High Pressure Nitrogen and Air Mass Spectrometry with Microscale Ion Traps

STUDENT AWARD WINNER

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There are numerous field measurement problems that would benefit from handheld mass spectrometry including safety and security applications where rapid detection of hazardous chemicals is required. Miniature cylindrical ion traps (CITs) allow high-pressure operation, significantly reducing pumping technology requirements and thus enable mass spectrometry platforms with small size, weight, and power (SWaP). Our initial work in high pressure ion trap mass spectrometry was limited to helium buffer gas. Nitrogen and air have larger collision cross sections, which results in lower mass resolution. However, they are ideal buffer gasses for handheld mass spectrometry since they are easily obtained from the atmosphere.

A differentially pumped vacuum system was used to allow ionization and mass analysis at pressures up to 2 Torr, while maintaining electron multiplier pressure below 30 mTorr. A glow discharge source was used for internal electron ionization. CITs with radii of 500 µm, 350 µm, and 225 µm were used for mass analysis. Headspace samples of volatile organic species were used as analytes.

A CIT with r_o = 500 µm was used to characterize the effects of nitrogen and air buffer gas pressure on mass-to-charge resolution for p-xylene from 0.5 to 1.7 Torr at constant RF drive frequency. We observe a linear decrease in resolution with increasing buffer gas pressure. Because RF voltage requirements increase with RF frequency, CITs with critical dimensions below 500 µm were used to investigate the effects of RF drive frequency on resolution at 1 Torr air from 6 to 20 MHz. Mass spectral resolution decreased linearly with RF drive frequency, counteracting peak broadening from high buffer gas pressure.

This work demonstrates that high pressure microscale CIT operation in nitrogen and air addresses pumping challenges associated with miniaturizing mass spectrometers. The resulting reduction in SWaP represents a significant advance in the pursuit of handheld mass spectrometers.