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A Study the Mixed Metal Oxide Preparation for Gas Sensor Applications

Dharmendra Kumar Khatik[1]*, Dr. Rajesh Kumar Kushwaha[2]

[1] Research Scholar, Shri Krishna University, Chhatarpur M.P.

[2] Associate Professor , Shri Krishna University, Chhatarpur M.P.

Abstract- Gas sensors are used in environmental observing, industrial safety, disease diagnostics, & traffic safety. Toxic environmental pollutants & dangerous gas escapes from factories are two of their most common uses. In order to supplement more traditional approaches, such as optical or spectroscopic analyzers, there is a growing interest in developing inexpensive gas sensors for use in environmental & civil monitoring applications. Finding novel materials that combine long-term functioning devices with excellent sensitivity & selectivity is the current focus of gas sensor research. Portable equipment & devices that run on batteries are in high demand for a wide range of uses. It has recently come to light that metal oxides are the superior material class for gas sensor applications. More promising over-the-applet detectors appear to be metal oxide films, either thin or thick. Porous pallets, thick films, & thin films made of metal oxides are utilised. The deposition of thin films can be accomplished using a variety of approaches. The two main types of these techniques are chemical deposition & physical deposition.

Keywords- Metal Oxides, Gas Sensors, Chemical Gas, Thin Film

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INTRODUCTION

In civil applications such as environmental surveillance, occupational protection, disease detection, and traffic safety gas sensors have played a significant role. They are widely used for the identification and prevention of harmful chemical emissions from the sector. In addition to traditional approaches such as optical and spectroscopic analyzers, development of low-cost gas sensors is increasingly interested in civil and environmental monitoring applications. The increasing need for gas sensors to address health and ecological concerns has led to a search for more responsive & sensitive gas sensors focused on the identification of flammable gasses such as H_2, ethanol, hydrocarbons and poisonous gasses including H2S, CO, NO_2, C_{l2} etc. Metal oxide semiconductor sensors have been the subject of much study because of the ease of their design, the cheapness of their materials, and the fact that their conductivity may be controlled by the adsorption or desorption of gas molecules on their surfaces. By enhancing the efficiency of well designed content at the micro and nano scale, one can achieve the benefits of a large surface area and/or quantum mechanical phenomena. Metal oxide gas sensors so garnered a lot of attention from both the academic & commercial communities.

CHEMICAL GAS SENSOR

A system that may be quantified and monitored when exposed to gaseous creatures or molecules changes one or more physical features, including density, electrical conductivity, dielectric responses, or optoelectronic properties. This improvement includes an electric signal whose amplitude is proportional to the level of gas being tested and calculated as gas to be exposed to the sensor.

Almost every facet of life can benefit from sensor engineering and research, including protection, tracking, safety, & awareness. Gas sensors & monitoring systems for the industrial process and production sectors are in high demand due to the increased awareness of environmental pollution. These systems must be both dependable and affordable. The capacity to measure or control physical and chemical characteristics, including chemical composition, pressure, or temperature, is the foundation of contemporary industrial monitoring. This highlights the critical need for improved and more targeted sensor technology. In our daily lives, gas sensors are vital for gathering data, processing it, and carrying out various tasks. The performance, cost, & dependability of a sensor are the determining factors in its successful implementation. Better sensors with linear outputs have been designed as a result of recent advances in both the understanding of sensing principles and the enabling technology (Gardner 1999). Air gas analyzers and identifiers have numerous practical applications in human life, such as detecting explosive and poisonous gases in mines, locating gas leaks in homes, and managing air pollution (Dal

Santos et al 2003). Environment observing, biotechnology, analysis of chemicals, & online product identification are just a few of the many areas that rely on gas sensors. Consequently, sensors pave the way for a plethora of uses, from the living room to the production line. They were originally created in Japan for use in measuring instruments & gas leak alarms. Furthermore, gas sensors have a significant influence on a wide range of other applications in sectors such as the oil and automobile industries, among many others. Millions of gas sensors are produced annually to meet these demands on a global scale.

WHY NANOMATERIALS?

In the SI unit, the expression nano is 10-9m, i.e. a billionth. The substance creators became aware of the peculiar properties of nanomaterials and structures on the nanometer scale. Nano-dimensional materials of at least one size below 100 nm may be considered. The nanometer device derives its nano prefix from a Greek term that means dwarf or incredibly thin. Compared to a nanoscale nano particle, the thickness of a human hair is around 5 orders greater. The nano-world lies at half-way amongst the reach of nuclear and quantum pheromones & size of bulk materials, not only just another phase of miniaturization, but a separate arena altogether! In the 20th Century, technology needs to miniaturize devices into nanometers thus greatly improving their accuracy. This poses many problems for new materials for achieving precise flexibility and selectivity, which is why the analysis of nanoscale materials about its fundamental properties, organizing superstructures and applications lately has been very interesting.

