FEASIBILITY TEST OF A FAST MICRO GAS CHROMATOGRAPHY SYSTEM USING FIVE MICROVALVES AND A MICROCOLUMN

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ABSTRACT

We present a new type of a fast MEMS Gas Chromatography (GC) system that integrates five microvalves and microcolumn for rapid detection of species for a flame ionization detector (FID). The integrated GC samples mixed-gas species, preconcentrates them, and injects a sharp band into the microcolumn with 50 μ s pulse width. The microcolumn can then separate and detect 8 components in the species within 10 seconds with 25 psi of the carrier gas. The fast speed of this GC is enabled by microsecond switching microvalve, low dispersion design, and a new coating technique on the microcolumn.

INTRODUCTION

Many efforts have been made to build fast and portable micro-GC systems for various applications. Homeland security and many on-site industrial applications need fully integrated micro-GC systems with injector microvalves, preconcentrator (PC), microcolumn, detector, and a micropump for sampling. However, no fully integrated system has been developed yet. MEMS PCs including [1] have been published but without integration of other components. A micropump-driven GC system was developed by Kim *et al.* [2], but their system still employs a separate injection system, lowering GC speed and resolution. Microvalves integrated with a PC was reported by Bae *et al.* [3].

In this paper, we present a new type of a fast MEMS GC system that integrates five microvalves and microcolumn for rapid detection of species for an FID.

SYSTEM CONFIGURATION

Figure 1 shows a schematic diagram and device pictures of five microvalves and a microcolumn. Figure 2 shows photographs of all

the layers of the microvalves and how they are stacked. To achieve fast operation, the five microvalves employs electrostatic actuation, and each valve can switch states in 50 microseconds [4]. The five integrated microvalves consist of two microvalves to load the sample gas, and three microvalves to route and inject the sweep gas through a one- μ L chamber to the microcolumn that is designed for low dispersion and has a new deactivation method applied. The microcolumn has 34 cm-long serpentine channels whose cross-section is 100 x 100 μ m² with a design generates the lower dispersion than spiral [5]. The integrated GC samples mixed-gas species, preconcentrates them, and injects a sharp band into the microcolumn with 50 μ s pulse width. The microcolumn can then separate and detect 8 components in the species within 10 seconds with 25 psi of the carrier gas. The fast speed of this GC is enabled by MEMS sizing and fabrication, microsecond switching microvalve, low dispersion design, and a new coating technique on the microcolumn, which enables the detection of poisonous gases, toxic industrial compounds, and other volatile compounds to be separated in seconds, rather than tens of minutes with conventional GC systems.

RESULTS

Figure 3 shows a separation of 8 chemical components using a standalone microcolumn with 25 psi H₂ carrier gas and temperature setting of 90~98°C. As an injected plug moves down the column, the plug experiences broadening due to diffusion, velocity-induced shearing, and smearing at bends. Figure 4 shows toluene peaks through the same microcolumn as the one used in the previous experiment. Toluene vapor is sampled at ambient temperature and injected every 10 seconds by the microvalves following the sequence in Fig. 1a to the microcolumn. The H₂ sweep gas is 3 psi,

Figure 1: (a) A schematic diagram shows how all the five valves are used for sampling gas (blue line) and for sweeping the sample through to the column with H₂ (yellow line); device pictures of (b) five microvalves and (c) microcolumn; and SEM images of the cross-sections of (d) a microvalve and (e) the microcolumns.

Figure 2: Photos of all the layers of the microvalves and how they are stacked.

which is more than 8 times less than the pressure used for the standalone column in Fig. 3. Figure 4 (b) shows that the 100 ms width peaks are as sharp as and slightly faster than the peak from the standalone microcolumn. This result is attributed to the microsecond switching performance of the microvalves in addition to the design of the low dispersion microcolumn. To integrate the five microvalves and microcolumn, a connecting layer was fabricated that not only connects the five microvalves to the microcolumn, but also has inlet and outlet fluidic ports where Nanoports® are used as shown in Fig. 5.

CONCLUSIONS

The feasibility of a micro-GC system that uses five fast-acting microvalves and a microcolumn has been shown through

Figure 4: Toluene peaks through the same microcolumn as the one used in the previous experiment. (a) Toluene vapor at ambient temperature being sampled and injected every 10 seconds by five microvalves to the microcolumn via a capillary, with H_2 carrier gas at 3 psi, which is more than 8 times less than the pressure used for the standalone column. (b) The 100 ms width peaks are as sharp as and slightly faster than the peak from the standalone microcolumn. This result is attributed to microsecond switching performance of the microvalves in addition to the design of the low dispersion microcolumn.

Figure 3: A separation of 8 chemical components using a standalone microcolumn with 25 psi H_2 carrier gas at a temperature between 90~98°C. As an injected plug moves down the column, the plug experiences broadening due to diffusion, velocity-induced shearing, and smearing at bends.

simple testing. The peak width will be even sharper by removing a dead volume between components that increases band broadening, allowing higher pressures to be used, and thereby reducing analysis time further.

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Figure 5: A photo of the five microvalves integrated with the microcolumn.