IoT VOC Monitoring with a Fully Autonomous MEMS-based micro-GC

Presented by:

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Omniscent Platform

Analytic MEMS Sensor
- Simultaneous multi-gas detection
- LoD < 1ppb
- Dual detectors
- Ambient air as carrier gas
- Low power consumption

OMNI-2200
- Autonomous, Remote Management
- BTX speciation
- WiFi / LTE connection
- Edge computing
- Lightweight 10.4 lb

Analytics (OMAP)
- Cloud Analytics
- Remote management via Internet
- Data Visualization on portal
- End-to-end data encryption
- User-defined alerts & notifications
Micro-GC MEMS Chip Architecture

MEMS Chip Components

• Pre-concentrator
  ✔ Two sorbent beds in series:
    (Carbopack X™ & Carbopack B™)

• Separation column
  ✔ 0.6m long with an OV-1 equivalent stationary phase

• Two complementary capacitive detectors

• Flow rate sensor

• Four temperature sensors
  ✔ One for the Pre-concentrator
  ✔ Three for the serpentine GC column
Proprietary MEMS µGC Benefits

A monolithic µGC chip based on Micro-ElectroMechanical Systems Technology

• Benefits of MEMS
  ✔ Small, light weight
  ✔ Integrated, repeatable, rapid, and low-power temperature control
  ✔ High throughput batch production

• Benefits of monolithic integration
  ✔ Simplifies assembly post-fabrication
  ✔ Reliable fluidic interconnect between µGC components
## Current Gas Library

- Benzene
- Toluene
- Ethyl Benzene
- m-Xylene
- o-Xylene

## Next Library

- Styrene
- Methylal

<table>
<thead>
<tr>
<th>#</th>
<th>Chemicals</th>
</tr>
</thead>
<tbody>
<tr>
<td>a1</td>
<td>n-pentane</td>
</tr>
<tr>
<td>a2</td>
<td>n-hexane</td>
</tr>
<tr>
<td>a3</td>
<td>n-heptane</td>
</tr>
<tr>
<td>a4</td>
<td>n-octane</td>
</tr>
<tr>
<td>a5</td>
<td>n-nonane</td>
</tr>
<tr>
<td>a6</td>
<td>n-decane</td>
</tr>
</tbody>
</table>

| Aromatic Hydrocarbons          |
| b1 | benzene             |
| b2 | toluene             |
| b3 | m-xylene            |
| b4 | o-xylene            |
| b5 | mesitylene          |

| Halogenated Hydrocarbons & Aldehydes |
| c1 | hexanal             |
| c2 | chlorobenzene       |
| c3 | chlorohexane        |
| c4 | 4-chlorotoluene     |
| c5 | 1,3-dichlorobenzene |
| c6 | Tetrachloroethene   |

| Terpenes & Other Compounds |
| d1 | cycloheptane        |
| d2 | α-pinene            |
| d3 | 3-carene            |

Gases detected by Current MEMS Column:
Proprietary MEMS µGC Workflow

*Scrubbed ambient air used as the carrier gas during separation*
MEMS Micro-GC Operation

Vapor sampling
User-programmable sampling time
(Sampling flow ≈17 sccm)

- **2 minutes** for high concentration levels (≥200 ppb)
- **10 minutes** for low concentration levels (≥10 ppb)
- **40 minutes** for ultra-low concentration levels (≤1 ppb)

Other steps
- Purging steps for regenerating the analytical path for the next run
- Temperature stabilization
- Data processing and upload

Separation
Parameters optimized by Omniscent staff

- Pre-concentrator desorption
- Temperatures at three locations along the separation column
- Separation starts at the rising edge of the flow
Tolerance to Environmental Stressors

- **Humidity**
  - ✔ Nafion® tube used in the *sampling* flow path to remove sample moisture
  - ✔ Moisture filter used in the *separation* flow path to remove carrier gas moisture
  - ✔ Both Nafion® & the Moisture Filter are self-regenerated *in situ*

- **Temperature Stability**
  - ✔ The µGC chip has a temperature-controlled enclosure

- **Dust Removal**
  - ✔ Dust Filters installed at sample inlet & carrier gas inlet
Design Enhancements

• Hermetically sealed enclosure with O-ring:
  □ Hermetically sealed enclosure design for high RH tolerance
  □ All connectors are tight-sealed to unit enclosure
  □ Equipped w/ Internal Heater for < 5°C ambient temp
  □ All units tested in environmental chamber for:
    ✓ RH ≥95%
    ✓ Temperature range (0°C – 60°C)

• False-Positive VOC Flagging (based on Det1/Det2).

• Continuous Operation mode (endless # of cycles).

• Weather sensor config & link to the full meteorological data page

• Coating of all electronic board with water resistant film.
Proprietary MEMS µGC Dual Detectors

Capacitive Detector Structure

- Interdigitated thin metal electrodes on glass
- Vapor-sensitive polymer (OV-1 equivalent) covers electrodes
- Capacitance change ($\Delta C$) by polymer swelling and change in dielectric constant ($\varepsilon$) upon vapor absorption

Principle of detection

- CapDet1: **Thin** OV-1 coating; $\Delta C$ dominated by swelling; $+\Delta C$ for all chemicals.
- CapDet2: **Thick** OV-1 coating; $\Delta C$ dominated by $\varepsilon$-change; $+ \text{ or } - \Delta C$ depending on $\varepsilon_{\text{chemical}} - \varepsilon_{\text{OV-1}}$
Compound Identification Using Two Detectors

- Peak height ratio of our two detectors ($\Delta C_1/\Delta C_2$):
  - Provides an extra level of chemical identification beyond just the retention time metric

- $\Delta C_1/\Delta C_2$ is:
  - $\approx -3$ for Benzene
  - Between 0 & $-0.5$ for alkanes
  - $>0$ for polar & mildly-polar chemicals
Web-based User Interface
Omniscent BTX Fenceline Monitoring

- Autonomous, portable
- Near real-time
- Speciation
- In-system, onsite analysis
- Low CapX, OpX

40 mi to report
Solar-Power Option

- Solar-powered
- Onboard WiFi
- Anemometer
- Mobile platform

- 240 Watt PV system
- Sustains 6.5 days of no-sun
- 265 A–hr Battery

This platform is conducive for emissions monitoring in remote locations.
Field Deployment

- Small & simple form factor to deploy in tight spaces.
- Easy access to web interface (portal) for data viewing & retrieval.
- Text alerts for threshold-exceeding user-set VOC values.
- Low detection limits: sub-1ppb.
- Flexible sampling times and intervals.
- Solar power for off-grid operation.
- Wind speed & direction measurements for emissions source attribution.
Fast GC Analysis – High Conc. Scenario

OMNI-2100 µGC achieves ultrafast analysis of BTX in less than 40sec cycle

![Graph showing GC analysis results with peaks for Benzene, Toluene, m-Xylene, and o-Xylene]
COP26 & Methane Monitoring

- US & EU announced joint pledge to cut Methane emissions.
- Commitment to reduce 30% Methane emissions by 2030.
- 300,000 Oil & Gas well sites to be monitored in the US.
Omniscent Low Cost IoT Methane Sensor

- A new high-performance, low-cost and small-size NDIR sensor module with sub-ppm resolution.

- Measures CH\(_4\) at 0.1ppm resolution.

- Measures H\(_2\)O & reports dry mole fraction.

- Measures Total Hydrocarbons at 1ppm resolution.

- GPS + WiFi/Cell.

- Commercial units available in Q4.