

Development of Packaging Systems and Interconnects for Microfluidics Applications

by

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Abstract

The objective of this research program is to develop effective packaging techniques and methodologies for selected micro-electro-mechanical systems (MEMS) used in microfluidics applications. The developed packaging system will be aimed at standardising the process of packaging for most of the microfluidics devices including microfluidic edge connectors and manifold dispensers, and their development will include the use of rapid prototyping technologies such as Fused Deposition Modelling. The work will be aimed at reducing the overall time and cost of developing and assembling the packaging system for microfluidics devices. The consideration of designs for polymer microfluidic connections and packaging will be described in this paper.

1. Introduction

Over last few decades, micro electromechanical system (MEMS) devices have found considerable applications in human beings' daily lives. Specifically, microfluidics systems (a part of the MEMS technology) has developed over the last two decades offering the potential to improve our way of life. The medical, pharmaceutical, environmental, electrical, and chemical industry have all benefited, with significant changes to drug delivery systems, blood gas monitoring systems, chemical analysis systems, biomedical research and genetic diagnostics systems. With the development of the microfluidic device components, such as pumps, valves, mixers and fluidic switches, there are dramatically increasing markets for microfluidic systems. The demand for the “lab-on-a-chip” type technology has increased in the marketplace, where effective testing can be achieved in less time, using less sample materials and reagents.

Polymers have been used to build microfluidic systems. It appears that polymers show wide advantages in medical, chemical and biomedical applications (Gonzalez et al. 1998), (McDonald et al. 2000). Microfluidic systems made of low cost polymers has become an attractive area for many research institutes and manufacturing companies (Martin et al. 1999). Polymers in microfluidic systems is a new field, which compares with silicon in the MEMS industry, and needs a lot of development to push into mass

production for marketplace. This research will aim at developing polymeric systems for packaging and interconnecting of microfluidic systems.

2. Industrial implications

As the market increases, microfluidic systems become increasingly multi-functional and more complex and deal with larger varieties of environmental, material and reaction requirements. The small size advantage of a microfluidic system has often been reduced due to the cost and size of packaging. It is not unusual that the packaging content accounts for 75% to 95% of the overall cost of a micro-electromechanical component or system. These factors, prevalent in the early days of electronic integrated circuits, contributed toward large-scale integration in that industry, in order to minimize the impact of packaging on overall cost and size.

Microfluidic systems require the separation of fluid from the electronic side with reliable sealing and connections. High-density packaging methods, such as surface-mount technologies, are today at the core of advancements in electronic packaging. In contrast, the evolution of microfluidic system packaging is slow and centres largely on borrowing from the integrated circuit industry in an effort to benefit from the existing vast body of knowledge.

The sophisticated packaging technologies have proved critical for the penetration of microfluidic system into industrial markets. Unfortunately this has resulted in high-volume applications and a minimum level of technology standardization. The process of manufacturing microfluidic system needs to be standardised in order to produce them cheaper and more effectively.

3. Packaging System for Microfluidics Applications

3.1 Packaging

Packaging is the process of “packing” micro-electromechanical components and systems inside a protective housing. Combining engineering and manufacturing technologies, it converts a micro-machined structure or system into a useful assembly that can safely and reliably interact with its surroundings. The definition is broad because each application is unique in its packaging requirements. Microfluidic system differs from the integrated circuit industry, as it must account for a far more complex and diverse set of parameters than high-frequency electrical signals. It must

- Protect micro-machined parts in broad-range of environments
- Provide interconnects to electronic circuit and microfluidic channels
- Provide reliable access to and interaction with the external environment

For example, a pressure sensor requires intimate contact with the pressurized medium while being protected from exposure to any harmful substances within it. Moreover, valves require interconnections with both electrical and fluid components. These are all critical functions of the packaging used. As a consequence of these diverse requirements, standards for microfluidic packaging have often been based on proprietary standards which varied between companies. This failure to adopt an industry standards has resulted in a packaging process that is engineering-resource-intensive, which is very expensive.

3.2 Microfluidic Connections

The essential components of Microfluidic packaging systems are microfluidic connections, as they determine the size, cost, flexibility and reliability of a system. The following techniques and materials have been used for microfluidic connections, based on the material, fluid type and system requirement.

