Advanced Fabrication of Electroactive Nanowell Sensors

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Abstract/Introduction:

Particle trapping using electrical fields presents as an effective way to trap particles for many biological applications. An investigation was conducted into the ability to effectively fabricate a flexible electronic architecture for use in electroactive nanowell particle trapping. This architecture consists of perpendicular fluidic channels and gold electrodes patterned into PDMS, which allows for controlled particle flow and specific targeting of wells. The lack of adhesion between PDMS and gold requires the use of a self-assembling monolayer, mercaptosilane, to effectively transfer the gold pattern. The patterned PDMS chip is then bonded to a polyimide surface, which contains micron-scale wells. By flowing polystyrene beads through this device and applying a voltage across the wells and electrodes, localized electrophoretic and electroosmotic effects can be used to trap these particles in the wells [1]. The techniques presented here can be furthered to allow for individual x-y addressability of wells and individual particle manipulation.

Fabrication Process:

The device structure consists of two independently fabricated substrates which are then bonded together. The bottom substrate is made from glass-ITO, with wells patterned in polyimide, serving as a dielectric insulator. The well sizes range from 5 to 25 μm. Fabrication of this substrate had been completed in prior research.

The focus of this project was to develop a process for fabrication of the top substrate, a PDMS chip consisting of perpendicular fluidic channels and gold electrodes (Figure 1). This was done in 3 steps: a) patterning fluidic channels on a silicon wafer, b) patterning perpendicular gold electrodes on top of these fluidic channels, and c) transferring the pattern in its entirety into PDMS. Standard photolithography using SU-8 10 was performed in creating fluidic channels that were 40 μm wide and 10 μm high with 200 μm spacing. In order to pattern gold electrodes on top of these fluidic channels, lift-off was performed using a very thick resist (Shipley 1075 spun at 2000 rpm) such that the layer of resist would overtop the already patterned fluidic channels. The lift-off method used was resist surface modification using toluene [2], resulting in perpendicular 40 μm gold electrodes with 200 μm spacing (Figure 2). Gold continuity was maintained along the fluidic channels by using a 2-stage evaporation at 45°, resulting in coating of the fluidic channel sidewalls (Figure 3).

Figure 1: Diagram of top PDMS substrate.

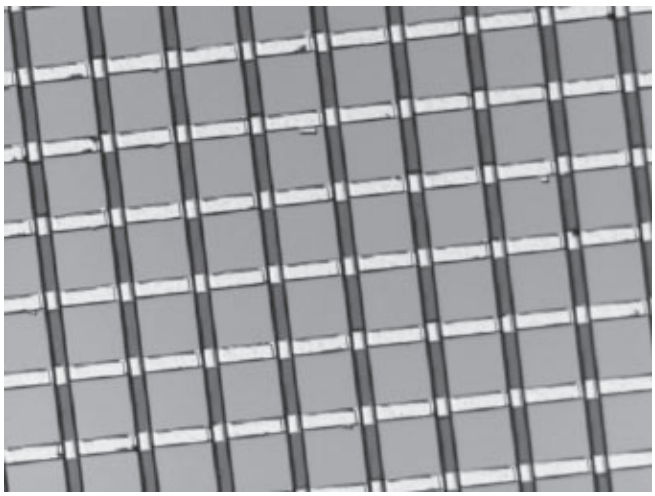

Figure 2: Gold electrodes and fluidic channels on Si wafer.

In order to transfer this pattern to PDMS, the wafer was first soaked in a 15 mM solution of 3-mercapto-propyltrimethoxysilane in IPA for 2 hours, assembling a monolayer for effective PDMS-Au adhesion [3]. Sylgard PDMS (10:1) was then poured onto the wafer and cured at 80°C. After fabrication of the PDMS chip, the chip was subsequently bonded to the polyimide surface by first plasma cleaning both surfaces for 30 seconds, and then bonding the substrates so as to achieve alignment between the wells, fluidic channels, and gold electrodes.

