Digest Journal of Nanomaterials and Biostructures Vol. 5, No 1, March 2010, p. 255 – 261

EXPERIMENTAL OBSERVATION OF VALVELESS MULTI-SWITCHING PHENOMENON IN A MICROFLUIDIC BIO-CHIP USING ELECTROKINETIC INSTABILITY

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Experimental investigation of valveless multi-switching phenomenon with electrokinetic flow mixing for bio-analytical chip applications is presented. By DC electrokinetic instability (EKI) induced technique, a designed 5x5 microfluidic device which possesses microfluidic sample handling in flow multi-switching has been fabricated. The device not only control single sample flows into different outlet considered but also the multi-sample injection into specific outlet ports. Experimental results indicate that the sample flow could be electrokintcally pre-focusing to a narrow stream with single or double injection and then guided into desired outlet ports and successfully control devices in the microfluidic chip.

(Received February 14, 2010; accepted March 5, 2010)

Keywords: Microfluidic chip, Electrokinetic instability (EKI), MEMS

1. Introduction

Recently, the use of Micro-Electro Mechanical Systems (MEMS) technology has been a attracting approach applied in various fields. For example, the MEMS have been widely employed for biochemical analysis in recent years. One interesting application of this technology is a biosensor or a more sophisticated "lab-on-a-chip". The advantages of this kind of bio-chips includes the ease of biochips scanning, process, and rapid biological data interpreting. Bio-chips are interesting integrators which rely on microchips and microelectronic technology and bring the life sciences together within a new understanding from information technology. For a micro-fabricated bio-analytical system, fabrication is performed on planar substrates which are advantageous for rapidly sampling materials, chemical manipulation, manipulating small sample volumes, and integrating sample pre-treatment and separation strategies [1-2]. To carry out a complete assay, many different kinds of functional elements can be designed and serially integrated in microchips. Over the last decade, there has been a dramatically increasing interest in the development and realization of microfluidic systems using MEMS techniques. Microfluidic chips contain interconnected fluidic microchannel networks, reaction chambers and valves, which can carry out conventional bio-chemical measurement with increased speed and reliability at reduced costs [3]. Among these bio-chips, the liquid phase separation techniques were the first to be miniaturized into microchips and the on-chip realization of the micro total analysis system with bio-chips will by all means possess high potential in the future.

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2. Experimental

Initially, the glass substrates were cleaned in a boiled H_2SO_4:H_2O_2= 3:1 etching solution. The plates were then coated with an AZ4620 positive photoresist (PR) to provide a mask for wet chemical etching. UV lithography was performed using a mask aligner with an exposure time for 30 seconds and the exposed substrates were then immersed in a developer solution (AZ300K), before being etched in a 6:1 BOE (used as the buffer oxide etching) solution. Following the etching process, the substrates were cleaned in a boiling Piranha solution for 10 minutes together with blank glass plates. The plates were then thoroughly rinsed in DI water. The resin solution spreads uniformly into the gap between the substrates under the action of capillary forces due to the resin solution is similar to aqueous liquid. The acetone possesses a volatile property and therefore ensures that the gap between the glass substrates is filled by the resin. In addition, to prevent the resin from blocking the microchannels, the resin solution is removed from the reservoir of channels using a pump immediately after the steps. The substrates are pressed by several large glasses for about 30 seconds before the chip is bonded. The focusing/valveless switching microfluidic photograph of fabricated microchannel chip with five inlet ports and five outlet ports (5x5) is shown in Fig.1.

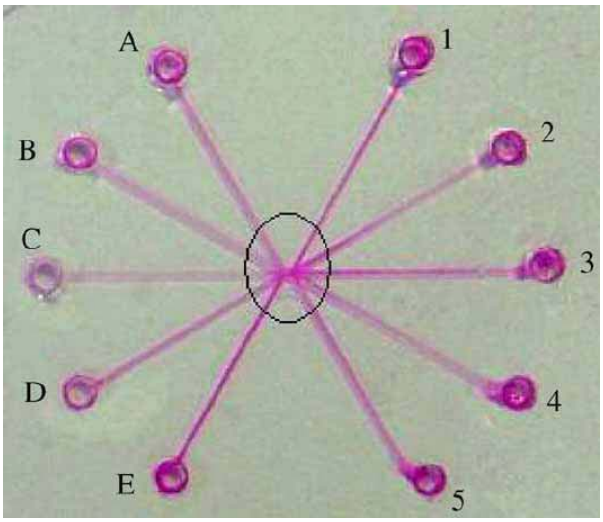

Fig.1. Top view of the valveless multi-switching microfluidic chip with five inlet ports and five outlets (5x5).

Fig. 2 presents a schematic diagram of the experimental setup for bio-chip measurement. In the experimental arrangement, the fluid sample manipulations within the microchip were observed by mercury lamp induced fluorescence using a charge-coupled device CCD camera. The experimental images were captured by an optical microscope, filtered spectrally, and then measured by the CCD device. Temporal profiles of the switching process were obtained using a detection system similar to that presented by Alarie et al [4].

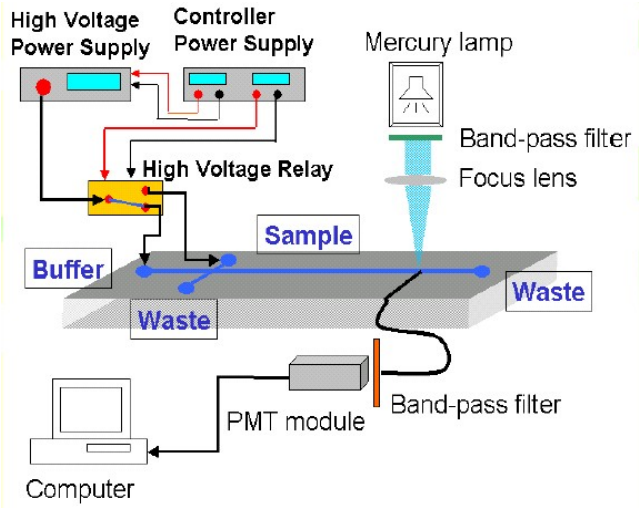

Fig.2. The schematic illustration of experimental setup for bio-chip measurement.

The details of the measurement principle can be referred to the published literature [5], and the operating process is described briefly in the following: (1) the sample was introduced into the inlet channel via the application of an electrical potential to the sample inlet channel, [6-7] (2) the same electrical potential was applied to each of the focusing channels in order to generate sheath flows to focus the sample into a narrow stream, and (3) the outlet channels were electrically isolated or grounded, as appropriate, in order to drive the focused sample flow electrokinetically to the required outlet port. The present microfluidic chip was fabricated on glass substrates using standard photolithography and wet chemical etching techniques. Applying the bonding procedure described above, the microfluidic device was successfully bonded using a UV epoxy solution. Fig.3 illustrates the microfluidic chip following completion of the photolithography and bonding processes. Its channel width and depth are 200um and 20um, respectively.

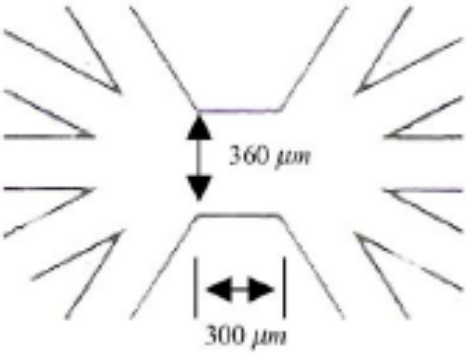

Fig.3. The schematic diagram of microchannel configuration with complete dimension

3. Results and disscussion

First, it is important to check whether if the bonded microchip can sustain high pressure in the microchannel. The sodium hydroxide solution, DI-water and hydrochloric acid solutions are used respectively loaded into the channel and raised the pressure to 1.792 ×102 kPa (26 psi). The vacuum pump is also used to suck in these solutions sequentially into the channel. Every chemical solution was continuously loaded into the channel for three minutes and it required about nine

minutes to complete a cycle. Three cycles (about 30 minutes) were conducted. Then, a blue dye was loaded into microchannel to observe any leakage.

Then, a series of experimental images are demonstrated the ability of the simple control to switch the sample flows to outlet channels for mixing using the EKI effect. Note that in these images, an electrical potential of 800V is applied to inlet channels, while the potentials of the outlet channels are grounded or isolated as appropriate. Figure 4(a)-(c) shows the continuous sample injection stream distributions for three different output modes. In figure 4(a), the sample is injected through channel B and then directed electrokinetically to output channel 1. Node B is biased with 800V and the outlet 1 is relatively used as the ground. Similarly, figures 4(b) and (c) also show the clear single flow switching from inlet B to outlet 2 and 3, respectively, at a voltage difference of 800V.

