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Design And Development of O_2 Gas Sensor Using Metal Oxide Material For Control of The Air-To-Fuel Ratio of Internal Combustion Engines At Low Temperature

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Abstract An electronic sensor system is highly desirable to provide on-line monitoring of the chemical composition of gas emitted from combustion facilities, in order to minimize engine faults then indirectly air pollutions, and maintain the concentrations of dangerous gaseous species within the limits stipulated by regulations. Semiconductor metal oxide (SMO) gas sensors are considered as one of basic technologies for identification and measuring the concentrations of gas in combustion Engines. These microelectronic devices offer a wide variety of advantages over traditional analytical instruments such as low cost, short response time, easy manufacturing, and small size.

The studies aim at (a) Development of sensors with better sensitivity with composite material as sensor film (b) Design of sensors with a view to miniaturize them.(c) To design a sensor for O_2 at low temperature which is for to control air-to-fuel in engines.

1. INTRODUCTION

To measure Gas of O_2 and is very impartment measurement in industries, To increase quality of Engines and low fossil exhaust gas of engines, In many Industries gases have become increasingly important as raw materials and for this reason among others it has become very important to develop highly sensitive gas detectors..such devices should allow continuous monitoring of the concentration of particular gases in the environment in quantitative and selective way it.

Metal Oxides, which are stable physically and chemically, have been widely investigated for gas sensing at low temperature are mostly based on ionic conductivity. Use of conductivity polymers for gas-sensing applications has been an important . The key to success in developing a single functional gas-sensing devices is technology of masking undesired functions such as cross sensitivity with others gas species, The chemical gas sensors generally contain a physical transducer and chemically selective layer.

Physics, chemistry, and technology of sensors require a better understanding of both the bulk and surface properties of the sensing materials. One expects that a sensing element should have high sensitivity and selectivity, small response and recovery times, minimum environment, low temperature, low power consumption, Gas sensors in form of thin films seem to be more promising detectors over the pellet form, because they low cost.

The Developing of Gas sensors in the form of thin films is justified for technological reasons because it is possible device prepare device with small size and low power consumption, which can easily ne integrated in an array. In zirconium Oxide material deposition on supporting metal like Fe, Thin film technology combined with micro machined silicon transducers offers easy processing of the active gas-sensing material directly onto a silicon wafer and to integrate the sensing and actuating functions with the signal processing part of the device on a single chip. This way one can reduce the power dissipation within the device. Because of these advantages there has a big effort in miniaturizing semiconductor gas sensors and making their fabrication technology towards microelectronic a compatible one. Reduction of power consumption is a key aspect to reduce local thermal stress and also to obtain battery-operated devices for smart sensor nets.[6]The Oxide gas measurement air pollution caused by exhaust gases from automobiles has become a critical issue.

The main sources of anthropogenic O_2 are internal combustion engines such as the reciprocating types (gasoline and diesel) used in cars and trucks , gas turbines in small power plants, and airplanes and tanks , as well as non-engine based uses such as coal-fired power plants , and process heaters. So the development of miniaturized sensor for a O_2 gases for different applications is required. Zirconium oxide (ZrO2) oxygen sensors consists of a cell made of stabilized zirconia ceramic forming a crystal lattice structure with as a solid electrolyte, typically, the cell is shaped like a test tube where the inner and outer surface are each coated with an ultra-thin layer of porous platinum to acts as cathode and anode electrodes. At high temperatures (above 650 c), opening in the crystal lattice permit the movant of oxygen ions. As long as the oxygen partial pressures are equal on both sides, the moment of ions within the lattice is random, and there is no net flow with in the lattice. When a sample gas containing oxygen is introduced on one side, oxygen ions migrate through the crystal lattice to form a concentration gradient from the higher O2 partial pressure side to the lower pressure side. The gradient, which determines the amount of oxygen in the sample gas, is measured by the ration of O2 partial pressures between a sample gas on one side of the lattice and reference gas, (typically ambient air) on the side of the lattice. Suitable for combustion control applications and industrial heat chambers.

