FACTORS AFFECTING THE CHOICE OF VOC SENSOR

VOCs (Volatile Organic Compounds) perform many vital roles as fuels, solvents, cleaners, feedstock, sterilants etc. However, they can be harmful to health and the environment, so it is often necessary to monitor their concentration. By definition, organic compounds contain the element carbon, and exhibit similar chemical properties, which is advantageous from a monitoring perspective. However, these properties unfortunately vary widely between the many thousands of different VOCs, so in the following article Arthur Burnley, Sales and Marketing Director of sensor manufacturer Alphasense, explains the factors affecting the choice of sensor – for both end-users and manufacturers of monitoring instruments. Arthur also discusses the key questions that must be addressed, but first it is important to be aware of the technologies currently available.

What is the main application?

This is the most important consideration because it impacts the choice of technology. For example, the ability to measure a specific VOC may be required, and this would rule out many of the technologies if other interfering VOCs are likely to be present. Similarly, whilst the cost might be attractive, the potential presence of certain inorganic gases may mean that Metal Oxide sensors are unsuitable. However, in applications such as process monitoring the identity of other gases may be known so the response of a specific type of sensor may be solely attributable to the VOC of interest.

Regulatory monitoring of VOCs in applications such as industrial stack emissions and ambient air quality necessitate certain technologies such as GC/MS and FTIR. However, these technologies are less well suited to applications such as leak detection, surveys, workplace safety, personal safety, Hazmat etc due to cost, power requirements and portability. The most popular technologies for these applications are electrochemical, metal oxide and PID, and by offering all three technologies, Alphasense is able to recommend the most appropriate technology for these applications, taking into account a wide variety of factors such as:

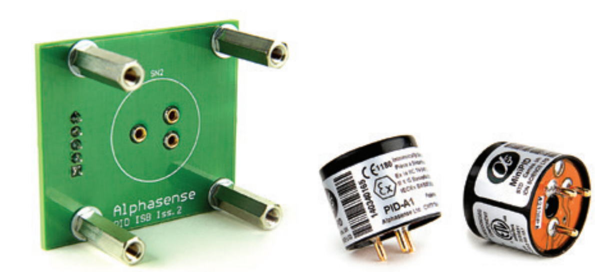
- Sensitivity
- Range
- Speed of response
- Specificity
- Accuracy
- Interferences
- Maintenance requirements
- Longevity
- Cost

Electrochemical VOC sensors

With resolution from 10 to 50 ppb, electrochemical cells are low cost, low power, compact sensors. Electrochemical sensors need to be optimised for the target VOC because each VOC requires a different ideal bias voltage for best sensitivity. Also, electrochemical cells respond in about 25 seconds, in comparison with 1-2 seconds for PIDs. Nevertheless, electrochemical sensors are suitable for some applications, where cost is important and performance characteristics are known. For example, Alphasense has developed an electrochemical Ethylene Oxide sensor for applications including fumigation of certain agricultural products and sterilisation of medical equipment.

Metal Oxide (MOS) VOC sensors

Metal oxide sensors are compact and low cost but require more power than electrochemical sensors. Humidity sensitivity and baseline drift are all characteristics of traditional n-type MOS sensors, but Alphasense p-type metal oxide gas sensors have more stable baselines and very low humidity sensitivity. MOS are not as sensitive at low concentrations, compared with PIDs. MOS sensors also respond to high concentrations of some inorganic gases such as NO, NO_2 and CO. MOS may be a more suitable technology than PID in applications requiring the measurement of halogenated VOCs such as CFCs.



PIDs PCB HR

PhotoIonisation (PID) VOC sensors

PIDs respond to most VOCs except for small hydrocarbons such as methane, and for some halogenated compounds. Each VOC has a characteristic ionisation potential and the peak photon energy generated in a detector depends on the PID lamp used. For example, a Xenon lamp = 9.6 eV, a Krypton lamp = 10.6 eV and an Argon lamp = 11.7 eV. Hence, the use of an argon lamp provides the largest detection range of VOCs, whereas a Xenon lamp can increase selectivity.

Clearly, the choice of lamp is dictated by the likely VOCs to be measured, lamp lifetime considerations, and the sensitivity and level of selectivity required.

The Xenon lamp (9.6 eV) is suitable for many aromatics and unsaturated VOCs containing at least 6 carbon atoms (C6+). For example, this lamp is commonly used for the selective detection of compounds such as BTEX (Benzene, Toluene Ethyl Benzene and Xylenes).

