Revised November 21, 2003

Operation principle of solid state-sensor technology

1 Operation Principle

The sensing material in the solid-state gas sensors is metal oxide, most typically SnO2. When a metal oxide crystal such as SnO2 is heated at a certain high temperature in air, oxygen is adsorbed on the crystal surface with a negative charge. Then donor electrons in the crystal surface are transferred to the adsorbed oxygen, resulting in leaving positive charges in a space charge layer. Thus, surface potential is formed to serve as a potential barrier against electron flow. (Figure 1)

Inside the sensor, electric current flows through the conjunction parts (grain boundary) of Sn2 micro crystals. At grain boundaries, adsorbed oxygen forms a potential barrier which prevents carriers from moving freely. The electrical resistance of the sensor is attributed to this potential barrier. In the presence of a deoxidising gas, the surface density of the negatively charged oxygen decreases, so the barrier height in the grain boundary is reduced. The reduced barrier height decreases sensor resistance. (Figure 2)

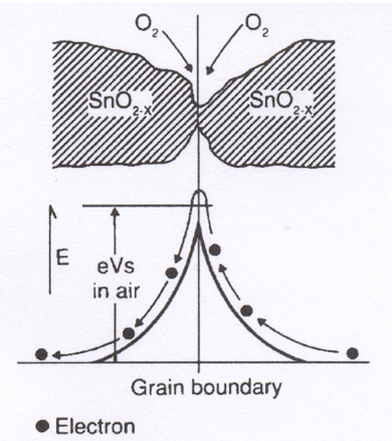

Figure 1 - Model of inter-grain potential barrier (In absence of gases)

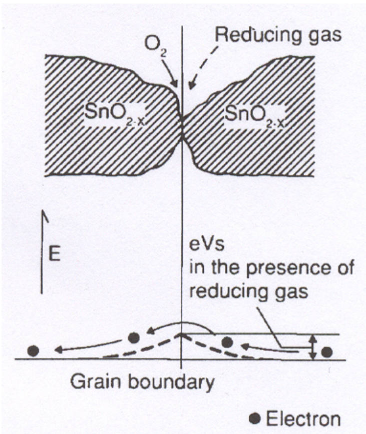

Figure 2 - Model of inter-grain potential barrier (In the presence of gases)

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2. Sensor Characteristics

2-1 Dependency on partial pressure of oxygen

Figure 3 illustrates the relationship between oxygen pressure in the atmosphere (PO^2) and the resistance of a typical sensor in clean air. Note that reduced oxygen pressure will decrease the sensor's resistance.

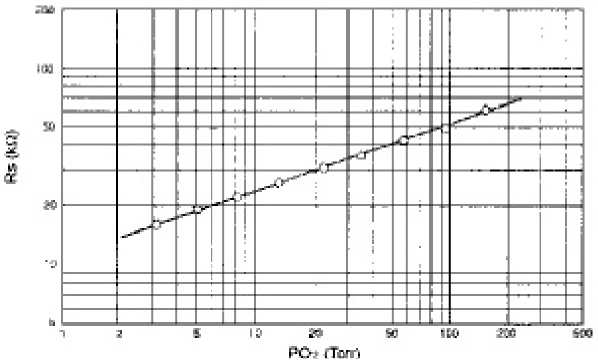

Figure 3 - Typical dependency on PO2

2-2 Sensitivity to gas

The relationship of sensor resistance to gas concentration is linear on a logarithmic scale within a practical range of gas concentration (from several ppm to several thousand ppm). Figure 4 shows a typical example of the relationship between sensor resistance and gas concentration. The sensor will show sensitivity to a variety of deoxidising gases, with a relative sensitivity to certain gases optimised by the formulation of sensing materials and operating temperature. Since actual sensor resistance values vary from sensor to sensor, typical sensitivity characteristics are expressed as a ratio of sensor resistance in various concentrations of gases (Rs) over resistance in a certain concentration of a target gas (Ro).