1.1 National and International status

Performance and environmental requirements impose advanced control strategies in this context controlling combustion represents a key challenge Guzzella and amstutz 1998,kienche Nielsen 2000 several t tentative solutions are combustion torque control and estimation Guezennec and gyan 1999, chaweien 2004 moulin et..at One important step is the control of invidual air to fuel ratio AFR which is good representation of torque produced by engine its results from various inputs such as infacted quentities and timings [9].

A reduction in the operation temperature of zirconia ceramic gas sensors is highly In early 1900, Nernst worked on various means of producing better Light than the carbon filament lamp. He observed that oxygen evolved at anode while a dc voltage was applied on mixed oxides such as 15%y_2O_3 -85% ZrO_2 and suggested that a nearly pure Oxygen ion conduction occurred. The conductivity is due mainly to oxygen ions in the mixed oxides [10].

Wagner established the theory of the electromotive force of asolid electrolyte cell 1975. Four years later, weissburt and Ruka fabricated their solid electrolyte sensor. In 1976 Bosch CO. made a practical use of oxygen sensors for automobiles.

In the last 20 years, oxygen sensor have been extensively used in various applications.

2. METHODOLOGY

The present focus is to Design , Fabrication & Prototype Testing of gas sensor with low cost , low power consumption , High sensitive, High selectivity for the O_2 gases which can be done in the following three steps Change in conductance of the oxide due to electrochemistry of gas molecules to the sensing layer, by zirconium Oxide. The model sensor based on basic physics and chemistry is a useful tool for understanding the effects of the various physiochemical processes involved in the operation of electrochemical sensors. It can also provide guidance in optimizing sensor performance for specific applications by suggesting suitable structural and materials modifications.[6] At present such cell formations on silicon and alumina substrates are not popular and the compatibility.

2.1 Selectivity: The response of the sensor to reactive gases is dependent upon the choice of electrode material, In many applications, such as combustion control, the required oxygen measurement is usually that pertaining to thermodynamic equilibrium in such cases pt is normally the preferred choice of electrode material because of its high catalytic activity, However, there are situations where the actual O_2 content of a reactive gas mixture is required. Sandler (1971) found that in CH_4/O_2 mixture Ag showed negligible catalytic acivity and responded only to the total O_2 content of mixture.

Solid electrolyte sensors are normally considered to be highly selective because the ceramic may be chosen with single mobile action.[10].

TABLE 1: Evolution of oxygen sensors in the automobile industry [5]

Year (Company)	Sensor type	Features	Applications/Market
1976 (Bosch)	Thimble YSZ based potentiometric sensor	Operation temperature relied on the exhaust temperature; light-off time >1 min.	First use in Volvo vehicles as air/fuel—λ sensor
1982 (Bosch)	Heated thimble type YSZ based potentiometric sensor	Separate heater controlled operation; light off time ∼30 s.	λ sensor in many of the vehicles. Nearly 33 million sensors are produced every year by Bosch
1984 (Toyota-Denso)	YSZ based limiting current amperometric sensor	Best suited for lean-burn engines (λ =22:1)	In Japan car market
1985 (NGK)	Semiconducting titania thin film sensor	Heater controlled; drift in the sensor signal; poor durability	Used in less than 1% of the O2 sensor equipped vehicles
1991 (NGK)	Dual cell limiting current amperometric sensor (Universal exhaust gas oxygen sensor-UEGO)	Suitable for the whole range of λ values from stoichiometric point to lean burn conditions	Both in USA and Japan car industries
1997 (Bosch)	Thick film YSZ based planar potentiometric sensor	Heater integrated; smaller in size; low thermal mass; light off time ∼10 s.	Being used in nearly 30% of the O2sensor equipped vehicles

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2.2 Deposition Technologies: One of the basic steps in MEMS processing is to deposit thin films of zirconium Oxide material, which provides the sensing surface of zirconium Oxide material, The process allow the fabrication of films to have a thickness anywhere between a few nanometers and about 100 micrometers[8]

1. Deposition and Characterization of Sensing film for better performance like fast response, quick reversibility and sensitivity - process optimization.
2. Design of various geometries of Micro heaters to give uniform and required heat to the sensing surface with minimum power consumption.
3. ASIC design which includes analog and digital readout circuitry for collecting the required information.