GAS SENSORS

In order to detect gas molecules, gas sensors use a physical change, which in turn generates an electrical signal whose amplitude is directly proportionate to the gas concentration. When gas is introduced to solid-state sensors, it alters the material's resistance through a process known as adsorption. The sensor gets back to normal when the gas goes out.

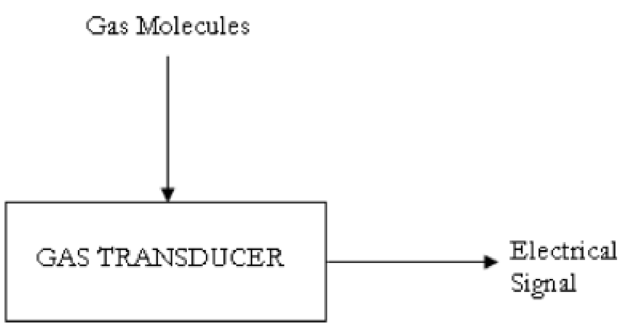

Figure 1 Conceptual framework for microsensors and microsensor networks

Due to the fact that no energy is used during the detecting process, solid-state sensors, when made correctly, have an extended endurance. By adjusting the surface temperature of a solid-state sensor, one can make it more sensitive to a certain gas while making it less sensitive to others.

The gas sensor needs to be sensitive to the gas being measured, insensitive to other gases (selectivity), and able to measure gases quickly in order to be effective.

Gain error, long-term drift, & noise are some of the aberrations that can arise when the sensor is inadequate.

Solid-state Gas sensors

Despite the prevalence of gas & liquid sensors, all three phases of matter are capable of bearing sensors. More than 150 distinct gases, including those that would have previously required costly analytical equipment, can now be identified utilising solid-state sensors. There are a number of solid-state sensor manufacturers to choose from, and the quality & performance offered by each is unique (Gardner 1999). A solid-state sensor's greatest virtue is its long life expectancy. In clean applications, a well-made sensor can live for ten years or more. Considering that most sensors, like electrochemical ones, only survive a year or two, this is a huge plus (http://www.intlsensor.com/pdf/solidstate.pdf).

Bulk sensing element sensors, including phototransistors and silicon photodiodes, are examples of solid-state sensors (Gardner, 1999). Micro sensors are solid-state devices that use thin film sensing elements. Smaller sensors are typically more useful since they are easier to transport and use less materials in their production, which in turn reduces their manufacturing costs. Many applications have been made possible by the low cost, excellent reliability, & small size of solid-state sensors.

Technology optimization

In the process of creating an electrical sensor, the optimisation problem plays a crucial role. Due to the lack of a quantitative theory that would characterise the operation of gas sensors, this problem takes on some additional significance & quirks when applied to gas sensors. Optimisation is still an empirical art form because to the enormous number of physically & chemically defined sensor qualities, some of which are impossible to manage. When it comes to gas sensors, optimisation implies getting the sensitivity, selectivity, response, & recovery times to where they need to be or as close to where they can be achieved by making the right parameter selections (Brinzari et al., 2001).

The majority of gas sensors on the market today work by observing how the gas changes the physical properties of a particular substance through chemical reactions. Because the gas-sensitive material changes over time as a result of exposure to either high working temperatures or ambient humidity, these sensors become less reliable with age. Because the working temperature is typically boosted for higher sensitivity, gas sensors that rely on the physical features of the species to perceive can amplify this problem.

In essence, a sensor's characteristic performance dictates whether it is suitable for a given application. The fundamentally diverse sensor performances can be needed for various applications. Effectiveness is a measure of how well a micro sensor system or individual micro sensor performs in the aggregate (fig. 2). The capacity, dependability, and accessibility of a micro sensor are crucial elements that influence its efficacy (Gardner 1999).

