# Microfluidic Devices for Biological Applications

**Frank Cleary, Physics, Cornell University**
***NNIN REU Site: Nanotech, University of California at Santa Barbara***

*NNIN REU Principal Investigator: Andrew Cleland, Physics, University of California, Santa Barbara*
*NNIN REU Mentor: David Wood, Physics, University of California, Santa Barbara*
*Contact: fbc4@cornell.edu, anc@physics.ucsb.edu*

**Abstract:**

In recent years much interest has been generated in devices in which fluid is moved through micrometer scale channels. These so-called microfluidic devices show great promise in their application to biology and medicine. One possible application is a cheap, disposable cell sorting device that requires only small sample sizes. Such a device would be very useful in immunology and cancer research as current cell sorting technology has none of these desirable properties.

One key problem in creating a microfluidic cell sorter is that the fluid flow must be switched between two or more collection points. By fabricating a microfluidic device in which fluid flow is switched by the application of an electric field, an important element of a microfluidic cell sorter is completed. We have investigated the fabrication and use of such a device made out of polydimethylsiloxane (PDMS), a silicon elastomer. We present our fabrication process as well as data on device performance. We also present data from simulations of a bead in a microfluidic channel as it moves over a coplanar waveguide, a promising scheme for the detection of cells.

## Introduction:

The need to separate specific cell types from a diverse population is essential to modern cancer and immunology research. Current technology relies on Fluorescence Activated Cell Sorting (FACS). A FACS machine differentiates cells by shining a laser on them and detecting fluorescence. The cell is then encased in a droplet of water charged according to the type of cell. The droplet is deflected by an electric field into the proper container.

Although FACS provides fast, efficient sorting of cells, it has several major drawbacks. FACS machines are expensive, hard to clean and require relatively large sample sizes. A microfluidic cell sorter could be made to be cheap and disposable, requiring only very small sample volumes. The microfluidic devices we have fabricated show potential for use in a microfluidic cell sorting system.

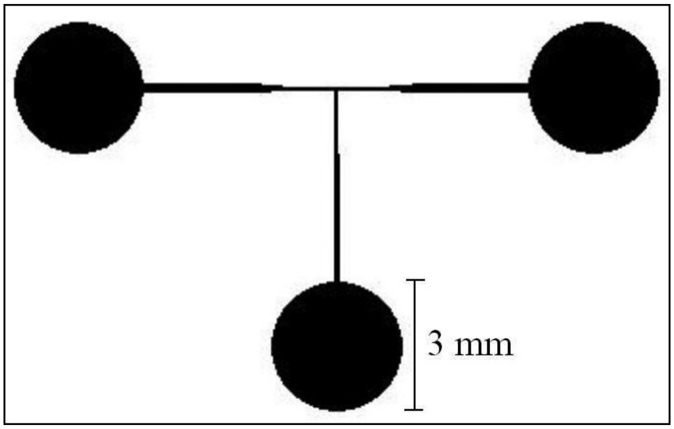

*Figure 1: A schematic of a microfluidic device.*

Our microfluidic devices (Figure 1) were designed to use electroosmosis as a means of switching fluid flow from one collection point to another. Electroosmosis is a phenomenon that arises because of the buildup of charged ions along the walls of the device. Applying an electric field causes these ions to move, dragging the rest of the fluid with them.

Besides switching fluid flow, another key problem in the creation of a microfluidic cell sorter is that of detection. Current laser detection systems are large and expensive. In exploration of new detection schemes we have simulated the motion of a Teflon™ bead as it passes over coplanar electrodes. As the bead moves over the electrodes its presence changes the resistance and capacitance between them. This demonstrates the potential for an electronic detection method that would be far cheaper than current optical techniques.

## Methods:

PDMS microfluidic devices were fabricated as described in [1]. Roughly, 50 μm thick SU-8 photoresist was patterned on a 3” silicon wafer. PDMS prepolymer was mixed with curing agent then poured over the wafer and baked. The cured PDMS was then peeled off and individual devices cut from it. The devices were bonded to glass microscope slides. Predrilled holes in the slide were used to connect the device to external fluid lines.

We attempted to create electroosmotic flow by placing platinum electrodes in two different collection wells and applying a high voltage (~150 V) between them. Flow was visualized using 10 µm diameter polystyrene beads.

