Fabrication of Microfluidic Devices for Synthesis of Janus Particles

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Abstract:

Microfluidic flow focusing devices (MFFD) are an easier, more accurate and repeatable way to create monodispersed Janus particles. Size, shape, and uniformity of droplets determine particle application, which is dependent on channel width. Decreases in channel width allows for more biological applications. The goal of this study was to fabricate a MFFD to synthesize Janus particles using a T-junction design using three immiscible liquids. To do this, a mask was designed with the negative image of five of the same MFFDs to reduce cost, material waste, and increase repeatability. Quartz wafers were used due to lower etch rate, smoothness, and purity compared to other transparent materials. An adhesion layer was spun prior to photoresist to help with developing. Chromium was deposited and etched to create the channels to be fusion bonded to Pyrex® wafers. Ongoing studies will apply this design process to recreate MFFDs with 15 μm and 3 μm channel widths.

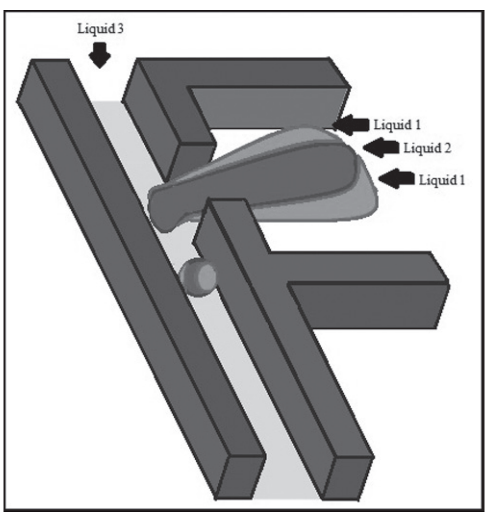

Figure 1: MFFD with three immiscible liquids.

Introduction:

Microfluidic techniques for Janus emulsions composed of two immiscible liquids have the continuous phase coming from either side of the device with the dispersed phase through the center channel in stokes flow [1]. A MFFD creates Janus emulsions through flow-focusing, where the liquids are forced through a narrow channel causing symmetric shearing [1]. Decreases in droplet size allows for more biological applications including drug delivery, diagnostic testing, and biosensing [1].

A MFFD was created due to ease of use, design, repeatability, and accuracy. A T-junction design uses cross flowing streams to create the forces for pinchoff with the shear force and interfacial tension, shown in Figure 1. This geometry can form droplets with nontraditional shapes and morphologies with precise control [2].

Background:

Here, T-junction configurations with two immiscible co-flowing liquids were tested as a means of creating droplets ranging from 1 to 3 μm. The popularly tested PDMS-on-silicon was not able to be tested for the smaller channel widths; due to the size of the channel versus the O_2 layer, the corresponding wettability for the smaller channel sizes with the hydrophilic polydimethylsiloxane (PDMS) method prevents the correct morphology of the Janus droplet—hence, the quartz-on-Pyrex method [1].

T-junctions create droplets of equal size with steady flow from the upstream pressure due to the junction shape. Droplet formation occurs when viscous stresses overcome interfacial tension [3]. The size of the droplets can be altered by channel width and the forces that change the fluid flow rates [4].

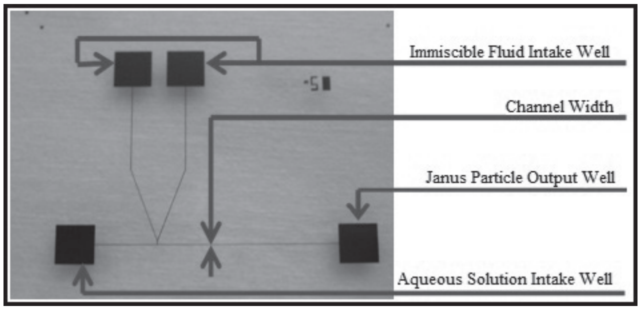

Figure 2: T-junction design with specified features.

