Undergraduate Report

An Approach for the Thermal Bonding of Micro-Fluidic Devices

by Adam Vela
Advisor: Don DeVoe

UG 2001-8

An Approach for the Thermal Bonding of Micro-Fluidic Devices

Adam Vela, Mechanical Engineering, University of California, Berkeley
Advised by Dr. Don DeVoe, Mechanical Engineering, University of Maryland, College Park

Abstract

With the advent of polymers micro fabrication methods for micro-fluidic devices, there has developed the need to investigate various forms of sealing such devices for practical applications. This research documents work performed on the thermal bonding of polymer micro-fluidic devices that contain both channels and reservoirs on the same plane.

Background

Over the last few years there has been abundant interest in the study of micro fluidics (Martynova, 1997). The primary goal is the successful design and fabrication of micro channels for miniaturized analytical systems, known at micro-TAS (Total Analytical Systems), for sensing or processing, commonly used in genomics and proteomics. Typically involved in such systems are channels and reservoirs for electrophoresis.

Previous to polymer embossing, various other materials were and are currently used for fabrication of micro-TAS devices. Common substraights are glass, quartz, and silicon, fabricated using techniques primary developed by the microelectronics industry. However there are problems associated with these materials and processes. The most dominant issues are the material and process costs, as well as the long amounts of time to reproduce devices (Becker, 1998). Also, because silicon is a semi-conductor it is not a viable material for electrophoresis (Boone, 1998).

A possible solution to the shortcomings of the above-mentioned materials is polymer hot embossing. Using a silicon master mold (a positive or raised pattern) fabricated with standard lithography techniques; polymers can be molded on a hot embosser to have channels and reservoirs on the micro scale. The material costs for polymers are relatively inexpensive, while the fabrication time is short, typically taking one hour per device. Coupled with the hydrophobic nature and clear optical properties of plastic make it promising material for micro-TAS devices. The transparency of plastic allows for Laser Induced Fluoresces Detection. Also, since polymers are electrical insulators they are well suited for electrophoresis, which require high voltages.

While there has been substantial research and success into the accuracy and capabilities of replication of polymers using hot embossing, there have been a limited number of publications on the sealing of such channels and reservoirs by means of thermal bonding of another polymer wafer. Currently it is common to seal polymer micro-channels through lamination, or use simple designs for polymer thermal bonding. While adequate for sealing, lamination does not provide a strong and durable seal, and often results in trapped air bubble at the interface.

Investigation Objectives

The purpose of the research documented below was a proof-of-concept for the University of Maryland, MEMS laboratory. The goals were two fold: to develop and implement a system and procedure for hot embossing of microfluidic devices on PC and PMMA substraights, and to find a method for thermal bonding to seal an embossed polymer substraight with a blank polymer wafer.

Thermal Bonding

In association with the Analytical Chemistry Department at the University of Maryland, a set of etched wafers was fabricated with particular design constraints and objectives in mind. First, the devices contain large integrated reservoirs with the micro-channels. It is current practice of research organizations and industry to not integrate reservoirs into the devices. Instead of designing silicon templates with reservoirs, the reservoirs are formed by drilling access hole over the channels on the blank wafer to store the sample and act as a reservoir. (refer to figure 1).