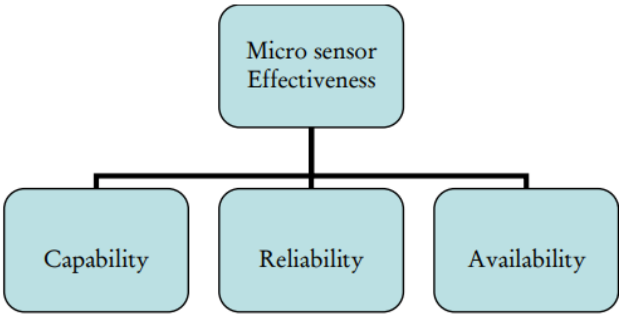

Figure 2 Efficiency of a micro sensor configuration

Micro sensors are only considered capable if they can carry out the intended task in the given environment. A micro sensor is considered reliable if it can carry out its intended job for an allotted time while staying true to its technical specifications. Having a tiny sensor on hand means it can carry out a necessary task at the exact moment it is needed. Plus, its repair rate & failure rate are what really set it apart (Gardner 1999).

TYPES OF GAS SENSORS

In the last decade, scientists have created different kinds of gas sensors to detect gases based on the different concepts of work. Some are referred to as below.

Electrochemical Sensors

As gas is chemically adsorbed on an electrode surface, electrochemical sensors work with an electrode signal. These sensors work by interacting with the test gas and generating a signal that is proportionate to gas levels. It is comprised of an electrode sensor and a counter electrode isolated by a thin electrolyte film.

Catalytic Sensors

Catalytic sensors operate by catalytic oxidation and reduction. The catalytic sensor theory is focused on flammable gas oxidation: once a fuel gas comes into contact with the catalyst surface, the catalytic sensor is oxidized. The reaction produces heat, causing the wire to adjust resistance. Catalytic sensor consists of two components: a detector element that includes a catalytic and fuel-sensitive material and an inert counterpart element. Fuel gasses only burn on the detector part, creating an increase in its temperature and as a result, its resistance increases. Normally, for precise resistance estimation, a Wheatstone bridge network is used. The voltage of the output signal is proportionate to the gas level.

Infrared Sensor or IR Detectors

These sensors are based on the absorption & emission by chemical bonds of a limited volume of energy owing to the phenomenon of resonance the longer wavelengths of IR radiation are less dispersed by haze or gas particles than visible radiation.

FTIR Based Sensors

When a gas is found in the optical direction, the power of the light transmission among transmitter & receiver would be affected. The modified light condition allows to measure the gas level in a certain volume.

Gas Sensors Acoustic Wave

Sound-based gas sensors are called a wave-based acoustic gas sensor. This kind of sensor is often used in piezoelectric films or bulk shapes with one or more transducers on the surface.

Capacitance Based Gas Sensors

In this form, the concentration of the test gasses is determined by the difference between the electrodes in the dielectric constant of the films.

METAL OXIDES GAS SENSING MECHANISM

One way to understand how a metal oxide gas sensor works is by observing the resistance of metal oxide semiconductors when they undergo oxidation or gas reduction. This variation in resistance results in a wide-ranging, reversible signal. It is known that reversible surface adsorption/desorption events are crucial to the detection mechanism. Adsorption of gases through a chemical reaction on the picture's surface atoms was thought to be responsible for the changes in electrical conductivity. Because of the slow bond on the surface film and the chemical interaction of gas species, the electrical conductivity shifted due to adsorption. By forming surface-bound charged ions or compounds, metal oxide facilitates the transfer of electrons between the gas and the film, or vice versa. When exposed to decreasing oxygen, the resilience of the film reduces when exposed to increasing gas oxidation.

METAL OXIDE GAS SENSOR OPERATING PRINCIPLE

Oxygen is adsorbed to the surface as thin metal oxide film becomes exposed to clear air. Adsorbed oxygen absorbs free electrons from inside metal oxide for its strong electron attraction, which forms a possible grain barrier. This possible obstacle inhibits the movement of electrons that trigger high air resistance to sensors as seen in Figure 3 (a)

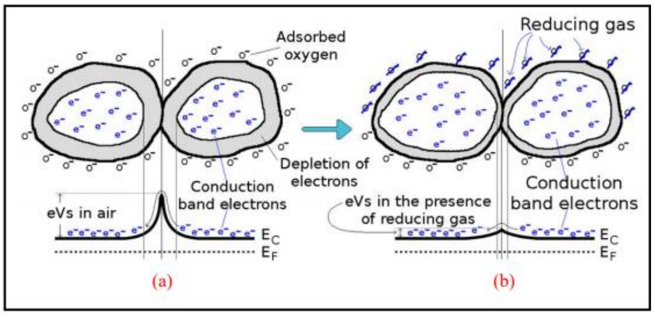

Figure 3 Shows the adsorbed oxygen species and grain loss regions when the sensor is subjected to (a) air (b) reduced gas.

