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Review Article

# Metal Oxide based Nanoparticles use for Pressure Sensor

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***Abstract***

*The present review on some metal oxide nanoparticles used for pressure sensor, various metal oxide containing such as ($SnO_2$, ZnO, $Al_2O_3$, $WO_3$, $Fe_2O_3$, $Ga_2O_3$, $TiO_2$ and SiC, ...etc.) responds detection pressure measure in kbar unit through oxygen activity as oxidation or reduction process of an integrated in devices sensor (MEMS, CMOS, MOX and MOXQ1D...etc.) that devices measuring of pressure as steam, air, gas, humidity and other substances. Pressure is extensive variable in physiochemical and thermodynamics investigation of matter at atmosphere.*

***Keywords**: Metal oxide; nanoparticle; pressure sensor; KBr.*

## 1. Introduction

Metal oxide is a chemical compound, molecular based empirical formula (XO) that contains at least one oxygen atom and one other element in its chemical formula. Metal oxides typically contain an anion of oxygen in the oxidation state of ($^{-2}$). Nowdays Metal oxides major role play in field of science including nanoscience and nanotechnology, formation of sensors for monitoring purpose in sciences. These sensor activity properties classified according to function Based integrated as Optochemical and electrochemical. Metal oxide nanoparticles used for gas, pressure sensor, various metal oxide containing such as ($SnO_2$, ZnO, $Al_2O_3$, $WO_3$, $Fe_2O_3$, $Ga_2O_3$, $TiO_2$ and SiC…etc.) responds detection pressure measure in kbar unit.

Focus presents a complement on Metal Oxide Nanoparticles used in pressure measurement as pressure sensor, metal oxide semiconductorcompatible silicon carbide absolute capacitive pressure sensor for harsh environmental applications. The pressure sensor was fabricated by bulk micromachining technology. Low temperature silicon carbide film was deposited by the plasma enhanced chemical vapor deposition process and utilized as the moveable membrane of the device. Even though the deposited film has a good mechanical property and high chemical resistance, it takes low electric conductivity, however tungsten (W) used as the sensor's electrodes. This pressure sensor exhibits a linear response over a pressure range of 2 bars (Fig.1), with a total change of 507.1 mV (i.e. 0.274 pF). Furthermore, it is confirmed to withstand KOH etching for more than 30 min (Wei Tang *et al.*, 2011).The recent advances in sensor devices have allowed the developing of new applications in many technological fields of nanotechnology (Diego L. *et al.*,2002). Metal oxide materials are widely used for gas sensing and capable of operating at elevated temperatures and in harsh environments, they are mechanically robust and relatively in expensive and offer exquisite sensing capabilities, the performance of which is dependent upon the nanoscale morphology.

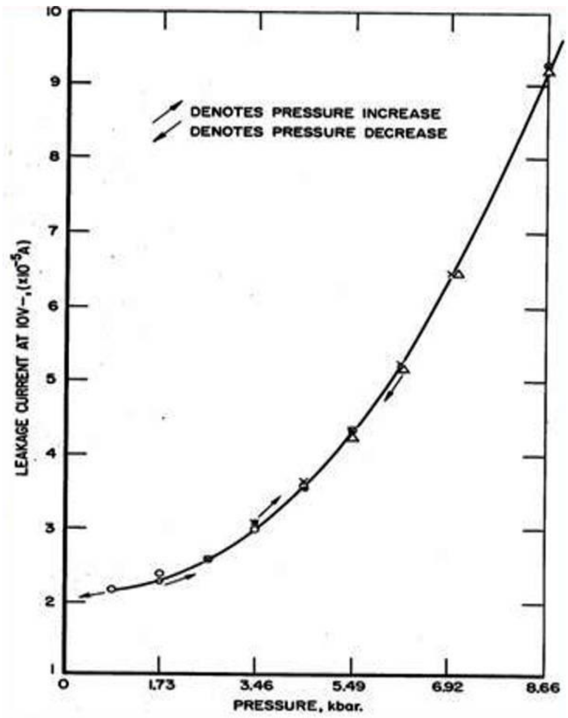


**Fig. 1** Pressure measure unit kbar

In this work different routes for the fabrication of metal oxide nanoarchitectures useful to sensing applications, including mesoporous thin films, nanowires, and nanotubes, Such as sensors $Al_2O_3$ for humidity sensing (Fig.2), and $TiO_2$ for hydrogen sensing (Oomman K. *et al.*, 2003).

