

experimental procedure and equipment used to perform all of the experiments referenced in this specification are given elsewhere in this specification.

[0046] FIG. 4 is a graph that illustrates the same experimental set up as FIG. 3, with the electroosmotic flowrate of 0.81 cm/s. The line 402 represents the results of the measurement taken with no mixing wells present. The line 404 represents perfect mixing. The line 406 represents the actual experimental results.

[0047] From the results illustrated in FIGS. 2B, 2C, 3, and 4, the degree of mixing exiting the mixer was 87.2% and 80.5% respectively, for the flowrates of 0.06 cm/s and 0.81 cm/s. To achieve the same degree of mixing, theoretical predictions state that a channel length of 0.2 cm and 2.3 cm for electroosmotic flowrates would be required if no mixer were present and based on diffusional mixing, assuming that the diffusion coefficient of the fluorescent material, Rhodamine B, is  $2.8 \times 10^{-6} \text{ cm}^2/\text{s}$ . These results indicate that the length of the present embodiment is 22% and 2% of the length of a comparable diffusive mixer for the present application.

[0048] FIG. 5 is a graph that illustrates the results of the same experimental set up of FIGS. 2, 3, and 4, with a pressure driven flow. The measurements were taken at 443  $\mu\text{m}$  from the beginning of the confluence region. The curve 502 represents the perfect mixing results. The curve 504 represents the experimental results with a pressure driven flow at 0.21 cm/s. The curve 506 represents the experimental results with a pressure driven flow at 1.25 cm/s. Since the pressure driven flow is not a wall driven phenomenon and therefore the fluid is not forced to enter the wells like electroosmotic flow, the effects of the mixing are not as great with pressure driven flow as with electroosmotic flow. However, the presence of the wells does introduce some lateral transport across the channel. This suggests that a series of wells could be optimized for mixing under pressure driven flow.

[0049] FIG. 6 illustrates a second embodiment 600 of the present invention. Two inlet streams 602 and 604 are combined and mixed in the mixing region 606 to produce a mixed flow that exhausts out of the outlet 608. The mixing region 606 comprises several wells 610, 612, 614, and 616 that are recessed into outlet 608. The measurement region 618 is 183  $\mu\text{m}$  from the point of confluence of the inlets 602 and 604. The shape and dimensions of the channels and wells are the same as with embodiment 100 of FIG. 1. The wells 610, 612, 614, and 616 are parallel to each other.

[0050] FIG. 7 is a white light microscopy image of an example of embodiment 600.

[0051] FIG. 8 is a graph that illustrates the degree of mixing of two reagents using embodiment 600 and an embodiment similar to embodiment 600 but with three wells instead of four. The experimental results of FIG. 8 show results for electroosmotic flow of 0.06 cm/s taken 183  $\mu\text{m}$  from the point of confluence of the inlet flows. The horizontal axis is the position across the width of the outlet stream 608 and the vertical axis is the normalized intensity of Rhodamine B. The same experimental setup was used for the results of FIG. 3 as FIG. 8, with the differences being the configuration of the mixing region and the position of the measurements.

[0052] The curve 802 represents the mixing profile of the two inlet streams when no mixing wells are present. The curve 804 represents the perfect mixing of the two streams. The curve 806 represents the mixing profile for the electroosmotic flowrate of 0.06 cm/s and a three well mixer. The curve

808 represents the mixing profile for the same flowrate and a four well mixer. The three well mixer is the embodiment 600 with well 616 removed.

[0053] FIG. 9 illustrates the results of the same experimental set up as FIG. 8 with a higher electroosmotic flowrate of 0.81 cm/s. The curve 902 represents the mixing profile of the two inlet streams when no mixing wells are present. The curve 904 represents the perfect mixing of the two streams. The curve 906 represents the mixing profile for a three well mixer. The curve 908 represents the mixing profile for a four well mixer. The three well mixer is the embodiment 600 with well 616 removed.

[0054] The curve 908 forms two distinct humps, 910 and 912, indicating that the four well mixer may be able to split the incoming streams into two streams of similar concentrations. The number of wells, the shape, dimension, and placement of the wells may be adapted to provide different dilutions of the incoming fluid. Such adaptations may depend on the reagents and the diffusivity constants of the various components of the confluent streams. As such, the particular result desired, such as splitting a stream or mixing a pair of confluent streams may be obtained by adjusting the quantity and position of the various wells.

[0055] FIG. 10 illustrates an embodiment 1000 of a stream splitter wherein inlet port 1002 and inlet port 1003 form a confluent stream wherein the fluid that is on one half of the channel is split into two streams due to the presence of the slanted wells, where the split streams are located on opposite sides of the channel that then exit through outlet 1004 and outlet 1006. The flow of the microfluidic stream passes over three wells 1008, 1010, and 1012 of similar design and construction as those of other embodiments described in the present specification.

[0056] In lab-on-a-chip or  $\mu$ -TAS (micro Total Analysis Systems), the use of a series of wells within a microchannel may greatly enhance the effectiveness of the entire system, especially when the system is limited to the laminar flow regime. The present invention is effective for low flowrates ( $<1 \text{ cm/s}$ ) as well as high flowrates ( $>1 \text{ cm/s}$ ). The present invention is further able to effectively mix flows that are driven electrokinetically, electroosmotically, or by pressure.

[0057] Several embodiments of the present invention may be used in series, such that one stream is separated and split, then separated and split again, with the end result being several outlet streams with differing dilutions of the original incoming stream. Such a system is known as serial dilution.

[0058] FIG. 11 illustrates an embodiment 1100 of a four-well mixer that was analyzed with computational fluid dynamics techniques for variations in the present invention. The computational analyses were designed to correspond to the experimental results shown in the previous figures. The channel geometry and fluid properties were selected to closely match those of the experiments. The inlet 1102 contains a buffer fluid with Rhodamine B that is mixed with a second inlet 1104 that contains only the buffer fluid. The fluid exits the embodiment 1100 via the outlet 1105. The four wells 1106, 1108, 1110, and 1112 are located at an angle theta 1113 from the centerline axis of the mixer. The geometry of the embodiment 1100 is similar to the previous embodiments described herein. Cross-section line A 1114 will be used to illustrate the incoming streams prior to mixing. Cross-section line B 1116 will be used to illustrate the mixing of the streams while in the well 1112, the last of the four wells. Cross-section line C 1118 will be used to illustrate the mixing of the streams