METHOD FOR MICROFLUIDIC FLOW MANIPULATION

CROSS REFERENCE TO RELATED APPLICATIONS

This application is based upon and claims priority to U.S. provisional application 60/323,509 entitled "MICRO-CHANNEL DESIGNS FOR MIXING AND SPLITTING MICROFLUIDIC STREAMS UNDER ELECTROKINETIC OR PRESSURE DRIVEN FLOW" filed Sep. 19, 2001 by Timothy J Johnson, David J Ross, and Laurie E Locascio, the entire disclosure is specifically incorporated herein by reference for all that it discloses and teaches.

BACKGROUND OF THE INVENTION

a. Field of the Invention

The present invention pertains generally to microfluidic flow devices and specifically to mixers and splitters of microfluidic flow.

b. Description of the Background

The application of microfluidic analytical devices to chemical or biological assays has developed rapidly over the last decade. Although microfluidic devices have been highly successful, several performance limitations exist, notably reagent mixing.

Most mixing devices rely on diffusive mixing, wherein the natural laminar flow effects and the reagent's inherent diffusion coefficient cause the reagents to mix. Therefore, the mixing chamber/channel is usually extended to lengths that will ensure a completely mixed outlet stream. This approach may be acceptable for low flowrates, but high flowrates (>1 cm/s) or low analyte diffusion coefficients ($<10^{-7}$ cm/s^2) will require excessively long mixing channels. The difficulty in rapidly mixing reagents results from the fact that the system is restricted to the laminar flow regime (Re<2000) and also because the feature sizes are too small (typically <100 μm) to incorporate conventional mixing mechanisms.

The lack of turbulence in microfluidic systems has led to device designs that utilize multi-laminate, or flow splitting techniques to accomplish mixing in channels of shorter length. These designs split the incoming streams into several narrower confluent streams to reduce the mixing equilibrium time. Once mixing is complete, the narrow channels are then brought back together into a larger main channel for further transport, processing, and/or detection. The effectiveness of the flow splitting concept is based on the fact that the equilibrium time scales quadratically with the width of the channel. For example, if the width of the channel decreases by two, then the equilibrium time and the channel length decreased by a factor of four, or 25% of the original length. However, even a mixing length of 25% may still be unsuitable for some applications.

Other techniques for mixing may rely on active mechanical mixing, such as stirring paddles and the like. For very small fluidic passages, such devices are extremely fragile and difficult to manufacture.

It would therefore be advantageous to provide a device and method of mixing two confluent microfluidic laminar flows that did not require an excessively long channel to effectively mix the flows. Further, it would be advantageous to provide a splitting mechanism that may be able to split a stream of reagents into two streams of differing concentrations.

SUMMARY OF THE INVENTION

The present invention overcomes the disadvantages and limitations of the prior art by providing a device and method for effectively mixing two confluent laminar reagents within a very short stream length. This is accomplished by passing the confluent laminar flows over a series of narrow wells that are angled across the width of the channel. The device and method may also be used to split incoming streams into multiple streams of equal or non-equal proportions. Additionally, the present invention may be used for the mixing of plugs of reagents while minimizing axial dispersion of the reagent plug.

The present invention may therefore comprise a mixer of laminar microfluidic streams propelled by electrokinetic flow comprising: a first inlet channel; a second inlet channel; a mixing channel starting at the confluence of the first inlet channel and the second inlet channel; and a plurality of wells disposed in the mixing channel, the wells being obliquely oriented substantially across the width of the mixing channel.

The present invention may further comprise a splitter of a substantially laminar microfluidic stream comprising: a splitting channel coupled to at least two inlet ports and at least one outlet port in which the substantially laminar microfluidic stream has an axis of flow; and a plurality of wells disposed in the splitting channel, the wells being oriented substantially longitudinally across the width of the channel and diagonally across the axis of flow, the wells being deeper in profile than in width.

The present invention may further comprise a method of mixing two confluent laminar flows in microchannels comprising: providing a first inlet stream and a second inlet stream that meet at a confluence point to produce a confluent stream; passing the confluent stream through a mixing channel, the mixing channel comprising a plurality of wells, the wells being oriented substantially longitudinally across the width of the mixing channel and diagonally across the mixing channel, the wells being deeper in profile than in width; and producing a mixed laminar flow at the output of the mixing channel.

The advantages of the present invention are that flows may be combined and mixed without the conventional long lengths of diffusive mixing. The device may be further adapted to create two or more streams of equal or non-equal proportions of reagents. The device may be adjusted to tune the mix of the flows by adding various wells at different orientations, depths, and with various electroosmotic mobility coatings, all of which may have a substantial effect on the performance of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings,

FIG. **1** is an illustration of an embodiment of the present invention of a microfluidic mixer.

FIG. **2**A is a white light microscopy image of the embodiment of FIG. **1**.

FIG. **2**B is an image of the fluorescence of Rhodamine B introduced in the first inlet mixed with the buffer solution introduced in the second inlet.

FIG. **2**C is a similar image as FIG. **2**B, except the flow is 0.81 cm/s.

FIG. **3** illustrates experimental results of the degree of mixing of the embodiment of FIG. **2**A, wherein an electroosmotic flow of 0.06 cm/s was achieved.

FIG. **4** illustrates the same experimental set up as FIG. **2**C, with the electroosmotic flowrate of 0.81 cm/s.

FIG. **5** illustrates the same experimental set up of FIGS. **3** and **4**, with a pressure driven flow.