Fabrication of Glass Microfluidic Devices

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Abstract

The University of Utah Microfabrication Core Laboratory, in conjunction with the State of Utah Center for Biomedical Microfluidics, now possesses the technical expertise to fabricate glass microfluidic devices. High quality microscope slides are being used as the substrate material. The glass is masked with layers of chromium and photoresist, and then patterned with a wet etchant solution. Glass to glass fusion bonding is used to enclose the etched troughs, forming microfluidic channels that can be accessed by through holes drilled in the glass. This fabrication protocol has been used to manufacture prototypes of varying geometry and complexity for affiliated research laboratories.

Cross-Sectional View of Fabrication Steps

- Fisher Finest Microscope Slide (25 mm x 75 mm x 1.1 mm)
- Chromium (300 nm)
- Shipley 1813 Photoresist (2 µm)

A chromium layer is deposited on the glass with the Denton Discovery 18:
- Power - 150 W
- Argon flow rate - 12.5 sccm
- Sputter time - 6 min
- Deposition rate - 50 nm/min
- Pressure - 2.5 mT

The glass slides are pre-cleaned in a fresh piranha solution (3 H₂SO₄ : 1 H₂O₂) for 10 minutes.

The etched glass substrate. As can be seen, the etch depths from mask

The exposed chromium layer is removed by immersing the substrate in CR-14-S chromium etchant for 90 seconds.

All photoresists are removed with acetone, and the substrate is immersed in the CR-14-S until all chromium is removed.

The photoresist is deposited and patterned:
- Spin rate - 2000 rpm
- Spin time - 30 sec
- Soft bake - 90 sec @ 95°C
- UV - 8 sec exposure (EV 420 Mask Aligner)
- Developer - 60 sec (Shipley 352)
- Hard bake - 5 min @ 150°C

The backside of the substrate is masked with a 1 mil polyimide tape (Kapton) with silicone adhesive. The substrate is then immersed in an etchant bath of 1 HF : 3 HNO₃ : 10 H₂O to etch the exposed glass at a rate of 1.5 µm/min.

Access holes are made with a Dremel rotary tool (30,000 rpm), a Dremel tool press, and a diamond-tipped Dremel bit. Water is used as a cooling fluid. All pieces are then cleaned in a piranha bath.

The photoresist is deposited and patterned:
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- Spin time - 30 sec
- Soft bake - 90 sec @ 95°C
- UV - 8 sec exposure (EV 420 Mask Aligner)
- Developer - 60 sec (Shipley 352)
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The channels are sealed by sandwiching the etched substrate and a blank glass slide between graphite paper, which is then sandwiched between 0.5 kg stainless steel blocks. This stack is heated to 600°C at a rate of 10°C/min, baked for 4 hours, and then allowed to cool. This fusion process creates a single glass substrate with embedded channels.

Because of the isotropic nature of the etch, the final channel width will be two depths wider than the mask opening.

These photographs show the cross-sectional geometry of representative channels. The protocol described here has been used to fabricate channels of varying geometries and depths. Depths from 10 µm to 140 µm have been achieved. Widths between 30 µm and 1 mm have been successfully demonstrated, although the wider channels can narrow significantly and even collapse in the center when the fusion time and/or temperature are exceeded.

This photograph shows a top view detail of an etched glass substrate. As can be seen, the etch process creates smooth features with few defects.

This photograph shows a microfluidic device that was fabricated with this protocol. Nearly a meter of channel length is contained within the glass. This chip is used to perform DNA analysis of human samples when placed in the heating platform shown in the inset. Because these chips were fabricated in-house, iterative development of this concept was achieved in a fraction of the time, and at a fraction of the cost than would have been otherwise possible.

Motivation

Great improvements in health-care related quality of life are anticipated to accompany the emerging field of personalized medicine. Many new medical instruments are being developed which take analytical capabilities from clinical laboratories and place them in the doctor’s hand. This is being achieved through the application of microfluidic technologies, which allow for the miniaturization of these diagnostic tools. In addition to their reduced size and cost, microfluidics-based instruments are typically faster, less expensive to operate, and more sensitive than traditional equipment. For researchers in this emerging field, commercial entities exist that can provide prototype fabrication, although accompanied with high cost, long turn-around time, and rigid design guidelines. By bringing this manufacturing capability to the Utah Microfabrication Core Laboratory, microfluidics researchers are now able to accelerate product design and development, while reducing the necessary expenses typically associated with prototype fabrication.

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