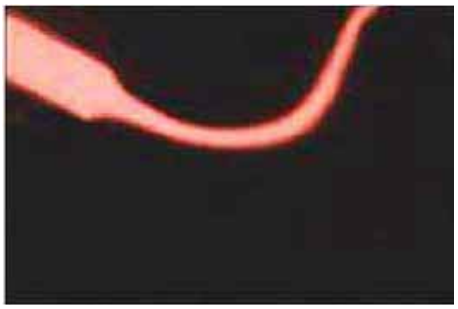

Fig.4(a) Single flow switching from inlet B to outlet 1 with applied DC voltage, the voltage difference between B and outlet 1 is 800V

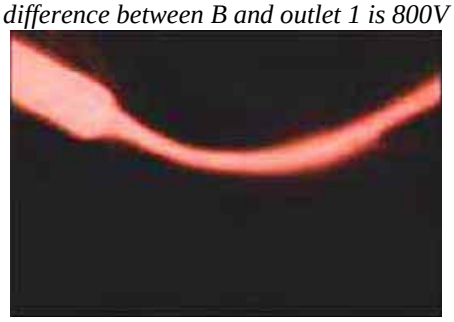

Fig.4(b) Single flow switching from inlet B to outlet 2 with applied DC voltage, the voltage difference between B and outlet 2 is 800V

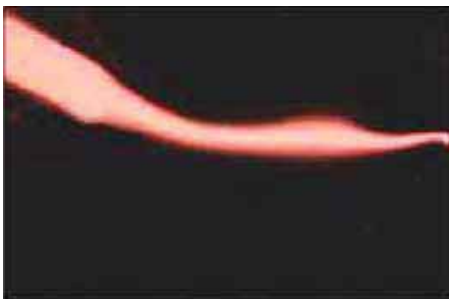

Fig.4(c) Single flow switching from inlet B to outlet 3 with applied DC voltage, the voltage difference between B and outlet 3 is 800V

From experiment, the similar results are also obtained from both microfluidic chips, i.e. irrespective of whether the chips employ UV epoxy resin or thermal fusion bonding techniques. The UV epoxy resin bond joining the blank cover plate to the etched plate can be separated by heating the microfluidic device to a temperature of approximately 100^{o}C. At this temperature, the polymer structure of the bond is destroyed, and the UV epoxy resin loses its adhesive property. Therefore, the plates can be separated and any obstructions in the microchannel cleansed by

immersing the plates in a sodium hydroxide solution or Piranha solution (H_2SO_4:H_2O_2= 3:1). The plates can be re-bonded for another application if necessary.

In addition, figures 5(a), (b) and (c) show the interesting double flow switching phenomena from two inlets to two outlets in a microfluidic chip with double DC voltages and having a voltage difference with each other. In Fig.5(a), the B, D inlet voltages are 400V and 1000V, respectively. The crowding phenomenon is observed and the microfluid will flow toward the nearest ground under lower voltage difference. When two ground positions are getting closer, the crowding phenomenon also becomes clear. In Fig.5(b) and (c), the B inlet voltages are 300V and 200V, respectively at a constant D inlet voltage of 1000V. From experiment, it is worth to note that the larger voltage difference will get the smaller channel crowding phenomenon while using two DC voltages and two different grounds.

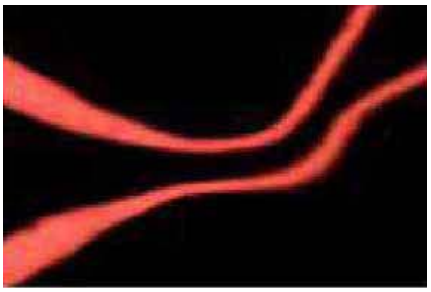

Fig.5(a) Double flow switching from inlets B, D to outlets 1 and 2, the voltage difference between B and D is 600V

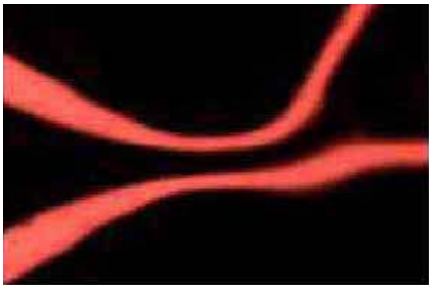

Fig.5(b) Double flow switching from inlets B, D to outlets 1 and 3, the voltage difference between B and D is 700V

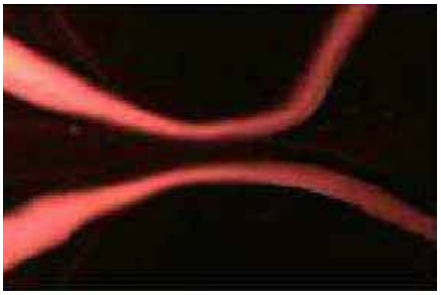

Fig.5(c) Double flow switching from inlets B, D to outlets 1 and 4, the voltage difference between B and D is 800V

4. Conclusions

A valveless multi-switching microfluidic chip was fabricated in glass substrates using conventional photolithographic and chemical etching process, and the chip was bonded via a high-temperature fusion method. The flow direction can be adjusted by applied voltage and connection to the assigned position. Finally, the microfluidic chips presented within this study possess an exciting potential for use in a variety of techniques, including high-throughput chemical

analysis, fraction collection, fast sample mixing, and many other bio-applications within the micro-total-analysis systems field.

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