MULTIPLEXED PNEUMATIC VALVE CONTROL SYSTEM FOR LARGE SCALE INTEGRATED MICROFLUIDIC CIRCUIT (LSIMC)

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ABSTRACT

An efficient control method of a large number of individually controlled and arrayed pneumatic microvalves is proposed. This method can control (2^n) valve matrix with (2n+2) control pressure lines, where n is bit number. With this method, the number of off-chip valve controller and world-to-chip connector are reduced remarkably. A prototype 2^4 (16) microvalve array controlled by 2*4+2 (10) control lines is fabricated. Any on-chip valve is switched within 200 msec individually.

KEYWORDS: micro valve, pneumatic valve, multiplexed valve control

INTRODUCTION

The chemical processing on a chip is a promising tool for the combinatorial chemistry. In the various kinds of on-chip valve, the pneumatic actuation is most commonly used due to its simple structure and easy fabrication [1,2]. However, the operation of pneumatic valve is given by off-chip solenoid valve, a large scale integration of microvalves require the same numbers of off-chip control solenoid valves and world-to-chip connectors. On the other hand, there is a symmetry between large integrated circuits (LSI) and microfluidic circuit (MC) [3]. To overcome the interface difficulties, we propose an efficient control method considering addressing method which employed in the metal-oxide-semiconductor field-effect transistor (MOSFET) devices.

CONCEPT

This method consists of the pressure inputs of a drive line, a gate line and selective lines as shown in Figure 1. The drive line is used to switch the state of the on-chip valves. The gate line applies the pneumatic pressure of gate valves that select the on-chip valve to activate. The multiplexed selective lines choose one gate valve of the addressed on-chip valve. Figure 2 shows the three steps pneumatic pressure control for changing one valve state. To make the valve close, the pressure is applied to the drive line and the binary signals are input to the selective lines as shown in Figure 2(a). Then the pressure is applied to the selected on-chip valve from the drive line after the gate valve was opened as shown in Figure 2(b). The selective lines maintain the close state of the other gate valves. The gate valve is closed by applying the pressure to the gate line for keeping the state of the on-chip valve as shown in Figure 2(c). It is the same way to make the on-chip valve open except venting the drive line at the first step as shown in Figure 2(d-f).

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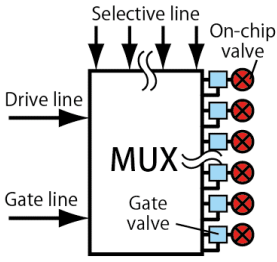

Figure 1 Schematic concept of the multiplexed valve control system. The system is consisted of drive line, gate line, and selective line that addresses the activate valve.

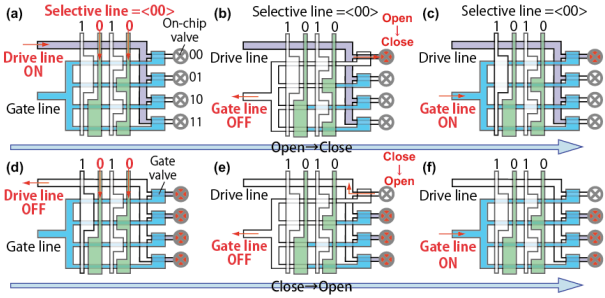

Figure 2 Schematic 2-bit valve operation (a-c) open to close and (d-f) close to open of valve 00. Each switching has 3 steps. First is applying activating pressure of ON(a)/OFF(b) to drive line and binary signal <00> to selective lines. Second is opening of gate valve. Third is closing the gate valve for keeping the valve state.

EXPERIMENTAL AND RESULTS

A prototype device of 2^4 (16) microvalves as shown in Figure 3 was fabricated. The device has a laminated structure consist of three layers of PDMS [3,4]. Figure 4 shows the SEM images of the mold of first and second layer. Figure 5 shows the experimental setup.

