Microfabrication of Micropillars inside a Microchannel

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Primary CNF Tools Used: AutoCAD, AJA sputter deposition, photolithography processes, AJA ion mill

Abstract:

Boiling generates bubbles and predicting the movement of these bubble can be challenging. In this research, we fabricated micropillars and heaters in specific locations inside a microchannel and operate the heaters in calculated sequences. We moved the bubbles in the direction that we planned, and these movements pushed the liquid inside the channel toward the outlet.

Summary of Research:

The microfabrication process was conducted at the Cornell NanoScale Science and Technology Facility (CNF). Photolithography masks were designed and drew with AutoCAD and fabricated before they were taken to the CNF to be used during the fabrication process.

The fabrication was started on a Borofloat® wafer with the thickness of 500 μm and the diameter of 100 mm. Borofloat wafer was chosen because of the low heat conductivity (1.2 $W/(m \cdot K)^{-1}$), outstanding thermal resistance, very good temperature stability, excellent resistance to thermal shock, and a low coefficient of linear thermal expansion of around 3.25×10^{-6} K^{-1}.

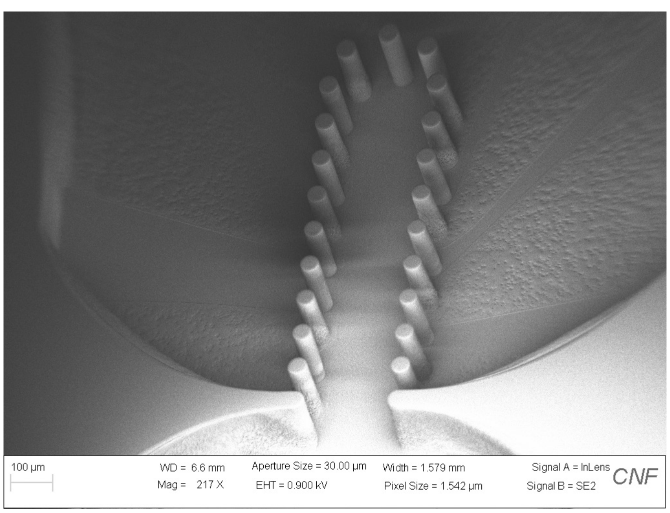

Figure 1: An image of the micropillar section of the microchannel that has been captured with a scanning electron microscope (SEM).

The Borofloat wafer was first cleaned with hot Piranha. After this step, the cleaned wafer was taken to the deposition tool so that 0.5 μm of Si_3N_4 was deposited on the substrate. This layer provides insulation between layers and acts as a mechanical isolation/buffer membrane. Depositing the vias and heaters was the next step.

The wafer was placed in the sputter deposition tool so that a 7 nm layer of titanium (Ti) could be deposited on it to enhance the deposition of a 30 nm layer of platinum (Pt). This layer of Pt is going to form the heaters of the device. Finally, a 1 μm layer of aluminum (Al) was deposited to provide the electrical connections. The first photolithography process was performed next and the excessive Al was removed by wet etching. After another photolithography process, the ion mill was used to etch the excess Pt and Ti. To insulate the heaters and vias layers from the flow inside the channel, a 1 μm layer of SiO_2 was deposited on the substrate. Contact pads should be the only parts of the wafer without the insulating layer of SiO_2, therefore, another process of photolithography was performed and the surplus SiO_2 layer was removed by dry etch.

To start the fabrication of the channel and the micropillars from SU-8, the wafer was first dehydrated in the oven. SU-8-100 was chosen as the appropriate SU-8 type and spun on the wafer in the spinning room. To conduct the soft bake step, the wafers were gradually heated up and kept at the temperature of 65°C for two hours and then baked at 95°C for a few more hours. The contact aligner was the selected tool to expose the SU-8 to the microchannel and micropillar designs that were fabricated on the photolithography mask then a post exposure bake was carried out to prepare the SU-8 for development. The development phase included submerging the wafer upside down in SU-8 developer to remove the SU-8 from the unexposed part of the SU-8 layer. At the end of the SU-8 development process, the wafer was rinsed with isopropanol and SU-8 developer, and then blow dried with nitrogen.

To fabricate the top part of the device, double-coated film bonding tape was attached to a cleaned bare Borofloat wafer. A CO_2 laser machine drilled the holes into the top wafer by vaporizing the substrate. These holes were arranged in a way that after attaching to the bottom wafer, the contact pads would be accessible to operate the heaters. Next, the flow inlet and outlet on the bottom wafer were drilled. Top and bottom wafer was taken to the contact aligner once again to be attached to each other precisely. The final step in the fabrication process was cutting the wafer. A dicing saw was employed to cut the marked lines on the wafer to separate it into individual devices.

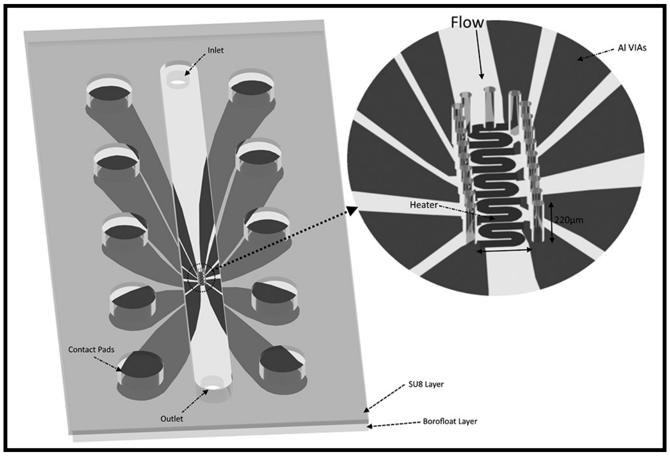

Figure 2: Schematic illustration of microchannel, which consists of arrays of micropillars within.