Sealing and Bonding Techniques for Polymer-Based Microfluidic Devices

by

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Abstract

This paper overviews research being conducted at the Industrial Research Institute Swinburne (IRIS). This research project commenced in August 2001, with funding provided by the Cooperative Research Centre (CRC) for Microtechnology. The goal and purpose of this project is to develop novel sealing techniques for polymer-based microfluidic devices. The main challenge is bonding planar microfluidic parts together hermetically without affecting the shape and size of micro-sized channels. In this paper a number of bonding techniques such as induction heating will be reported; and their advantages will be discussed. Also, progress to date and future work will be presented. The channels were fabricated by using Excimer laser equipment.

1. Introduction

The ability to create structures and patterns on micron and smaller length scales has triggered a wide range of scientific investigations, and development of fluidic devices to transport, store, and manage very small quantities of fluids. These devices are finding increasing application in many fields and systems such as chemistry, biology and medicine. The potential applications of microfluidic devices are shown in Table 1.1.

The majority of microfluidic work has involved the fabrication of glass and silicon based chips [1,2]. However, the wide spread interest in microfluidic devices for bio-analytical applications has resulted in efforts to facilitate the use, and to reduce the cost of such devices. As a result, polymeric materials have been explored as more versatile alternatives for the fabrication of microfluidic devices. This is primarily driven by the fact that polymers are less expensive and easier to fabricate than silicon-based substrates. In the literature much work relating to polymer microfluidic devices has been reported, including microfluidic devices fabricated from a range of polymers. Microfluidic systems fabricated using polydimethylsiloxane (PDMS) have been reported by [3,4,5]. While Locascio *et al.* [6] and Lee Gwo-Bin *et al.* [7] have reported fabrication of microfluidic devices on polymethylmethacrylate (PMMA) substrates. In this project, polymers such as polycarbonate, polystyrene and PMMA will be used.

Area	Application
Miniaturized analytical systems Genomics and proteomics	Rapid, high density sequencing, DNA fingerprinting, Combinatorial analysis, forensics, gene assays.
Chemical/biological warfare Defence toxins;	Early detection and identification of pathogens and Early diagnosis; triage
Clinical analysis	Rapid analysis of blood and bodily fluids, point of care Diagnostics based on immunological or enzymatic.
High throughput screening	Combinatorial synthesis and assaying for drugs. Toxicological assays
Environmental testing	*In situ* analysis of environmental contamination
Biomedical devices Implantable devices	Devices for drug delivery, monitoring for diseases.
Tools for chemistry and Biochemistry organic synth.	Combinatorial synthesis
Studies of chemical reactions	Enzyme-substrate

Table 1.1 - Potential applications of microfluidic devices [8]

2. Overview of Bonding Techniques

In the area of microfluidics, the issues of bonding polymer materials to other polymers, whilst maintaining the integrity of the micro-features, are still to be satisfactorily resolved. Many bonding techniques such as adhesive bonding [9] and thermal bonding [10,11] have been reported. Glasgow *et al.* [12] reported a solvent bonding technique in which a layer of polyimide precursor and solvent with dissolved precursor was placed in contact with patterned structures made of uncured polyimide precursor. Paulus *et al.*[13] have reported sealing of structures by heating the polymer and applying a force to close the channels. Polymers can be sealed and bonded by local melting due to heat generated by a laser. This has been successfully demonstrated in the fabrication of micropumps [14], however no reports have been published on other microfluidics. Some of these techniques have certain negative aspects, for instance adhesive bonding, has the main disadvantage that the presence of an adhesive can change the channel size and channel wall properties. The bonding techniques chosen and used will depend on the adherends, facilities available, and the end device applications. Hence in this project, resistive heating, induction welding, and laser welding techniques will be used as alternative sealing methods. This will present a new approach to bonding based on the concept of localized heating. The latter two are discussed below.

2.1 Induction Heating

Induction heating is a joining technology, which is utilized to weld and bond polymer materials. It is a non-contact electromagnetic process allowing precise heating through the use of specially designed coils and offers a localized method of heating. Induction heating of a material occurs when an induction coil, which generates a magnetic field, is placed near the material and heats a susceptor such as metal screen or powder. In the literature, the efficiency of various susceptors such as iron, iron oxide, stainless steel was investigated Schwatrz [15] and Benatar *et al.* [16]. Generally, the process is suitable for welding long/thin parts and according to Fernie *et al.* [17], the main advantage of this process is the ability to make continuous joints by moving the coil along the joint. A further advantage of induction heating is that it is highly directional; very small areas of the work-piece can be heated without affecting surrounding areas and heat is delivered only where it is needed. The induction heating process is shown in Figure 2.1

