LOW-COST MICRO MASS SPECTROMETERS FOR HANDHELD CHEMICAL ANALYSIS AND DISTRIBUTED NETWORKS FOR SPACE FLIGHT MISSIONS. F.H.W. van Amerom, A. Chaudhary, R.T. Short, SRI International, 450 8th Av SE, St Petersburg, FL, 33706, Friso.vanAmerom@sri.com

Introduction: Mass spectrometers (MSs) are highly sensitive and versatile chemical analyzers that have the capability to detect a wide range of organic compounds, gases, and minerals. Micro electromechanical systems (MEMS) and nanotechnology open up a world of possibilities for cost-effective, large-scale batch fabrication of mass spectrometers that are far smaller than those presently available.

In addition to the obvious advantages of Lab-On-Chip flight instruments, batch fabrication will make possible low-cost networks of chemical analyzers. An order of magnitude smaller than current MSs, these analyzers will ultimately lead to multiple-sensor systems for use in space flight missions, allowing the analysis of chemical distributions over large areas simultaneously [1].

Distributed networks of such sensors will be very powerful tools in the mid- to long-term Mars Exploration Program, ensuring the safety of astronauts, enabling chemical monitoring in multiple locations throughout spacecraft/habitats, surface vehicles, and astronaut suits, as well as for Mars surface deployments, and potentially improving redundancy capabilities for long space flight missions [2]. The system's functionality would therefore be very useful for challenge area number 1: *Instrumentation and Investigation Approaches.*

Individual components of such miniaturized systems are being developed, integrated, and tested at SRI International (SRI). Arrays of micromachined µ-cylindrical ion trap mass spectrometers (µ-CIT MSs [3-8]) have already been successfully tested for the analysis of gases.

Approach: MEMS methods were used to fabricate µ-CIT MSs in a silicon-on-insulator (SOI) wafer using photolithography, deep reactive ion etching (DRIE), and metal deposition to obtain the metalized endplate and ring electrodes. Figure 1 is an illustration of the µ-CIT electrodes. The performance of each of the 54 µ-CITs in the array was individually investigated using a rasterable electron gun to ionize gas molecules inside each trap.

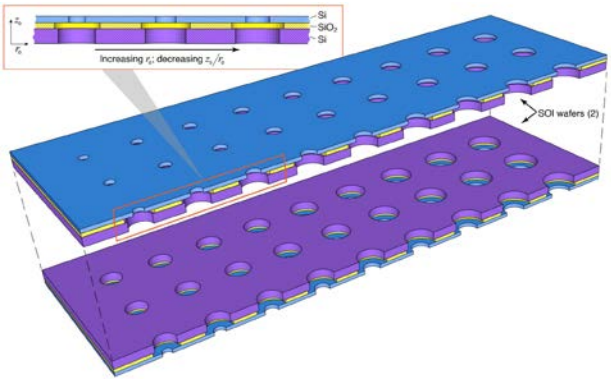

Figure 1: A cross-sectional schematic of a µ-CIT array fabricated in an SOI substrate.

Results: Figure 2 shows the fabricated µ-CIT electrodes (consisting of 54 ion traps). The µ-CIT electrodes were operated under vacuum in the presence of background Kr gas at 4.10^{-5} Torr to test the quality of the mass spectra obtained from each trap.

Figure 2: The two symmetrical µ-CIT array half-structures before bonding (left); the complete µ-CIT array obtained after bonding the two half-structures and mounting them on an Au-coated PCB substrate (right).

The individually tested ion traps depicted in Figure 2 were able to produce mass spectra from gases such as Ar, CO_2, O_2, N_2 and Kr^{2+}. The resolution (full width half maximum) of a single µ-CIT (less than 0.5 m/z) is comparable to a single, larger-sized commercial ion trap MS. The mass spectrum obtained from an individual µ-CIT in the array of 54 is shown in Figure 3.

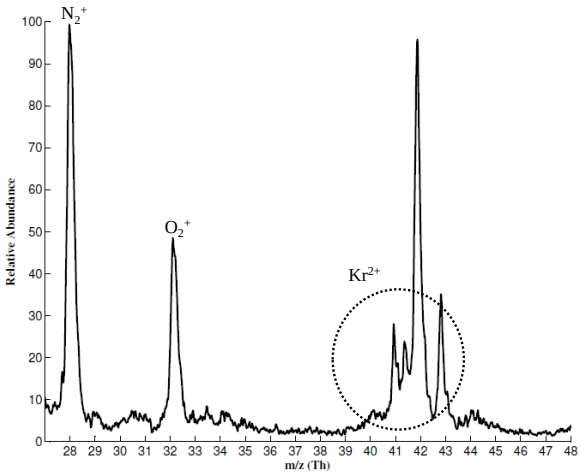

Figure 3: Experimental mass spectral data from a single trap (z_0/r_0 = 0.97) in the μ-CIT array. Axial modulation was used to obtain better-than-unit mass resolution. Krypton doubly charged ions correspond to masses 82, 83, 84 and 86.

Other developments being pursued at SRI include the fabrication of a broad beam electron ionization source, a small vacuum system, and a multi-anode ion detector that will simultaneously read the mass spectra from each μ-CIT to increase sensitivity while reducing the size and power consumption of the device.

Conclusions: MEMS technology provides a viable key approach for the extreme miniaturization of mass spectrometers. Ultimately, this approach will lead to versatile organic chemical and gas analyzers that are a full order of magnitude smaller than the conventional analyzers used in current space flight missions. These compact, batch-produced analyzers could be used to produce a low-cost, networked safety system for space-flight missions while allowing for increased redundancy at the same time—further increasing safety on space missions.

References:

[1] T.P. Griffin et al. (2008) *J. Am. Soc. Mass Spectrom., 19,* 1411-1418.

[2] Precursor Science Analysis Group (P-SAG), presentation, http://mepag.jpl.nasa.gov/reports/Initial_SKGs_05-01-12_v10.pptx

[3] G.E. Patterson et al. (2002), *Analytical Chemistry*, 74, 6145-6153.

[4] A. Chaudhary et al. (2000) *J. Microelectromech. Syst., 18,* 442-448.

[5] F.H.W. van Amerom et al. (2008) *Chem. Eng. Comm., 195,* 98–114.

[6] M.G. Blain et al. (2004) *IJMS*, 236, 91-104.

[7] O. Kornienko et al. (1999) *Rapid Commun. Mass Spectrom.,13,* 50-53.

[8] S. Pau et al. (2006) *Phys. Rev. Lett., 96,* 120801.