Gas Detection: Market needs driving innovation

John Saffell,
Technical Director, Alphasense Ltd.Great Notley, ESSEX CM77 7AA
jrs@alphasense.com

User needs for gas detectors are changing: tightening specifications, new regulatory requirements and heightened public awareness of “at risk” persons are pushing gas detector performance to levels not previously required. Smaller, more intuitive and intelligent handheld electronic devices are becoming the norm. Integrated GPS and GPRS technologies are now expected, but add chemical sensors and the problems start.

The matrix below summarises the combinations of gas detection markets and available technologies, with scores from 1 (not relevant) to 5 (technology driver).

| Components | Domestic | Automotive | Industrial | Process | The Law | Emerging markets |
|------------|----------|------------|------------|---------|---------|------------------|
| Lasers and optics | 2 | 4 | 4 | 4 | 3 | 5 |
| UV, IR, microplasma sources | 3 | 4 | 4 | 5 | 5 | 3 |
| Wavelength separation MEMS | 3 | 3 | 4 | 2 | 3 | 5 |
| Low cost optics, detector arrays | 2 | 3 | 3 | 4 | 4 | 4 |
| Fibre optics | 1 | 2 | 4 | 4 | 4 | 4 |
| Micro GC | 1 | 2 | 3 | 3 | 3 | 5 |
| Micro MS | 1 | 2 | 1 | 1 | 1 | 1 |
| PIG, IMS | 1 | 4 | 2 | 1 | 4 | 2 |
| QMB, SAIF, BAW | 1 | 2 | 1 | 1 | 1 | 1 |
| Sensor arrays | 3 | 4 | 4 | 4 | 4 | 4 |
| Microprocessors/ FPGAs/ PICs/ ASICs | 3 | 3 | 5 | 5 | 5 | 3 |
| Wireless | 3 | 3 | 2 | 3 | 4 | 4 |

| Technologies | MEMS | Nanomaterials (QD, CNT, nano MO) | Polymers, liquid crystals | Electrochemistry | Separation science | Physical chemistry (enthalpy, speed of sound) |
|--------------|------|----------------------------------|--------------------------|------------------|-------------------|-------------------------------------|
| Lasers and optics | 2 | 5 | 5 | 5 | 5 | 5 |
| UV, IR, microplasma sources | 3 | 3 | 5 | 5 | 5 | 5 |
| Wavelength separation MEMS | 3 | 3 | 5 | 5 | 5 | 5 |
| Low cost optics, detector arrays | 2 | 3 | 4 | 4 | 4 | 4 |
| Fibre optics | 1 | 2 | 4 | 4 | 4 | 4 |
| Micro GC | 1 | 2 | 3 | 3 | 3 | 5 |
| Micro MS | 1 | 2 | 1 | 1 | 1 | 1 |
| PIG, IMS | 1 | 4 | 2 | 1 | 4 | 2 |
| QMB, SAIF, BAW | 1 | 2 | 1 | 1 | 1 | 1 |
| Sensor arrays | 3 | 4 | 4 | 4 | 4 | 4 |
| Microprocessors/ FPGAs/ PICs/ ASICs | 3 | 3 | 5 | 5 | 5 | 3 |
| Wireless | 3 | 3 | 2 | 3 | 4 | 4 |

| Products | NIR spectrometers | IR single the absorption | IMS | Nanoparticle fluorescence | IR, Visible, THz gas cameras | Ultrasound, thermal conductivity imaging | Electrochem/ optical/polymer/nano arrays |
|----------|-------------------|-------------------------|-----|--------------------------|-----------------------------|-------------------------------|-------------------------------------|
| Lasers and optics | 2 | 5 | 4 | 5 | 3 | 5 | 5 |
| UV, IR, microplasma sources | 3 | 3 | 5 | 5 | 5 | 5 | 5 |
| Wavelength separation MEMS | 3 | 3 | 5 | 5 | 5 | 5 | 5 |
| Low cost optics, detector arrays | 2 | 3 | 4 | 4 | 4 | 4 | 4 |
| Fibre optics | 1 | 2 | 4 | 4 | 4 | 4 | 4 |
| Micro GC | 1 | 2 | 3 | 3 | 3 | 5 | 5 |
| Micro MS | 1 | 2 | 1 | 1 | 1 | 1 | 1 |
| PIG, IMS | 1 | 4 | 2 | 1 | 4 | 2 | 4 |
| QMB, SAIF, BAW | 1 | 2 | 1 | 1 | 1 | 1 | 1 |
| Sensor arrays | 3 | 4 | 4 | 4 | 4 | 4 | 4 |
| Microprocessors/ FPGAs/ PICs/ ASICs | 3 | 3 | 5 | 5 | 5 | 3 | 5 |
| Wireless | 3 | 3 | 2 | 3 | 4 | 4 | 4 |

28/05/2009

© 2009 IOP Publishing Ltd
We will consider four gas detection applications where market requirements are changing:
- Combustion and flue gas monitoring
- Urban air quality monitoring
- Climate change
- Indoor air and cabin air quality

**Combustion and Flue Gas Monitoring**
New boiler designs and the regulatory requirements for increased flue monitoring are demanding more checks by both boiler installers and boiler maintenance contractors.

New condensing boilers are energy efficient, but also cause problems by concentrating acid gases in the exhaust. This problem is only now being understood, and can lead to early failure of gas detectors for measuring carbon monoxide, oxygen and nitrogen oxides. Another issue with condensing boilers is that they contain a gas/air ratio valve which must be accurately adjusted for continued stochiometric operation. Recent HSE research has led CORGI (and more latterly the Gas Safe Register) to strongly recommend checking the combustion performance by an analysis of the gases in the flue.

Carbon dioxide concentration is currently calculated by dilution of the oxygen concentration. However, this is now being reviewed and direct measurement of carbon dioxide concentration using non-dispersive infrared (NDIR) technology is the preferred technology. NDIR increases the cost, but gives a secure CO₂ measurement.

Flue gas analysers (FGAs) have traditionally measured CO and oxygen to calculate boiler efficiency, but newer, more expensive FGAs now measure nitrogen oxides and “spillage” of CO and CO₂. Measuring NOₓ allows the engineer to better tune the boiler for minimum emissions and best efficiency, and checking for CO and CO₂ spillage ensures that the family is safe from leakages, which may cause long term health problems.

**Urban air quality**
We are all living in a more densely populated environment, with increased risk from pollutants. Historically, these risks have been monitored from a few cabins located in large cities, but this is not adequate. Research in the UK (MESSAGE project) had shown that we can map in real time the pollutant concentrations in cities that have previously been ignored. For example, the city of Cambridge is being monitored in real time with thirty wireless boxes, thanks to the combined efforts of the Chemistry, Engineering and Applied Mathematics departments at the University.

VOCs are health risks that are gaining increased attention. For example, BTEX VOCs (benzene, toluene, ethyl benzene and xylenes) are highly regulated, specifically benzene. However, there is currently no reasonable cost sensor system that measures specifically benzene, ignoring toluene and the xylenes. Work is underway, but this is one of the toughest problems to solve.

Very low concentrations of ozone and the hydroxyl radical dominate our atmospheric chemistry, affecting especially the health of at-risk persons, where asthma and allergies can degrade their quality of life. The gas detection industry needs to confront these problems and provide gas sensors and detectors that meet urban air requirements, keeping people healthy.

**Climate change**
Atmospheric chemists need more data to test their global warming models. They depend on the gas detection industry to provide them with affordable, high volume, accurate detectors to measure carbon dioxide, methane and trace gases. A tough problem, but solving it is necessary for advancing scientific understanding of global warming.
Indoor and cabin air quality
Air quality in offices has been a priority for many years. More recently, air quality in planes and now air quality in cars and lorries has gained importance. Cabin air quality in planes focuses on hydraulic fluid by-products, while car air quality is concentrating on plasticisers in PVC and other cabin plastics.

This new challenge of volatile organic compounds (VOCs) is difficult because we can not measure specific VOCs in real time and we often have not quantified the risk they pose. This is a tough problem that needs to be tackled. Quick “sniffers” are now available - photo-ionisation detectors (PIDs) measure VOCs to the parts-per-billion (ppb) concentration level, but do not tell you whether the detected VOC is dangerous. The gas sensor industry is researching new technologies to help users determine the risk of VOCs, but this will take years. Controlled working environments can be sampled using Tedlar bags and laboratory procedures such as GC-MS and GC-GC with thermal desorption to pre-concentrate the low concentrations of VOCs, so repetitive operations in a known environment can be assessed, but VOC risk assessment in the field can only be guessed. A correct profile of VOC risk using real time instrumentation is years away, but combined PID-IMS, micro MS and micro GC are opportunities.