BIOL

Direct Writing for Biological Applications: Cell Patterning into Microfluidic Channels and Nanoparticle Writing onto Patterned Substrate

Benjamin Vizy
Biological Engineering, Purdue University

NNIN REU Site: Lurie Nanofabrication Facility, University of Michigan, Ann Arbor, MI
NNIN REU Principal Investigator and Mentor: Pilar Herrera-Fierro, Ph.D. Lurie Nanofabrication Facility, University of Michigan
Contact: bvizy@purdue.edu, pilarhf@umich.edu

Abstract and Introduction:

Direct writing is an alternative method of patterning that is gaining popularity in many fields, particularly in biological applications. This alternative to conventional lithography can have many applications in biology, in which there are many cases where the ink, or substances to be jetted (patterned) cannot be exposed to the radiation, solvents, or temperatures needed for lithography. We will present two different applications of this technique.

Patterning cells is a practice that mimics a cell's natural environment. This allows different tests to be performed to see their natural response, such as cell-cell interactions, signals, and responses to new biotechnologies [1]. Two-phase cell patterning makes the process less harmful to cells than previous methods because it allows the cells to be patterned in a completely aqueous environment.

Two solutions of immiscible polymers, dextran and polyethylene glycol (PEG), were prepared for this experiment. Dextran was deposited onto a substrate, allowed to dry, and then rehydrated by PEG. In two-phase cell patterning, one of these solutions would contain cells, and because of PEG and dextran's interfacial tension, the cells would move to either fluid based on affinity [2]. One goal of this project was to show that dextran printed by the ink-jet method could provide similar results in microfluidic channels.

Another goal of this project was to use the ink-jet method to print fluorescent nanoparticles on a patterned substrate. Intracranial pressure (ICP) is the pressure exerted on the inside of the skull, and is generally measured after a surgery or head trauma to decrease chances of additional harm. Because this is usually measured by inserting a catheter into the brain, a more comfortable solution using microelectromechanical (MEMS) systems was recently developed [3], where quantum dots (QDs) are patterned onto small pillars and implanted in the skin. Depending on the pressure inside the head, shining infrared light on the skin will cause one layer of QDs to emit a more intense wavelength than the other, which allows ICP to be read [3]. Previous methods of patterning QDs — in which QDs were mixed into the pillar materials during lithography — were inefficient. The goal of this project was to direct-print the QDs onto the patterned pillars to increase the fluorescent signal of the pillars.

Methods:

For printing with 500 kDa dextran, 5% and 12.8% dextran by volume solutions were prepared in deionized water with a small amount of rhodamine B for fluorescence; 5% 35 kDa PEG was also used. The 12.8% solution was used to test the relationship between dextran and PEG. The 5% dextran was printed on microfluidic channels made with polydimethylsiloxane (PDMS) using the Dimatix inkjet printer (Fuji). Upon printing in the channels, the PDMS was activated and bonded to a clean glass slide. PEG was run through the channels and observations were made using the Olympus BX-51 fluorescent microscope.

For printing with QDs, a solution of toluene and rhodamine B was prepared for testing, along with a wafer covered in SU-8 pillars 250 μm in diameter. After the toluene was able to be printed on the pillars, a 1:1 solution of toluene:QDs was prepared and printed onto the pillars.

Printing on pillars also required alignment of the stage, in order to print them exactly in the center of the pillar.

Results and Conclusions:

For ink-jet printing with dextran, high voltages were used with the printer in order to get the viscous polymer to jet. Cleaning cycles on the Dimatix printer that jet fluid through the nozzles

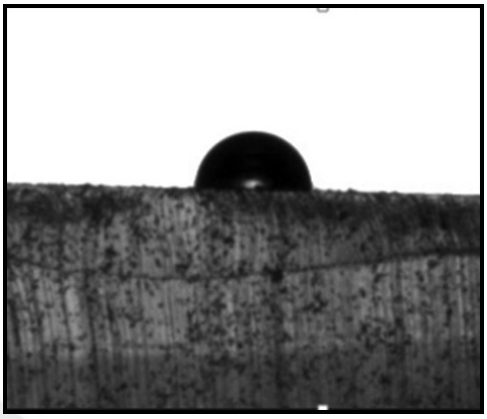

Figure 1: Dextran's contact angle on PDMS is around 88.8 degrees.

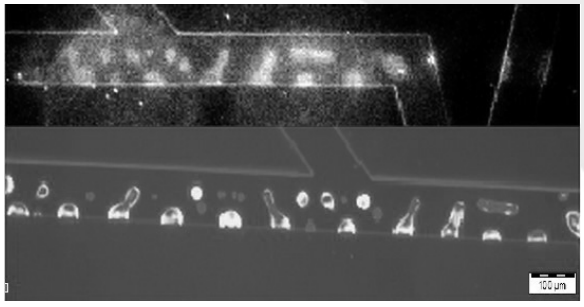

Figure 2: Top; Dextran in microfluidic channel after PEG was introduced. Bottom; Dextran in microfluidic channel before PEG was introduced.

