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DEPARTMENT OF MECHANICAL ENGINEERING

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MICRO-SCALE GAS PUMPING TECHNOLOGY FOR MINIATURIZED ENVIRONMENTAL MONITORING SYSTEMS

Dr. Hanseup Kim
Department of Electrical Engineering and Computer Science
University of Michigan

Emerging microsystem applications increasingly demand on-chip gas flow generation and control to reduce power consumption and size while maintaining the fluid manipulation capability. These applications include environmental and health monitoring, gas sensing, breathe analysis, and micro fuel cells. For example, a micro gas chromatography (μGC) for detection of air pollutants requires a micro-scale pumping system with a high flow rate (>a few sccm) and a high pressure (>10 kPa) while consuming only small power (<100 mW) and fitting in a small volume (<1 cc). However, previous gas micropumps have shown only limited capabilities, such as low flow rate, low pressure, or a large volume thus failing to meet the requirements of the systems. The limited gas pumping capabilities are mainly caused by the small stroke volume, slow operation, and weak force of a pumping membrane in the micro scale as well as the gas compressibility. My talk addresses the development of highly efficient gas micropumps that overcome such limitations and its application for environmental monitoring: (1) New pumping concepts to handle compressible gas and obtain high pressure and high flow rate pumping, (2) Novel microfabrication technologies developed to realize such concepts, (3) Final micropumps successfully microfabricated using those developed technologies resulting in promising pumping capabilities, and (4) integration of the fabricated micropumps with other micro components to establish the first functioning MEMS Gas Chromatography (GC) system featuring a micropump. The developed micropump operates at 17 kHz fluidic resonance in an 18-stage configuration, and produces an air flow rate of 4.0 cc/min and a pressure of 17500 Pa, consuming a total power of ~57 mW. It has operated over 20-month span for a total of ~400 minutes and has a volume of 25.1×19.1×1 mm^3 (~0.5 cc). The pump is combined with a micro-column and a chemiresistor array to form the first micropump-driven μGC where 11 VOC vapors including toluene, xylene, and mesitylene are identified within 24 seconds.

Dr. Hanseup Kim received the B.S. degree in 1997 in Electrical Engineering from the Seoul National University, Korea, and the M.S. and Ph.D. degree in 2003 and 2006 from the Department of Electrical Engineering and Computer Science, University of Michigan, Ann Arbor. From 2006, he is employed as a Post-Doctoral Research Fellow in the Center for Wireless Integrated MicroSystems (WIMS), Department of Electrical Engineering and Computer Science, University of Michigan. His research interests include microelectromechanical systems (MEMS), microfluidics, micro/nano sensors and actuators, micro/nano fabrication technologies and structures, and polymer technology development. He has authored and co-authored two book chapters and over 25 papers in refereed journals and conferences and holds one patent.

For more information, please contact Prof. EH Yang at Eui-Hyeok.Yang@stevens.edu or 201-216-5574