





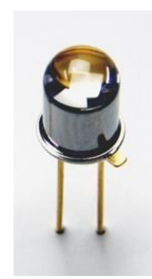
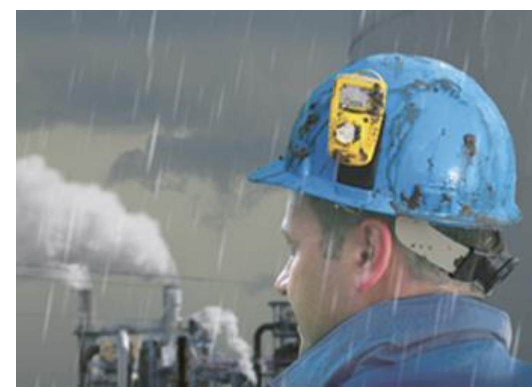

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October 2016

GAS SENSORS FOR PORTABLE APPLICATIONS – CHALLENGES AND OPPORTUNITIES

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

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

Development of Pellistor technology
Increased range of toxic sensors
New applications

Longer life sensors (O_2 etc)
More robust & reliable
Smaller & lower power

1970s — **1980s** — **1990s** — **2000s** — **TODAY**

CITY TECHNOLOGY LIMITED

CAPTEUR SENSORS

SensoriC Gas Sensors

Honeywell

Developed toxic sensor range
Help to drive H&S practise

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

World leading manufacturer of gas sensors for industrial safety

Long history of innovation

Applications

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





Typical users – workers in hazardous zones & confined spaces

Critical life safety applications

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

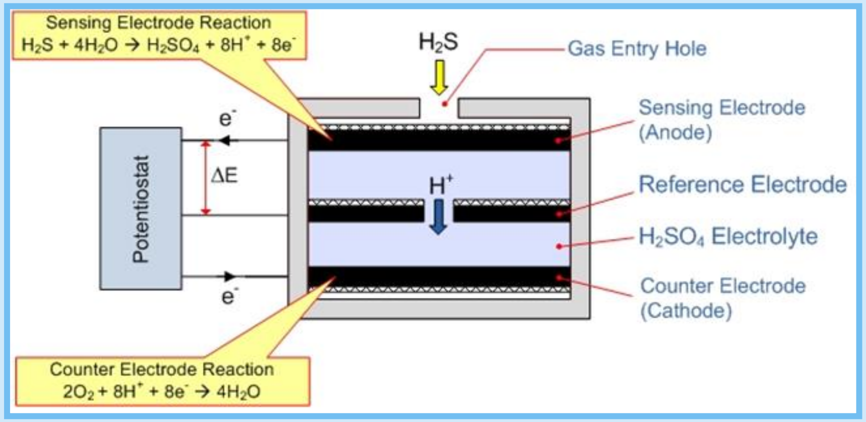
Calibration & testing can represent a major cost

Life

Users expect long life (years) – not disposable products

Complex mixture of demands

Common Sensing Techniques (1) - Electrochemical



Electrodes – precious metal (Pt black) on PTFE tape
Electrolytes – strong acid (H_2SO_4)
Wicks and separators - retain & transport electrolyte

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

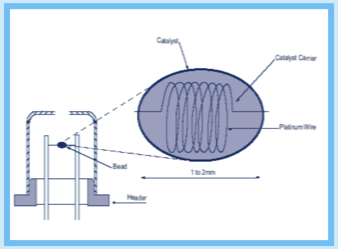
Consumable anode approach (using lead) also available for oxygen

- ☺ 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 CO_2)

Well established – industry standard

Common Sensing Techniques (2)

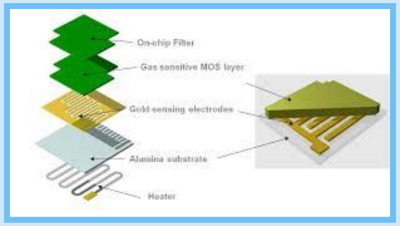
Catalytic

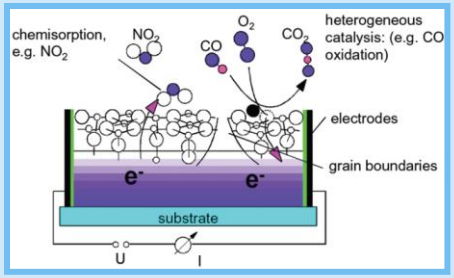


Microcalorimeter
Platinum wire coil and refractory bead with catalyst
Heat to ~500C by passage of current
Flammable gas reacts with oxygen at surface
Hydrocarbon + $O_2 \rightarrow CO_2 + H_2O$ + ***heat***
Detect resulting change in coil resistance
No consumable element

