

Engineering Research Center for Wireless Integrated MicroSystems
PROJECT DESCRIPTION

Title: Integrated Low-Power, High-Pressure, High-Flow Gas Micropump

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Funding Source: WIMS ERC

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Work Began: 05/01/2007

Project Goals:

An efficient, low-power, high-flow, high-pressure, and small-volume gas micropump is needed in many emerging microsystem applications, such as a micromachined gas chromatograph μ GC. Especially the WIMS μ GC needs a pump that supports the two different operation modes of the μ GC: sampling and analysis. Previous gas micropumps have shown only limited capabilities, such as low flow rate, low pressure, and large volume, thus failing to meet the requirements of the WIMS μ GC. In a recently completed project, a micromachined pump has been developed and has demonstrated for the first time that a much higher flow rate and pressure could be produced. In this project, we propose to continue developing this micropump to achieve a higher pressure and higher flow rate than achieved to date. The goals of this research are: 1) to develop a high-performance gas micropump overcoming the limitations of previous micropumps and 2) to demonstrate its operation in the WIMS Environmental Monitoring Testbed.

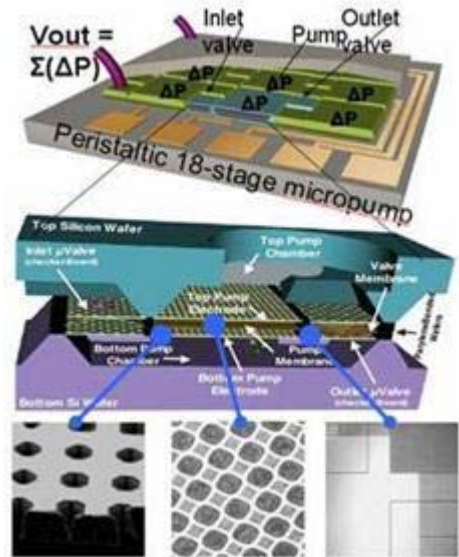


Figure 1: SEM picture of each part of the micropump. From Left: Electrode, parylene membrane, pathway between pump and valve.

Approach and Methodology:

The WIMS μ GC requirements can be met by developing a peristaltic, high-speed micropump with integrated active microvalves, where a high pressure is accumulated through multiple stages and a high-flow rate is generated by high-frequency membrane actuation. The peristaltic pump actuates a highly flexible polymer film using ‘pull-pull’ dual electrodes to maximize gas flow (Figure 1). The integrated active ‘checkerboard’ microvalve timely controls gas flow for multiple operation modes. Two adjacent pump chambers are stacked up sharing a single pumping membrane for a compact design. The development of future micropumps would focus on the performance improvement and compatibility with the full environmental monitoring systems. (1) New actuation mechanisms of pump/valve membranes will be investigated to increase the overall pressure generation capability of the pump. (2) Monolithic integration of an electrostatic filter, flow sensors, a separation column, and a gas sensor will be considered for a truly integrated gas chromatography system. (3) Closed-loop control over the multistages will be pursued for accurate and stable gas flow.

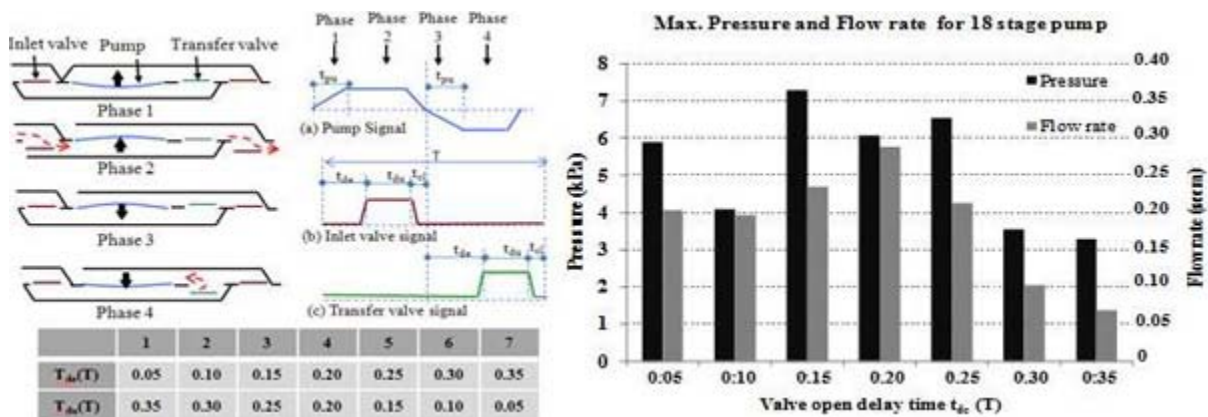


Figure 2: Valve timing control to achieve higher flow rate and pressure (left), variable pump performance range for fabricated micropump (right).

Role in Supporting the Strategic Plan and Testbeds:

This vacuum micropump is a critical part of the microGC in the Environmental Monitoring Testbed. It enables the GC to operate without the need for a carrier gas. The approach proposed here can also lead to the development of microvalves needed in other parts of the GC.

Results and Accomplishments:

18-stage micropumps have been fabricated and tested. Recently, intensive analysis was done to optimize the valve and its control timing for higher performance. Valves play a crucial role in a multi-stage pump because it allows pressure accumulation and distribution along each pump chamber. Valve open timing and open duration were varied to optimize valve control. When the duration of time when microvalves are opened is changed between 0.05 and 0.35 cycles, the micropump produced wide ranges of pressure between 7.3 and 3.3kPa and flow rates between 0.29 and 0.07sccm. These results correspond to a variation of pressure and flow rate by 110% and 400%, respectively (Figure 2).

Plans for the Coming Year:

Currently, a new architecture of multi-stage pumps is being designed and fabricated. In order to simplify the process and increase the device operating frequency, a new polymer-free fabrication process is being developed.

Expected Milestones and Dates:

- Design and fabrication of the micro-pumps with revised architecture and materials (01/30/2010)
- Extensive testing and more detailed characterization new micro-pumps and test structures (04/30/2010)

Expected Contributions, Deliverables, and Company Benefits:

- New conceptual designs and new MEMS fabrication technologies for a micropump for the μ GC
- Microactuator designs for low-power, high-frequency, mechanically resonating, or electrostatic microstructures
- Guidelines for the development of high-flow rate and high-pressure gas micropumps

References and Recent Publications:

1. S. Lee, S. Y. Yee, A. Besharatian, H. Kim, L. P. Bernal, and K. Najafi, "Adaptive Gas Pumping by Controlled Timing of Active Microvalves in Peristaltic Micropumps," *Transducers 2009*.
2. H. Kim and K. Najafi, "Characterization of Wafer-Level Transfer of Thin and Flexible Parylene Membranes," accepted and in press, *IEEE Journal of Microelectromechanical Systems (JMEMS)*, 2007.
3. H. Kim et al., "Micropump-Driven High-Speed MEMS Gas Chromatography System," *Proc. 14th Int. Conf. on Solid-State Sensors, Actuators, and Microsystems (Transducers '07)*, Lyon, France, pp. 1505–1508, June 2007.
4. H. Kim, A. Astle, K. Najafi, L. Bernal, and P. Washabaugh, "Fully Integrated High-Efficiency Peristaltic 18-Stage Gas Micropump With Active Microvalves," *MEMS '07*, pp. 131–134, Kobe, Japan, January 2007.