ZR100 ZIRCONIUM OXIDE SENSOR

TECHNICAL BULLETIN 024

Trace to percent oxygen measurement
For high purity applications

Introduction

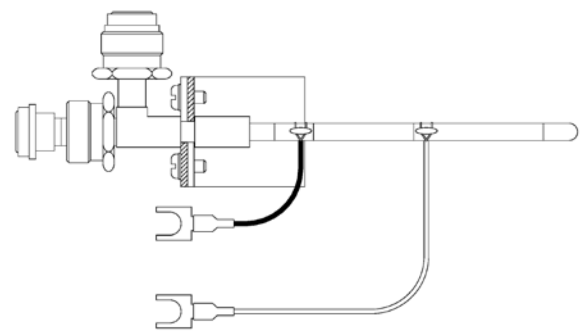
The Neutronics zirconium oxide (ZrO2) sensor is a ceramic, solid-state device that features an extremely fast response to oxygen, a wide measurement range, and a robust design. Unlike other sensor technologies, the ZrO2 sensor does not absorb oxygen molecules. This gives it an extremely fast response to oxygen with the ability to measure ppm levels from air in less than 10 seconds and ppb levels from air in less than 15 minutes. In contrast to other sensors that are best suited for either high or low oxygen measurement, the ZrO2 sensor can accurately measure concentrations in a wide range, from 100% down to ppb oxygen. Unaffected by position or motion, the robust sensor design provides accurate and reliable measurement even if it's turned upside down.

Description

The ZrO2 sensor is responsive to changes in the partial pressure of oxygen in the sampled gas ranging from 100% oxygen to parts per billion (ppb) concentrations.

The sensor is constructed of a porous, high-temperature ceramic electrolyte tube (see figure 1) made from a special formulation of yttria-stabilized zirconium oxide material. Coated on the inside and outside with a layer of porous platinum, each coated surface of the tube serves as an electrode – one as a cathode and the other as an anode. A high-performance ceramic heater assembly and thermocouple probe provide a controlled temperature environment for the sensor operation.

At temperatures exceeding 650° C (1200° F), openings within the ceramic tube lattice allow oxygen ions to pass. If the partial pressure of oxygen is equal on both sides of the ceramic lattice, then there is no net flow of ions between the electrodes (the sample gas and reference gas are both air). However, when the partial pressure of oxygen of the sample gas is different than the reference gas, there is predictable ionic transfer.



Features

- Rapid response time – reads ppm oxygen from air in < 10 seconds
- Wide measurement range – measures oxygen concentrations ranging from 100% to ppm or ppb
- Robust sensor design – the ZrO2 sensor is unaffected by position or motion
- Precise sensor temperature control – a high-speed heater modulator provides precise sensor temperature control, critical to reliable performance and rapid response 316 stainless steel wetted parts
- Long service life – the sensor service life of >5 years ensures maintenance-free operation

Applications

Air separation	Glove box systems
Blanketing gas analysis	Inert gas purity/nitrogen purity systems
Contact lens manufacturing	Process ovens
Cryogenic gas generation	Dryers
Food and beverage packaging	Semiconductor manufacturing
Glass and fiber optics manufacturing	Welding

ZR100 ZIRCONIUM OXIDE SENSOR

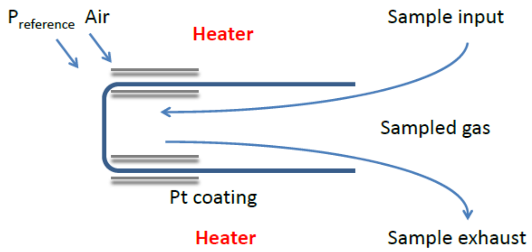


Fig.1

At the elevated operating temperature, oxygen is electrochemically reduced at the cathode. Oxygen ions migrate through the ceramic electrolyte and are electrochemically oxidized at the anode. As a result, an equal amount of oxygen is produced at the anode and at the same time, oxygen is reduced at the cathode.
The simultaneous reactions are as follows:

Cathode: $O_2 + 4e^- \Rightarrow 2O^{-2}$
Anode: $2O^{-2} \Rightarrow O_2 + 4e^-$

The voltage produced is proportional to the net difference in the partial pressures of oxygen in the reference gas (air @ 20.9% oxygen) when compared to the sampled gas. The voltage output of the sensor follows a logarithmic function and can be expressed by Equation 2, the Nernst equation:

$$E = \left[\frac{RT}{4F} \right] \ln \left[\frac{P_r(O_2)}{P_s(O_2)} \right]$$

Where:
R = gas constant (1.98762 cal. K-mole)
T = absolute temperature of the cell (650°C or 923°K)
F = Faraday's constant (96,485 C/mol)
P_r = partial pressure of oxygen of reference gas
P_s = partial pressure of oxygen of sample gas

What about hydrocarbons?

The presence of hydrocarbons can offset oxygen readings when using a zirconium oxide sensor. The zirconium oxide sensor is a heated device with platinum electrodes. At high temperatures and in the presence of platinum, hydrocarbons can react with oxygen. However, this reaction will not damage the sensor – just create an offset in the signal.

It is important to note that hydrocarbons and other reducing gases are considered contaminants in pure gas applications. Gas manufacturers have gone to great lengths to ensure that pure inert gases are provided for critical applications such as integrated circuit manufacturing and other high-temperature, ultra-clean process applications. If these contaminants were indeed present, many processes would be subject to quality degradation. In fact, for years hydrocarbon analyzers have been indicating less than 0.5 ppb hydrocarbons present in most ultra-pure inert gas streams. The requirement to install hydrocarbon analyzers on ultra-pure inert gas streams has been lifted in many instances. Process engineers have found out that these contaminants are just not present in any significant amount.

Technical specifications

Sensor	ZR100
Type	Zirconium oxide (ZrO2)
Measurement range	50 ppb to 100% or 0.1 ppm to 100%
Accuracy, 0.1 ppm to 100%	± 2% of range @ CTP or ± 0.5 ppm, whichever is greater*
Response time	T_{90} < 5 seconds for order of magnitude change
Response time	< 10 seconds from air to ppm
Response time	< 15 minutes from air to ppb
Warm up time	20 to 30 minutes
Expected service life	5 to 7 years
Relative humidity	0 to 95%, non-condensing
Operating temperature	32 to 104° F (0 to 40° C)

*Accuracy in the ppb range is subject to the quality of the sampling system

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