MANUFACTURING POLYMERIC CAPSULES FOR ENCAPSULATION OF LIQUID ABSORBENTS and LIQUID ION EXCHANGE MEDIA USING GLASS CAPILLARY MICROFLUIDICS AND ON-THE-FLY PHOTOPOLYMERISATION

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In this study, we have developed a novel continuous process for the fabrication of monodispersed core/shell capsules of controllable size and shell thickness using microfluidic emulsification and "on-the-fly" in-situ photopolymerisation. The process allows for 100% encapsulation efficiency of the core material and can be used to encapsulate liquid ion exchange media inside an ion-permeable polymer shell. Conventional methods for fabrication of core/shell capsules such as internal phase separation, interfacial polymerization, complex coacervation and layer-by-layer deposition typically require multi-stage processing and do not allow precise control over the shell thickness and capsule size [1,2]. The process was tested by encapsulating an aqueous solution of K_2CO_3 of different concentrations and the capsules were used to capture CO_2 from the environment (Fig. 1).

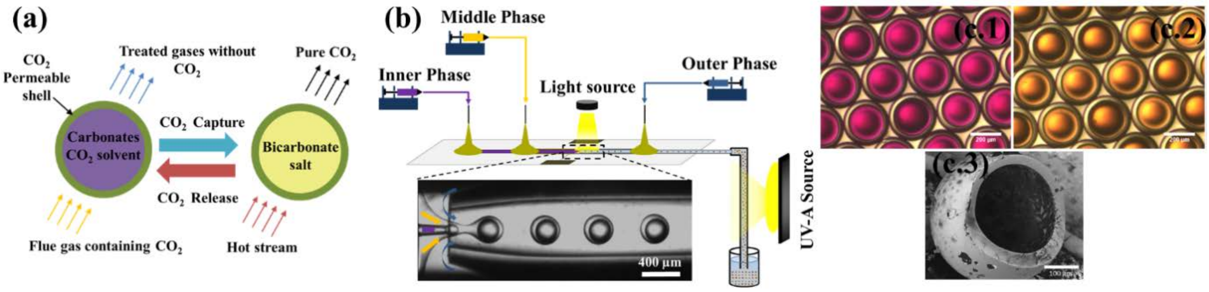

Figure 1. (a) A conceptual schematic of CO_2 capture and release by the microcapsules; (b) Schematic view of the experimental set-up consisting of a glass capillary microfluidic device for generation of core/shell droplets and a UV-A source for on-the-fly in-situ photo-polymerisation of the shells; (c.1) The synthesised capsules with purple blue dye prior to CO_2 capture test, scale bar is 200 µm. (c.2) Microcapsules after CO_2 capture, 200 µm. (c.3) A FIB/SEM image of a microcapsule, 100 µm.

The shell phase was a UV-curable liquid silicon rubber (Semicosil® 949) containing 0-2 wt% Dow Corning 749 Fluid added as a lipophilic stabilizer. The minimum UV light intensity and the minimum exposure time for a complete shell polymerization were 13.8 $mW \cdot cm^{-2}$ and 144 s, respectively. It was found that the drop generation process was stable for more than one hour. The capsule diameter and the shell thickness were precisely adjusted over the range of 200-400 and 20-30 µm, respectively by controlling the flow rate of the three fluid streams. Prior to CO_2 uptake, the capsule interiors were purple because the pH was above 11 (Fig. 1c.1). After exposure to CO_2, the core liquid turned to yellow (pH < 7.5, Fig. 1c.2), due to the chemical reaction: $K_2CO_3 + H_2O + CO_2 \rightarrow 2KHCO_3$. The capsule can be regenerated by heating, which causes the reaction to proceed in the opposite direction and a pure stream of CO2 is released: $2KHCO_3 \rightarrow CO_2 + K_2CO_3 + H_2O$. The capsules were thermally stable up to at least 180°C and they kept structural integrity during regeneration cycles.

References

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[2] Nabavi, S. A., Vladisavljević, G. T., Gu, S., Ekanem, E. E., Chem. Eng. Sci. vol 130 (2015), 183–196.