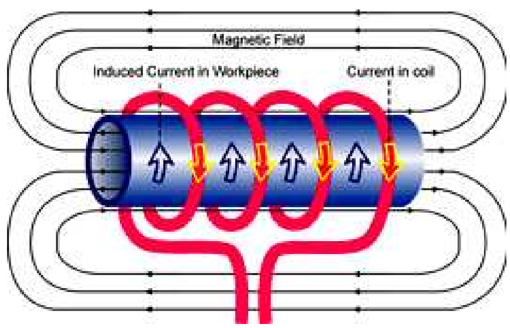

Figure 2.1 - Induction heating diagram showing coil, work-piece and current flow

2.2 Laser Heating

A high intensity laser beam can be used to increase the temperature at the joint interface of thermoplastic materials to, or above, the melt temperature [14,18]. By selecting an upper material which is transparent to the laser wavelength, and a lower material which is highly absorbing, the beam is able to penetrate to the depth of the interface. Laser beams can also be focussed to small spots (typically a few tens to hundreds of microns in diameter) so that welding can be performed locally. This process also lends itself to high throughput, continuously-moving production lines.

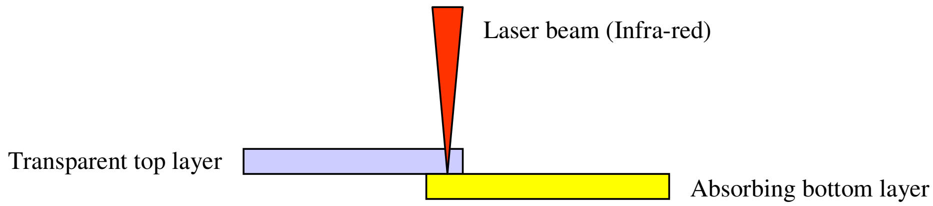

Figure 2.2 - Schematic diagram of laser welding showing transparent top layer, and strongly absorbing bottom layer.

3. Progress to date

A literature review, material evaluation and experimental planning have been completed. From this work, several heating methodologies have been short-listed. The following experimental work has been performed:

- Simple fluidic channels 400µm wide, 17mm long, and 38 to 200µm deep have been prepared in polycarbonate samples (shown in Figure 3.1) using excimer laser ablation. These samples are to be used to test the resistive, induction and laser bonding methods.

Figure 3.1 - Laser-ablated microchannels in polycarbonate. Channels are 400µm wide, 17mm long and vary between 38 and 200µm deep. The channels are separated by 5mm.

- Microfluidic pump parts have also been made using the excimer laser. Attempts were made to bond these parts using adhesives, and highlight the problems of this method (Figure 3.2).

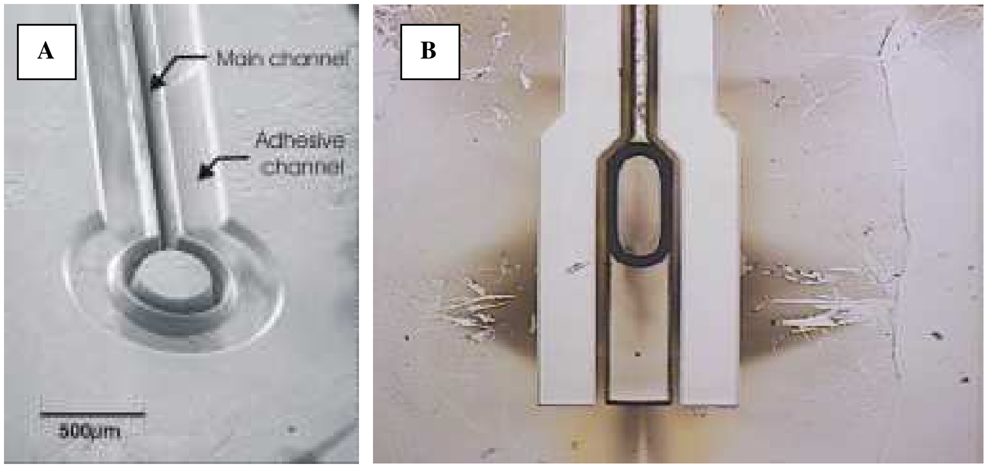

Figure 3.2 - Excimer laser fabricated parts, showing central fluidic channel surrounded by channel for containing adhesives. Figure 3.2(b) clearly shows where the adhesive has wicked into the fluidic part and totally blocked the channel.

4. Future work

- To perform induction heating experiments for sample sealing at Induction Pty Company, Melbourne
- Heating experiments with several induction coil geometries will be performed and the heating rate and temperature distribution will be measured. The coil will be produced such that the frequency may be kept constant for all coil geometries.
- To consider other bonding techniques such as laser welding and resistive heating.
- To evaluate the bonding efficiency for sealed samples by conducting testing such as leak test, SEM analysis and shear test.
- To develop an optimized procedures for bonding processes.

5. Conclusion

Bonding is a major challenge in the fabrication of plastic microfluidic devices and based on this fact, the purpose of this project is to develop effective bonding techniques without clogging the channels, changing their physical parameters or altering their dimensions. Most of the initial work will focus on using induction heating and laser welding as a means of sealing microfluidic devices and evaluating bonding efficiencies. A literature review, preliminary sample preparation and experimental procedure design were conducted.

6. Acknowledgement

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7. References

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