Gas Sensing Film

- Solid state metal oxide sensors are the most versatile of all the other sensors.

Advantages of Zirconium Oxide:

- Can be utilized in high temperature environments
- Excellent response time characteristics
- Can be used to measure 100% oxygen, as well as parts per billion concentrations

Zirconia gas sensors have to be operated at elevated temperatures, typically 500 to 800°C. Currently, operation at lower temperatures restricts the measurement range, lengthens response times and results in greater measurement inaccuracies. There are several advantages to be gained by lowering this temperature requirement which would enhance the marketability of these devices. Firstly there would be a reduced power consumption of the heating facility. The power consumption is not great at present but is sufficient to prevent inclusion in portable systems limiting, opportunities for sensor employment. Secondly there would be a benefit in terms of sensor life-expectancy.[8] Current fabrication materials are able to withstand the elevated operation temperatures required but, over time, they do degrade and become more liable to failure. Sensors are particularly vulnerable through thermal shock during temperature ramping. Exposure to high temperatures will also lead

- ZrO_2 is the most efficient and used sensing element for O_2 gases sensing among all other metal oxides[6].
- ZrO_2 films of various thicknesses and porosity are deposited on the Aluminum, Fe silicon substrate by reactive RF sputtering technique.

Process parameters like RF power, operating gas pressure,O_2/Ar ratio and substrate temperature are varied in the RF sputtering process to optimize the film thickness and porosity for an improved performance of the sensing layer.

2.3 Micro-Heater design

- The Design of micro-heaters is optimized
- Low thermal mass
- Better temperature uniformity across the device
- Low power consumption

The concept for lowering the heating power by orders of magnitude was to minimize the mass to be heated and to thermally insulate it as effectively as possible from the surrounding frame that is to remain at ambient temperature.

to an acceleration of device ageing with a performance deterioration from electrodes, electrolyte and connecting components . Reduced temperatures would mean a reduction in thermal stresses leading to increased reliability and reduced system maintenance costs. Finally fabrication options for both sensors and supporting structures are currently limited by the high temperature requirement. Reducing the temperature requirement would open further possibilities concerning the materials and techniques used in construction. Maskell & Steele [1] reviewed solid electrolyte Potentiometric sensors. They identified the areas of reducing costs, miniaturisation and lower operation temperatures as areas for further research. They also suggested however that, for boiler.

Some of the results of winnubst et al (1985) are in shown below fig. Response times were determined for 10-90% response and showed several interesting features: in particular, under the conditions of the work, the response of electrodes on ZrO_2 –based electrolytes was faster than BiO_3-base materials; also a Au electrode superior performance to Pt.[10]

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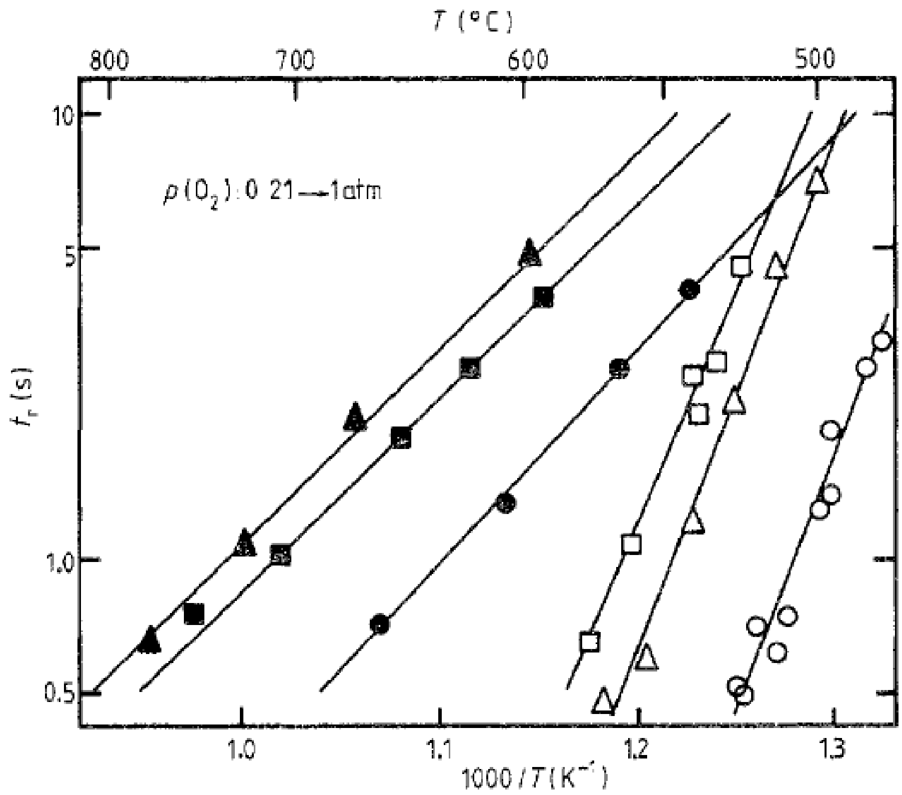

