Recent Advances in Gas Detection

What has been happening in the gas detection industry? With nanotechnology and new materials, advances in the internet and faster electronics, surely the gas detection industry has seen improvements. This article reviews recent improvements to the industry, first considering market trends, then sensor advances and finally electronics and internet opportunities.

CoGDEM
The Council of Gas Detection and Environmental Monitoring

"Many sensor companies have been improving their gas sensors and sensor systems during the last few years. What are these improvements and how do they help?"

Developing Markets are Gaining Traction

Many markets are well understood: industrial safety, stack emissions, domestic safety, automotive emissions, medical gases, confined space entry and process control. Two other markets have recently reached maturity.

Air Quality is receiving more press and greater interest by citizens world wide. Previous attempts to monitor air quality have been at the extremes: either expensive but analytical Air Quality Monitors (AQMs) or low cost, but only indicative metal oxide sensor networks. Amperometric electrochemical sensors have shown their ability to measure the principal air quality gases with stability and selectivity at low ppbv concentrations, but this requires excellent electronics and correcting algorithms as well as good scientific data analysis of big data sets. Currently networks are being set up in over twenty cities on four continents. An important development is adding particulate measurement (PM_{10} and $PM_{2.5}$) to gas and VOC monitoring- an irreversible trend.

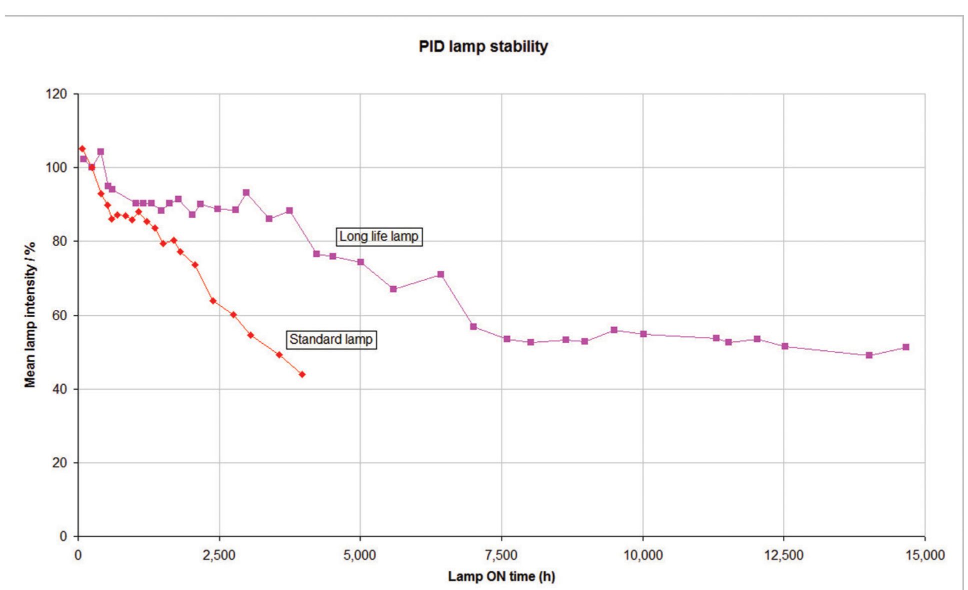
Protection of **Third World** workers in confined spaces has been limited by gas detector costs, so companies are now trying to reverse the trend of more features, higher cost of ownership to the other extreme of lowest cost and simple traffic light indication of exceeded limits, rather than digital display of concentration. Expectations are that a four-gas detector will be available within two years at affordable cost.

Sensor Technologies are Improving

Many sensor companies have been improving their gas sensors and sensor systems during the last few years. What are these improvements and how do they help?

The dominant oxygen sensor technology is the mass flow galvanic electrochemical cell, using lead as the anode material. Fears that the RoHS lead exemption will be revoked in the near future are unfounded, but this fear has led to development of alternative oxygen monitoring technologies; the difficulty for all of these alternative technologies is the need to measure oxygen concentrations from 19% to 23% oxygen with an expected total error of 0.2% oxygen from -30°C to +50°C with minimal pressure and pressure transient response and little humidity dependence and low humidity transient response. A tall order for a low cost gas sensor.

Oxygen pumps ("lead free oxygen sensors") are a three-electrode amperometric cell, similar to toxic electrochemical sensors but with the challenging problem of generating oxygen at the counter electrode; this generated oxygen must be kept away from the working electrode to avoid unacceptable errors. Various solutions have been proposed with varying levels of success. Equally important is the problem that the sensor must remain biased at typically -650mV when the gas detector is switched off- the gas detector must provide a negative bias voltage and provide power continuously to the gas detector. This is a problem in portable gas detectors, but should not deter fixed site applications which are powered continuously.



Krypton 10.6eV lamps have improved lifetime

Fluorescence decay has been used in biosensors and water quality monitors to measure oxygen concentration for decades; it is now being redesigned to measure oxygen in the gas phase. This elegant technology offers a very fast response time and can operate in environments where other technologies fail, but robust correction algorithms are required. These sensors will be available soon, with acceptable power requirements and fast warm-up time.

