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Bio-particle separation using microfluidic porous plug for environmental monitoring

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Abstract

This paper deals with (i) fabrication of microfluidic devices using living radical photo-polymerization method with various polymers (aromatic urethane diacrylate, photo-initiator, and photo-iniferter), and placement of porous plug using salt-leaching technique in microfluidic channel, (ii) determination of the pore size of the porous plug using flow field-flow fractionation, and (iii) investigation of separation of various particles including latex micro-particles and bacteria. It was demonstrated that the microfluidic device with porous plug could be used as a new and simple tool for particles (including microorganisms) separation based on their sizes and a miniaturized filter for water sample analyses.

Keywords: Microfluidic device; Living radical photo-polymerization; Porous plug; Particle (including micro-organisms) separation

1. Introduction

Nano/micro-particles and microorganisms separation based on their sizes may be one of key technologies in environmental analyses areas. Separation with size has been studied using various different techniques, including field flow fractionation (FFF), capillary hydrodynamic fractionation, and membrane filtration. These methods require relatively long separation time, large sample volume, and external forces. Recently, miniaturized particle separation system using microfluidic device has been developed to overcome disadvantage of previously existing methods [1–3].

The microfluidic technology has been rapidly developed since micro-total analytical system was proposed by Manz et al. [4]. Microfluidics

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have been applied in various research fields including biological and chemical analyses, medical diagnosis, and drug delivery. Use of microfluidic device has a number of well known advantages: (1) small amounts of required reagents and analytes, (2) ease of portability, and (3) relatively low fabrication costs [5,6]. Silicon and glass have been mainly used for the fabrication of microfluidic device. However, they also have some disadvantages such as relatively high cost and complicated fabrication procedures. In contrast, microfabrication with polymers are getting more attraction due to its relative low cost compared to silicon and glass-based microfluidic devices; polydimethylsiloxan (PDMS) has recently been widely used as a material suitable for microfluidic devices fabrication for various research areas using soft lithography [7]. Most recently, microfluidic devices fabrication using living radical photo-polymerization (LRPP) has been developed [8]. LRPP includes photo-polymerization of a monomer formulation which contains photo-initiator and photo-iniferter precursors. The photo-iniferter provides re-initiated radicals on fully polymerized surfaces, allowing surface modification or providing subsequent layers with covalent bonding [9]. The LRPP method has several advantages as compared to other methods. It can provide relatively easy and rapid fabrication of microfluidic devices and allow multi-layer devices with three dimensional pathways and grafted functional materials on the surface [10].

LRPP has been developed to fabricate microfluidic devices [8]; photo-initiator was identified accountable for polymerization, and photo-iniferter may provide re-initiated radicals on fully cured polymer surfaces and allow subsequent layers to be built with covalently bonding [9,11]. Iniferter can lead to a reversible termination reaction which can be used to create block copolymers by successively polymerizing different monomers [12–14]. One of big advantages of the LRPP is its ability to rapidly make multi layer channels of devices with three dimensions. Each layer of a device can be made by exposing monomer solution to UV light through designed photomask. All the exposed regions can be polymerized to be solid device, meanwhile, monomer mixture underneath the patterned regions is not cured. Each cured layer provides radical sites upon re-exposure to UV light as the monomer solution has a photo-iniferter precursor. The monomer is covalently bonded with the cured layer through the photo-iniferter produced radical site, as monomer solution is placed over a cured layer of the device and exposed to UV light [10].

Flow FFF (FlFFF) is a technique designed to separate and characterize various solutes from macromolecules with relatively low and high molecular weights to particulate materials (nano and micro-ranges), using separation chamber consisting of laminar flow and field flow of which direction is perpendicular to the laminar flow [15–17]. FFF can provide chromatographic-like fractionation but accomplish very wide range of separation and high resolution as well as other capabilities such as highly speedy separation, relatively easy operation, and flexibility to be connected with other measurement devices [15,18]. Hyperlayer mode FlFFF (Hy FlFFF) is also a sub-technique of FlFFF which can separate a range of micron size particles (approx. 0.5–50 μm). Unlike the normal FlFFF driven by the Brownian motion, particles can be affected by the shear force/hydrodynamic lifting force in the Hy FlFFF mode so that larger particles can be eluted earlier than smaller ones. The retention theory of Hy FlFFF can be described [19,20].

$$R = 6\lambda + 3\frac{\gamma d}{w} \tag{1}$$

where R is the retention ratio of the void time for the channel flow to sweep out one channel volume to the retention time for the sample to be eluted, γ the dimensionless correction factor,