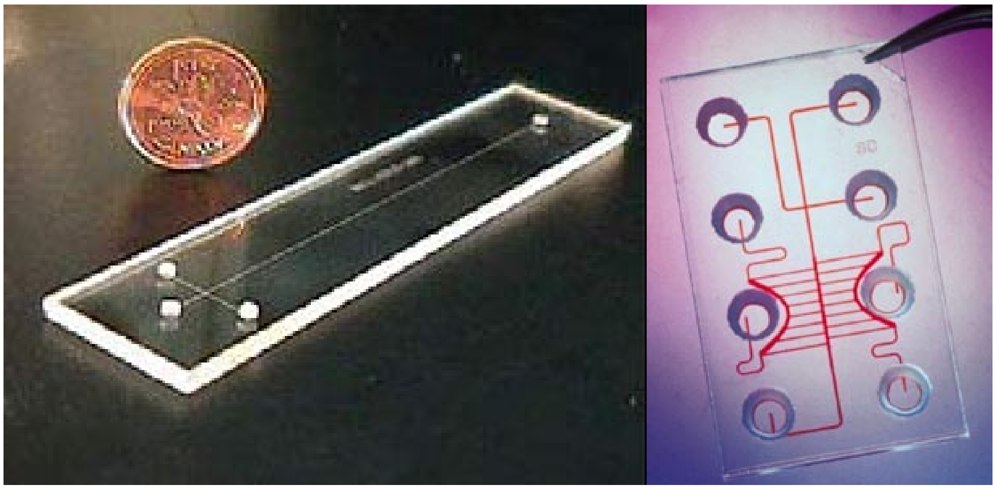

Figure 1: examples of reservoirs formed by holes in cover plate

In contrast to the examples above, the designs tested for thermal bonding contained reservoirs on the same plane as the channels. The figures below represent the masks used for fabricating the silicon masters (figure 2). The geometry of the devices is as follows: 150-micron channels, .5 cm x.5cm smaller reservoirs, and large reservoirs 3cm x 1 cm. While feature dimensions are significantly larger then reservoirs found in other devices, the primary goal of this research is to determine the limitations of reservoirs geometry in thermal bonding.

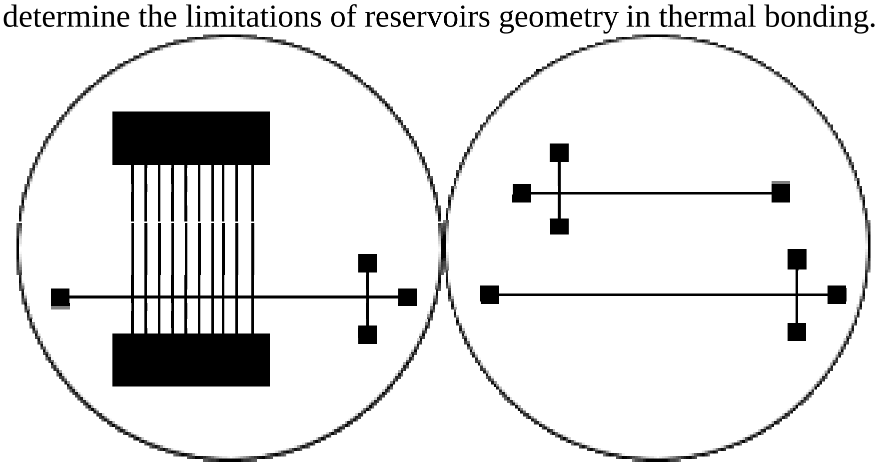

Figure 2: Design of devices utilized for thermal bonding

Thermal bonding was performed using three different methods. The first employed the hot-embosser as a heating device to perform thermal bond the polymer wafers. Due to limitations of the embosser, which could only apply a minimal force of 300 kN, both the channels and reservoirs would be filled by the blank wafer at all temperatures tested for (100-170 C for PMMA, and 140-180 C for PC).

From the limitations of the hot-embosser an alternative approach was taken. A set of aluminum platens (figure 3) was designed and constructed to hold and apply pressure to the polymers for thermal bonding while inside a small vacuum oven. Using this approach, several embossed polymer wafers were bonded with relatively poor results. Later, it was discovered that it is possible to perform thermal bonding a standard convection oven, without the presence of a vacuum. Similarly results did not prove completely successful for both designs. However, there exists some promise in the results.

