Making a Microfluidic Device to Mimic Flow Through Porous Medium

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Primary CNF Tools Used: CAD software L-Edit, photolithography tool set, ABM contact aligner, hot press, CorSolutions microfluidic probe station

Abstract:

With the rapid depletion of known oil reserves, detecting properties of the oil reservoirs and optimizing oil extraction is critical. By measuring the aqueous properties of the reservoirs, decisions can be made on which reservoirs to drill and the available quantity of oil to extract, with minimal environmental impact. Utilizing hairy nanoparticles in testing can provide a variety of information about the reservoir. The objective of the proposed work is to characterize the behavior of hairy nanoparticles at the oil-water interface in order to optimize their use as subsurface sensors. In order to complete the optimization, a microfluidic model for the environment needs to be developed. This past year's work involves making microfluidic devices to mimic water flowing through the subsurface and oil trapped in pores. The design and mold to make the mold was developed in the CNF first using photolithography to create a mold with negative photoresist that was used to make microfluidic channels out of polydimethylsiloxane and later using positive photoresist and etching to create a mold to make microfluidic channels out of polypropylene.

Summary of Research:

This research at the CNF has consisted of using microfabrication techniques to make a microfluidic device. Using the CAD software L-Edit, we make patterns to transfer to a mask using the Heidelberg mask writer. In the past year, we have made two types of masks: one for positive photoresist and the other for negative photoresist. The first set of microfluidic devices we made used the negative photoresist (SU-8) to make a mold.

The process of making a mold with photoresist (photolithography) consist of the steps; 1) Pour and spin photoresist onto a wafer (using CNF spinner), 2) Bake photoresist (using CNF hot plates), 3) Wait time, 4) Expose photoresist (using ABM contact aligner), 5) Second wait time, 6) Development photoresist. At the end of the process, we have a mold out of SU-8 on top of a wafer.

In the Kirby research group's lab, we made microfluidic devices by pouring PDMS on top of the mold, and then baking and attaching the molded PDMS to a glass slide through plasma cleaning. Unfortunately, for our application, we need the PDMS to be very hydrophobic and PDMS was not hydrophobic enough for these experiments. Therefore, we switched to making devices out of a polypropylene — a much more hydrophobic material.

To make the molded polypropylene pieces, we use hot embossing, which is done on the CNF hot press. Because of the large pressure applied during embossing, we needed a stronger mold than SU-8, so we switched to making molds out of silicon.

To make a mold out of silicon, a positive photoresist is spun instead of negative and after the photolithography process, the wafer is etched on the deep reactive ion etcher in the CNF. The mold is used in the CNF hot press to hot emboss the pattern onto polypropylene, which is then bonded using the hot press. We also used the CorSolutions microfluidic probe station for a time as a connection method for the tubes to the device. However, we determined that epoxy was a better method for the connecting tubes to the microfluidic device due to the pressure exerted by the CorSolution arm causing particles to clog.

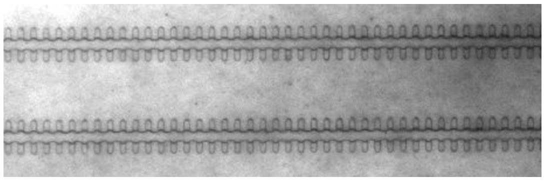

Figure 1: Developed positive resist pattern on wafer.

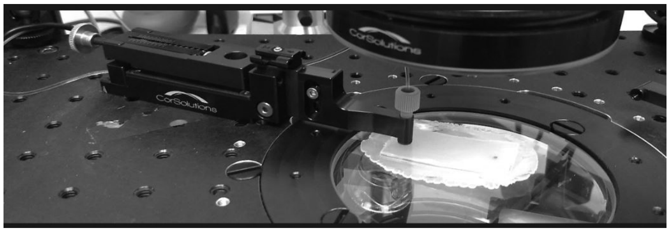

Figure 2: Embossed channels in polypropylene.

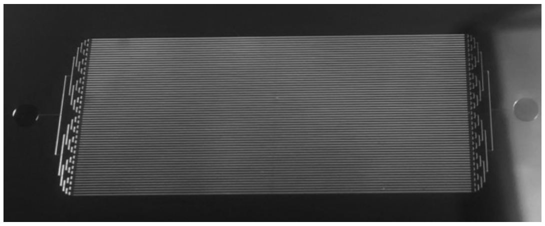

Figure 3: Device on CorSolutions microfluidic probe station.