Inexpensive Mass Spectrometers for Field Applications

Henry W. Rohrs, Bella Bloom, David R. Asher, Joel R. Brandt, Mark V. Reinders, Rajiv S. Chhatwal, Philip S. Berger, W. Ronald Gentry, and Jorge A. Diaz*

Mass Sensors, Inc. 1350 Baur Blvd. St. Louis, MO 63132-1904 www.mass-sensors.com

**University of Costa Rica, Escuela de Fisica, San Jose, Costa Rica*

ABSTRACT

In many industrial applications mass spectrometry (MS) has not been used because of its high cost or perceived complexity. Traditionally, MS has been coupled with other techniques (e.g., gas chromatography) to provide two-dimensional analysis of complex sample streams, but MS is not often used in simpler applications because of its initial and operational expense. We believe that it is possible to provide MS solutions in these areas by reducing the size and complexity of the MS to deliver a package with an attractive price-to-performance ratio. We have accomplished this using a ExB sector field geometry pioneered by Gentry, Giese, and Diaz.[1] We present data from a variety of applications including plasma rocket diagnostics, landfill monitoring, and helium leak detection. Our present sensitivity is 10 microamps/Torr at m/z = 4. We discuss advantages and limitations of our system with regard to a number of parameters including performance, cost, internet and wireless connectivity, and portability.

DISCUSSION

Our mass sensors are based on a compact double-focusing mass spectrometer pioneered at the University of Minnesota (CDFMS).[1] The design employs superimposed electric and magnetic fields to achieve both direction and energy focusing. This allows the devices to be compact without sacrificing resolving power.

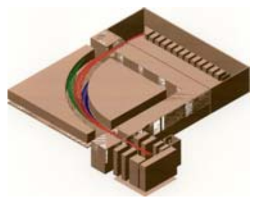

Figure 1 SIMION model of Alpha R8 Separation of m/z = 3,4,5

A SIMION model of a 50 amu sensor is shown in Figure 1. The unit consists of three parts: source, analyzer, and detector. An electron impact source generates the ions, crossed **E** and **B** fields separate the ions, and an electron multiplier detects the ions.

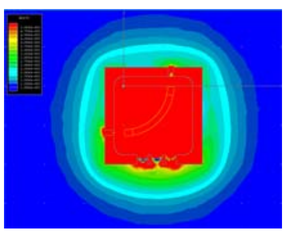

Figure 2 FEA data for B Field

SIMION and FEA modeling are used to focus on viable designs for miniaturizing the sensor and getting adequate performance in a package that can be mass produced.

Our LabView-based software provides full interactive control of the sensor and supports full scan, selected ion monitoring, and leak test modes. It provides powerful plotting and analysis tools and direct export of data into Excel format files. The sensor controller can also operate in full standalone mode, providing continuous monitoring, data processing via downloaded calculation scripts, and extended data logging to nonvolatile memory.

Our CyberSpec™ concept is to have a distributed network of mass sensors that are accessible through the Internet. Thus, users can retrieve the data from a network of sensors any time, anywhere as long they have a device which can access the Internet. This should allow desktop or PDA monitoring of real time harsh environment data (e.g., around a volcano, along a pipeline) that is being collected anywhere in the world. This network may be either a wired LAN or a wireless implementation.

At present we have made two sensors, a 50 amu unit (R8, Figure 3) and a 150amu unit (R20, Figure 4). When produced in low quantities, we are able to sell them for ~$6000. Table 1 lists some of their properties. The sensors have been tested in a variety of beta sites in both industrial and laboratory settings.[2-5]

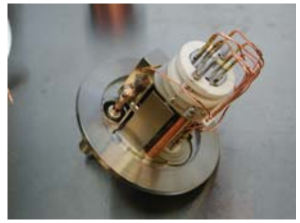

Figure 3 R8 on NW50

Figure 4 R20 on NW100

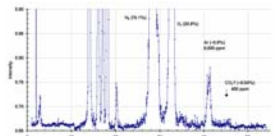

Figure 5 Air Monitoring with R8

Figure 5 shows the sensitivity for an R8 with our source 1 in an air monitoring experiment conducted at an industrial site. The development of the new ion source is expected to extend the sensitivity down to the 1-10 ppm range.