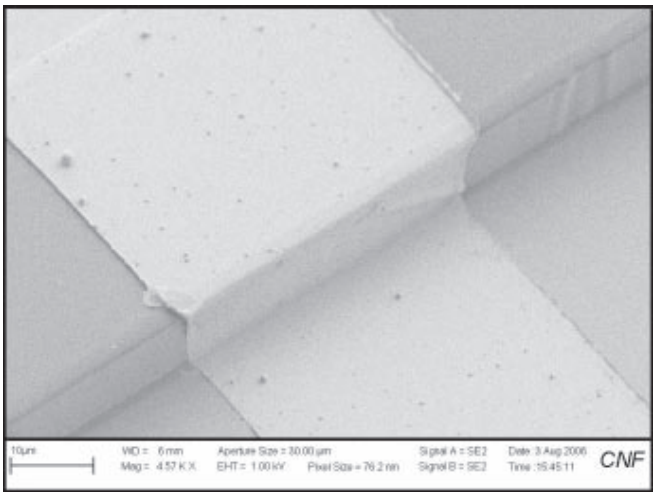

Figure 3: Gold continuity along fluidic channel sidewall.

Experimental Results and Conclusions:

Experiments were performed using 2 μm polystyrene beads which had been chemically treated to provide charge and fluorescence. These particles were mixed with de-ionized water and flown through the PDMS fluidic channels using a syringe pump. The first experiment conducted involved observing the effects on these particles of an applied electric field over an ITO bonding pad, i.e. a large area of ITO (1 cm^2). It was observed that at relatively high voltages (around 5 to 6 V), the trapping phenomenon could consistently be observed, as all the particles over the bonding pad would come to a complete stop. This was likely due to a combination of electrophoresis, dielectrophoresis, and electroosmosis, causing the electric field lines to extend well beyond the boundaries of the gold electrodes and "trap" particles over a very large area. More importantly, this result led to the conclusion that the fabrication of the device itself was sound and gold continuity was maintained such that an electric potential can be propagated along the electrodes in the PDMS chip.

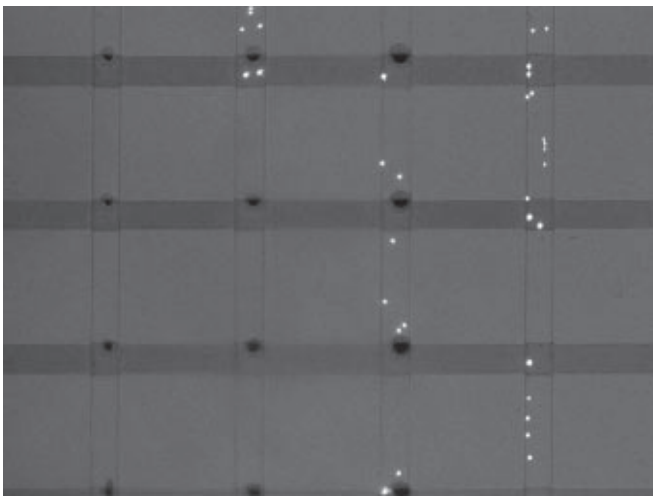

Figure 4: Unpredictable response of particles around wells.

The second experiment conducted involved trying to trap these particles in the micron-scale wells, which was the primary goal of the device. Inconsistent results were observed, as the particles occasionally migrated toward the wells, but did not get trapped in them (Figure 4). Velocity changes for the particles could also be observed when voltages were applied, but not in a predictable manner. It was believed that the main reason for the unpredictable effects of the electric fields around the wells is gold-ITO contact at the ITO bonding pads, causing many of the gold electrodes to short and creating undesirable effects downstream. As a result, the device design needs to be slightly modified to prevent this from occurring.

Future Work:

In accordance with experimental results, future work will focus on slightly modifying the substrate architectures to eliminate the possibility of gold-ITO contact and shorting of electrodes. In addition, optimization of the fabrication process, particularly in regards to the concentration of mercaptosilane used and the PDMS delamination method, can contribute to improved repeatability and consistency. Ultimately, this device can be used for x-y addressability, i.e. individual well targeting, and enhanced particle manipulation.

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References:

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