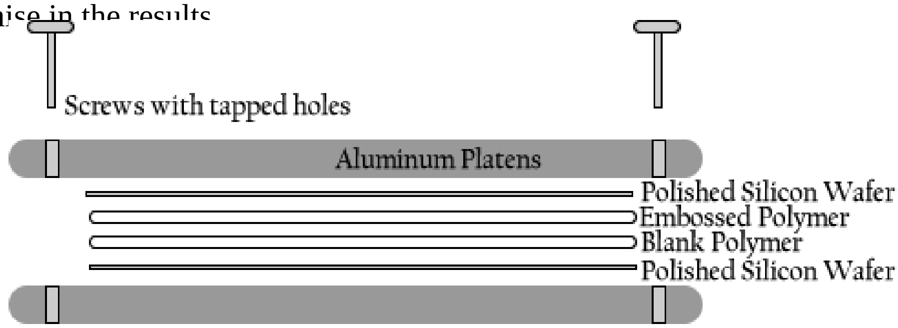

Figure 3: Device for Thermal Bonding

Conclusions

From tests performed in both the vacuum and convection ovens a series of conclusion can be made. First, it is difficult, if not impossible, to successfully thermally bond embossed micro-fluidic devices that contain large reservoirs and channels in a single stage process. Channels and reservoirs appear to require different procedures for thermal bonding. Channels successfully bond at a range of temperatures, but required longer times to bond (approx. 10-15 minutes). Large reservoirs on the other hand, are destroyed from longer dwell times that provide the polymer with a long enough period to flow despite its viscous nature; the longer the time period, the more significant the filling of embossed reservoirs. More success was achieved bonding large reservoirs at higher temperature for at shorter times (approx. 2 minutes).

The best results to date were able to seal the majority of the channels, while still allowing flow and not filling the reservoirs. However, the areas close to the interface between the channels and the reservoirs did not seal properly, allowing for fluids to flow between channels (PMMA, 140 C, 13 min).

Due to limited resources and time, further tests were not complete. The current work does present a variety of solutions to integrating large reservoirs into the same plane as channels. Tests with smaller reservoirs as shown in figure 2 did prove rather successful. Possible solutions include designing smaller reservoirs, or if larger reservoirs volumes are required on the same plane of the channels, more inventive reservoir designs should be considered, an example would be linked over-flow reservoirs. If it is possible to have reservoirs on a different plane, another solution includes bonding two embossed polymer wafers, one that contains the channels, the other with reservoirs. The sub straights should be aligned for the end of each channel to be coinciding with the reservoirs on the other wafer, in this manner the liquid could flow one reservoir to another (figure 4).

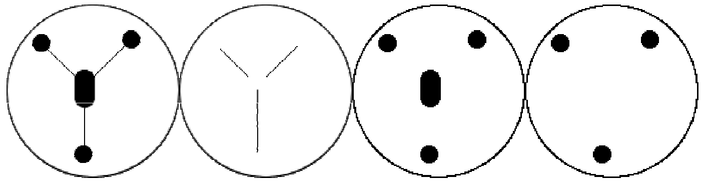

Figure 4

a) Final Design

b) Bottom layer, containing channels

c) Middle Layer with reservoir and mixing chambers

d) Cover with access holes.

Acknowledgements

I would like to thank Dr. Don DeVoe for advising me, as well as Chris Kimball for his help. And a special thanks goes to Nathan Sniadecki and Jesse Busch for their willingness not only to teach me, but also to make sure I enjoyed my summer research experience.

References

1. Becker, Holger and Dietz, Wolfram, Microfluidic device for micro-TAS applications fabricated by polymer hot embossing. SPIE Vol. 3515, 1998

2.Boone, Travis and Hooper, Herbert, Multiplexed, Disposable, Plastic Microfluidic Systems for High-Thoughput Applications. Micro-TAS Conference, 1998.

3. Martynova, Larisa, et. Al, Fabrication of Plastic Microfluid Channels by Imprinting Methods. Analytical Chemistry, Vol. 69, No. 23, December 1, 1997.