The oxidation reaction of a gas with adsorbed oxygen is done on the surface when the film is subjected to a reduces gas such as H2S. Consequently, the oxygen level adsorbed decreases and reduces the barrier height. The reduced potential barrier starts with simple electron wave. This decreases the sensor resistance. The gas level is determined by the sensor resistance reduction as exposed in fig..3 (b)

OXIDE GAS SENSORS FOR THE THIN FILMS

Applied as porous pallets are metal oxides, heavy films and fine films. The pulverized material generated by various techniques is usually compressed under high pallet pressure. The gas sensors are more promising than the pellet, in the form of thick & thin films, since they are cheap, robust and use less power to operate. For the deposition of thin films, different techniques are usable. These are generally divided into two groups, specifically the technique of physical deposition & chemical deposition.

TIN OXIDE AS GAS SENSOR

SnO2 is better understood as an N-type among the different metal oxides because of its outstanding electrical characteristics and low expense. Tin oxide or SnO2 is present in the form of powder and in color white. It is used as a heterogeneous catalyst in the petroleum industry. SnO2 was the most common gas sensing material of all metal oxide semi-conductors. There has been extensive study to develop the gas sensor characteristics of SnO2-based sensors. This content is still being worked by several groups today. SnO2 crystallizes in the crystal tetragonal system and is rutile isostructural.

SnO2 has been commonly used throughout gas sensor applications in the previous four decades. Using mass, thick & thin films, gas sensors have been developed. Most of today's gas sensors are produced with SnO2 in thick film, thin film or porous pallet shape. The benefit of use of this substance is that various gasses are less costly, are highly sensitive and can be miniaturized to integrate micro machinery substrates.

SnO2 is a semi-conductor of metal oxide with a 3.6 eV band break. The surfaces (110) and (100) are their normal growth faces. A 5S2 electron configuration is provided in an ionic frame. There is no bad stretching, i.e., smooth belt surface.

As a gas sensing material, SnO2 demonstrates enhanced surface conductivity thanks to its powerful gas-adsorption and surface reaction-facilitating capabilities, most notably oxidation. It is also proven that the exposure to certain gases and high working temperatures is considered to be low in terms of selectivity, are needed to improve detection. Striving to solve these problems is male. One approach to change substrate properties is to apply appropriate dopants.

For the synthesis of nanostructured SnO2 sensing material, different techniques are used. They are aerosol technique, vapor condensation step, solid vapor process regulated. Hydrothermal therapy, method of laser ablation Updated wet chemical routing technique MOCVD Technical PECVD Sol-gel dip cover procedure, chemical method of solvothermal therapy, thermal evaporation, etc. Nanobelts, nanocrystalline films, or nanoparticles are several nanostructures synthesized for substance SnO2. Nano powder nanoribbons, nanorods, nanowires, etc.

The influences affecting the gas sensing properties of these products have been shown to be the scale of the grain, additional substances, microporous composition and thickness of the gas sensing organism. Most are reports of conductometric sensors focused on changes in electric conductivity at different levels of the test gas in the atmosphere.

APPLICATIONS OF GAS SENSOR

- Process control industries
- Alcohol breath tests
- Fire detection
- Boiler control
- Environmental monitoring
- Detection of harmful gases in mines
- Home safety

METAL OXIDES: A CRITICAL ROLE AS A GAS SENSOR

Many researchers are interested in transparent & strongly conducting semi conducting oxide films because of their many potential uses in both academia and business. There has been a lot of study on semiconductor gas sensors due to the recent worries about pollution & safety in industries that use toxic gases (Hartnagel et al. 1995). It has been found that semiconducting transparent coatings of certain metallic oxides, like cadmium oxide, tin oxide, indium tin oxide, zinc oxide, Ag2O, BaTiO3, and others, show great promise in detecting the emission of harmful gases into the atmosphere (Salehi 2002; Patel et al 2003; Mitra et al 1998; Jinzhong Wang et al 2002; Park and Seo 2004). Because they are dependable & stable, they have many uses.

