The Right Sensor Technology for the Job

How do you know that your gas detector is the right tool for the job? The different sensors found inside gas detection instruments can use several different technologies. Understanding the basics of these technologies can help users to make sure they are getting the best performance. Most importantly it's vital to know the limitations of each technology so that personal safety is not compromised.

In this article Gordon Haddow, Technical Specialist at e2v, looks at four of the main technologies used in gas sensing: Electrochemical Cells, Pellistors, Infrared, and Metal Oxide Semiconductors. The applications of each are highlighted together with some of the pitfalls that users need to look out for.

Electrochemical Cell Sensors

Since the 1970s, electrochemical cells have been used for the detection of toxic gases such as carbon monoxide, nitrogen dioxide, chlorine and many others. In these devices the gases diffuse into the sensor and undertake a chemical reaction to generate an electrical current proportional to the concentration of target gas. Electrochemical cells use very little power which makes them easy to incorporate into intrinsically safe instruments and also helps to provide long battery life. However, for certain gases, electrochemical cells require a constant voltage bias to be applied which is needed even when the instrument is turned off otherwise there will be a significant stabilisation time whenever the power is re-applied. This often means that an instrument is never fully off and will always draw a small current from the battery.

Electrochemical cells are basically chemical devices and in order for the chemical reaction to occur they must operate within the right temperature range and also with sufficient oxygen concentration. Their use is normally restricted to temperatures up to about 50°C beyond which they start to dry out as water evaporates from the electrolyte. They will also not function correctly in an area or system with very low oxygen levels as oxygen is required as part of the chemical reaction.

Another issue to be careful with is cross sensitivity. Users need to be aware that many electrochemical sensors respond to more than just the 'headline' gas type. For example a carbon monoxide sensor would typically have a noticable response to hydrogen. Careful reading of the datasheets and application notes is needed to see what other gases the chosen sensor might respond to and whether this will be suitable for the application.

A lifetime of only three years is common with lead based electrochemical O_2 sensors as the internal chemistry becomes depleted, just like in an alkaline or zinc-carbon primary cell. However e2v recently introduced to its range a new electrochemical technology for oxygen detection which overcomes this problem. A much longer lifetime is possible because it is not limited by the sacrificial mass of a lead anode which is typically used in these devices. Also by removing the lead content, this technology is now compliant with the updated 'RoHS2' directive (Restriction of Hazardous Substances) which will soon apply to industrial gas sensing.

Pellistor Sensors

Pellistor bead sensors have been in use for even longer than electrochemical sensors. Primarily suited to the detection of flammable gases, they have a coil of platinum wire coated in a catalyst and carrier which is heated to temperatures around 500°C. In the presence of gases such as methane and hydrogen, oxidation occurs which further warms the platinum coil resulting in a change in coil resistance according to the proportion of gas. Normally a non-reacting 'compensator' bead is used together with the pellistor in a Wheatstone bridge arrangement to counteract changes in ambient conditions and give a voltage output.

Pellistors continue to be used extensively as they are relatively low cost and the electronics required to drive them is quite straightforward. However they do consume a lot of power in order to heat up both the detector and the compensator beads. The high coil temperatures mean that they cannot be certified intrinsically safe - they have to be mounted behind a flameproof barrier such as a mesh or sinter.

Other operational issues which users should be aware of include poisoning and drift. Pellistor devices can easily be damaged by exposure to very low levels (parts per billion) of certain substances, especially silicones, which are present in many everyday chemicals such as glues and cleaning materials. Users of pellistor based gas sensors should check the content of any chemicals and materials being used near the instruments to minimise the risk of poisoning. Another issue is the output tending to drift over time, so the user must have a regular calibration regime to ensure the sensors read correctly.

Advancements in the design of pellistors have led to more modern devices which are far less susceptible to poisoning than earlier types and have reduced drift - but the issues have certainly not gone away. The biggest concern for users is that there is no indication that a pellistor has been poisoned until the next bump test or calibration. Therefore it is vital that instruments containing pellistor devices are regularly tested to make sure they give reliable protection to workers in hazardous areas.

Infrared Sensors

Infrared gas detection has now become a mature technology, primarily used for monitoring hydrocarbons and also carbon dioxide. It is an optical system which relies on the ability of many gases to absorb light at particular wavelengths. Typically this is done in the 3 to 5 micron waveband known as Medium Wave Infrared (MWIR). However the same techniques can be applied to other parts of the spectrum such as ultraviolet which is commonly used for ozone detection.