- Printed circuit board with microfluidic channel and interconnections (Wego *et al.* 2001)
- Wafer to wafer interconnections (Gray *et al.* 1999)
- Ribbon type multi channel connection (Man *et al.* 1997)
- Modular interconnections (Schuenemann *et al.* 2001)

Many materials are used for the connectors (Puntambekar and Ahn, 2002), (Attiya *et al.* 2001; Tsai and Lin, 2001) allowing connections between and within systems. Past research has aimed to reduce the dead volume (Bings *et al.* 1999) and investigate better sealing (Yao *et al.* 2000). As new materials, functions and applications are identified, more interconnections are needed. At the time of this research, many microfluidic connections are required to be glued by hand which resulted in excessive delays and poor quality control. This is not acceptable at any stage of a product's development.

4. Consideration of Designing Connectors and Packaging

4.1 Introduction

The fundamental requirement for the commercial microfabrication success is an application with a very large demand. This requires that microfluidic test applications are relatively inexpensive, especially in medical industry. Microfabrication using polymer has attracted a great deal of interest as it tends to have a lower cost and exhibits excellent properties that can be used in the medical field. These connectors must have the following characteristics.

- No-leakage
- Reliability
- Low dead volume

- Inexpensive
- Quick connection
- Be useful for biomedicine and chemical analysis application

As disposable cartridges have become very popular, the connections must ensure that dangerous samples are properly sealed during operation.

4.2 Quick connector

Using polycarbonate and complying with the specification in section 4.1, a quick microfluidic connection has been developed (see Figure 4.2). This connector has low volume and uses a thin polymer layer to seal. It is designed for normal, short and long term connection, general link up and flexible connection with short operation time. As we reach the prototype fabrication and test stage, more sizes and uses will be tried.

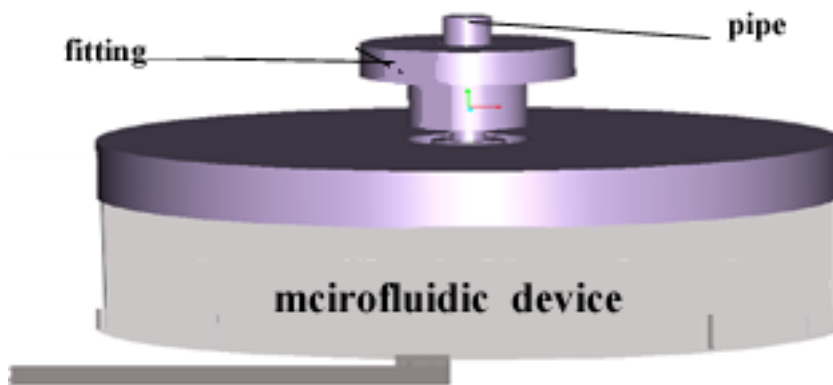


Figure 4.2 - Microfluidic Connection

4.3 Multi channel connector

A multi-channel connector is formed by more than three layers of plastic which contained connection holes and multi-channels (see Figure 4.3). There are multi-channels or dispensers in the middle layer. After all layers are bonded together, it becomes a multi-channel connector. One end of this connector can be bonded to one polymer microfluidic device during the device bonding process. The other end can be fixed on to another microfluidic device. As the thickness of each layer depends on its application, the connector can be very thin and flexible for more applications. Since the thin polymer sheet can be fabricated easily, it is suitable for mass production with low cost. As the channel can be kept to the micro scale, the connector uses minimum fluid volume and reduces dead volume.



Figure 4.3 – Multichannel Connector

4.4 Modular Connector

To provide a modular packaging design (see Figure 4.4) we aim to find a method, such as micro-injection moulding, micro-machining, rapid prototyping and sacrificial material, to produce microfluidic channels inside a modular case. This will ensure that all channels and connectors are in the micro scale, thus reducing the fluid requirements to meet the multi-functions and complex applications.



Figure 4.4 – Modular Packaging Design

5. Future work

To develop effective packaging and interconnects system for commercial microfluidics applications, we must work on a real microfluidic application with consideration of materials, machines, environment, and tools used in fabrication. The proposed designs are for a general purpose microfluidic packaging system. To determine its effectiveness a full series of tests must be performed including leakage, flow characteristics, connection and disconnection force and time, and reliability for connector and packaging according to the process.

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