Figure (a) : Response time Time as a function of Temperature for stabilized ZrO_2 and BiO_3 based electrodes. (Diagram courtesy chapman Hall Ltd London). [10].

2.4 IC Design & Testing

- Sensor film characterization
- Simulation &Test results
- Gas Sensor System Design
- Sensor readout Module

Materials requited: ZrO_2 (For low temperature applications)
Sensing element form: Small rectangular chips cut from pressed powder disks
Sensor physical property: Element electrical resistance change
Processing Compatibility: Hybrid micro circuits

Detecting Range: 0.1 to 100%(Gas) 1 to 1200 mol/kg (liquid)
Sensing element form: Electrochemical cell Thin films on Ytrium-stabilized zirconia
Sensor physical property: Resistance, I–V characteristics & device drain current
Processing Compatibility: Silicon processing
Sensor Physical Parameter : Cell EMF Variations.
The sensor can be designed with different materials compositions towards achieving higher sensitivities.

In this review the electrode needs to be a good catalyst for oxygen reduction and oxidation. The electrode conduction of some solid materials shown below table.

TABLE 2: Electrical conductivity values of solid Oxide electrolytes at 600°c

Oxygen ion conducting solid electrode	Conductivity Ωcm^{-1}	Ref
Bi_2O_3	$3*10^{-3}$	[11]
Gd_2 doped CeO_2	$4*10^{-3}$	[12]
$Bi_2 Cu_{0.1V0}.9\ O_{5.35}$	$1*10^{-1}$	[13]
YSZ(8mol %$Y2O_3$)	$5*10^{-2}$	[14]
ZrO_2 (Y_2O_3) (For low tempe applications)	10^{10}	[8]

In this review by using $ZrO_{2\ solid}$ material sensor it will more advantages for combustion engine performance will increase throughout all the electrical characteristics expected.

TABLE 3: Review Expected values ZrO_2 sensor for to control air to fuel ratio of combustion engine.

Material	Operating Temperature Range	Detecting range	Volume Resistivity	Response time
ZrO_2 (Y_2O_3:	200 to 600^{0}c	0.002 to0.3 bar	10^{10} ohm.cm	60 s

3. CONCLUSION

This is paper Reviewed O_2 MEMS sensors, To sense O_2 with different materials for different required applications tin oxide material is use for low temperatures, but in combustion engines fuel and air is different ratio's so the combustion engines exhaust gases will pollutants and engine effienencies also varies, in this The review of air to fuel papers with different materials will damage due to engine temperatures then the O_2 sensors will damage, from this reviewed of papers Zirconium oxide material is suitable for both high and low temperatures O_2 sensor, and It has high melting temperature and high temperature tolerance band and good accuracy and it can characteristics of electrical parameters voltage and current, power consumption is low in ions concentration of zirconium oxide sensor, of so sense O_2 concentration in the range of 0.002 to0.3 bar in the Manufacturing industries, Automobile Industry , Engines manufacturing industries sector.

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