MEMS Micro-vacuum Pump for Portable Gas Analyzers

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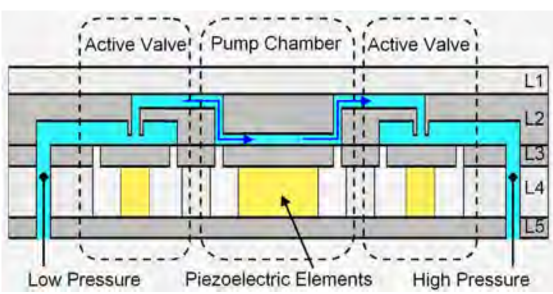
Sponsorship: DARPA

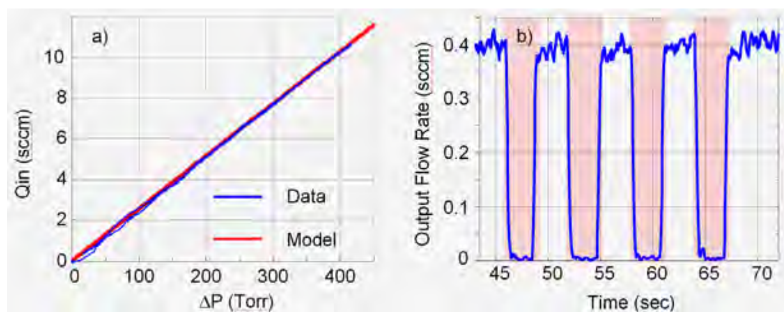
There are many advantages to miniaturizing systems for chemical and biological analysis. Recent interest in this area has led to the creation of several research programs, including a Micro Gas Analyzer (MGA) project at MIT. The goal of this project is to develop an inexpensive, portable, real-time, and low-power approach for detecting chemical and biological agents. Elements entering the MGA are first ionized, then filtered by a quadrupole array, and sensed using an electrometer. A key component enabling the entire process is a MEMS vacuum pump, responsible for routing the gas through the MGA and increasing the mean free path of the ionized particles so that they can be accurately detected.

There has been a great deal of research done over the past 30 years in the area of micro pumping devices [1, 2]. We are currently developing a displacement micro-vacuum pump that uses a piezoelectrically driven pumping chamber and a pair of piezoelectrically driven active-valves; the design is conceptually similar to the MEMS pump reported by Li et al. [3]. We have constructed an accurate compressible mass flow model for the air flow [4] as well as a nonlinear plate deformation model for the stresses experienced by the pump parts [5]. Using these models, we have defined a process flow and fabricated three generations of the MEMS vacuum pump over the past year and are currently working on the fourth.

A schematic of the pump is shown in Figure 1. For ease in testing we have initially fabricated only Layers 1-3 and have constructed a testing platform that, under full computer control, drives the pistons and monitors the mass flows and pressures at the ports of the device. The lessons learned from the first three generations of the pump have led to numerous improvements. Every step from the modeling to the etching and bonding to the testing has been modified and improved along the way. The most recent third generation pump test data is shown in Figure 2. Figure 2a shows the pressure versus flow rate characteristics of the pump; note that the data compares very well with models. Figure 2b shows the output flow rate versus actuation characteristics of the pump. Notice that the flow goes to zero each time the piston is actuated upwards (red bar). All three pistons demonstrated similar performance illustrating a pump with fully functioning pistons and tethers. Next, we hope to characterize the pumping characteristics of this and the upcoming fourth-generation pumps.



▲ Figure 1: Schematic of the MEMS Vacuum Pump. Layers 1 and 4 are glass, Layer 2 forming the chambers and channels is DSP silicon, Layer 3 forming the pistons and tethers is SOI silicon, and Layer 5 is SSP silicon.



▲ Figure 2: a) Pressure versus flow rate characteristics of the pump compares very well with models (ΔP = input pressure – output pressure). b) Output flow rate versus actuation characteristics of the pump. Notice that the flow goes to zero each time the piston is actuated upwards (actuation indicated by transparent red bar).

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