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# OXYGEN SENSING: A REVIEW PART 2: SOLID STATE TECHNOLOGIES

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**Abstract**. *This paper reviews the status of oxygen sensing for combustion control and environmental monitoring at both commercial and research level. The evolution of potentiometric and chemoresistive sensor for automotive applications is described in detail, but also the optical principles for $O_2$ sensing in medical applications are treated. The main limitations of the existing devices are pinpointed, and the emerging technologies based on SOI-CMOS hot places and their challenges are also described.*

**Keywords:** Oxygen Sensing, Zirconia Potentiometric Sensor, Resistive Gas Sensor, SOI Micro-hotplate, CMOS-compatible

## 1. Introduction

The high efficiency of fossil fuel burning in automotive and process industries, and the demand for a cleaner exhaust gas of internal combustion systems have been made possible by the extensive use of robust $O_2$ sensors, used both for the control of an optimum air-fuel mixture admission (as part of closed-loop feed-back control algorithm), as well as for monitoring the operation and ageing status of the exhaust gas after treatment systems [1]. This was possible due to the introduction (Bosch, 1976) of the thimble-type potentiometric, solid-electrolyte, galvanic $O_2$ sensors based on stabilized zirconia ($ZrO_2$) – well known under the name of "Lambda Sensor"; since then these sensors have played a very important role for the control of air/fuel (A/F) ratio (named λ) in internal combustion engines.

In these sensors, also known as "$O_2$ Nernst concentration cell", for a small change of the air-fuel mixture, moving from a fuel rich-region ($\lambda < 1$) to a fuel – lean – region ($\lambda > 1$), the voltage response will sharply decrease from about 0.8 V to about 0.2 V. Due to this huge Nernstian type response, combined with a rather small sensitivity outside this value, we can conclude that this "Lambda Sensor" has a "quasi-digital" (switch-like) operation.

In general, a two-electrode galvanic sensor is made of a solid electrolyte with high oxygen ionic conductivity (yttria-stabilized –zirconia ($Y_2O_3$-$ZrO_2$) – for example), which is sandwiched between two platinum electrodes (these being the place where the redox $O_2/O^{2-}$ electrode reactions occur).

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