A simple solution to lead anode based oxygen

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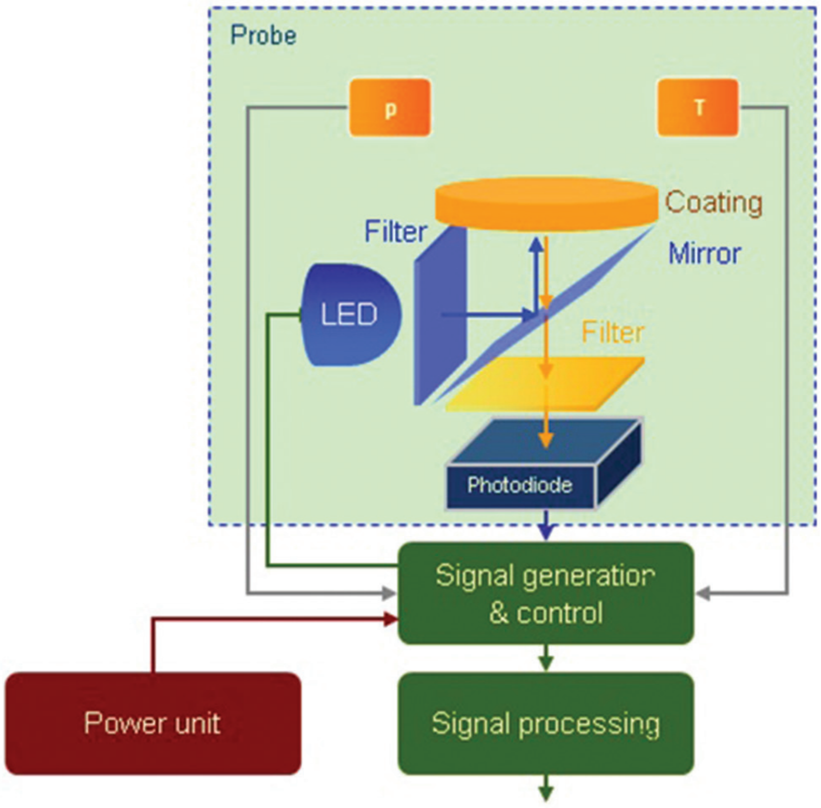


Fluorescence oxygen quenching rivals galvanic oxygen sensors

sensors is to use non-lead anodes- this is being explored by a few companies with varying degrees of success. The problem is to find another anode material that behaves as well as lead and at a reasonable cost- not easy because lead has unique properties that suit it for this application. These alternative materials are worth considering because they should be drop-in replacements for lead-based galvanic oxygen sensors.

Toxic amperometric electrochemical gas sensors are improving incrementally as the selectivity, sensitivity and stability continue to get better. Three notable new opportunities include more suppliers for dual gas sensors (eg H_2S/CO and H_2S/ SO_2) with two working electrodes, planar sensors only 2mm thick and ppb sensors for air quality/trace measurements. Several suppliers have improved their specifications, so customer validation of latest toxic gas sensors is necessary.

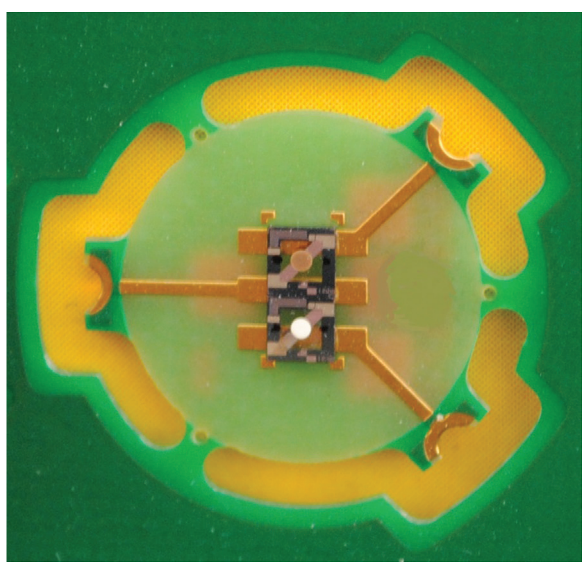
VOC detection: Photoionisation Detectors (PIDs) continue to be the sensor of choice when measuring VOCs due to their very good stability and sensitivity, albeit with little selectivity other than whether the VOC ionisation potential is above or below the lamp energy. Improvements have focused on the lamps: they are lasting longer with 5,000 and 10,000 hour lifetimes, "strikability" has improved greatly and a new 10.0 eV lamp is the best lamp when measuring BTEX at low ppb concentrations. The troublesome 11.7 eV lamp apparently has been improved, offering lifetime in days/ weeks rather than hours/ days.