- ☺ 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





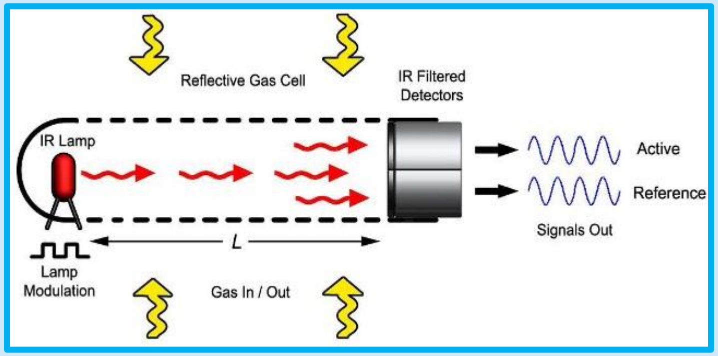
Porous semiconducting metal oxide
Chemically adsorbed oxygen on surface - **[O]ads**
Can react with many gases when heated (100-600ºC)
Change in **[O]ads** alters oxide electrical resistance
No consumable element

- ☺ 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)

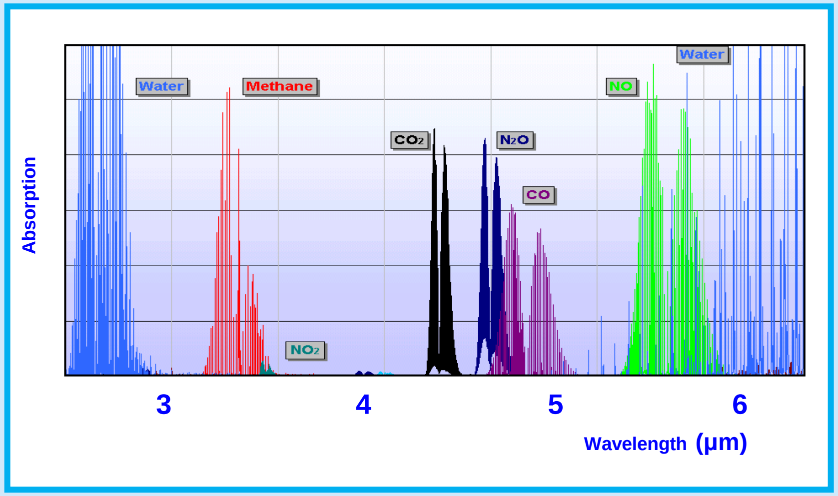
High temperature gas-surface interactions