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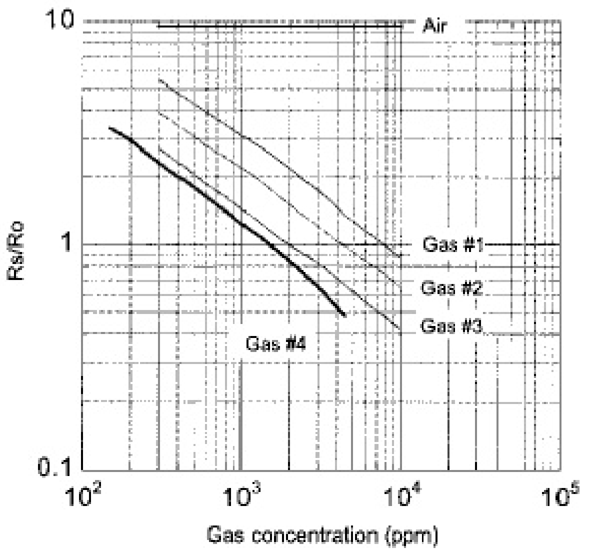

Figure 4 - Typical sensitivity characteristics

2-3 Sensor response

Figure 5 demonstrates typical behaviour when the sensor is exposed to and then removed from deoxidising gas. Sensor resistance will drop very quickly when exposed to gas, and when removed from gas its resistance will recover to its original value after a short time. The speed of response and reversibility will vary according to the model of sensor and the gas involved.

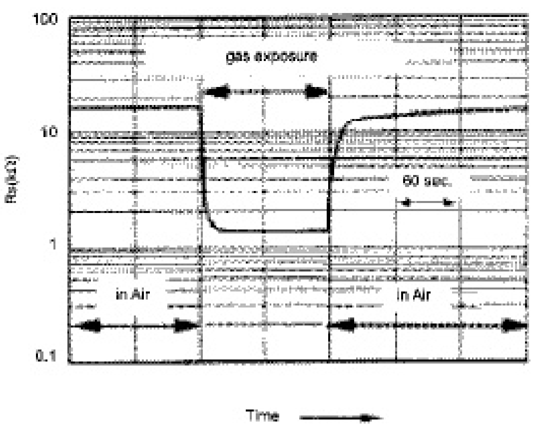

Figure 5 - Typical sensor response

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2-3 Dependency on temperature and humidity

The detection principle of the solid-state sensors is based on chemical adsorption and desorption of gases on the sensor's surface. As a result, ambient temperature will affect sensitivity characteristics by changing the rate of chemical reaction. In addition, humidity causes a decrease in Rs as water vapour adsorps on the sensor's surface. Figure 6 shows a typical example of these dependencies. A compensation circuit for temperature dependency should be considered when using solid-state sensors.

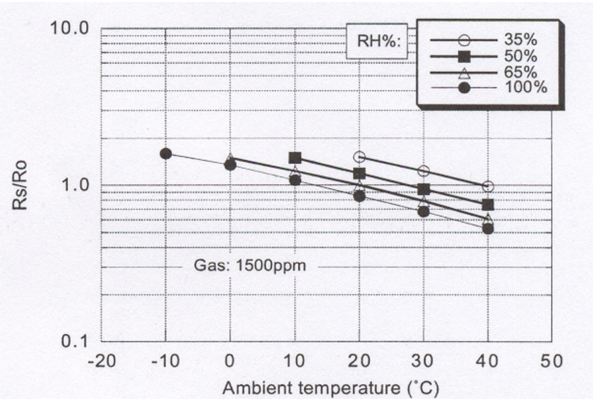

Figure 6 - Typical temperature and humidity dependency

2-4 Long term stability

Figure 7 shows typical data of long term stability for solid-state series sensors. Generally, this sensors show stable characteristics over time, making them suitable for maintenance-free operation.

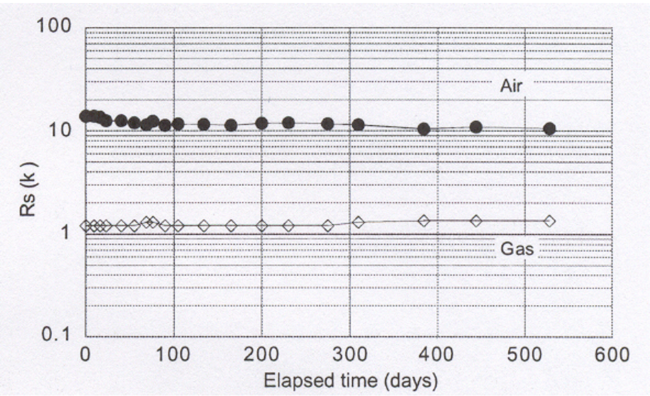

Figure 7 - Typical long term stability

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