FABRICATION OF THROUGH-WAFER FLUID INTERCONNECTS WITH LOW DEAD VOLUME AND INTEGRATED BACK-PLANE FLUID JUMPERS
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ABSTRACT
We present the fabrication process and test results of a through-wafer fluidic channel interconnect with low dead-volume (~2.75 nl) and integrated back-plane fluid jumpers. A back-plane fluid jumper connects two through-wafer interconnect holes. An efficient, high-yield fabrication process has been developed.

Keywords: Through-wafer Interconnect, Fluid Jumper, Deep Reactive Ion Etching, Parylene

1. MOTIVATION AND INTRODUCTION
We developed through-wafer fluid interconnects for two major application scenarios:

(1) Through-wafer fluid interconnects allow the various components of a fluidic system to be built on both sides of a wafer rather than on just a single side. This physical separation can lead to flexibility in fabrication and the realization of high-density, complex systems. In most existing microfluidic systems, fluidic components (e.g., channels and reaction chambers) and electromechanical components (e.g., valves, pumps, electrodes, mixers) tend to reside in one common plane, which ultimately requires that complex systems consume a large chip area.

(2) By using fluid interconnects, two streams of fluid can cross over one another by diverting one stream to a different physical plane and returning that stream at a different location on the original plane. Analogous to using air-bridges in integrated circuits, this fluid jumper could simplify the design of complex fluid systems that may otherwise require crowded channel routing.

Deep reactive ion etching (DRIE) has been explored for creating multi-level microfluidic devices [1,2]. Here we demonstrate the use of DRIE to create through-wafer fluid...
interconnects and back-plane jumpers, generically diagramed in Figure 1. A lab-on-chip device is made by bonding two pieces: a PDMS piece with recessed channels and reaction chambers, and a silicon piece with microfabricated through-wafer interconnects and back-plane fluid jumpers. Biochemical fluids can travel both in plane and across the thickness of the silicon wafer. It is important to minimize dead volume associated with the through-wafer interconnects and fluid jumpers.

Figure 1. Schematic diagram of a generic microfluid chip that utilizes through-wafer fluidic interconnects. Channels and reaction chambers are formed by bonding a PDMS layer (top piece) to a silicon piece (bottom piece). Through-wafer interconnects in the silicon piece allow fluid to traverse back and forth between the top and bottom planes. A back-plane fluid jumper is a short channel that connects two through-wafer holes and can be used to bypass areas on the front plane. Sophisticated on-chip pumps and valves can be built on the back plane, separated from fluidic channels on front in terms of physical location and fabrication.

2. DEVICE FABRICATION

DRIE is ideal for creating deep holes with high aspect ratio. We have developed a new microfabrication process (Figure 2). Through-wafer holes are selectively drilled in the silicon using DRIE. The holes are then filled with photoresist. To accomplish this, we first seal one end of the hole by backing the silicon piece against a cured slab of Polydimethylsiloxane (PDMS). The surface facing the PDMS is kept clean. Photoresist is then dropped on the opposite side and any trapped air in the holes is replaced by the photoresist while under a vacuum. The photoresist is cured slowly in a vacuum to minimize dimensional contraction due to loss of solvents. After sufficient curing, a new layer of photoresist is deposited and patterned on the clean surface side, followed by parylene-C deposition. We then remove the photoresist, both in the holes and on the surface, using acetone. A resultant back-plane jumper consisting of two through-wafer holes connected by a short segment of channel is shown in Figure 3.
3. RESULTS AND DISCUSSION
Experiments were conducted to verify that fluid can travel in the through-wafer interconnects and jumpers without leaking. A PDMS piece with matching recesses serving as fluid channels is bonded to the silicon chip. Figure 4 shows representative fluid channels connected via back-plane jumpers (not shown) and filling with a color dye solution. Another micrograph illustrating a closer view of fluid passing through a network is shown in Figure 5. Figure 6 depicts two completely filled channels leading...
into a reaction chamber. Discontinuous channels are connected by back-plane jumpers not visible in the picture.

Figure 5. Segments of in-plane flow channels connected through vertical interconnects and two back-plane jumpers. This is a snapshot of the channels as they are being filled with a fluid traversing from right to left. The left-most segment is not yet filled.

Figure 6. PDMS fluid channels and a reaction chamber filled with a methanol solution of fluorescein. Through-wafer interconnects are visible as circles in the flow path.

4. CONCLUSION
A method for fabricating through-wafer fluid interconnects and back-plane fluid jumpers has been presented. This 3-dimensional architecture can be used to separate different system functions on different physical planes. The use of fluid jumpers greatly increases the possible density of fluid networks.

REFERENCES