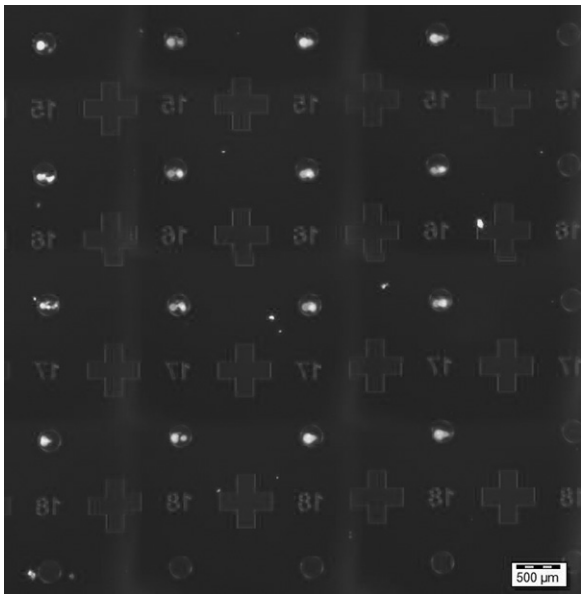

Figure 3: Toluene printed on 250 µm-wide pillars are around 140-180 µm in diameter.

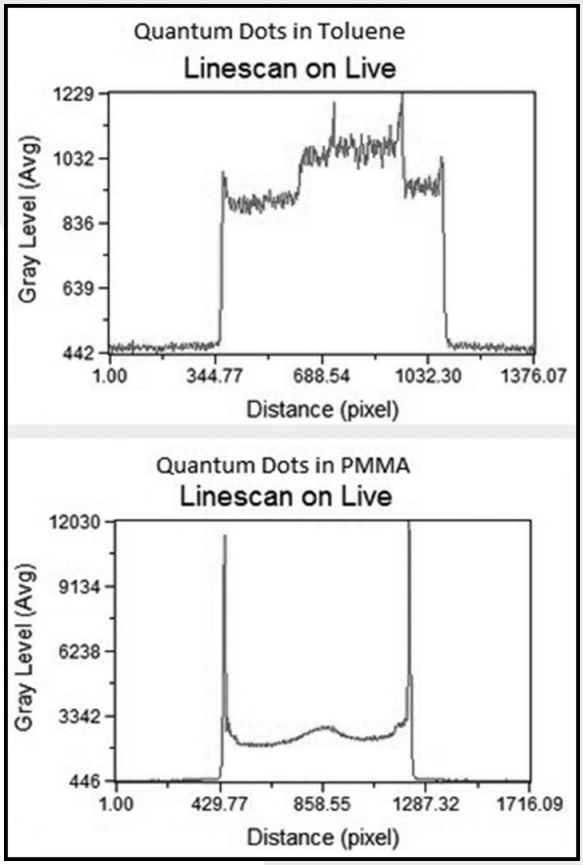

Figure 4: Top; QDs in toluene fluoresce around 1040 units. Bottom; Quantum dots in PMMA fluoresce around 3340 units.

were used before the start in order to assure jetting. Printing dots of dextran 40 μm apart in a line resulted in drops 13-17 μm in diameter, small due to the near 90 degree contact angle of dextran on PDMS (see Figure 1). Upon running PEG through the channels and using a background subtraction effect on the microscope, we were able to see that the dextran still existed in its original pattern on the channels. Larger dots were printed in the channels to further illustrate this effect (see Figure 2).

This shows that direct printing with the Dimatix Inkjet is a possible solution for two-phase cell patterning.

For toluene, a high vapor pressure liquid, printing was achieved by using low voltages. A pattern of 3×3 drops was printed on the pillars, as it contained the most area while still being somewhat consistent. Two layers were printed on the pillars, as any more did not show a significant increase in diameter. Figure 3 shows the results of toluene drops on SU-8 pillars. The diameters range from 140-180 μm. Mixing QDs in the toluene unfortunately did not achieve the desired fluorescence for this project. As shown in Figure 4, the light intensity of the QDs in toluene is around 1040 units, whereas in a previous experiments using QDs and poly(methyl methacrylate) (PMMA), fluorescence was around 3340 units. This meant that the use of Dimatix printing would not be used further in this project.

Acknowledgements:

I would like to thank the NNIN Research Experience for Undergraduates Program and the National Science foundation for giving me this opportunity, Dr. Pilar Herrera-Fierro for leading my research, Amrita Chaudbury, who was in charge of the QD project, and Brandon Lucas, Trasa Burkhardt, and the University of Michigan for coordinating this research experience.

References:

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