GAS SENSORS FOR PORTABLE APPLICATIONS – CHALLENGES AND OPPORTUNITIES

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Outline

Portable Industrial Gas Detection
City Technology – company background
Today’s Industrial Safety markets

Requirements for Portable Gas Detection
Key attributes of a good gas sensor

Common Sensing Techniques
Widely used approaches
Main strengths & weaknesses

Further Ahead
New markets – impact of Internet of Things (IoT)
Technologies offering new opportunities
City Technology - Evolution

1970s
Research at Wolfson Unit
City Technology founded 1977
Developed first oxygen sensor

1980s
Developed toxic sensor range
Help to drive H&S practise

1990s
Development of Pellistor technology
Increased range of toxic sensors
New applications

2000s
Exotic toxic gas sensors (Sensoric)
Optical sensors (NDIR)
Miniature gas sensors
Semiconductor sensors

TODAY
Longer life sensors (O₂ etc)
More robust & reliable
Smaller & lower power

World leading manufacturer of gas sensors for industrial safety

Long history of innovation
## Applications

<table>
<thead>
<tr>
<th>Oil &amp; Gas</th>
<th>Chemical &amp; Petrochemical</th>
<th>Power &amp; Utilities</th>
<th>Water &amp; Waste</th>
<th>Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exploration, production &amp; transportation of oil &amp; gas: primary refining of crude oil</td>
<td>Production of chemicals from organic &amp; inorganic feed stocks – including refined products</td>
<td>Generation &amp; distribution of power from coal, oil, gas and nuclear fuel</td>
<td>Water distribution, waste water treatment &amp; supply of water to homes &amp; industry</td>
<td>Spot-check monitoring emissions from boilers / furnaces in domestic &amp; industrial environments</td>
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</table>

**Typical users – workers in hazardous zones & confined spaces**
Requirements

Sensitivity

Most users require measurements at regulatory alarm concentrations

Selectivity

Cross interference can lead to false alarms

Speed of response

Time to alarm is critical – toxic, asphyxiating & explosive hazards

Power consumption

Battery life in instruments has practical consequences (cf mobile phone charging)

Environmental performance

Temperature (-40 to +55C); humidity (0-100%RH); pressure; dust…

Steady state and transient changes

Cost

Purchase price of sensors is only part of the total cost of ownership

Stability & calibration requirements

Short- and long-term drift will reduce reliability of the output

Calibration & testing can represent a major cost

Life

Users expect long life (years) – not disposable products
Common Sensing Techniques (1) - Electrochemical

Target gas reaction - sensing electrode
Balancing reaction - counter electrode
Reference electrode (optional) - maintains sensing electrode at optimum potential via potentiostat
Similar approach for range of toxic gases and oxygen pumps; no consumable parts

*Consumable anode approach (using lead) also available for oxygen*

- Zero or very low power
- Sensitive (ppm) and selective – wide range of target gases
- Fast response (few seconds)
- Low cost
- Simple instrument integration
- Proven long term field experience
- Meet overwhelming majority of requirements
- Extreme environmental performance limited by electrolytes
- Not a good solution for flammable gases (or CO₂)

Electrodes – precious metal (Pt black) on PTFE tape
Electrolytes – strong acid (H₂SO₄)
Wicks and separators - retain & transport electrolyte

Well established – industry standard
Common Sensing Techniques (2)

**Catalytic**

*Microcalorimeter*
- Platinum wire coil and refractory bead with catalyst
- Heat to ~500°C by passage of current
- Flammable gas reacts with oxygen at surface
- \( \text{Hydrocarbon} + O_2 \rightarrow CO_2 + H_2O + \text{heat} \)
- Detect resulting change in coil resistance
- No consumable element

- Well understood, widely accepted
- Flammability indication across many compounds
- Relatively low cost
- Power Consumption – up to 230mW for beads (improved with MEMs substrate)
- Silicones etc can permanently poison catalyst
- Not failsafe - need regular calibrations.

**Semiconductor**

- Porous semiconducting metal oxide
- Chemically adsorbed oxygen on surface - [O]_{ads}
- Can react with many gases when heated (100-600°C)
- Change in [O]_{ads} alters oxide electrical resistance
- No consumable element

- Cheap to produce (in volume)
- Can be small and mechanically robust
- Can operate over wide environmental range
- Consume milliwatts even with MEMS substrates
- Output depends on environmental conditions
- Sensitivity typically drifts over time (regular calibration required)
- Prone to poisoning
- Not very selective (can be an advantage for ‘air quality’ applications)
Common Sensing Techniques (3) - Optical

Non Dispersive Infra Red

Many gases have IR absorptions due to molecular rotation & vibration
Broadband source / interference filter selects required region of spectrum

Sources and detectors – thermal or photonic
Bulb, MEMs hotplate, LED
Thermopile, pyroelectric, photodiode

- Immune to chemical poisoning
- Photonic components can be very low power
- Component costs have historically been high
- Thermal sources are slow & power hungry
- Pathlength dependence of absorption

Improved components → new opportunities
## Comparison Table

<table>
<thead>
<tr>
<th></th>
<th>Electrochemical</th>
<th>Catalytic</th>
<th>Optical</th>
<th>Semiconductor</th>
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</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>Green</td>
<td>Red</td>
<td>Yellow</td>
<td>Green</td>
</tr>
<tr>
<td>Selectivity</td>
<td>Green</td>
<td>Yellow</td>
<td>Red</td>
<td>Red</td>
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<tr>
<td>Power</td>
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<td>Yellow</td>
<td>Red</td>
<td>Yellow</td>
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<tr>
<td>Speed</td>
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<td>Yellow</td>
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<tr>
<td>Cost</td>
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<td>Lifetime</td>
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<td>Oxygen</td>
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<tr>
<td>Toxic (excl CO₂)</td>
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<td>Yellow</td>
<td>Red</td>
</tr>
<tr>
<td>Flammable</td>
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<td>Red</td>
<td>Yellow</td>
<td>Yellow</td>
</tr>
<tr>
<td>VoC</td>
<td>Red</td>
<td>Red</td>
<td>Yellow</td>
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</tr>
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</table>

No solution meets all requirements.
New Opportunities - Industrial Gas Sensing & Beyond

**Miniaturisation**
New sensor approaches → smaller devices and easier integration
Combine with other personal protective equipment (masks, clothing)
More sensors in more places

**Connectivity**
Improved wireless and other communication methods – **beyond the instrument**
Integrate gas detection with location monitoring, biological sensing etc
Use of cloud computing to process data & increase information content
The ‘Connected worker’

**New Markets – The Internet of Things**
Interconnected control / wider availability of information
Greater awareness of environmental issues (especially China)
Rise in personal gas sensing capabilities
Thank You

Any Questions?