Development of a Salivary Microfluidic Diagnostic Device using Hot Embossing

CNF Project Number: 1872-10
Principal Investigator: David Erickson
User: Elizabeth Rey

Affiliation: Sibley School of Mechanical and Aerospace Engineering, Cornell University
Primary Source of Research Funding: National Science Foundation
Contact: de54@cornell.edu, egr42@cornell.edu

Primary CNF Tools Used: Heidelberg DWL2000, YES vapor prime oven, ABM contact aligner, Unaxis 770 Deep Si etcher, P10 profilometer, Zeiss Supra SEM, DISCO dicing saw, hot press, Harrick plasma generator, micro drill

Abstract:
Point of care diagnostic devices allow people to get fast, accurate information about their health and well-being without the need to go to a clinic or hospital. The device that we are designing will determine the concentration of cortisol from a sample of the user’s saliva. Cortisol is a steroid hormone associated with stress levels and expressed in human saliva [1,2]. This microfluidic device will contain a microbead-based immunoassay that will determine the cortisol content from a saliva sample. The device is manufactured using a hot embossing process, which uses a silicon master made with traditional lithographic processes. The device will be made from a thermoplastic called Zeonor 1020R, which is a transparent, semi-rigid plastic that can be used in large-scale manufacturing processes such as injection molding and hot embossing. All of the fabrication of the device is being done in the Cornell NanoScale Facility.

Summary of Research:
The microfluidic device is made using a hot embossing process, which involves the high-temperature pressing of a mold into a piece of thermoplastic. The mold used in this process is made of silicon and is fabricated using photolithographic processes. The design for the mold is made using L-Edit and transferred to a photomask using the Heidelberg Mask Writer (DWL2000). This mask is then used to transfer a pattern to a photoresist on a silicon wafer. The photoresist (SPR-220-7.0) is spun onto a bare silicon wafer, which has been previously primed in the YES Vapor Prime Oven, to a thickness of approximately 7 µm. After spinning, the photoresist is soft baked on a 115°C hot plate for 2 minutes and 30 seconds. The wafer is allowed to sit for an hour and then exposed using the mask and the ABM Contact Aligner. The wafer is again allowed to sit for an hour and then is developed using the Hamatech Steag Wafer Processor. The pattern is now developed and can be used to etch the silicon wafer.

We etched the wafer using the Unaxis 770 Deep Si Etcher to a depth of 100 µm, and monitored the etch depth and etch rate using the P10 Profilometer. Upon reaching the desired depth, we removed the photoresist in the chemical strip bath. In order to ensure that the process was working as desired, we used the scanning electron microscope (SEM) to image the various features of the device. An SEM image of the smallest features, around 20-40 µm in size, can be seen in Figure 1. We then used the Unaxis 770 again to deposit a thin layer of fluoropolymer onto the wafer in order to prevent sticking in the hot emboss process. In order to separate the individual patterns into separate masters, we cut the wafer into pieces using the DISCO Dicing Saw. Masters are then ready to be used in the hot emboss process. Some of these masters can be seen in Figure 2.

Figure 1: SEM image of small trapezoidal features.
The hot emboss process uses the CRC Prepreg Mini Test Press, which applies heat and even pressure. The silicon master is adhered to a glass backing, for strength, and then the plastic piece is placed on top of the master, with another glass backing on top of that. This whole stack is placed in the hot press once the hot press reaches the desired temperature and pressed for several minutes. The setup is allowed to cool below the glass transition temperature of the plastic and then the pressure is released and the plastic is de-embossed. The pattern is transferred from the master to the plastic. We then drill through-holes in a blank piece of plastic using the custom-made micro drill. This blank piece is then bonded to the patterned piece to create the microfluidic device. For the bonding process, we used the Harrick Plasma Generator to activate the surfaces of the plastic pieces and immediately put the pieces together and put them in the hot press again to thermally bond.

The microfluidic device is now complete and ready to be turned into an immunoassay. A completed device with blue dye shown for visualization of the channels can be seen in Figure 3.

References: