Miniature, High-Resolution Quadruple Mass-Spectrometer Array: Applications to Environmental Monitoring and Control

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ABSTRACT

A miniature quadrupole mass spectrometer array has been designed and tested. It consists of 16 rods in a 4 x 4 array. The ionizer is of a miniature Nier-type, and the detector is a channel-type multiplier. The demonstrated mass range is 1-300 u, and the resolution of the system is 0.1-0.5 u (FWHM), or $m/\Delta m = 600$. The present sensitivity is measured and calculated to be approximately 1 x 10'2 counts/torr-sec. Applications to NASA missions will be outlined, along with military and commercial uses.

INTRODUCTION

Applications of a small quadruple mass-spectrometer array (QMSA) are many, especially if a parallel path of *electronics miniaturization* is followed. Space-based applications include the following: monitoring for major and trace species in the Shuttle and Space Station air locks and cabins, monitoring the modification of the low-earth orbit plasma by Shuttle or Space Station (including any spacecraft leaks), monitoring major and trace species in long-duration human missions to the Moon, Mars and beyond where mass, volume, and power are at a premium; and carrying out studies of the atmospheres, ionospheres and magnetospheres of the outer planets. Earth-based applications include protection of military sites against nerve-and blister-agent attacks, environmental monitoring, analytical chemistry, and residual-gas analysis. Because of the small size of the sensor, one may now envisage spectrometers at multiple locations.

MAIN SECTION

Described herein is a miniature quadruple mass spectrometer array in which the ionizer, rods, and detector regions were scaled downwards in size in such a way that mass range and resolution were not sacrificed, and the sensitivity was held comparable to that of its larger commercial cousins. The QMSA consists of 16 rods in a 4 *x* 4 array to form nine separate quadrupolar regions. Each rod is 25 mm long and 2 mm diameter. The ionizer is of a miniature Nier-type design, and the detector is a channel-type electron multiplier. The overall sensitivity to positive-ion detection is approximately 1 x 10'2 counts/torr-sec. The demonstrated mass range is 1-300 amu, with a resolving power of m/Am = 600. This corresponds to a resolution of 0.1-0.5 amu (FWHM). The entire unit is approximately 7 cm in length and 3 cm diameter, including separate shields around the rod array and the detector. Total system mass with shields is approximately 30 grams.' This system differs considerably from a commercial unit[2] in that the rods here are positioned to a 0.1% dimensional tolerance, all dielectric surfaces are shielded from electrons and ions, a Faraday cup or multiplier may be used as a detector, electrical contacts are rigidly attached without distorting the positional accuracy of the poles, and separate shields against stray photons, ions and

electrons are provided around the quadruple and detector regions.

To illustrate the low-mass and high-mass operation of the QMSA, Fig. 1 is a mass spectrum of a H_2-He mixture taken at a radio-frequency of 12.9 MHz. The resolution in the features is 0.1 and 0.2 u (FWHM), with the zero blast clearly separated from the $m = 1$ feature.

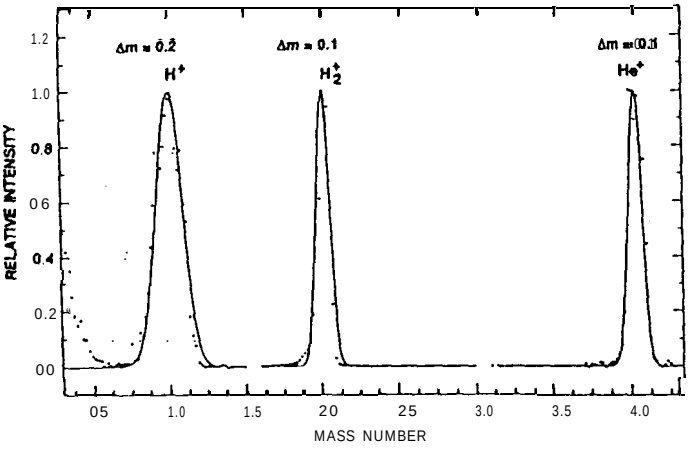

Figure 1. Spectrum of a H_2-He mixture. The rising portion toward *zero* mass is the zero blast.

To illustrate the high-mass operation of the QMSA, Fig. 2 is a spectrum taken of C_6F_{12} (dodecafluorodimethylcyclobutane) with a molecular weight of 300 u. The operating frequency is 5.3 MHz, and the resolution at 300 u is 0.5 u, or m/Am = 600.

Work is presently under way to increase the sensitivity of the system by redesign of the ionization-extraction section. Calculations are done in a full 3D geometry, with due regard to the space-charge loading of the ionizing electron beam.[3]

CONCLUSION

A miniature quadruple mass spectrometer has been designed, built and tested. Its characteristics are as follows: mass range 1-300 u, mass resolution $m/Am \simeq 600$, sensitivity approximately 1 x 1012 counts/torr-sec, with channel-multiplier detection. Its mass (without electronics) is 30 grams. One could use one or more of these systems in satellites and spacecraft (air-quality monitoring, planetary aeronomy), environmental applications, and for protection of transportation systems, buildings and military perimeters.

ACKNOWLEDGEMENTS

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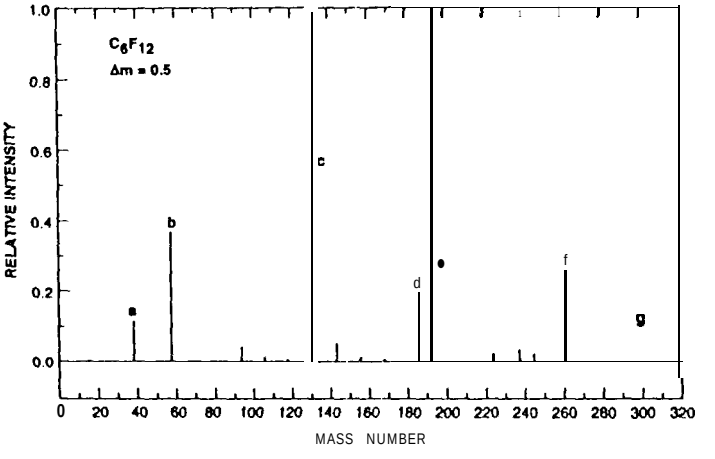

Figure 2. Mass spectrum of C_6F_{12}. Identification of the more intense features are: (a) F_2^+, (b) F_3^+, (c) $C_3F_5^+$, (d) $C_6F_6^+$, (e) $C_6F_7^+$, (f) $C_6F_{10}^+$, (g) $C_6F_{12}^+$.