Since the resolving power of the sector instrument is constant, it excels at separating ions at low mass. Figures 6 and 7 show a plasma rocket experiment in which He, used as a propellant component, was monitored during the firing of a rocket.[3] Figure 8 shows the 0.1 s response time of an R8 (on the MSI vacuum system) to a He leak of 2E-6 std. cc./sec. Figures 9 and 10 show an R8 used to monitor landfill gas in Italy. [4]

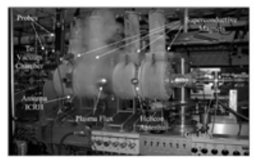

Figure 6 Plasma Rocket Firing

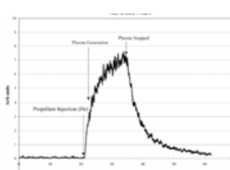

Figure 7 He from Plasma Rocket

R20 measurements carried out to fulfill a NASA contract are shown in Figures 11 and 12.[5] They found good agreement between the NIST database and integrated intensities measured by the R20. They were also able to detect 200 ppb of benzene in water in a membrane experiment. Figures 13 and 14 show a GC-MS using an R20 and data from experiments conducted at LLNL.

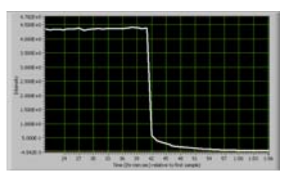

Figure 8 He Response

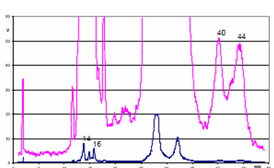

Figure 9 Landfill Gas

Figure 10 Landfill Site in Italy

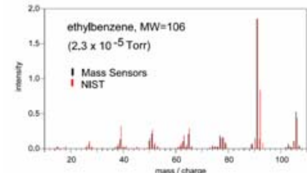

Figure 11 R20 with NIST data

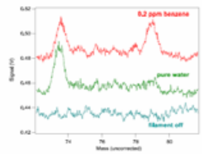

Figure 12 MIMS Data

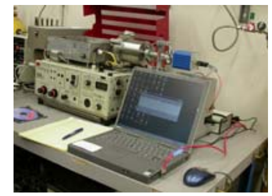

Figure 13 R20 with Mini-GC

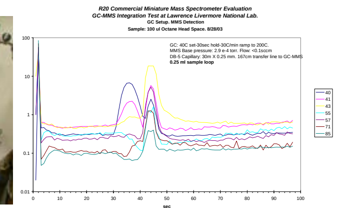

Figure 14 GC Data

TABLE 1

	R8	R20
Weight (with flange)(g)	150	2200
Vac. Chamber Dims. (cm)	5 Ø, 7 H	10 Ø, 11 H
Sensor Radius (cm)	0.8	2.0
Max. Oper. Press. (Air, Torr)	10^{-4}	10^{-5}
Power Consumption (W)	25	25
Mass Range(amu)	50	150
Resolving Power (FWHM)	40	100
Sensitivity (A/Torr, He) Source 1	1E-7	1E-7
Source 2	1E-5	1E-5
Min. Det. Leak, EM, He (std. cc/s)	10^{-9}	

SUMMARY

MSI can provide low-cost, miniature mass sensors for a broad range of applications. The units have begun to be tested at a variety of beta sites. We are addressing problems with contamination, sensitivity, and response time. Work is already underway on integrating the sensor, pressure gauge, high vacuum pump, and inlet into a single housing to reduce size, weight, and cost. We have a versatile software platform based on LabView and will soon have a standalone mode running for remote operation.

REFERENCES

1. *Sub-miniature ExB Sector Field Mass Spectrometer* J. A. Diaz, C. F. Giese, W. R. Gentry *J. Am. Soc. Mass Spectrom.* 2001.

2. *Evaluating Mass Analyzers as Candidates for Small, Inexpensive, Rugged Single Point Mass Spectrometers for Analysis of Permanent Gases* C. R. Arkin, A. K. Ottens, J. A. Diaz, T. P. Griffin, D. Follistein, F. Adams, W. R. Helms *49th ASMS Conference on Mass Spectrometry and Allied Topics* Chicago, 2001.

3. *Test of a Miniature Double-Focusing Mass Spectrometer at the Advanced Space Propulsion Laboratory for Real Time Plasma Monitoring* J.A. Diaz, F. Chang-Diaz, J. P. Squire, V. Jacobson, G. McCaskill, A. Mora, H. Rohrs, and R. Chhatwal *Tr. Anal. Chem.* 2002.

4. *Field and Laboratory Test of a Miniature Double Focusing Mass Spectrometer Sensor for Landfills and Gas Management* E. Davoli, L. Cappellini, and R. Fanelli *51st ASMS Conference on Mass Spectrometry and Allied Topics* Montreal, 2003

5. *A Novel Sensor for Spacecraft/Habitat Chemical Contamination* D. S. Bomse, S. M. Massick, and M. A. Zondlo, NASA Contract No. NAS 9-99146