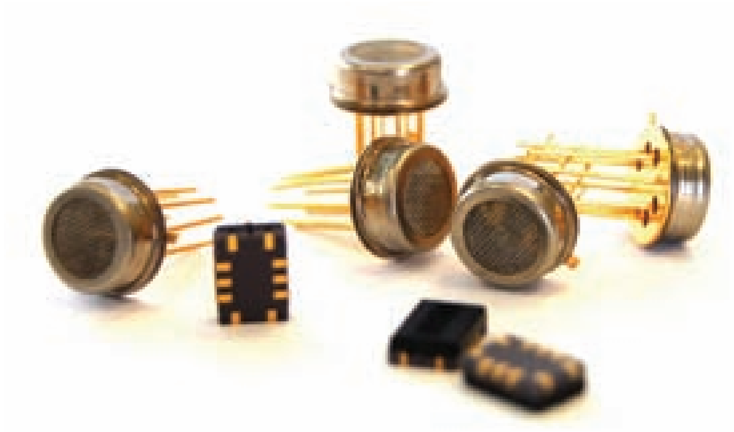
Infrared sensors have several advantages over pellistors, being fail safe and having higher reliability. They are also available with intrinsically safe certification which simplifies their use in hazardous areas. The downside for instrument designers is that the electronics and software required to use them tends to be more complex and they have a higher initial cost. To get the best performance the electronics must be well designed and a microprocessor is necessary both for temperature compensation and also to correct for the gas absorption not being linear with concentration.

Again it is important to consider carefully cross-sensitivities. Both pellistors and infrared devices will respond to a range of hydrocarbons, not just methane, but the relationship between different gases is certainly not the same for both types. Also, if hydrogen is present, an infrared sensor will not detect this.

Infrared sensing is making a serious challenge to pellistors for flammable gas monitoring in fixed systems but for portable instrumentation infrared has further to go. Most infrared sensors contain a relatively fragile filament based infrared source which can be susceptible to the shock of dropping an instrument. While good instrument design can mitigate this issue to a great degree, companies such as e2v are developing technology solutions to increase the toughness of the basic sensor. This is likely to lead to a big increase in the use of infrared sensing in the portable instrumentation market in future.

Metal Oxide Semiconductor Sensors

Finally a more recent technology in gas sensing uses Metal Oxide Semiconductors (MOS). These exist in different forms but a common type of MOS sensor contains a miniature integrated circuit heater structure to warm up a chemically responsive coating. The resistance of the coating layer varies as the gas concentration changes.



The big advantages of this technology are comparably low cost, fast response times and high responsivity to gas. The sensitive area is physically very small and can respond to gas changes in fractions of a second. They can even be used for detecting gas levels down to the ppb (parts per billion) region. Such properties make them ideal for detecting fast changes in the environment such as leak detection and early fire detection. They are commonly used in automotive HVAC systems to close the air intake flap when driving into high levels of pollution such as tunnels, or when stuck in traffic queues. In such systems MOS sensors are chosen which respond to carbon monoxide, VOCs and nitrogen dioxide.

MOS technology can also be applied to industrial and environmental gas detection in suitable applications. Again care must be taken in their use as MOS devices can have some susceptibility to poisoning

although not to the same extent as pellistors. They also suffer from drift which can make them more suited to measuring change of gas rather than absolute levels. However with careful design and compensation even these obstacles can be overcome.

A typical example is in ozone measurement. MOS sensors are being used in low cost networks to provide an ozone measurement system over a wide area using distributed sensor heads. In this system a single high quality UV ozone analyser is used to calibrate the multiple MOS sensors in situ which are then stable enough for data gathering over a period of several months.

Conclusions

Four of the main gas sensing technologies have been discussed and it can be seen that each method has its own advantages and disadvantages. Instrument designers and users need a basic knowledge of how a particular sensor type works in order to understand the limits of that technology.

When selecting or designing a new system it is very important to read the sensor manufacturer's datasheets and application notes very carefully, especially to consider the environmental operating conditions, cross sensitivity to other gases and any other conditions of use. For new applications where experience is lacking it is always best to talk directly with the gas sensor manufacturer. A good manufacturer will have engineers and technical staff that can offer a wealth of relevant expertise and make sure you are using the right tool for the job.

AUTHOR DETAILS

Gordon Haddow is a Chartered Engineer and a Technical Specialist in the Gas Sensors and Thermal Imaging Cameras engineering group at e2v. He is a Member of the Institution of Engineering and Technology (IET).

e2v Waterhouse Lane,
Chelmsford, Essex
CM12QU, UK
Tel: +44(0)1245 493493
Fax: +44(0) 1245 492492
Email: enquiries@e2v.com
Web: www.e2v.com/gassensors