There has been a lot of curiosity in using semiconducting oxides, including tin oxide & zinc oxide, for gas sensing ever since Seiyama et al. published their findings in 1962. Countless sensors have been created since the Figaro gas sensor, which utilised a sintered tin oxide pellet, was introduced to the market. In recent times, there has been a surged in the fabrication of planar micro electronic sensors using silicon technology. This has several benefits, such as being inexpensive, requiring little heating power, allowing for precise temperature control, and making it easier to realise multisensors. These sensors could improve selectivity and be utilised for gas mixture analysis. Additionally, they could allow for the possibility of integrated circuits on a single chip (Wan-Young Chung et al 1994).

METAL OXIDE GAS SENSORS FOR REDUCING GASES

When used in semiconducting gas sensors, oxygen lowers conductivity by removing electrons from metal oxide films. In the presence of a reducing agent, the conductivity of the material is enhanced by the injection of electrons.

The electrical conductivity changes are caused by differences in the relative energy of the electronic charge carriers before and after adsorption. These energies are determined by the structure and composition of the semiconducting oxide's bulk and surface. Intentional surface modification allows for effective control of gas sensing behaviour due to the fact that chemisorptions of gas species dramatically alter oxide electronic characteristics (Mishra and Agarwal 1998). Some metal oxides exhibit reversible conductance changes that occur in tandem with chemisorptions of reactive gases on their surfaces. Conductance changes in semiconductor materials are mainly caused by changes in the concentration of electrons or valence band holes, as opposed to the tiny modulation in conductance caused by absorption in metal films, which is caused by changes in mobility as a result of changes in surface scattering.

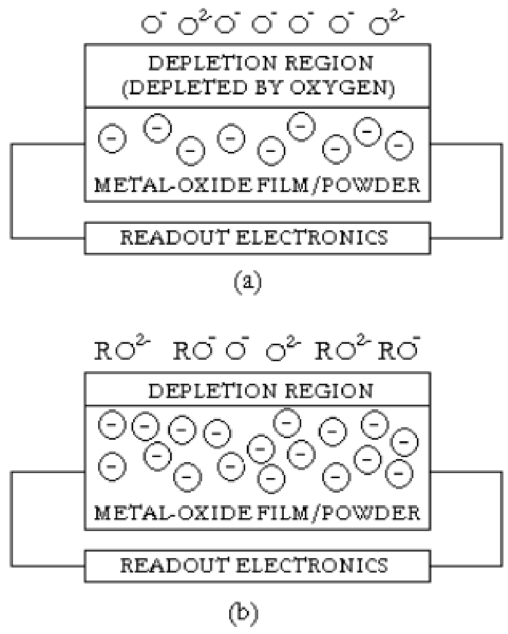

Figure 4 Electricity conduction is affected by changes in gas chemisorption during gas reduction.

In semiconductor sensors, the concentration of electrons in the conduction band changes almost linearly with pressure throughout a range of eight decades, with typically only a slight fluctuation in mobility. It appears that the electrical conductivity of semiconductors is greatly affected by gas chemisorptions onto their surfaces. One of the main draws of semiconductor materials for gas sensing electronic devices is their significant and reversible fluctuation in conductance with active gas pressure (Hartnagel et al 1995). It is also known that humidity, in addition to ambient oxygen, has a significant impact on gas detection. Variations in sensor element temperature & material activity dictate the specific gas-surface oxygen reaction. Gas detection entails the following procedures.

(i) Creating contacts that can measure a material's conductivity.
(ii) A "target gas" that alters conductivity is introduced.
(iii) The reduction or oxidation of oxygen species absorbed on the surface of SnO2 alters the surface conductivity, which is the target gas's reaction.
(iv) For certain target gases at a constant concentration, dopants and additions can enhance changes.

CONCLUSION

A sensor is an instrument that can take in signals from the physical, chemical, or biological world & transform them into an electrical signal that may be used in electronic circuits. This interpretation might be bolstered by looking at the word sensor's etymological roots. It is possible to detect this reaction through measuring changes in capacitance, work function, mass, optical characteristics, or the reaction energy produced by the gas/solid interaction, additionally to the conductivity change of the gas-sensing material. As active layers in these gas-sensing devices, a variety of materials, including porous ceramics, are deposited as thick or thin films. Typically, solid-state chemical detection principles are employed in chemical processes that detect the gas by a selected chemical reaction with a reagent. Thicker layers of the sensing material can have their microstructure controlled to increase gas sensitivity by, for example, reducing grain size or scattering tiny pores at grain boundaries. Another crucial metric is gas selectivity, which quantifies how well a sensor can isolate one gas from a mixture.

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Corresponding Author

Dharmendra Kumar Khatik*

Research Scholar, Shri Krishna University, Chhatarpur M.P.