Expanding the range of threats detected with a miniature mass spectrometer by the integration of novel sample inlets

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Abstract

A next generation chemical detection system has been developed using a cylindrical ion trap based mass spectrometer. While mass spectrometry has the potential to provide security forces, homeland defense, and first responders with highly specific detection, reduced false alarm rates, and a wider range of detectable threats; portable mass spectrometers are limited to the detection of samples in the vapor phase. However, in many deployments, threats are present in forms other than vapor (e.g., liquid, particulate, etc.). To enable a mass spectrometer to detect non-gaseous threats, users are typically required to prepare samples off-line for introduction to the instrument (e.g., SPME, pyrolisis, etc.). While proven in a laboratory setting, these preparation techniques require expertise, consumables, and increase the logistical burden for field applications. The system proposed here overcomes these challenges by presenting several mechanisms for enabling the collection and analysis of low volatility and non-vapor samples in the field.

Miniature Mass Spectrometer

The instrument developed by the authors is a small (< 20 l volume, < 8 kg weight) mass spectrometer based on an ion trap architecture. 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 pre-concentrator)
- Power consumption: < 45 W
- Sensitivity: < 200 ppb VOCs (< 1 ppb with pre-concentrator)

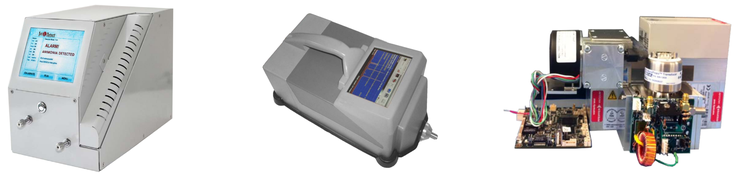

Figure 1 – Photographs of 3 variants of 1st Detect miniature mass spectrometer including bench-top (left), handheld (center), and sub-component (right)

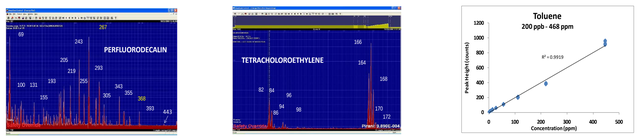

Figure 2 – Representative spectra including perflourodecalin (left), tetra-chloroethylene (center), and a calibration for toluene (right) showing linear response over 200 ppb – 468 ppm

Figure 3 – Example of MS^n (MS/MS) mode of operation

Purge and Trap

The enable collection of threats agents from non-gaseous media, a novel purge and trap system has been developed.

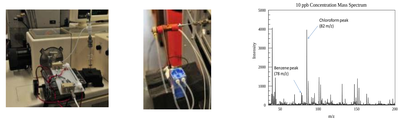

Figure 4 – Photograph (left and center) of water sampler and representative data (right) showing measurement of 10 ppb benzene and chloroform in water

Explosives Sampling

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.

Figure 5 –photograph of MCD with evacuated desorber explosives sampler

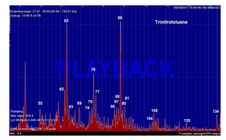

Figure 6 – mass spectrum of TNT measured on the MCD

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. The novel method of operation yields gains in the range of 10^4. Typical analysis times are less than 30 seconds.

Figure 7 –photograph of pre-concentrator (right) and external location for easy maintenance

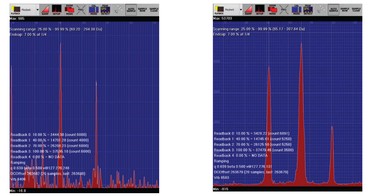

Figure 8 – Low concentration sample showing direct injection (left) and after pre-concentration (right)

Conclusion

The Miniature Chemical Detector (MCD) represents a breakthrough in chemical detection allowing high performance analysis to be deployed in applications where simplicity, ease of use, and low size & cost are critical drivers. By leveraging the specificity of an ion trap mass spectrometer in a small, portable package, laboratory quality analysis can be performed in the locations away from a controlled environment.

Contact Us

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