Simulations were run using Ansoft's HFSS software. A model with a 25 x 25 µm channel of seawater running over coplanar electrodes was constructed (see Figure 2). Electrical impedance data as a function of bead position was extracted from the simulations.

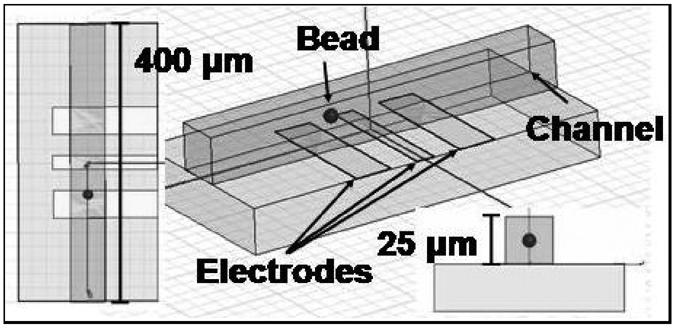

*Figure 2: Three views of the model used to simulate the motion of a bead over a coplanar waveguide.*

## Results and Discussion:

Working microfluidic devices were fabricated and 10 µm diameter polystyrene beads were observed moving through the channels. Electroosmotic flow was not observed although electric current was flowing between the electrodes. A possible explanation of this is that the minimum channel dimensions of 50 x 30 µm were too large for electroosmotic flow to occur. Smaller channels would possibly improve electroosmotic flow.

A typical plot of impedance vs. bead position is shown in Figure 4. In this case, the bead was made of Teflon™, an insulating material. A conducting bead will cause the real and imaginary parts of the impedance to change in opposite directions.

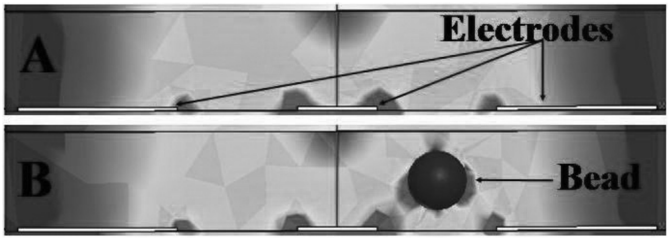

*Figure 3: Electric field magnitude (side view of channel). Note change when bead is present (in B).*

Simulations of a bead as it moves over coplanar electrodes show promising results for the electronic detection of cells. With a working detection model different objects can be simulated giving researchers data on what geometries and materials will provide the greatest signal.

## Conclusion:

We have constructed a microfluidic device that is capable of supporting fluid flow. The method used is fast and inexpensive since the mold used to make the device can be reused, eliminating the need for further photolithography.

By simulating the passage of a bead over coplanar electrodes, we demonstrate the theoretical basis for a promising detection scheme. In the future, researchers will be able to use this simulation model to experiment with different geometries and materials without going through a long and difficult fabrication and testing process.

## Acknowledgements:

Omair Saadat contributed greatly to the microfluidic device fabrication process in the course of his work alongside the authors. Chris McKenney, Michael Stanton and Loren Swenson aided in various parts of the project. We also thank Martin Vandenbroek and Mike Wrocklage for their technical assistance. Funding was provided by the National Science Foundation and the NNIN.

## References:

[1] Micro-fluidics Lab Process Summary (M.I.T., unpublished) Available: http://hackman.mit.edu/6152J/SP_2004/lab_manuals/sp_2004_fluidics_manual.pdf

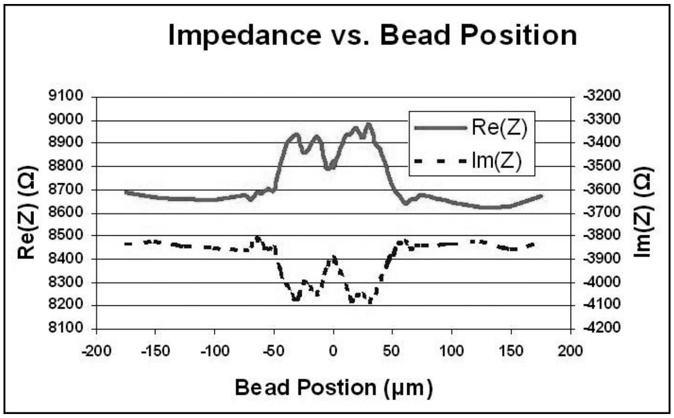

*Figure 4: Real and imaginary parts of the electrical impedance of the system as the bead moves through the channel.*