Utilizing Polymer Nanofibers in Microfluidic Devices for Liquid Separation Applications

CNF Project Number: 2603-17

Principal Investigator: Professor Margaret Frey

User: Mesbah Najafi

Affiliation: Department of Fiber Science and Apparel Design, Cornell University

Primary Source of Research Funding: USDA National Institute of Food and Agriculture

Contact: mfw24@cornell.edu, mn574@cornell.edu

Primary CNF Tools Used: Hot press, UV-Ozone, Microdrill

Abstract:

The purpose of this project is to examine the efficacy of polymer nanofibers inside microfluidic analytical devices for liquid purification applications. To achieve that, the microfluidics device was made from poly(methyl methacrylate) (PMMA) plates and nanofiber fabrics using hot press and UV-Ozone equipment. Methylene blue dye solution was used for the adsorption experiment. The results showed that the nanofibers inside the device channels can effectively capture the dye from the solution.

Summary of Research:

In this study, composite electrospun nanofibers were first developed for dye adsorption application. This was achieved by adding a percentage of poly methyl vinyl ether-alt-maleic anhydride (PMA) to polyvinyl alcohol (PVA), which resulted in composite nanofibers with combined properties of appropriate adsorbent groups (from PMA) and high mechanical properties (from PVA) [1,3]. The obtained nanofibers were then used in a microfluidic analytical device. To achieve that, the nanofibers fabric was collected for 15 min by electrospinning method. The brass template with raised channels (30 mm × 1 mm × 50 μm) was used for embossing the PMMA sheets.

Figure 1: Hot press and UV-Ozone equipment used for making microfluidic device.

The hot press was heated up to 110°C. A 5 cm × 5 cm PMMA square was placed between the channel template and a blank piece of metal. Then, the upper hot plate was moved to touch the sandwiched PMMA for about 5 mins. Next a pressure of about 1000 lbs was applied for 5 min. Inlet and outlets holes were drilled into the PMMA using a 1.2 mm drill bit. PMMA sheets were activated in an ozone generator (oxygen flow rate 0.5 L/min) and with UV-light for 10 min. Then, the nanofiber fabric was placed between the PMMA pieces and the assembly was placed inside the hot press with the temperature

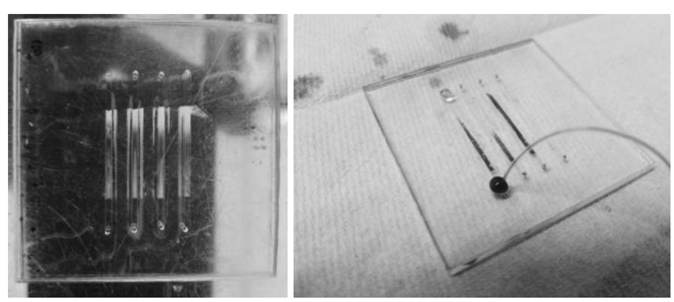

Figure 2: Nanofibers fabrics inside microfluidic channels before (left) and after (right) methylene blue adsorption.

of 80°C. A cover plate was added and both plates were thermostatically controlled for 5 min.

A pressure of 1100 lbs was used for 5 min and then the plates were allowed to cool to room temperature [3,4].

Figure 2 shows the nanofiber fabric inside the microfluidic device before and after dye adsorption experiment. The capture of the dye by the nanofibers can be clearly seen. The adsorption mechanism is based on the electrostatic attraction between the negatively charged nanofibers and the positively charged dyes. PMA has functional groups maleic anhydride, which is hydrolyzed/ionized into carboxyl groups. Once in contact with water, these carboxyl groups ionized into COO — which results in negative surface charges on the nanofibers [5].

Future step would be utilizing these nanofibers for separation of proteins from a mixture.

References:

[1] D. Cho, S. Lee, and M. W. Frey, "Characterizing zeta potential of functional nanofibers in a microfluidic device," J. Colloid Interface Sci., vol. 372, no. 1, pp. 252-260, 2012.

[2] L. Matlock-Colangelo, B. Coon, C. L. Pitner, M. W. Frey, and A. J. Baeumner, "Functionalized electrospun poly(vinyl alcohol) nanofibers for on-chip concentration of E. coli cells," Anal. Bioanal. Chem., vol. 408, no. 5, pp. 1327-1334, 2016.

[3] L. Matlock-Colangelo, D. Cho, C. L. Pitner, M. W. Frey, and A. J. Baeumner, "Functionalized electrospun nanofibers as bioseparators in microfluidic systems," Lab Chip, vol. 12, no. 9, p. 1696, 2012.

[4] D. Cho, L. Matlock-Colangelo, C. Xiang, P. J. Asiello, A. J. Baeumner, and M. W. Frey, "Electrospun nanofibers for microfluidic analytical systems," Polymer (Guildf)., vol. 52, no. 15, pp. 3413-3421, 2011.

[5] M. Xiao, J. Chery, and M. W. Frey, "Functionalization of Electrospun Poly(vinyl alcohol) (PVA) Nanofiber Membranes for Selective Chemical Capture," ACS Appl. Nano Mater., p. acsanm.7b00180, 2018.