Microfluidic Fabrication of Macroporuos Polymer Particles for the Separation of Uranium in Aqueous Solution

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1. Introduction

Uranium is an important element for the production of nuclear energy. However, it also possesses high chemical and biological toxicity. Various nuclear-related activities have released excess amounts of uranium into environment. In this regard, the removal/separation of uranium is highly required. So far, many methods such as ion-exchange, solvent extraction and filtration and reverse osmosis have been developed to remove uranium from aqueous waste streams generated from nuclear activities. Among such methods, sorption has drawn much attention, thus has been extensively investigated due to its low cost, high sorption selectivity, capacity, and various choices for source materials. In particular, polymer-based porous adsorbents are advantageous due to their high surface area and highly interconnected macroporous structures that enable high transport rates [1]. Suspension, precipitation, dispersion and seeded emulsion polymerization, membrane emulsification and microfluidics (MFs) are the main techniques for the fabrication of such porous materials. Among those, MF approach makes it possible to precisely control particle sizes and morphologies.

In this study we present the MF preparation of poly (glycidylmethacrylate-co-ethyleneglycoldimethacrylate), P(GMA-co-EGDMA), polymer particle. Since 1980s, GMA and EGDMA have been widely used as monomers leading to macroporous beads with controlled porosity upon polymerization in the presence of inert diluents [2]. We further investigate the potential utilization of such particle for the removal of uranium from aqueous solution by copolymerizing the monomers with phosphate-containing monomers.

2. Experimental

2.1 Reagents

Poly(vinyl alcohol) (PVA, Mw 31 000−50 000 g/mol), GMA, EGDMA, vinylphosphonic acid (VP), bis(2-(methacryloyloxy)ethyl)phosphate (BMEP) 1-undecanol, and 2-hydroxy-2-methylpropriophenone (HMPP) were purchased from Sigma-Aldrich, Korea, and used as received.

2.2 Methods

A simple MF co-flow device was fabricated using common laboratory tubing, glass capillary and needles. Two immiscible liquids were introduced into the device by two separate syringe pumps allowing independent control of flow rates. The organic contained a mixture of GMA, EGDMA, and VP (or BMEP) in different proportions with 4.5wt.% of HMPP as a photo-initiator. The aqueous continuous phase was made of 2wt.% PVA. To obtain polymer particles, monomer droplets generated from the MF device were exposed to exposed to UV light (Innocure 2000, UV output: 3 W/cm2, 250~450 nm) for 5 min.

3. Results

Droplets with well-defined monodisperse

morphology are produced in the MF co-flow device. The resulting droplets are converted into micron-sized beads with macroporous surface morphologies upon UV polymerization (Figure 1a, b). Using a mixture of acrylate monomers with an inert diluent as a dispersed phase, the porosity of the particle surface is generated through phase separation between the growing polymer chains and inert diluent (Figure 1c). Both surface and inside of the bead consist of a network of interconnected polymer particles (Figure 1d). The co-polymerization of the functional polymers with a mixture of GMA-EGDMA was indirectly monitored by an energy-dispersive X-ray spectrometer (Figure 1d, inset).

The removal of uranium from aqueous solution was evaluated by adding 0.01 g of the synthesized beads into 10 μg/mL of uranium with different molarity of nitric acid. The efficiency increases as the acidity of the solution decreases (Figure 2) possibly due to the competition of H^+ ion and uranyl ion towards the functional group of the bead. We determined the maximum capacity of the beads reached 32.4 mg-U/g.
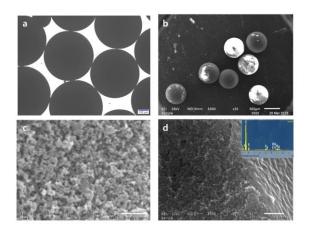

Fig. 1. MF preparation of phosphate-bearing P(GMA-EGDMA) macroporous particles. a) optical microscope image, b-d) SEM images of the P(GMA-EGDMA-BMEP) particles, particle surface, and internal morphology, respectively.
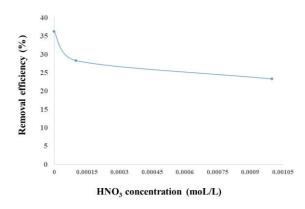

Fig. 2. Uranium removal efficient as a function of HNO_3 concentration.

4. Conclusion

We synthesized phosphate-bearing macroporous polymer particles using a MF method. We characterized the beads using different techniques and showed the beads possessed uranium sorption capacity to some extents. Current research is only preliminary, thus further studies will be carried out in near future.

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