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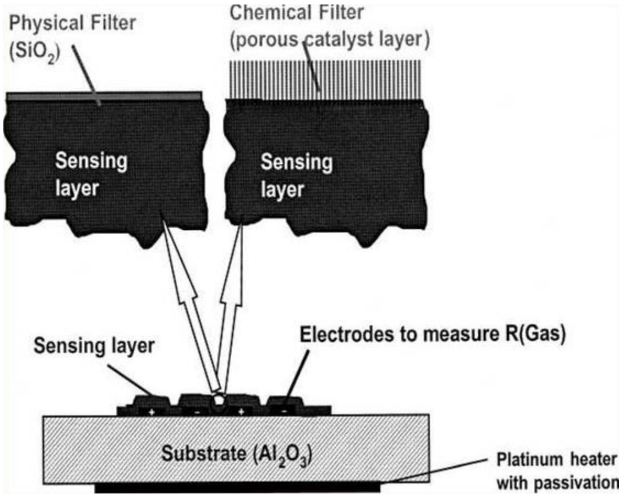


**Fig. 2** Metal oxide gas pressure sensor at the surface of the sensing material.

**2. Nano based MEMS and CMOS Pressure sensor**

For monitoring Purpose to describe development of Micro Electro-Mechanical System (MEMS) sensor technology to consider its current use in chemical gas and physical sensing and identify and discuss future technological trends and directions. The early research which lead to the development of MEMS sensors (Leo. O'Connor *et al.*, 1992). It considers subsequent applications of MEMS to chemical, gas and physical sensing and discusses recent technological innovations. Findings the greatly differing impacts exerted on chemical, gas and physical sensing by MEMS technology. MEMS devices in micro spectrometers, microGCs, microfluidics, lab-on a-chip and BioMEMS for analysis of pressure sensing(Robert Bogue *et al.*, 2007). A piezoresistive pressure sensor with a chip area of 2 mm to 4 mm has been fabricated by a standard CMOS (complementary metal oxide semiconductor) (Baltes H. *et al.*, 1993)process with additional MEMS post process. The sensitivities of sensors were measured as 0.53 $mVatm^{-1}V^{-1}$ and 13.1 $mVatm^{-1}V^{-1}$ prediction qualitatively (Chen-Chun Lai *et al.*, 2005).

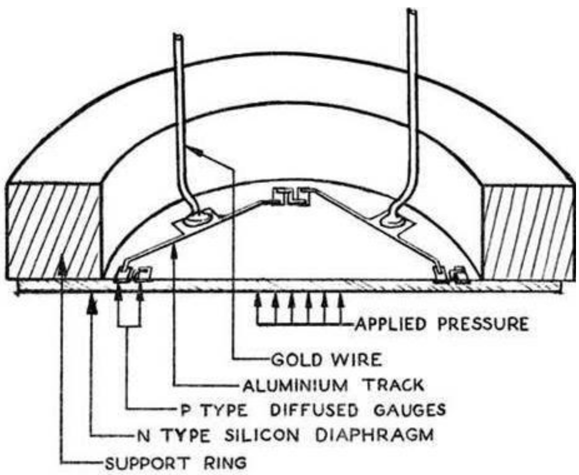


**Fig. 3** (Robert Bogue *et al.*, 2007) Schematic section of an early silicon pressure sensor

The CMOS (complementary metal-oxide-semiconductor) post process to monolithically integrate various capacitance type CMOS, MEMS sensors on a single chip. The CMOS post process consists of three steps:

(1) Front-side bulk silicon etching,
(2) Back side bulk silicon etching and
(3) Sacrificial surface metal layers etching

Using CMOS process and double side post process this study has successfully integrated several types of capacitive transducers and their sensing circuits on a single chip. Monolithic integration of pressure sensors of different sensing ranges and sensitivities, three axes accelerometers, and pressure sensors are demonstrated. The measurement results of the pressure sensors shows sensitivities ranging from 0.14 mV $kPa^{-1}$ to 7.87 mV $kPa^{-1}$. The three axes accelerometers have a sensitivity of 3.9 mV $G^{-1}$ in the in plane direction and 0.9 mV $G^{-1}$ in the out plane direction; and the accelerated measurement ranges from 0.3 G to 6 G (E. Lauwers *et al.*, 2001,Chih-Ming Sun *et al.*, 2009).

