A World-to-Chip Microfluidic Interconnection Technology with Dual Functions of Sample Injection and Sealing for a Multichamber Micro PCR Chip

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This paper presents a practical world-to-chip microfluidic interconnection technology with dual functions of sample injection and sealing for a multichamber Micro PCR (Polymerase Chain Reaction) chip. One of the primary challenges associated with the successful commercialization of fully integrated microfluidic systems is the development of world-to-chip microfluidic interconnects, that allow easy coupling between the micro-environment of microfluidic devices (e.g. Micro PCR chip, microfluidic-based reactors and sensors) and the macro-environment of the 'real world' (e.g. pipette, tubing and Luer fitting). In this work, we have introduced a microfluidic interconnection technology for both sample injection and sealing, which provides a zero dead volume, a zero leakage flow and biochemical compatibility. In addition, the technology is simple and cheap to fabricate, and is easy to interface with the real world by using conventional pipettes.

As shown in Figure 1, a cartridge consists of a 4-chamber Micro PCR chip, two plastic fittings and a plastic chip handler, which are mass-producible by a conventional plastic injection molding method. The chip (13×6×1 mm) is comprised of four identical microchambers (1 μL) on a silicon substrate with optical windows, and microchannels, inlets and vents on a glass substrate. The Micro PCR cartridge can be inserted in an individual PCR module, which is capable of thermal cycling and performing real-time PCR. The module has a silicon-based microheater/sensor, a cooling fan, an optic unit for light excitations and emissions, an embedded microprocessor and a computing unit.

The plastic fittings, which contain pipette guides and a rubber sheet, are set to fit conventional pipette tips for PCR sample loading. Once samples are loaded to the microchambers, the plastic fittings with the rubber sheet can be slided to the sealing mode to seal the inlets/vents without the dead volume.

If sealing or valving using the rubber sheet fails, the PCR sample will be pushed out of the PCR chamber, resulting in a failed PCR. The amount of pressure required to prevent degassing was estimated by Chiou et al. to be ~3.1 Psi [1]. In worst case, the presence of air bubbles between the sealing rubber sheet and the inlets/vents will cause additional internal pressure buildup of 3.7 Psi at 94 °C [2]; therefore, the rubber sheet has to withhold at least total pressure of 6.8 Psi. In this work, PDMS material is selected for biochemical compatibility and the fittings are designed to withstand at least 8.1 Psi.

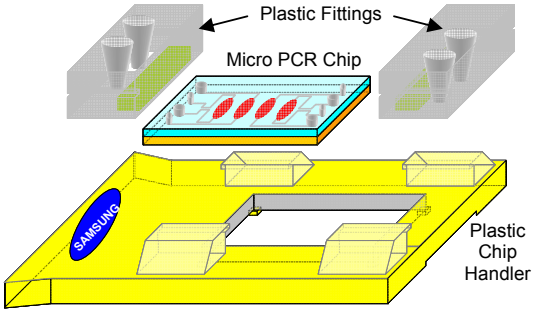

Figure 1. A schematic view of a cartridge.

After sample loading and sealing, leakage test is conducted by elevating the temperature upto 100 °C for 30 min. No leakage flows are found during the test for 10 cartridges. In addition, 3 chips are thermal cycled and the PCR products are analyzed by Bioanalyzer 2100. To achieve the same PCR yield in each microchamber, temperature uniformity is of great importance. The temperature uniformity between the microchambers is less than 0.5 °C and the % CV of PCR yields is less than 6.7%.

In conclusion, we have introduced a simple and cheap microfluidic interconnection technology for both sample injection and sealing, which provides a zero dead volume, a zero leakage flow, and biochemical compatibility. Also, this world-to-chip interconnection technology enables one or more operators to interface between the micro world and real world easily.

References

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2. Y. Liu, Cory B. Rauch, Randall L. Stevens, Ralf Lenigk, Jianing Yang, David B. Rhine, and Piotr Grodzinski, "DNA amplification and hybridization assays in integrated plastic monolithic device," Anal. Chem. 2002, 74, 3063–3070.