POLYELECTROLYTE DERIVATIZATION OF MICROFLUIDIC DEVICES

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims benefit of the filing date of copending Provisional Patent Application No. 60/232,951, filed on Sep. 15, 2000, the disclosure of which is herein incorporated by reference.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH

This invention was made by employees of the United States Government and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a microchannel device, and in particular, a microchannel device comprising a microchannel having microchannel wall surfaces with polyelectrolyte multilayers of alternate charge formed thereon.

2. Background of the Invention

In the past few years, there has been an increasing interest in the field now generally known as microfluidics. An important challenge in developing the first generation of microanalytical systems is in the successful design and fabrication of microcapillary channels and networks formed thereof, collectively referred to as microchannels. The microchannels may be composed of intersecting subchannels thereby forming a plurality of microchannel arms. These microchannels may be ultimately incorporated into self-contained analytical systems with detection and processing elements for use to perform chemical or biochemical measurements. Fluid transport in the microchannels may be accomplished using electroosmotic, thermal, or mechanical pumping. Chemical selectivity may be achieved using a number of analytical techniques including electrophoresis or chromatography (adsorption, affinity, or ion exchange).

Most prototype devices to date have been fabricated in glass or silica- or silicon-based substrates. Fine lithographic processing techniques are used to produce microchannels in the surface of a planar substrate that are then covered with a plate of similar material or different material thereby forming a lid over the microchannel.

For silica- and silicon-based devices, the most common methods for sealing the lid over the microchannels include high-temperature annealing, anodic bonding and wafer bonding depending upon the substrate material. Although successful prototype devices have been prepared using silica- or silicon-based substrates, the associated fabrication techniques of microchannel fabrication and sealing are generally difficult and/or expensive to implement.

Due to the aforementioned limitations associated with silica and silicon-based substrates, other materials such as polymers have been proposed as alternate substrates for the fabrication of microfluidic devices. Interest in using polymer substrates, such as plastics, for the production of microanalytical systems, is driven by the fact that these materials are less expensive and easier to manipulate than silicon or silica-based substrates. Further, plastics lend themselves readily to casting, molding, laser ablation, and machine operations. A wide variety of low-cost polymer materials enable selection for thermal and chemical resistance, molding temperature and surface derivatization properties.

A major obstacle in implementing microchannels fabricated in plastic substrates is that plastic surface chemical functionalities are not well characterized as compared to glass or silicon substrates. The surface can vary significantly from one plastic to another, and similar plastics can vary among commercial vendors. One such functionality is surface charge and surface charge density.

Surface charge and surface charge density is important in microfluidics for a number of reasons. Electroosmotic flow (EOF) is commonly used to move fluids through microchannels. This phenomenon is driven by charge (ionic) groups on the microchannel walls when an electric field is applied along the length of the microchannel. The direction and rate of EOF is determined by the charge and charge density, respectively, on the walls of the microchannel. Therefore, differences in microchannel surface chemistry can have a dramatic effect on flow rates and separations in devices utilizing EOF. For example, microchannels fabricated in various plastic substrates can exhibit dramatically different EOF mobilities (e.g., faster or slower flow rates). Thus, development of methods for controlling microchannel surface chemistry is critical for controlling flow rates and flow direction when EOF is employed to manipulate fluid flow.

Many common polymeric surfaces are either uncharged and extremely hydrophobic or negatively charged; however, biocompatible surfaces are generally hydrophilic with a net positively-charged surface. Therefore, for many applications of microfluidic devices in biotechnology, it would be desirable to identify coatings that could alter polymeric surfaces to make them hydrophilic and positively charged to minimize nonspecific adsorption of biological species.

Finally, many polymer-based microchannels require priming of the surfaces of the microchannel before use, i.e. the introduction of a fluid sample. Because several common polymers are hydrophobic in nature, priming of the microchannel may involve rinsing the microchannel with alcohol to first wet the surface, then filling the microchannel with water, and finally filling the microchannel with buffer solution. Air bubbles are often trapped in the primed polymeric microchannel when introducing a fluid sample, even if great care is taken to wet the surface prior to filling with buffer. These air bubbles may interfere with the analytical systems in which the microchannel is deployed. Therefore, coatings that reduce the hydrophobicity of polymeric microchannels are desirable.

BRIEF SUMMARY OF THE INVENTION

In accordance with the present invention, polyelectrolyte multilayers are used to alter the surface of microchannels fabricated in polymer-based substrates (e.g., either plastics or pure polymers). In addition, the polyelectrolyte multilayers (PEMs) can be used to control the direction of flow of a fluid through the microchannels in a microfluidic device. Further, complex flow patterns, including flow in opposite directions in the same microchannel, can be generated in a microchannel with opposing surfaces having opposite charges.

According to one aspect of the present invention, a microchannel device comprises a plastic substrate having a microchannel formed therein. Polyelectrolyte layers comprise alternating layers of at least one net positively charged layer or negatively charged layer. The polyelectrolyte multilayers are disposed along at least a portion of a microchannel surface. A lid is disposed over the microchannel with a lid surface facing the microchannel.

In accordance with another aspect of the present invention, a method is provided for manufacturing a micro-