A monolithically integrated multi-transducer microsystem to detect organic and inorganic gases is presented. The system comprises two polymer based sensor arrays based on capacitive and gravimetric transducers, a metal oxide based sensor array, the respective driving and signal processing electronics and a digital communication interface. The chip has been fabricated in industrial 0.8mm, Complementary Metal Oxide Semiconductor (CMOS) technology with subsequent post CMOS micromachining (M.Y. Afridi *et al.*, 2002). The simultaneous detection of organic and inorganic target analytes with the single chip multi transducer system has been demonstrated. The system is very flexible and can provide different information of interest: the capacitive sensors can, e.g., act as humidity sensors to deal with the cross sensitivity of the metal oxide based sensors to water, or the capacitive sensors can be coated with differently thick polymer layers to detect organic volatiles even in a background of water. The multi transducer approach provides a wealth of information that can be used to improve the system discrimination capability and performance in gas detection(Y. Li *et al.*, 2007 11). Advancement of gas pressure sensor technology over the past few decades has led to significant progress in pollution control and thereby, to environmental protection. An excellent example is the control of automobile exhaust emissions, made possible by the use of oxygen gas pressure sensors. Solid electrolyte based potentiometric, amperometric and metal oxide based semiconducting resistive type sensors are used for high temperature applications. For solution-based pollution monitoring, dissolved oxygen sensors based on Clark electrodes have played a major role. More recently, for biological and medical applications, optical oxygen sensors are beginning to have an impact. It focuses on high temperature as well as dissolved oxygen sensors(R. Ramamoorthy *et al.*, 2003).

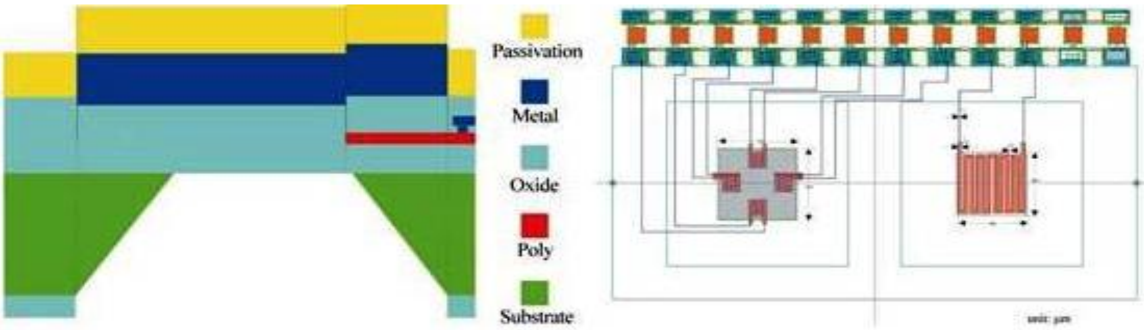


**Fig. 4** Cross section, layout of the CMOS pressure sensor

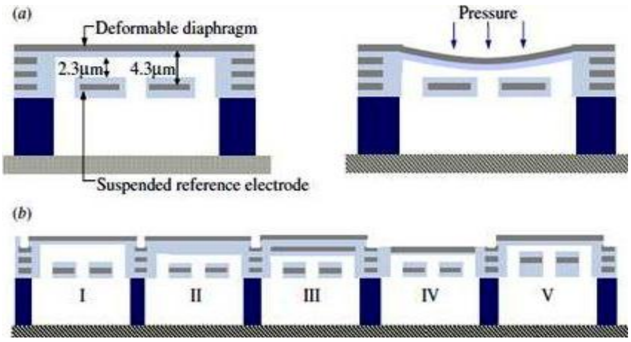


**Fig. 5** Design concept of the CMOS/MEMS pressure sensor (*a*) variation of the gap between sensing electrodes after pressure loading and (*b*) pressure sensors of different sensing ranges and sensitivities.

Gas pressure sensors based on semiconducting metal oxide nanostructures are expected to exhibit better sensing properties like sensitivity and selectivity, than gas pressure sensors based on other materials. Majority of the semiconducting materials possess n-type conduction and it is due to the presence of bulk oxygen vacancies. The sensitivity of the semiconducting material depends on the surface reaction between the chemisorbed oxygen and the reducing gases. Optimized indium zinc oxide thin films deposited at room temperature by electron beam evaporation technique were engaged as sensing elements for the detection of ethanol in this present study (G. J. Shyju *et al.*, 2012).

Metal oxide gas pressure sensors in general, show high sensitivity but poor selectivity if pure sensor materials are used. The performance in terms of reproducibility may be enhanced by using very stable materials, which may be operated at quite high temperature but this does not help in the problem of selectivity(Maximiliano S. Perez *et al.*, 2010).The metal oxide (MOX) gas pressure sensors have distinct response patterns with different gas sorts. The review show, a reaction model of MOX gas pressure sensors (N. Barsan *et al.*, 2007) is represented to simulate the sensor response patterns. The parameters of sensor responding to gas sort could be calculated out in the sensor response pattern simulations. The sensor response curves also could be reconstructed by parameters. A pattern matching method based on the sensor performance for gas sort. Volatile organic compounds (VOCs) were measured by a gas pressure sensor, towards a general applicable model for MOX gas pressure sensors (Shunping Zhang *et al.*, 2009). Sensor arrays were constructed using commercially available heated metal oxide. These arrays were exposed to several volatile organic compounds (VOCs) in air streams at concentrations levels in the range 0.01–0.30 parts-per-million (ppm), a range typical of indoor air quality studies. Partial least squares (PLS) calibration models were developed using the steady-state sensor array responses. These PLS calibration models were able to detect, differentiate, and quantify different VOCs at concentration typical of indoor environments (Edward J. Wolfrum *et al.*, 2006).

## 3. Carbon Nanotubes Based Pressure Sensor (Chip sensor)

This study shows the integration of a sensor based on carbon nanotubes using CMOS technology. A chip sensor (CS) was designed and manufactured using a 0.30 mm CMOS process, leaving a free window on the passivation layer that allowed the deposition of Single walled carbon nanotubes (SWCNTs) over the electrodes. We successfully investigated with the CS the effect of humidity and temperature on the electrical transport properties of SWCNTs (Fung C. *et al.*, 2005). The possibility of a large scale integration of SWCNTs with CMOS process opens a new route in the design of more efficient, low cost sensors with high reproducibility in their manufacture (Chen C. *et al.*, 2009).

## 4. Zinc oxide used as pressure sensor

Zinc oxide is a unique material that exhibits semiconducting and piezoelectric dual properties. Using a solid vapour phase thermal sublimation technique, nanocombs, nanorings, nanohelixes/nanosprings, nanobelts, nanowires and nanocages of ZnO have been synthesized under specific growth conditions. These unique nanostructures unambiguously demonstrate that ZnO probably has the richest family of nanostructures among all materials, both in structures and in properties. The nanostructures could have novel applications in optoelectronics, sensors, transducers and biomedical sciences. This article reviews the various nanostructures of ZnO grown by the solid–vapour phase technique and their corresponding growth mechanisms. The application of ZnO nanobelts as nanosensors, nanocantilevers, field effect transistors and nanoresonators is demonstrated(Ji.Haeng *et al.,* 2002, Zhong Li *et al.*, 2004). Fundamental science, synthesis, characterization, physicochemical properties and applications of oxide nanomaterials (Zhong Lin Wang *et al.*, 2004).

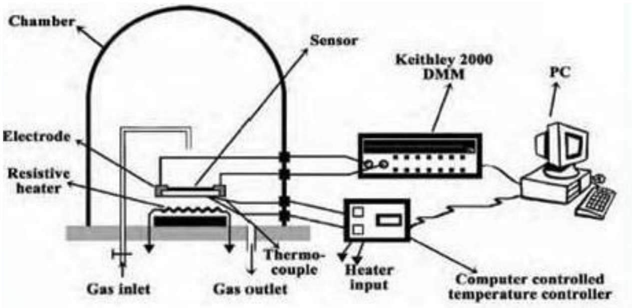


**Fig. 6** Experimental setup used for sensitivity measurements

## 5. Instrumentation process of Zinc oxide based pressure sensor

Sensitivity measurements are being characterized by any of the two methods, dynamic and static system. In the present study, static system is employed, which comprises an airtight chamber with air admittance and gas inlet valves. The entire setup for measuring sensitivity of the sensor is shown in Fig.6; the film sensor was placed inside an airtight chamber of known volume 25,000 cm3. The sensor was kept above a resistive heater and the temperature was monitored with a PID temperature micro-controller of VI microsystems India. Two gold electrodes were sputtered at the two ends on the surface of the film, from which ohmic contact were made. The gas injection was carried out with ethanol heater and through a needle valve, into the chamber. Initially, electrical resistance of the sensor layers was measured at a particular temperature in air ambient, using the response measured in air ambient is considered as a reference response for the calculation of sensitivity. After noting the reference, the test gas is injected inside the bell jar through a needle valve. In order to inject the gas easily, the chamber is evacuated to a base pressure of $10^{-3}$ Torr using a rotary vacuum pump. After injecting the test gas, all the valves are closed to avoid the leakage of the test gas. The resistance of the sensor is measured, with respect to time up to the saturation of the sensor to the gas, and then the air was allowed into the chamber. The resistance measurement of the sensor is continued up to the complete recovery of the sensor resistance to the air ambient value. The measurement was repeated for number of cycles to determine the cyclic nature of the sensor. The resistance of the sensor is measured for different temperatures in ethanol vapor air ambient.

## 6. Sensitivity of the Sensor with change in operating temperature

In the present study, the resistance of the indium zinc oxide film decreases on sensing the ethanol vapor. The sensitivity of the sensor is calculated using the equation,

$$S = \frac{Rgas - Rair}{Rair}$$

The decrease in resistance on sensing the ethanol vapor may be due to chemisorptions that exchange charges between absorbed gaseous species and the metal oxide surface.

The continuous evolution of nanotechnology in years by years led to the production of quasi-one dimensional (Q1D) structures in a variety of morphologies such as nanowires, core shell nanowires, nanotubes, nanobelts, hierarchical structures, nanorods, nanorings. In particular, metal oxides (MOX) are attracting an increasing interest for both fundamental and applied science. MOX Q1D is crystalline structures with well-defined chemical composition, surface terminations, free from dislocation and other extended defects. In addition, nanowires may exhibit physical properties which are significantly different from their coarse-grained polycrystalline counterpart because of their nanosized dimensions. Surface effects dominate due to the increase of their specific surface, which leads to the enhancement of the surface related properties, such as catalytic activity or surface adsorption: key properties for superior chemical sensors production. High degree of crystallinity and atomic sharp terminations make nanowires very promising for the development of a new generation of gas pressure sensors reducing instabilities, typical in polycrystalline systems, associated with grain coalescence and drift in electrical properties (Marcos Fernández-Garcia *et al.,* 2007). A hydrogen gas pressure sensor for detection of H2 dissolved in transformer oil has been developed for the use in a stand-alone dissolved gas analyzer (DGA) which will also assess the relative humidity saturation of oil. The sensor uses palladium nanoparticles as a sensitive material that is selective to hydrogen. The DGA will be capable of measuring dissolved hydrogen in concentrations from 50 ppm to 4000 ppm(E. Comini, *et al.,* 2009).

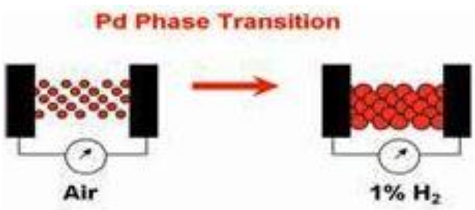


**Fig.7** Palladium transition sensor

Metal-oxide-semiconductor field effect transistor based humidity sensor which does not use any specific materials to sense the relative humidity, simply make use of the low pressure chemical vapor deposited (LPCVD) silicon dioxide's surface conductance change. When the gate is biased and then floated, the electrical charge in the gate is dissipated through the LPCVD silicon dioxide's surface to the surrounding ground with a time constant depending on the surface conductance which, in turn, varies with humidity (Ganesh E Patil *et al.,* 2011, G. Pauer *et al.,* 2004). Noise spectroscopy might be highly useful for improving gas pressure sensors selectivity if both theoretical model and sensing devices can be adequately developed. In a theoretical description of adsorption desorption noise in metal oxide gas pressure sensors. Using Langmuir's isotherm, as derive an exact expression for the adsorption–desorption noise in the case where only one molecular species reacts on the sensor surface (Seok-Ho Song *et al.,* 2012)

### *6.1. Other Metal Oxide Pressure sensors*

In situ transmission Fourier transform infrared (FTIR) spectroscopy was used to monitor both the charge conduction in the $SnO_2$ films and the gas-phase species. The $O_2$ pressure was observed to decrease the $SnO_2$ film conductivity(Sami Gomri *et al.,* 2005). Addition of CO pressure then increased the $SnO_2$ film conductivity. Static experiments also monitored the buildup of gas-phase $CO_2$ reaction products as the CO reacted with oxygen species. These results were consistent with both ion sorption and oxygen-vacancy models for chemiresistant semiconductor (Yashvant Rao *et al.,*2013)gas pressure sensors. Additional experiments demonstrated that $O_2$ pressure was not necessary for the $SnO_2$ films to detect CO pressure. The background infrared absorbance increased with CO pressure in the absence of $O_2$ pressure. These results indicate that CO can produce oxygen vacancies on the $SnO_2$ surface that ionize and release electrons that increase the $SnO_2$ film conductivity, as suggested by the oxygen-vacancy model. The time scale of the response of the $SnO_2$ films to $O_2$ and CO pressure was also measured by using transient experiments. The ultrathin $SnO_2$ ALD films with a thickness of ∼10 Å were able to respond to $O_2$ within ∼100 s and to CO within ∼10 s. These in situ transmission FTIR spectroscopy help confirm the mechanisms for chemiresistant semiconductor gas pressure sensors. Ultrathin tin oxide films were deposited on flat hotplate templates using atomic layer deposition (ALD) techniques with $SnCl_4$ and $H_2O_2$ as the reactants. The resistance of the $SnO_2$ ALD films across an electrode gap on the hotplate template was observed to oscillate and decrease versus the number of sequential $SnCl_4$ and $H_2O_2$ reactions at 250 ºC. The resistance also varied with exposure to $O_2$ and CO pressure at 300 ºC and 325 ºC. A wide range of $SnO_2$ ALD film thicknesses between 15.9Å and 58.7Å was prepared by varying the number of sequential, self-limiting SnCl4 and $H_2O_2$ reactions. The CO gas pressure sensor response was then measured for these $SnO_2$ ALD film thicknesses at 300 ºC. The CO gas pressure sensor response increased for increasing thicknesses between 15.9Å and 26.2Å and decreased for increasing thicknesses between 26.2Å and 58.7 Å. The results were interpreted in terms of the Debye length and resistance for the $SnO_2$ ALD films. The Debye length is comparable with the $SnO_2$ ALD film thickness of 26.2Å corresponding to the maximum responsivity for CO gas sensing. For film thicknesses >26.2 Å, the responsivity decreasewas explained by a larger fraction of the film with thickness greater than the Debye length that is not affected by the $O_2$ and CO chemisorption. For film thicknesses <26.2 Å, the responsively decrease was attributed to the increasing resistance of the $SnO_2$ ALD film. The gas pressure sensor response was temperature dependent and displayed its highest responsivity at temperatures between 250 ºC and 325 ◦C. The response times of the $SnO_2$ ALDgas pressure sensors were also faster at the higher temperatures >260 ºC (X. Du*et al.,* 2008)

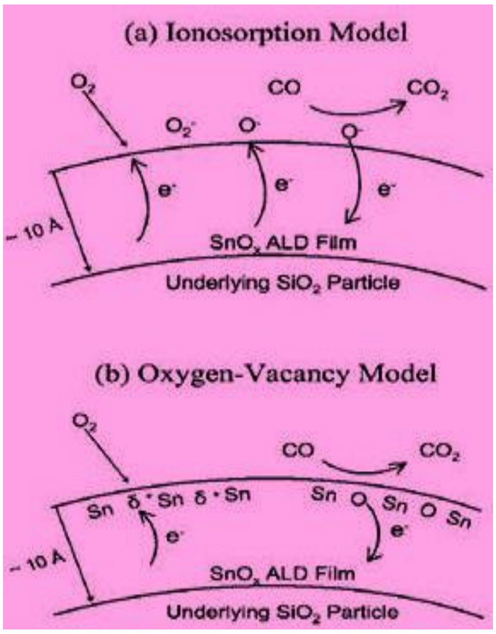


**Fig. 8** Activity of ionosorption and oxygen vacancy in sensor devices

It has long been known empirically that the electric resistance of a semiconductor gas pressure sensor under exposure to a target gas (partial pressure *P*) is proportional to *Pn* where *n* is a constant fairly specific to the kind of target gas (power law). This paper aims at providing a theoretical basis to such power laws. It is shown that the laws can be derived by combining a depletion theory of semiconductor, which deals with the distribution of electrons between surface state (surface charge) and bulk, with the dynamics of adsorption and/or reactions of gases on the surface, which is responsible for accumulation or reduction of surface charges. The resulting laws describe well sensor response behavior to oxygen, reducing gases and oxidizing gases (P. Montmeat *et al.,* 2004)

## 7. Metal Oxide Properties

Today metal oxides material used for well understanding to science and its more application in science field at various ways in which including Nanotechnology. Metal oxide finds are compounds formed by a metal and oxygen, in which the oxygen has an oxidation number (–2). Therefore its nomenclature is formed by two words. The first word is the name of the metal, followed immediately by the oxidation number between brackets and in Roman numbers write. The second word is the root of oxygen plus the suffix "–ide". The IUPAC also accepts the stoichiometric nomenclature for these oxides, though it is better to use the Stock´s nomenclature when there are metallic atoms and the stoichiometric nomenclature when all the atoms are nonmetals. In the formula: oxygen has an oxidation number (–2), and the oxidation number of the metal can be deduced by knowing that the compound is neutral. If it is always the same, we must know it and it is not necessary to deduce it.

*7.1. How to determine the oxidation number of the metal?*

Multiply the oxidation number of oxygen (–2) by its subscript. Change the sign of the result. Divide this result by the subscript of the metal. This it is the value of the oxidation number of the metal, and of the Roman number that you must use. As example:-
$MnO_2$ (Manganese IV oxide)
[+n +2(-2)]=0,
[+n (-4)]=0,
n=4
In the name: Remember that you must know the symbols of the elements and the oxidation numbers that are invariable.
1. Write the symbol of the first element with the oxidation number; it is either between brackets or you have to know it.
2. Write the symbol of oxygen with an oxidation number –2.
3. Calculate the fewest atoms of each element that you need so that the compound be neutral.Example:-$K_2O$
There are oxides which have oxygen united by a simple bond (–O–O–), as the oxygenated water or hydrogen peroxide $H_2O_2$ (H–O–O–H). The ion dioxide(2–) or ion peroxide, $O_2$ forms peroxides with elements of the groups 1, 2, 11 and 12.Thesecompounds oxygen has an oxidation number –1.
As nearly all the elements of the groups 1, 2, 11 and 12 have an invariable oxidation number, and we must know them, there is no confusion with the oxides of the oxide(2–) ion, $O_2$–. For example: table 1 the alkali metal oxides $M_2O$ (M = Li, Na, K, Rb) crystallize in the antifluorite structure.

**Table: 1** Stock's of metal Oxides and Peroxide

| Peroxide | Stock´s Nomenclature | Oxide | Stock´s Nomenclature |
|---|---|---|---|
| $Na_2O_2$ | Sodium peroxide | $Na_2O$ | Sodium oxide |
| $MgO_2$ | Magnesium peroxide | MgO | Magnesium oxide |
| $CaO_2$ | Calcium peroxide | CaO | Calcium oxide |
| $Cu_2O_2$ | Copper(I) peroxide | $Cu_2O$ | Copper(I) oxide |
| $ZnO_2$ | Zinc peroxide | ZnO | Zinc oxide |
| $K_2O_2$ | Potassium peroxide | $K_2O$ | Potassium peroxide |
| | | $Li_2O$ | Lithium oxide |
| | | $Ag_2O$ | Silver oxide |
| | | FeO | Iron(II) oxide |
| | | $Fe_2O_3$ | Iron(III) oxide |
| | | $CrO_3$ | Chromium(VI) oxide |
| | | $TiO_2$ | Titanium(IV) oxide |
| | | CuO | Copper(II) oxide |

## 8. Measuring techniques for pressure measurement

Pressure measuring techniques can be used to measure not only process or differential pressure, but also level, volume or mass in all areas of process technology. The measured media are commonly gases, vapours and liquids. The measuring ranges of pressure transmitter's start at a few mbar and go up to several hundred bar. Different measuring cells are used for pressure detection.Use the SurPASS electro kinetic analyzer in surface analysis to investigate the zeta potential of macroscopic solids based on a streaming potential and streaming current measurement. The zeta potential is related to the surface charge at a solid/liquid interface and is a powerful indicator for the surface chemistry (pH titration) and liquid phase adsorption processes. SurPASS helps you to understand and improve surface properties and to develop new specialized materials.Metal oxide gas pressure sensors are utilised in a variety of diverse rolesand industries. They are relatively cheap compared to other sensing technologies,strong, lightweight, long durable and benefit from high material sensitivity and quickresponse times. They have been used extensively to measure and examine trace amounts ofenvironmentally essential gases such as carbon monoxide and nitrogen dioxide. In thisreview the nature of the gas response and how it is basically linked to surfacestructure is explored. artificial routes to metal oxide semiconductor gas pressure sensors are alsodiscussed and related to their affect on surface structure.

## 9. Characteristics of pressure Sensors

In order to characterize pressure sensor performance a set of parameters is used. The most important parameters and their definitions are listed below.

- Sensitivity is a change of measured signal per analytic concentration unit, i.e., the slope of a calibration graph. This parameter is sometimes confused with the detection limit.
- Selectivity refers to characteristics that determine whether a sensor can respond selectively to a group of analyzes or even specifically to a single analyze.
- Stability is the ability of a sensor to provide reproducible results for a certain period of time. This includes retaining the sensitivity, selectivity, response, and recovery time.
- Detection limit is the lowest concentration of the analytic that can be detected by the sensor under given conditions, particularly at a given temperature.
- Dynamic range is the analytic concentration range between the detection limit and the highest limiting concentration.
- Linearity is the relative deviation of an experimentally determined calibration graph from an ideal straight line.
- Resolution is the lowest concentration difference that can be distinguished by sensor.
- Response time is the time required for sensor to respond to a step concentration change from zero to a certain concentration value.
- Recovery time is the time it takes for the sensor signal to return to its initial value after a step concentration change from a certain value to zero.
- Working temperature is usually the temperature that corresponds to maximum sensitivity.
- Hysteresis is the maximum difference in output when the value is approached with an increasing and a decreasing analytic concentration range.
- Life cycle is the period of time over which the sensor will continuously operate

## Conclusion

This invention relates to pressure sensing devices. Which measure pressure in the 0.5kbar to 10kbar range by determination of leakage current in pre stressed bodies of metal oxide varistermaterial? Pressure is not only an important extensive variable in physiochemical and thermodynamics investigation of matter, but also is an essential process parameter in certain specialized technologies which utilize a high pressure route for manufacturing a final product. Reproducible pressure reading may be obtained first by presenting a body of varistor material to a pressure above the range of measurement, subsequently releasing pressure to atmospheric level, and then applying an unknown pressure to the varistor body. It is therefore an object of this invention to provide methods and materials for continuously measuring pressure in the range from approximately 0.5kbar to approximately 10kbar. Shows schematic illustrations of the capacitance type pressure sensor design in this study, the present pressure sensor consists of a diaphragm and suspended structures, both of which have embedded sensing electrodes and are formed by dielectric and metal films of the CMOS process. The metal oxide thin films of the CMOS process act as sensing electrodes. The diaphragm and its embedded sensing are deformed by the pressure load, the pressure difference on both sides of the diaphragm leads to a gap and a capacitance change between the sensing electrodes.

The semiconducting metal oxides operated at high temperatures distinct advantages with respect to reproducibility of the devices. In case of selectivity, they show similar cross-sensitivity to other reactive gases steam pressure than conventional metal oxide operated at lower temperatures.

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