1st Detect

MINIATURE MASS SPECTROMETER WITH NOVEL SAMPLE COLLECTION

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MINIATURE MASS SPECTROMETER

The authors have developed a small (< 20 l volume, < 8 kg weight) mass spectrometer based on an ion trap architecture for the security, industrial, and healthcare markets. In short, the instrument is capable of:

- 10 – 450 amu mass range (covering most explosives, TICs, and CWAs)
- < 1 amu resolution (FWHM)
- Sample-to-sample time: < 1 second (30 seconds with described pre-concentrator or desorber)
- Power consumption: < 45 W
- Sensitivity: < 200 ppb VOCs (< 1 ppb with pre-concentrator)

Figure 1 below shows three variants of the instruments.

Figure 1 – Photographs of 3 variants of 1st Detect miniature mass spectrometer including, handheld (left), bench-top (center), and sub-component (right)

APPLICATIONS

The instrument is designed as a versatile detector for a wide variety of applications across several market segments. These include:

SECURITY:

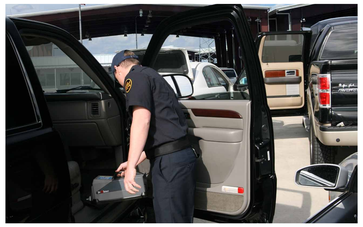
- Person–portable vapor detector for CWAs and TICs
  (investigation is under way to detect explosive and IED pre-cursors and degradation products in the vapor phase)
- Explosives and IED detector (with integrated evacuated desorber) at portals and checkpoints

INDUSTRIAL:

- Low cost, small footprint analyzer for laboratory screening / forensic analysis
- Production and research facility air quality monitoring / environmental health and safety
- Detector for customer specific sample preparation and collection systems (e.g., GC, IC)
- Person portable / remote laboratory environmental monitoring

HEALTHCARE:

- Low cost screening tool
- Exhaled breath analysis



PERFORMANCE

Figure 2 below shows representative spectra and calibration data for several chemicals of interest.

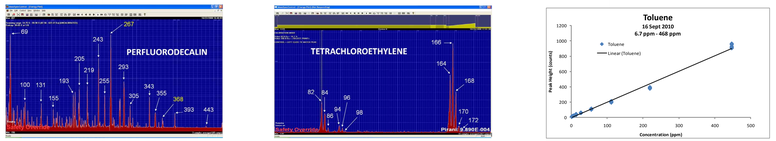


Figure 2 – representative spectra including perflourodecalin (left), tetrachloroethylene (center), and a calibration for toluene (right) showing linear response over 200 ppb – 468 ppm

Figure 3 below shows the repeatability of the system with 10 – 12 sequential experiments measuring xylene for several concentrations.

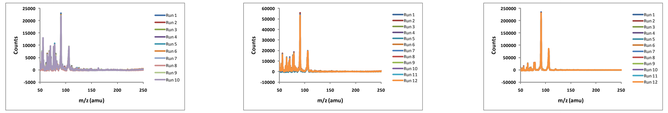
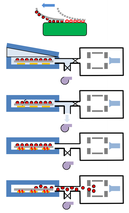


Figure 3 – Example of instrument repeatability showing xylene measured at 1 ppm (left), 2.5 ppm (center), and 10 ppm (right) for 10 – 12 sequential experiments.

EVACUATED DESORBER

To enable particulate and 'sticky' substances to cross the vacuum barrier into the mass spectrometer, a novel thermal desorption system is being developed. The sample inlet allows collection of explosive particulate using a swipe method similar to those in use today. However, to allow transfer of the vaporized explosive particulate into the vaccum chamber, the desorber is configured to evacuate the volume prior to desorption thus allowing direct injection of the sample into the instrument without the need for external ionization or ion transport (e.g., ion funnel or quadrupole ion guide).



- Particulate is removed from surface by swab
- Sample (swab) is placed in thermal desorber
- Background matrix (air) is evacuated
- Swab is heated releasing analyte and vaporizing particulate
- Analyte is introduced to mass spec for highly specific analysis

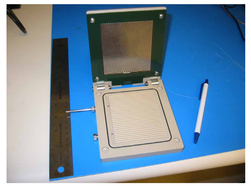
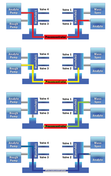


Figure 4 – schematic (left) and photograph (right) of evacuated desorber

PRE-CONCENTRATOR

A novel pre-concentrator has been designed that leverages the selective sorptive capabilities of advanced materials with a novel design that significantly reduces the analysis time compared to currently deployed instruments. In the design sorbent materials are placed in a tube with a heating element. The electrical leads of the heater is connected to a power supply controlled by a computer system. Because the tube housing the sorbent is evacuated thus minimizing the dead volume effect prior to thermal desorption, the overall concentration gain is a product of the adsorption and evacuation gains yielding a typical total gain in the range of 104. Typical analysis times are less than 30 seconds.



ABSORPTION

- Flow sample over coated mesh

EVACUATION

- Remove matrix from chamber

DESORPTION/ANALYSIS OF SORBENT

- Heat mesh to liberate analyte and introduce to mass spec

COOLING AND FLUSHING SORBENT

- Cool mesh and remove residual analyte

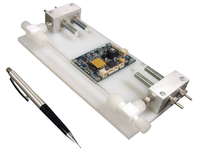


Figure 5 – schematic (left) and photograph of pre-concentrator

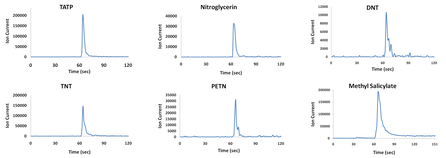


Figure 6 – Desorption profiles for representative explosives and CWA simulants

PURGE AND TRAP

The enable collection of threats agents from non-gaseous media, a novel purge and trap system has been developed utilizing the preconcentrator presented previously. A reduced pressure headspace is created over a liquid sample, and air bubbled through the system to release analyte. Preconcentration of the sample has been achieved with customized adsorption matrix in a geometry optimized both for maximum adsorption collection as well as efficient high yield desorption via direct introduction into the mass spectrometer at reduced pressure. The integrated design of the preconcentrator with the chemical detection system is targeted at sensitive analysis of vapor samples.

Figure 7 – Photograph (left and center) of water sampler and representative data (right) showing measurement of 10 ppb benzene and chloroform in water

ACKNOWLEDGEMENTS

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