Fabrication of Microfluidic Devices to Measure Thermal Properties of Nanoscale Ionic Materials

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Abstract:
A microfluidic device was fabricated in order to measure the thermal properties of nanoscale ionic materials (NIMs). Since the materials lie between liquid and solid states, they are challenging to measure. This study focuses on the fabrication of a micro fluidic device necessary to contain the NIMs prior to the measurement. Various steps for fabrication have been optimized except for the final etching step to make the wafer through holes. Several methods have been used in etching through the wafer and long etching processes using concentrated (49%) hydrofluoric acid were investigated.

Summary of Research:
Thermal conductivity is a crucial physical property in determining how materials can be used in applications. Nanomaterials have been shown to have unique properties, but the thermal conductivity of many are poorly known [1-6]. The motivation behind this work is to determine the thermal conductivity of novel nanoscale ionic materials, NIMs, using only small volumes (nano to microliters) of the material. Among many possible measurement methods, the 3ω method shows promise of accurately determining the thermal conductivity of our nanomaterials while using samples sizes on the order of microliters and down to even nanoliters.

The 3ω method is a simple, high sensitivity transient method that uses a relatively simple heater geometry whose behavior can be solved from the heat diffusion equation [7]. It has widely been used to determine thermal properties of materials [8-13]. The concept is that heating a thin film at a frequency (f) surrounded by a material generates variations in the voltage across the heater at the third harmonic (3f), which is directly related to the thermal conductivity. In order to apply the method with only a small volume of the available NIMs, a microfluidic device which contains the fluid and that has four-point electrical contact is necessary.

In this work we aim to fabricate a feasible microfluidic device to make future thermal property measurements on NIMs. In order to achieve this desirable structure, we experimented on different photolithographic, deposition, and etching methods.

All of the fabrication steps described in this section were done on Borofloat glass wafers that are 100 mm in diameter and 500 µm in thickness. Photolithography was done on both sides of the wafers with the through-hole mask to make overlapping patterns for electrical contact. Prior to photolithography, the wafer was RCA cleaned. Polysilicon was then deposited on the film. Both PECVD and sputtering were used to accomplish the deposition and no notable difference in film quality was observed. The polysilicon thickness was 200 ± 20 nm on both sides. On one side of the wafer, the microchannels were defined using Shipley 1813 photoresist, applied using the manual spin coater in CNF cleanroom. After a soft-bake at 90°C for 60 seconds, the film was exposed with a Suss MA6 contact aligner and developed. Following the development, a polysilicon etch was done with Oxford 82 Etcher using a polysilicon etching recipe that has an etching rate of 2400 nm/min with a selectivity of 1:7 for 10 seconds.

On the reverse side of the wafer, the identical processes for photolithography were done with a different exposure mask to define through-vias. After both sides were etched, a 20-minute silicon dioxide etch step took place to define the through-hole regions in 49% HF acid. The channel layer was then laid on top of the through holes with standard lithography steps. A subsequent etch step in 49% HF acid that lasts for about 30 minutes was designed to etch through the wafer.
The total etch time is approximately 50 minutes, and the polysilicon etch mask was not able to survive the duration due to delamination. Laser annealing of the layer was attempted to enhance the wafer-polysilicon adhesion but film degradation made this method unfeasible.

In conclusion, we discovered that 200 nm of polysilicon was not a sufficient mask for through-wafer etching. Possible future improvement could be made with thicker polysilicon layers or multilayers to reduce pinholes in the film.

References: