21. Microfluidic Measurement Technology

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Objective: To address the scientific and measurement issues involving microfluidic dynamic behavior, chemical selectivity, and detection that impede the development of "lab-on-a-chip" devices. (See also: Microscale Analytical Laboratory – Division 839)

Problem: Microfluidic, or so-called "lab-on-a-chip", devices are generating much excitement because of their potential for high-speed and high-throughput chemical analysis relative to conventional bench top chemical instruments. Miniaturized devices for DNA separations have recently been commercialized for DNA sequencing. However, expansion of the "lab of the future" to other applications is held back by numerous technical barriers, such as poorly characterized and irreproducible microfluidic behavior, the high cost of silicon-based devices, and the lack of integrated and chemically selective detection elements.

Approach: In the second year of this multi-year NIST Competence project, methods have been developed to accurately measure fundamental flow parameters in polymer-based devices, and modify microchannel surfaces for greater reproducibility and tailored applications. New developments have been made with Division 839 to improve methods for forming microchannels in polymer substrates. Because electroosmotic flow (EOF) is currently the most widespread method used for moving fluid in microchannels, we are measuring the fundamental EOF parameters of electroosmotic mobility and flow velocity in a suite of plastic substrates. The EOF is created in the polymer channels by applying an external electric field, as in capillary electrophoresis. Because of the high surface-to-volume ratio of microchannels, surface properties often dominate microfluidic behavior and ultimately device sensitivity. Therefore, polyelectrolyte multilayers (PEMs) have been used to modify microchannel surfaces. These derivatizations result in devices with reproducible surfaces and allow tailoring of channels for specific chemical analysis problems. For example, PEM coatings on channel walls can be used to control the direction of flow in the microchannels. Channels have been derivatized with a positively charged polyelectrolyte on the walls of one half of the channel and a negatively charged polyelectrolyte on the other half; thereby, producing EOF in opposite directions in a single channel. Figure 1 shows a plug of fluorescent dye in such a channel. With time, the plug separates due to the opposite flows.

Results and Future Plans: Microfluidic channels have successfully been made in a number of different plastics. An optical-based method has been implemented to measure electroosmotic mobility and flow profiles in different plastic devices. Flow profiles in a number of different plastic microchannels have been measured in order to examine the effects of different materials and fabrication methods on electroosmotic flow in plastics. Such fundamental data relating flow to surface properties will enable developers of this technology to tailor plastic microfluid channels for specific applications. In addi-

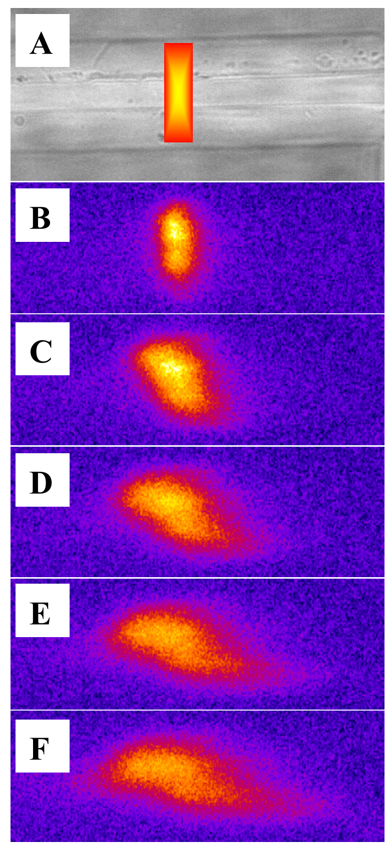

Figure 1: Time-step images an uncaged dye plug moving in a PEMs derivatized channel. A: Photomicrograph of the microchannel with schematic depiction of dye at instant of uncaging. B-F: Sequential fluorescence images of the plug movement, acquired every 67 msec.

tion, the plastic devices have been modified with polyelectrolyte multilayers which allow control of EOF in various plastics, as wells as unique methodology for patterning flow. Future research will include measurement of flow profiles and EOF in channels with complicated geometries, further development of plastic derivatization methods, and incorporation of sensors in the plastic channels.

Publications:

S. L. R. Barker, M. J. Tarlov, H. Canavan, J. J. Hickman and L. E. Locascio, ***"Plastic Microfluidic Devices Modified with Polyelectrolyte Multilayers"***, Anal. Chem. 72, pp. 4899-4903, (2000).

S. L. R. Barker, M. J. Tarlov, M. Branham, J. Xu, W. MacCrehan, M. Gaitan and L. E. Locascio, ***"Derivatization of Plastic Microfluidic Devices with Polyelectrolyte Multilayers,"*** In Micro Total Analysis Systems 2000, pp. 67-70, (2000).

S. L. R. Barker, D. Ross, M. J. Tarlov and L. E. Locascio, ***"Control of Flow Direction in Microfluidic Devices with Polyelectrolyte Multilayers,"*** Anal. Chem. (in press).