The Krypton lamp (10.6 eV) detects most non-halogenated C2,

Technology	How it works	Advantages	Disadvantages
Flame Ionisation Detectors (FIDs)	FIDs measure the concentration of ions produced when hydrocarbons are burned in a flame fuelled by hydrogen or a hydrogen/ helium mixture. The ions create a polarisation voltage between two electrodes, which is proportional to the VOC concentration.	• Measures all VOCs including methane • Standard reference method for regulatory emissions monitoring • Sensitive • Linear response	• Requires a fuel source • Different response factors for different VOCs • Bulky/heavy, so better suited to fixed and lab applications • No speciation unless coupled with a GC • Expensive
GC/MS	Gas Chromatography separates the components of a VOC mixture and Mass Spectroscopy quantitatively and qualitatively analyses the individual VOCs.	• Highly sensitive selective speciation • Traditional lab method	• Bulky/heavy, so better suited to fixed and lab applications • Not suitable for total organic carbon (TOC) measurements • Different columns necessary for different VOCs • Power hungry • Very expensive
FTIR	Spectroscopic analysis delivering simultaneous analysis of multiple components	• Highly sensitive selective speciation • Traditional lab method • Standard reference method for regulatory emissions monitoring	• Bulky/heavy so better suited to fixed and lab applications • Not suitable for total organic carbon (TOC) measurements • Power hungry • Unable to measure ppb in small volumes • Very expensive
Thermal Desorption or Tedlar Bag sampling bags	Samples are collected by pump or adsorbed by a passive diffusion tube for subsequent lab analysis – usually GC/MS	• Low capital cost	• Time delay before result • No real-time alarm capability • Results are averages over longer time periods
Colorimetric ('stain') tubes	A target compound in the sample induces a colorimetric change in a tubed solid reagent	• Low capital cost • Targets a specific VOC	• Poor accuracy • Disposal of toxic tubes • Non-continuous • Only provides an average reading over several days/ weeks • analysed by laboratory, so results reported days or weeks later
Electrochemical sensors	Gas diffuses into the sensor via a capillary to the working electrode where it is oxidised or reduced. This electrochemical reaction results in a current that is limited by diffusion, so the output from the sensor is linearly proportional to the gas concentration.	• Targets a specific group of VOCs (e.g. ethylene oxide) • Low cost • Low power • Compact • Continuous monitoring	• Responds only to VOCs that are electroactive • Sensor requires electronic optimisation for target VOC • Responds to families of VOCs, not specific VOCs.
Metal Oxide Semiconductor sensors (MOS)	The sensing principle relies on the interaction between the porous gas sensitive layer and the target gas: adsorption of the gas causes a change in the electrical resistance of the porous layer.	• Low cost • Compact • Continuous monitoring • Alphasense p-type metal oxide sensors have more stable baselines & very low humidity sensitivity • Measures CFCs	• Traditional n-type metal oxide sensors suffer from baseline drift & humidity sensitivity • Non-linear response • Responds to some interfering inorganic gases
PhotoIonisation Detectors (PIDs)	Sample gas diffuses into and out of the PID cell via a capillary or slot. The gas is ionised by UV light, generating a photionisation current.	• Fast response (1-2 secs) • Responds to most VOCs • Low cost • Choice of PID lamps for different applications • Known response factors enable quantitative analysis of specific VOCs	• No speciation of mixtures without GC or chemical filter • Wide variety of response factors requires knowledge of the suspected VOC. • Poor response to methane and halogenated VOCs

Metal Oxides

most C3 and C4+ VOCs. Among Alphasense customers, the Krypton lamp is most popular because of its high sensitivity and longest lifetime: these lamps can operate for up to 10,000 hours. A filtered Krypton lamp, operating at 10.0eV is the best choice for BTEX due to its higher intensity than the 9.6eV lamp.

The Argon lamp (11.7eV) can measure halogenated VOCs, but has a much shorter lifetime.

Users of PID instruments should be aware of the variety of response between different VOCs. Manufacturers of PID sensors provide a comprehensive list of response factors. These figures represent the response of a lamp to a specific VOC relative to its response to a calibration gas – generally isobutylene. So, if the response of a PID to a particular VOC is eight times smaller than it is for the same concentration of isobutylene, then the response factor would be 8. Similarly, if the response factor for a particular VOC is 0.5, the PID response is twice that for isobutylene at the same concentration. Many instrument manufacturers build in response factors to enable the quantification of a specific gas when measured in isolation.

Summary

This article highlights that different sensor technologies are better suited to some applications and careful consideration should be given before making a choice, through discussions with manufacturers such as Alphasense.

In addition to the technical considerations outlined above, it is also vitally important to choose the right supplier. For end-users, the effectiveness of their work relies on the accuracy and reliability of their monitoring equipment, and for instrument manufacturers, their brand reputation is built on the quality and reliability of their equipment. It is therefore important to seek suppliers with proven levels of quality and reliability.

For sensor manufacturers, quality management procedures should extend beyond the requirements of ISO 9001. All sensors should undergo a test and validation procedure ensuring complete stabilisation prior to characterisation. Test data should be stored for each and every sensor, including sensitivity, time of response and recovery, and zero off-set. This is important because some manufacturers simply record the average test data for a batch, or record test data for a sample from a batch. This increases levels of uncertainty and prevents traceability.

The choice of VOC sensor therefore starts with a discussion about the potential application and suitable technology, and ends with the delivery of an appropriate sensor with traceable test and validation data.

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