Methods:

Masks were designed using AutoCAD software for the three different channel thicknesses 50 μm, 13 μm, and 3 μm. On each mask is the negative image of five of the same MFFD, single MFFD shown in Figure 2. An adhesion layer, Microprime Primer P-20, was spun on the 4-inch quartz wafer prior to the photoresist to help the thin long lines to adhere. Photoresist SC1827 was spun to a thickness of 2.7 μm and then patterned. Chrome was deposited over the pattern in a uniform 1 μm layer. For the quartz to be etched, the 4-inch quartz wafer was mounted on a 6-inch silicon carrier using crystalbond or fomblin. Schematic of channel formation shown in Figure 3.

Results and Conclusions:

Significant progress towards fabricating a MFFD with a T-junction design was accomplished as well as creating protocols for lithography, deposition, etching, and bonding. During early stages of lithography the resist puckered, the thin long lines washed away during developing and there was not a uniform development. This was corrected using an oven and glass slides to create a uniform heating surface. During chrome deposition there was unequal deposition and peeling. By lowering the deposition rate, increasing the deposition time and using a CVC DC Sputter, this was corrected. During etching, the wafer cracked due to the different thermal properties of the quartz and silicon. By changing the etch process, it is possible to prevent cracking.

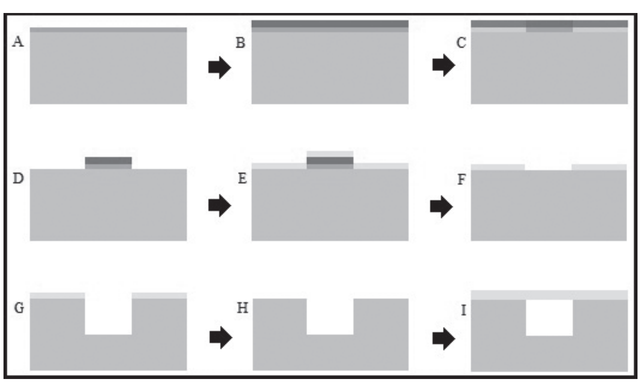

Figure 3: (A) Adhesion layer spun on quartz wafer; (B) Photoresist spun 2.7 µm thick; (C) Lithography of resist; (D) Resist developed; (E) Cr deposited 1µm thick; (F) Resist removal; (G) Quartz etched pattern; (H) Cr removed; (I) Fusion bond to Pyrex.

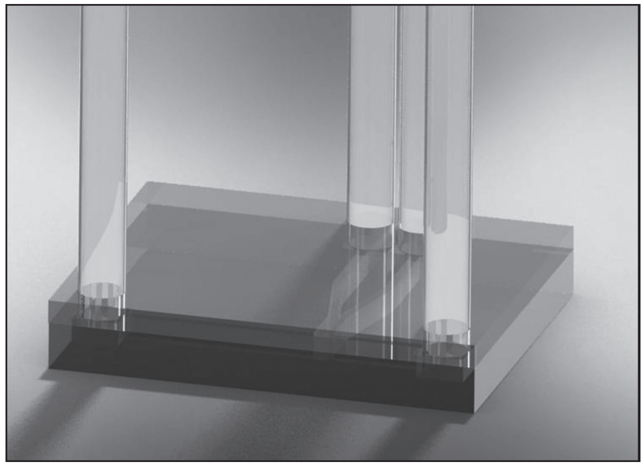

Figure 4: Final design of microfluidic flow focusing device.

Future Work:

Future studies will focus on finishing the fabrication of the 50 μm MFFD, shown in Figure 4. After etching, the two wafers will be separated with heat and the chrome removed. This segment of quartz will be fusion bonded to the Pyrex slide. Pyrex was chosen to insure a transparent top for real time imaging of droplet formation. Ferrule connectors will be placed into the channel, top down, to help thread the tubing into place and UV epoxy will be used to secure the tubing. The tubes will be attached to syringes to control various flow rates and a UV light source will be at the other end of the channel to continuously photopolymerize the droplets [5]. Work will also be done in creating a 15 μm and a 3 μm MFFD with the protocols that were created. Tests will be done with the immiscible liquids and determine how flow rates affect droplet formation.

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