Metal Oxide Chemresistors are making a comeback. Their excellent sensitivity has been balanced by poor stability and selectivity. The ubiquitous tin oxide n-type semiconductor is profiting from advances in materials science; deposition method and choice of alloy are improving, leading to more repeatable sensors, albeit baseline drift and humidity sensitivity, although better, do not meet expectations. Microprocessors are being added, along with multiple MO sensors to improve selectivity and to cancel some baseline problems; these are being marketed as air quality sensors but third party validation is not supporting these conclusions. p-type metal oxide semiconductor sensors have been ignored due to their higher resistance and more challenging manufacture, but they have re-emerged with very good baseline repeatability and negligible humidity sensitivity. GasFET metal oxides have been the technology of tomorrow and remain so.

Pellistors have shown slow progress with the exception of MEMS-based pellistors, recently introduced. Using a micromachined hotplate, these devices are lower cost, smaller size and lower power and are ideal for pulsed applications. Poisoning always remains a problem and shrinking the pellistor does not improve poison resistance.

NDIR is the most popular optical detection method for detecting CO_2 and competes directly with pellistors when monitoring methane and hydrocarbons. With a plethora of new suppliers entering the market, the gas detection designer must make four choices. For traditional NDIR, pyroelectric and thermopiles now compete closely as the detector element: the gap between price vs performance has narrowed, and average power can be reduced from 150mW to 40mW in some designs. Form factor is another important decision. Lowest price NDIRs offer unique form factors, often with interface PCBs but forcing single supply, while the standard 20.0mm (dia) x 16.6mm (ht) format is being offered by several suppliers, allowing for multiple suppliers. Some manufacturers are offering on-board linearisation so that the NDIR emulates a pellistor: useful for hydrocarbon detection. Finally, two manufacturers are offering very low power NDIR (<5mW) using semiconductor sources and detectors. Remember that much of the final performance is determined by the optical design and the quality of the IR detector and reference filters.

This industry has waited years for a **Gas Camera.** They now exist, but cost typically £75,000 and are designed around hydrocarbon detection. Expensive cooled InSb detector arrays are frequently used and Limit of Detection (LoD) depends much on the illumination source, which is normally the background IR, so these cameras work best in sunny conditions. Prices should drop as lower cost arrays are used, but the cameras need high sensitivity arrays to detect low concentrations- hopefully we will soon see more affordable gas cameras with filtering for other gases besides methane/ hydrocarbons.

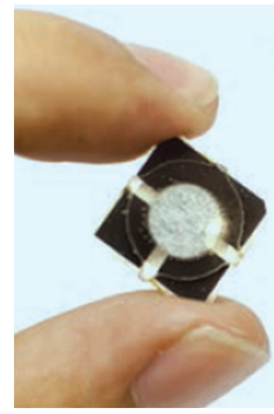


MEMS pellistor pair from SGX

Gas Detectors Follow the Lead from Smart Phones

Smart phones, tablets and other internet-connected devices have generated a massive global market that has driven chip manufacturers and network designers to commit the R&D and engineering resources that the gas detection industry can now harness.

Electronic design of a gas detector continues to get cheaper and easier. New microprocessors are offering fully functional capability for as little as $0.40, with low power as well. Most systems are ARM based, but Intel is fighting back and detector designers are going to be the winners. Analog Front Ends (AFEs) have been built traditionally from discrete components, but with first the TI 91000 series, and now with other manufacturers following, dedicated chemical/ gas sensor chips are appearing with different levels of integration, cost and performance (specifically S/N).



Electrochemical CO sensor from SPEC Sensors

Wireless Networks have seen an incredible improvement over the last years and this review just reminds all that different wireless systems are optimised for lowest power, best range, better security and robust self-healing capability. Wireless networks in industrial plants, although challenging, are achieved. Wireless networks in mines are a more difficult problem.

Joining gas detector networks with other overlaying networks is work in progress.

Big Data is the latest hot topic and with more communication capability, gas detectors are generating very large data sets; for example, a recent project at Heathrow Airport generated nine billion data sets. Analysing streamed data from dozens to hundreds of gas detectors/ air quality monitors requires advanced algorithms so mathematicians are back in vogue. Each detector manufacturer will decide how to use this glut of data and how to share the data stored in the cloud, confronting the conflict between open access and data security.

New **Calibration** methods are being developed, harnessing the advantages of big data and cloud communication. Co-location and cross-network calibration reduces calibration errors in air quality networks and Bayesian statistics can be used to watch calibration error trends following daily calibration or even data from bump gassing. The purpose of these new algorithms is to increase calibration periods with confidence and to reduce the variance of the measured concentrations.

Although industrial gas detection and related markets have a reputation as slow-moving and conservative, advances in many technologies are leading all companies to move faster and smarter. The future is bright.

About the Author

John Saffell has been Technical Director of Alphasense Ltd since it was founded in 1997. John is Chairman of the Council of Gas Detection and Environmental Monitoring (CoGDEM), a fellow of the Institute of Measurement and Control, a member of both ASTM and BSI standards committees and was previous Chairman of Sensors for Water Interest Group (SWIG).

Don't miss the follow-up to this article "Predicting the Future of Gas Detection" in the next issue of IET

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