AN INTEGRATED OPTICAL DETECTOR FOR MICROFABRICATED ELECTRICAL FIELD FLOW FRACTIONATION SYSTEM

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ABSTRACT

This paper addresses the fabrication and testing of a polymer optical waveguide detector for a micro electrical field flow fractionation system. This study involves fabrication of a monolithically integrated μ-electrical FFF channel and a waveguide detector.

KEY WORDS: Chromatography, Detector, Optics, and Polymer Waveguide

INTRODUCTION

Electrical field flow fractionation is a chromatography like separation technique and it is used to separate a variety of soluble and colloidal samples including biological materials. Recent reports on a number of microscale field flow fractionation systems indicate the potential application of such system in μ-TAS [1], [2], [3]. One of the most critical aspects of EFFF system is the need to detect the particles and predict the particle size as EFFF is capable of separating particles on the basis of both size and charge. In our earlier communications we have demonstrated the necessity of on-chip detection to gain the maximum system performance [4] and optical detection remains one of the most sensitive techniques for such analytical systems. In he case of μ-electrical FFF, optical detection presents a number of potential advantages which include, but not limited to, particle detection, particle size analysis, and biochemical analysis. An evanescent wave based detection scheme is especially useful for the separations obtained using EFFF systems as the sample particles generally reside within 1 μm of the channel wall as shown in Figure 1. This method also paves the way to the possibility of analysis of a number of biochemical samples with highly selective *in situ* sensing.

WAVEGUIDE DETECTION

Monolithic integration in the case of optical waveguides is the most efficient way to minimize optical losses and reduce the complexity of the system in general. In the current work we have fabricated an evanescent interaction based waveguide detector made of SU-8, a material that also defines the walls of the EFFF channel. This material selection not only enables us to fabricate both the EFFF system and detector in a single step, but it also opens up the possibilities for a number of different modes of operation such as: absorption, scattering and fluorescence. In addition the SU-8 has a high refractive index (compared to glass), and is an excellent material for waveguiding in the visible range. One of the major concerns in the design of this detector is the size and location of the detection region. Earlier work done by our group on the location of an on-chip conductivity detector was used to help decide the location of the detector [4]. Thus, the optical fiber ends are 100 μm away from the leading edge of the triangular end and the detection region is located in the mid-portion of the triangular end.

EXPERIMENTAL

3.1 Fabrication and Assembly

The design of the device includes self guiding fiber alignment and allows placing the fiber very close to the channel (about 100 microns) without any distortion in the microstructure [5]. Fabrication of the device started with drilling holes in glass for the input and output ports followed by the sputtering of the Titanium/Gold for the channel electrodes. Metal electrodes were patterned such that they did not interfere with the optical detector. 25 μm thick SU-8 was spun over the slide and patterned to realize the fluidic channel. On another slide 125 μm thick SU-8 was spun over the substrate and patterned to define both waveguide and optical fiber interface. A self guiding approach for interfacing the fiber to the waveguide was used to facilitate assembly later on [5]. This was followed by sputtering of the Titanium/Gold on both substrates to realize the electrodes using a shadow mask made of PDMS for patterning. Prior to metal deposition SU-8 was subjected to oxygen plasma treatment to promote adhesion. A 125 μm diameter fused silica fiber (Thor Labs Inc) was bonded using thin SU-8 and UV cured. Prior to UV curing, excess SU-8 was scraped away to prevent any unwanted bulge in the waveguide region. The device fabrication was completed by bonding two glass plates using UV curable adhesive.

3.2 Methodology

Fluorescently tagged polystyrene particles (Excitation 460 nm, Emission 540 nm, Bangs Laboratories Inc, IN) of 100 nm diameter are used for the characterization of the detector. A syringe pump (Kent Scientific, CT) was used to pass DI water at 1 cm/sec. A USB spectrometer (Ocean Optics Inc, Fl) with attached LED source (460 nm peak wavelength) was used to detect the optical signal. First, an experimental run was conducted to determine the amount of the sample that will be required to obtain the detectable fluorescent signal. For this experiment 1% polystyrene particle samples of different volumes were injected in the microsystem. Another set of experiments was carried out to determine the ability of the detector to detect the very low concentrations of polystyrene particles.

RESULTS

The detector proved effective at detecting the labeled polystyrene particles. Experiments involving the effect of sample injection volume on the response of the detector revealed that this detector can sense very low volumes of sample particles (~1µl) effectively (Figure 5a). This is the typical range of the injected sample in the case of micro EFFF systems. Experimental runs for varying concentration were carried out for a sample size of 0.2 µl and the detector was sensitive even at low concentrations of 0.1% solids (usual sample concentration for micro EFFF system, see Figure 5b). Note that FFF systems naturally dilute particles almost 100 fold.

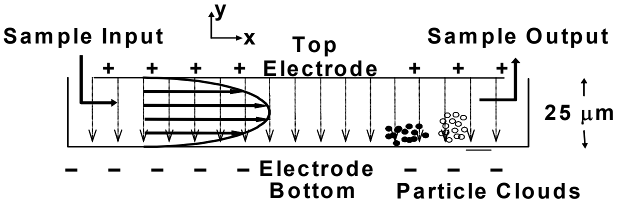

Figure 1 Diagram of operation of ElFFF system showing application of electric field, parabolic flow profile, and general separation mechanism. Particle cloud shown generally protrudes 1µm from the wall

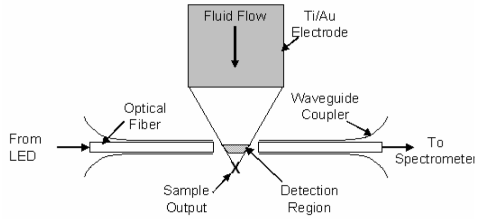

Figure 2 Schematic presentation of the integrated detector for micro-EFFF system

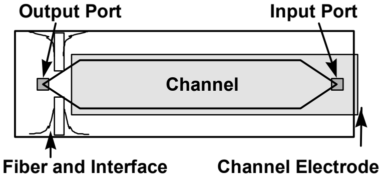

Figure 3 Top view of the microsystem

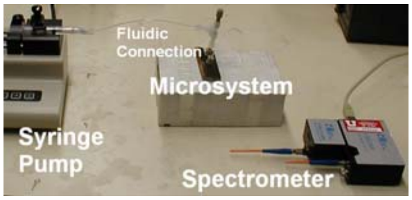

Figure 4 Experimental setup of the integrated detector for micro-EFFF system

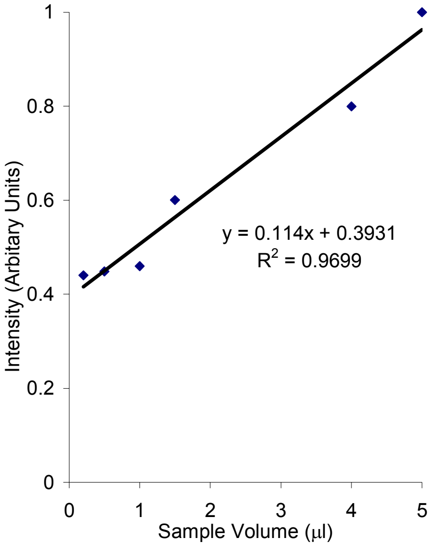

Figure 5 (a) Effect of sample injection volume

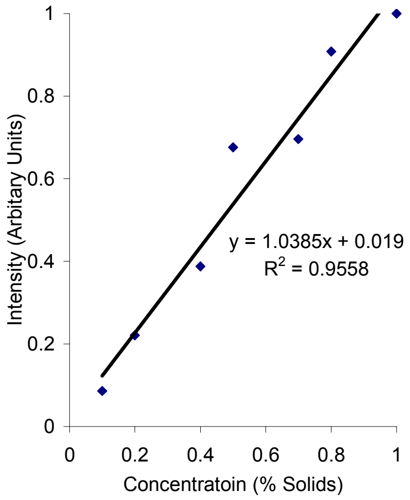

Figure 5 (b) Effect of concentration of sample

CONCLUSION

A monolithically integrated optical waveguide based detection scheme with micro-EFFF was reported. The response of the detector was found to be acceptable for the required operating conditions. With this optical detection scheme, EFFF and similar systems can be used more efficiently to separate and analyze a variety of biochemical analytes.

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