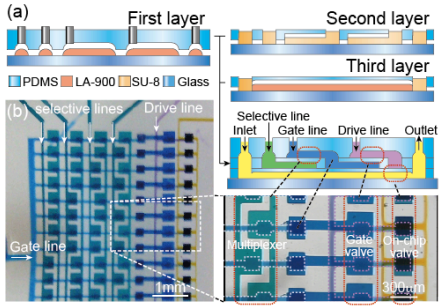

Figure 3 (a) Cross sectional schematic of the molds and PDMS device. (b) Top image of the fabricated device. Each layers are bonded after O_2 plasma pretreatment.

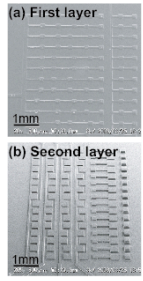

Figure 4 SEM images of (a) first and (b) second layer.

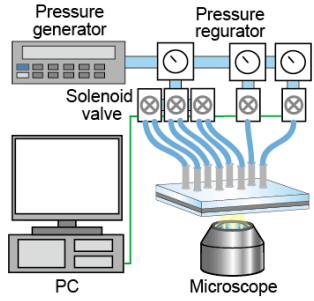

Figure 5 Schematic view of experimental setup. Timing of applying pressure is controlled by signal from PC.

Figure 6(a-f) shows the operation of open to close of the on-chip valve switching. The channels of the drive line and the gate line are filled with inert liquid to prevent gas leakage through the Polydimethylsiloxane (PDMS) structure. The applied pressures to the drive line, the gate line, and the selective lines are 130 kPa, 180 kPa, and 240 kPa respectively. Figure 7 shows the operation of 16 valves. The selected on-chip valve is switched within 200 ms.

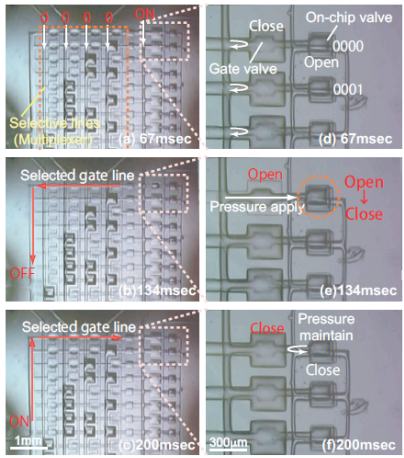

Figure 6 Images of switching steps of on-chip valve 0000. Top (a-c) and magnified (d-f) images show the three step switching from open to close respectively.

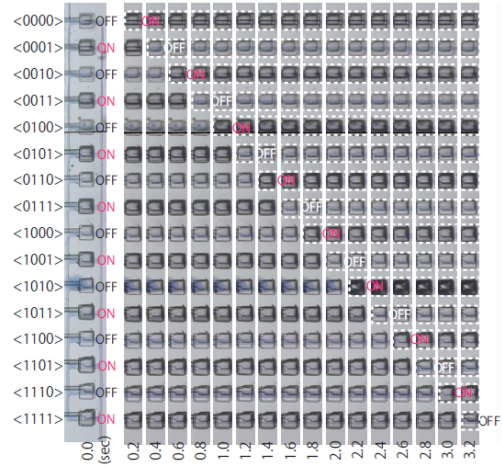

Figure 7 Operation images of 16 valves. Each image shows the every switching of the selected valve after three steps as shown in Figure 6. the alternate switching open and close with next valve to each other.

CONCLUSIONS

In order to control a large number of arrayed pneumatic microvalves efficiently, a multiplexed valve control system was proposed. Using a fabricated device of 16 microvalve array, 16 valves can controlled by 10 off-chip control valves. This structure can be applicable for large number of arrayed microvalves. We are currently going on further optimization of the device design and to control large scale integrated fluidic circuit of individually controlled 256 (2^8) microvalves by 18 (2*8+2) control lines.

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