Pewatron Application Note PAN-01: Zirconia oxygen gas sensor – Principle of operation

Fig. 1 shows a structure of the FCX zirconia oxygen-sensing element. Zirconium oxide (with proper dopant elements; zirconia) when heated > 350 °C is penetrable for oxygen ions. The FCX oxygen sensor series has the temperature working point at 450°C. The heating element and the oxygen-sensing element are heat bonded together ensuring a perfect thermal match and minimum power usage in the working point of the sensor. A voltage applied to the oxygen-sensing element, pumps the oxygen out of a closed inner chamber (Fig. 1). At a constant gas pressure, the quantity of oxygen pumped out is equal to the quantity of oxygen molecules diffusing in through a small capillary hole. It is independent of the voltage applied between the electrodes within a certain voltage range (Fig. 2). Oxygen gas is converted to ions at the electrode (Cathode), moving to the other electrode (Anode), where the ions are inverted to oxygen gas once again. The measurement current is proportional to the quantity of oxygen ions diffusing through the zirconia element. The relationship between the oxygen partial pressure p_{O2} and sensor current I_s is given by the formula I_s = constant x ln (1 - p_{O2} / p_t), where p_t is the total partial pressure in the system (Fig. 2).

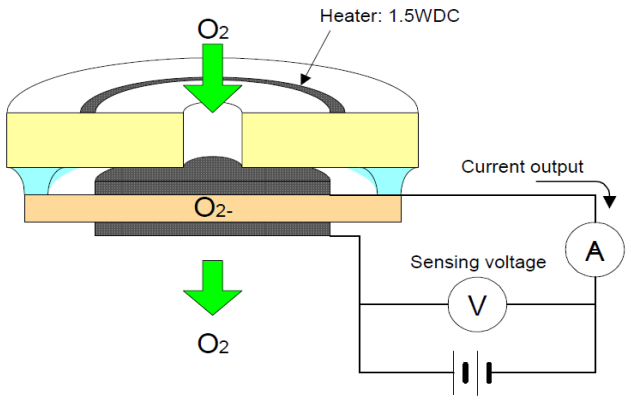

Fig. 1. Principle operation of the FCX oxygen sensor

For appropriate operation of the FCX zirconia oxygen sensor we recommend to use high quality electronic components and appropriate circuit design topologies. It is important to be able to control the heater voltage and the sensor voltage within narrow tolerances.

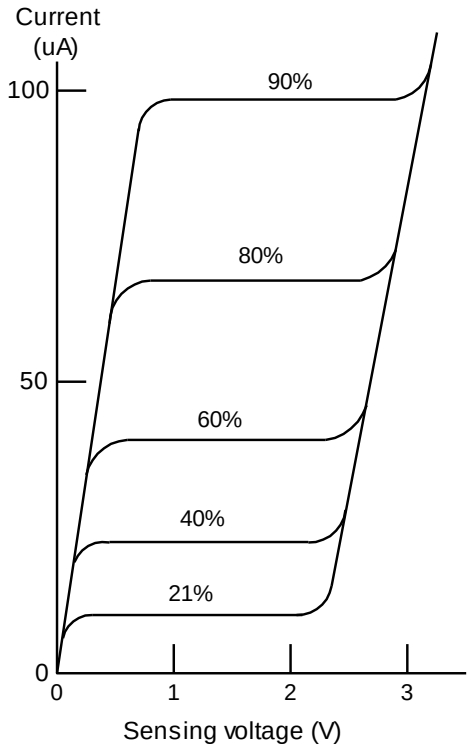

Fig. 2. Output (current) as a function of the applied sensing voltage and oxygen concentration.

a) Heater voltage

- Recommended heater power is 1.5WDC +/- 0.05W.
- Recommended heater voltage is provided with the CoA for each sensor.
- Regulated DC power supply is required.
- PWM power supply is generally not recommended.
- Heater voltage ramp up rate is maximum 40mV/sec.
- Heater voltage shall be continuously applied during operation.
- Frequent heat cycle may cause thermal shock to sensing element.

b) Sensing voltage

- Regulated DC power supply is required.
- Recommended sensing voltage for the FCX oxygen sensor is between 0.7 V and 1.8 V

c) Important issue for safety operation

- Sensor output signal shall frequently be checked by, for example, window comparator in order to detect the following two failure modes:
- Low output caused by electrical degradation or serious damage of the sensing element such as circuit open.
- High output caused by electrical degradation or serious damage of the sensing element such as mechanical destruction.

The FCX sensor is very tolerant with respect to humidity, pressure and temperature changes. Please see below for recommendations concerning flow rate, temperature, humidity and pressure corrections to the output signal:

1) Applicable flow rate is 100ml/min ~ 5 liter/min.
2) Sensor response time is as low as 2 seconds (forced flow) for reaching T_{90}
3) Sensor output is stable at –10 ~ +60 °C
4) Applicable pressure range is –40kPa ~ +500kPa gauge. Pressure (or flow rate) must be stabilized because the sensor's output is sensitive to sudden pressure changes; however, the output quickly recovers and becomes stable when the pressure is stable. Slow pressure drift, like atmospheric pressure change, does not affect to sensor output.
5) Fujikura oxygen module/monitor is calibrated using dry O_2/N_2 mixture gas. If any other gases or humidity is contained in sampling gas in the field application, the calibrated accuracy cannot be guaranteed and the sensor performance and lifetime can be negatively influenced. Pewatron application note PAN-03 describe in detail the gases to avoid and consequences thereof. Pewatron application note PAN-04 describe in detail the behavior of the FCX gas sensor in humid environments.

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