 wt% K₂CO₃ capsules with cavitation-formed vapour bubble; The scale bars: (a) 100 µm; (b-f) 200 µm.

The capsules containing 5 wt% K₂CO₃ and m-cresol purple (pH indicator) in the aqueous core: (a) prior to CO₂ capture; (b) after CO₂ uptake

Conclusions

- A single-step microfluidic method for continuous production of microcapsules with elastic semipermeable shells was developed and used to encapsulate liquid sorbents, particularly highly alkaline solutions
- To achieve 100% encapsulation efficiency of the core liquid, the middle phase should contain 0.5-2 wt% DC 749 stabiliser.
- The minimum energy density and UV light irradiance needed for complete shell polymerisation were 2 𝐹𝐹ffield and 5-30 wt% aqueous K₂CO₃ solution
- MF: 0.5 wt% Dow Corning® 749 Fluid in a UV-curable silicone rubber.
- OF: 70 wt% glycerol + 0.5 wt% Pluronic® F-127 in water.

References