Introduction

Plasmas have a long-standing analytical history. Energetic species in a otherwise non-thermal plasma both dissociates species of interest and excites the elemental constituents. The atomic emission spectrum serves to identify the compounds and ideally its molecular composition with intensity corresponding to concentration. Miniaturization permits atmospheric pressure operation and battery scale power requirements, thereby permitting mobile field analysis.

Materials and Methods

• Miniature spectrometers, Ocean Optics Maya2000 Pro, Stellar Net Black Comet and comparison to a λ meter (SpectraPro 275) spectrophotograph from Princeton Instruments.
• Two operational modes for ambient monitoring: Continuous and Pulsed for pre-collected solid and aerosol samples.
• Spectra acquired under air and Ar atmospheres.
• Voltages: 500-1500V, Currents: < 12 mA

Results

1. Development of Spectral Library
• Identification of compounds depends on associating the plasma emission with a spectral library. This spectral library is comprised of:
  1) Atomic emission spectra based on the NIST Atomic Spectra Database
  2) Diatomic emission spectra based on the LIBBASE database program
  3) MHGD spectra of known analytes.
• Figure 3 shows database spectra in which the transition strength is plotted against wavelength. Such discrete (non-overlapped) transitions enable straightforward identification of elements.

2. Continuous Flow Mode – Vapor Detection
• Gases were analyzed by exposing them to the MHGD. Survey spectra illustrate the MHGD capability to differentiate various analytes: heptane as a representative aliphatic hydrocarbon, nitrobenzene as a surrogate for TNT based explosives, methanol given its similarity to sugar- and gluten based explosives and chlorobenzene as a representative chlorinated aromatic.

• Powders and liquids were analyzed in a pulsed operational mode by deposition upon a conducting (metal) disk that served as a surrogate cathode in the MHGD element. Spectral transitions of target compounds for this operational mode are summarized in Table 1.

4. Temperature Measurements
• In non-thermal plasmas, gas temperature may be inferred from the intensity distribution of diatomic emission vibrational-rotational band intensities, as illustrated here by fitting the experimental emission intensity from NO to a numerical simulation using the LIBBASE program.

Conclusions

• A MHGD unit was successfully developed and applied to the detection of several chemicals related to explosives at trace levels as listed in Table 1. Continuous and pulsed operational modes for analyzing gases, liquids and solids were demonstrated at atmospheric pressure.

Table 1. Summary of signature transition(s) and relative intensities observed for compounds tested in pulsed operation.

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Transition(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PET</td>
<td>308.89 nm</td>
</tr>
<tr>
<td>RDX</td>
<td>305.07 nm</td>
</tr>
<tr>
<td>HMX</td>
<td>309.97 nm</td>
</tr>
<tr>
<td>Nitromethane</td>
<td>306.2 nm</td>
</tr>
<tr>
<td>Chloroform</td>
<td>309.89 nm</td>
</tr>
<tr>
<td>Benzaldehyde</td>
<td>309.97 nm</td>
</tr>
<tr>
<td>Acetaldehyde</td>
<td>306.2 nm</td>
</tr>
<tr>
<td>2 Chlorobenzene</td>
<td>305.07 nm</td>
</tr>
<tr>
<td>4 Chlorobenzene</td>
<td>305.07 nm</td>
</tr>
</tbody>
</table>

Acknowledgments

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For Further Information

Please contact ruv12@psu.edu. More information on this and related projects can be obtained at www.eme.psu.edu/faculty/vanderwal.html.

Literature Cited


New Electronic Sniffer by Atmospheric Pressure Glow Discharge Plasma

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Figure 1. Breadboard test system for micro-hollow cathode in glow discharge mode.

Figure 2. Micro-hollow glow discharge (MHGD) element: (a) schematic (b) photograph of nickel coated alumina disc.

Figure 4. Examples of plasma emission spectra from CH (A-X), CH (A-X), CN (A-X), CF (A-X) and NO (A-X) radicals between 200 – 900 nm.

Figure 3. A series of atomic emission spectra showing selected transitions based on NIST Atomic Spectra Database.

Figure 5. Spectra of model analytes tested in continuous operation.

Figure 6. A spectral simulation of NO (A-X) vibrational bands compared to observed MHGD spectrum to infer plasma temperature (~ 1300°C).