Common Sensing Techniques (3) - Optical

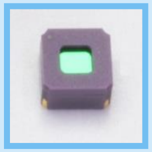
Non Dispersive Infra Red



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



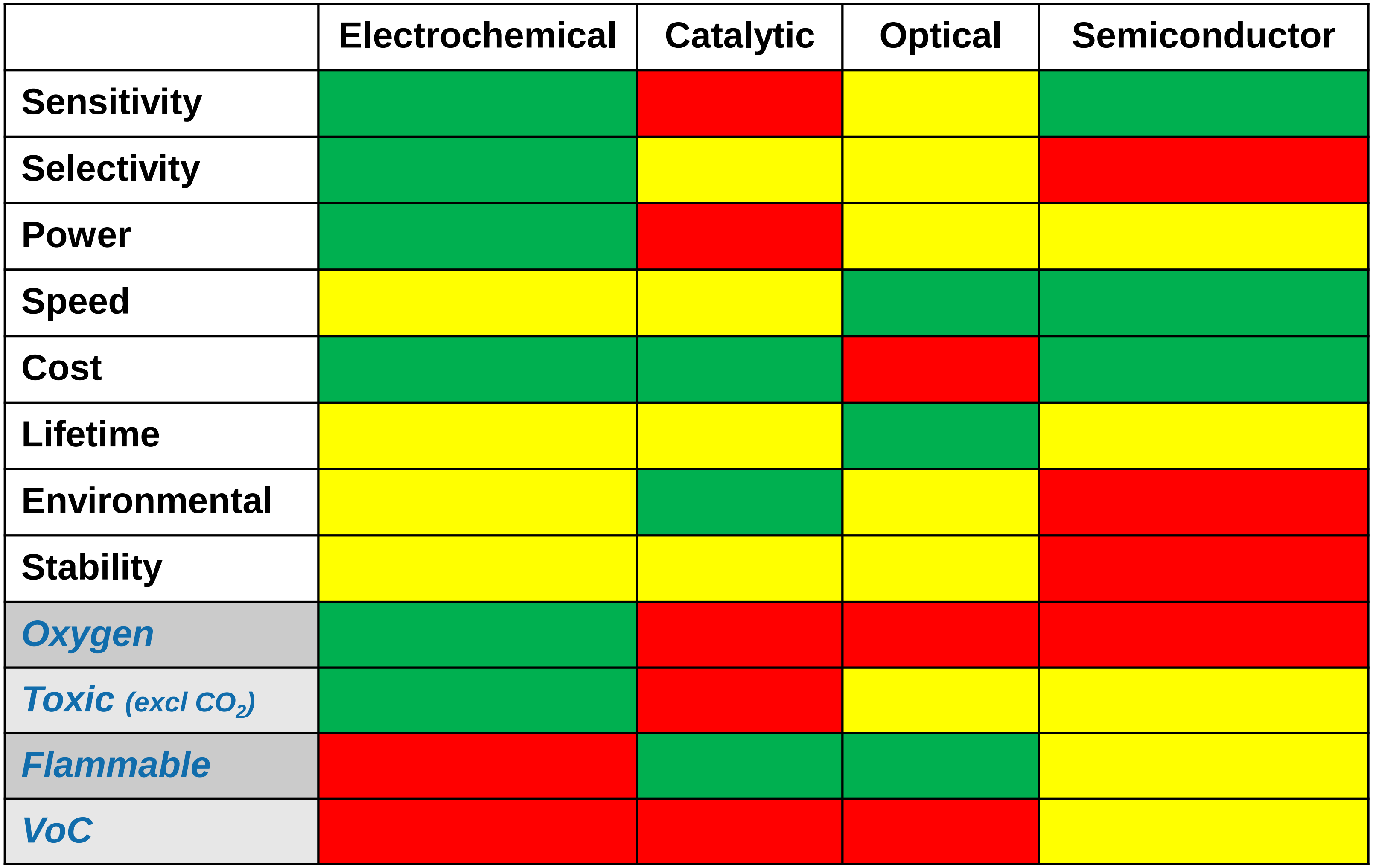
Sources and detectors – thermal or photonic
Bulb, MEMs hotplate, LED
Thermopile, pyroelectric, photodiode



- ☺ 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



No solution meets all requirements

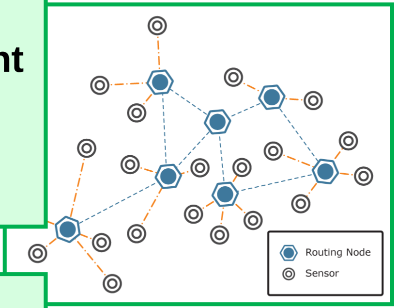
New Opportunities - Industrial Gas Sensing & Beyond

Miniaturisation

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

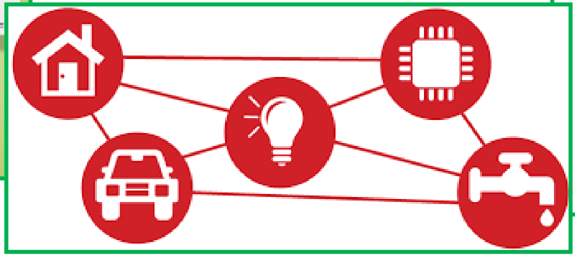
Connectivity

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



Improved offerings for industrial and consumer markets

Thank You

Any Questions?