AN EXPERIMENTAL VALIDATION OF THE PRESSURE CAPACITY OF A MODULAR GASKETLESS MICROFLUIDIC INTERCONNECT

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ABSTRACT

Fluidic interconnects provide the passages for the transport of liquid analytes, containing mass and information, from one component to another in a microfluidic system. The pressure capacity of a novel, modular, gasketless, chip-to-chip microfluidic interconnect that forms a seal with a liquid bridge suspended between concentric through-holes was evaluated experimentally (see Figure 1).\textsuperscript{[5]} The maximum rupture pressure measured for the gasketless interconnect was 21.4 kPa (3.1 psig), which corresponded to a measured assembly gap distance of 3.4 \textmu m. The gasketless interconnect withstood maximum pressures seen in microfluidic systems and is realizable within manufacturing variation.

KEYWORDS: microfluidic interconnect, chip-to-chip interconnect, gasketless, capillary forces, superhydrophobic, surface energy, surface tension, liquid bridge, meniscus stability

INTRODUCTION

Various groups have examined and reported on the design of world-to-chip [1, 2] and chip-to-chip [3] fluid interconnects. However, most of the designs added additional constraint between the component chips and to/from the microfluidic system leading to over-constrained systems. Over-constraint can induce strain in the microfluidic system creating dead volumes and leading to indeterminate alignment between component chips. These problems are magnified when working with highly parallel microfluidic systems that may require more than a hundred interconnects. Decoupling constraint from the interconnect allows alignment between component chips to scale favorably with an increasing number of fluidic interconnects. The gasketless interconnect decouples constraint from the interconnect design by using capillary forces, instead of physical contact between surfaces, to seal the connection. The passive seal is created when parallel superhydrophobic surfaces are patterned around the concentric microfluidic ports separated by a gap (see Figure 1).

Figure 1: Bottom: Schematic of a microfluidic system consisting of two adjacent component chips connected with a gasketless interconnect. Top: An image captured using a Nikon Measurescope MM-11 (Melville, NY) with a Diagnostic Instruments, Inc. microscope camera (Sterling Heights, MI), and SPOT advanced imaging software of the gasketless interconnect featuring deionized water dyed with red food coloring flowing across a 600 \textmu m gap from one component chip to another via two concentric through holes.
METHODS

A mathematical model based on the Young-Laplace equation [4] was used to estimate the maximum rupture pressure for the gasketless seal.

Sample chips were injection molded from Cyclic Olefin Copolymer (COC) (Topas® 5013S-04, TOPAS Advanced Polyomers, Florence, KY), and included injection molded through-holes (see Figure 2). Kinematic alignment structures were used to set the assembly gap distance and align the through-holes (see Figure 2). A commercially-available superhydrophobic surface treatment (Hydrobead-P®, Hydrobead, La Jolla, CA) was used to generate the seal faces. Sample chips were manually assembled in pairs with three, grade 5, 1/32” diameter silicon nitride ball bearings (Boca Bearing Company, Boynton Beach, FL) to create repeatable sample assemblies.

The pressure capacity was measured using a custom experimental apparatus that employed a 0-34.47 kPa (0-5 psig) closed-loop dual valve pressure controller (68027-60, Cole Parmer, Vernon Hills, IL) to control the driving pressure of the fluid supplied by a pressurized liquid reservoir, an ASDX pressure sensor (Honeywell S&C, Golden Valley, MN) to determine the pressure at the interconnect, and an NI USB-6212 DAQ board in conjunction with LabVIEW 2012 (National Instruments, Austin, TX) to automate the experiments (see Figure 3).
RESULTS AND DISCUSSION

Maximum pressure measurements from ninety-nine (99) sample assemblies with mean gap distances from 4-240 µm demonstrated that the model based on the Young-Laplace equation can be used to estimate the required gap distance for specified downstream pressure drops. The maximum pressure measured for the gasketless interconnect was 21.4 kPa (3.1 psig), which corresponded to a measured assembly mean gap distance of 3.4 µm. Figure 4 compares the rupture pressure to the measured assembly mean gap distance for a subset of the ninety-nine sample assemblies from four mold inserts with two different loading conditions.

CONCLUSIONS

The gasketless interconnect withstood maximum pressures seen in microfluidic systems, and is realizable within manufacturing variation. These results could motivate other microfluidic designers to adopt the gasketless interconnect as a simple chip-to-chip fluidic interconnect for modular component chips in microfluidic systems.

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REFERENCES


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