LOW TEMPERATURE BONDING FOR FABRICATION OF MINIATURIZED CHEMICAL ANALYSIS DEVICES

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ABSTRACT

A low temperature bonding process was developed for the fabrication of microchip devices for liquid phase chemical analysis. Photolithographically etched microchannels on glass substrates were closed by bonding a glass cover plate using sodium silicate as an adhesive. Good channel sealing was achieved at 90 °C for an hour. The performance of the device was evaluated by monitoring the electroosmotic flow on the chip. The strength of the bonding was studied using electrical and mechanical methods. The results were compared with that obtained from the device made from high temperature glass-glass direct bonding.

INTRODUCTION

Microfabricated miniature instruments for complete chemical analysis are receiving increased attention. Various microdevices have been fabricated that perform liquid phase analysis including capillary electrophoresis [1-3], electrochromatography [4], micellar electrokinetic capillary chromatography [5], DNA restriction fragment analysis [6-7], and on-chip chemical reactions with analysis [8]. The devices were fabricated by etching the channel manifolds into glass substrates using standard photolithographic and wet chemical etching methods. The first devices reported used a melting technique to bond the substrate and cover plate at 620 °C to form a network of closed channels [1]. A direct bonding technique was also developed by which the substrate and cover plate were joined and then annealed at 500 °C [3]. However, the high temperature bonding process hindered the further device fabrication, such as immobilizing biological species in the channel, or integration of structural features (e.g. electrodes, waveguides etc.) into the channel. A low temperature bonding process has been reported to bond silicon wafers at 200-300 °C using sodium silicate as a bonding layer [9]. Here, we report a modified process to perform glass-glass bonding using sodium silicate at the process temperature lower than 100 °C.

EXPERIMENTAL

Standard 50 mm x 25 mm glass microscope slide and 22 mm circular or 25 mm x 25 mm square coverslip were used for the bonding experiments. The substrate and the coverslip were treated as follows: (i) Hydrolyze in $\text{NH}_4\text{OH}/\text{H}_2\text{O}_2/\text{H}_2\text{O}$ (2:1:3) solution at 60 °C for 20 min. (ii) Spin-on a dilute solution of sodium silicate in water on the coverslip at 4000 rpm for 10 seconds. (iii) Immediately bring the coverslip in contact with the glass substrate. (iv) Anneal the sample at 90 °C for 1 hour.

The electroosmotic flow was studied on the chip using Rhodamine B as a probe and laser induced fluorescence. The schematic for the measurement of electrical breakdown of the bonding is shown in Fig.1 with a separation of 150 μm between the two channels. The specimens for the mechanical strength measurement were prepared by etching a glass slide to form a

Figure 1. Schematic for the measurement of dielectric strength between microfabricated channels.

triangular area 4 μm above the glass surface and bonding another piece of glass slide on the triangular area. The measurements were done on an Instron 4501 machine and the surface energy was obtained by integrating the area under the load vs. displacement curves [10].

RESULTS AND DISCUSSION

The electroosmotic flow measurements with the chip made using the low temperature bonding method are shown in Fig.2. The measurements were done after flushing the chip with water or 1N NaOH. The NaOH flush regenerates the hydrophilic glass surface and enhances the electroosmotic flow. The results compare well with that obtained from chips made using the high temperature direct bonding method.

Figure 3 shows the electrical breakdown data for the chip

Figure 2. Electroosmotic flow for chips made using the low temperature bonding method: (A) flush with water for 20 mins, (B) flush with 1N NaOH for 20 mins.

bonded with 2 wt.% sodium silicate. The data was used to determine the dielectric strength of the bonding layer. The breakdown occurred at the applied voltage of 6 kV, which corresponds to a dielectric strength of 400 kV/cm. The breakdown was irreversible since a current path was formed after the breakdown, which is believed to be due to the sodium ions in the sodium silicate bonding layer. Compared with the low temperature bonding, the high temperature direct bonding is much stronger with a dielectric strength of 1100 kV/cm, as shown in Fig.4. The breakdown was reversible, as can be seen in Fig.4 in that it "healed" after the applied voltage was reduced. This may be attributed to the fact that the breakdown was caused by the movement of the electrons relative to their nuclei to constitute a displacement current [11]. Therefore the breakdown current of the high temperature bonding is much lower than that of the low temperature bonding.

Figure 3. Electrical breakdown measurement of the chip made using the low temperature bonding method.

Figure 4. Electrical breakdown measurement of the chip made using the high temperature direct bonding method.

The surface energy obtained from the mechanical strength measurements for the sodium silicate bonding (2 wt.% at 90 °C) is around 2.6 J/m², which is comparable to the value of 2.2 J/m² obtained in conventional wet oxidized silicon direct bonding at 1400 °C [12], and also is comparable to the value of 3 J/m² obtained in the low temperature silicon wafer bonding with sodium silicate at > 200 °C [9]. The high temperature direct

bonding gives a surface energy of around 6.7 J/m² which is close to the virgin glass fracture energy [13].

CONCLUSION

The low temperature bonding process has provided strong bonds between glass surfaces and good channel sealing for liquid phase analysis. Further applications in fabricating various devices for chemical and biological analysis are under investigation.

ACKNOWLEDGEMENTS

This research is sponsored by Oak Ridge National Lab (ORNL). ORNL is managed by Lockheed Martin Energy Systems, Inc. for the U.S. Department of Energy under contract DE-AC05-96OR22464. Also, this research is sponsored in part by an appointment for H.W. to the ORNL Postdoctoral Research Associates Program administered by the Oak Ridge Institute for Science and Education and ORNL.

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