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STUDY THE GAS SENSING MATERIAL AND THEIR MECHANISM: A REVIEW

Mr.Sumit D. Rokade[a]*, Dr. D.V. Nandanwar[b]

[a]Department of Physics,
Yashwantrao chawhan arts,commerce and science college Lakhandur
[b]Department of Physics,
Mathuradas mohota science college Nagpur
Email: sumitrokade26@gmail.com

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ABSTRACT: This review paper studded gas sensing material which has widely investigated and utilised for detection of toxic and flammable gasses. such as CO, Co2,H2S,C6H6,02,NH3,H2,LPG etc there are several material used for gas sensing purpose. the detection of such gasses, numerous materials are used such as semiconducting metal oxide in SMO we are discussing about transition metal oxide and non-transition metal oxide and their factor for detection of various gasses. Carbon based material such as Graphene and carbon nanotube and some conducting polymers such as polyaniline(PANI) and discussing their advantages and disadvantage and studied how they perform with different parameters in terms of sensitivity selectivity, response time and stability and studied their sensing mechanism and performance for detection about different gas.

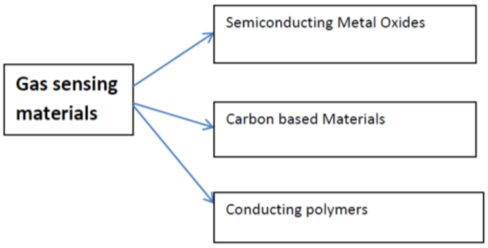
Key words: - Gas sensing, semiconducting metal oxide, carbon based material, conducting polymer , sensitivity.

INTRODUCTION :

Now days the demand of gas sensors is growing because of wide range use of several gases for industrial, domestic purposes and accidents due to leakage of gas are increasing. Many nanostructured metal oxides having favourable electrical, chemical properties and thermal stability are used as gas and humidity sensors for applications in many fields such as environmental monitoring , Medical diagnosis, health , energy, air quality monitoring, control of food quality or safety of industrial processes and homemade security system [1] Gas sensing technology has become more significant because of its well-known and common applications in the following areas:(1) industrial production (e.g., methane detection in mines) (2) automotive industry (e.g., detection of polluting gases from vehicles) (3) medical applications (e.g., electronic noses simulating the human olfactory system) (4) indoor air quality supervision (e.g., detection of carbon monoxide) (5) environmental studies (e.g., greenhouse gas monitoring) [2]

Throughout the last few years, with the quick industrial development and urbanization, the harsh air pollutant gasses are frequently attributed to automobile exhaust and factory emission has become a great threat to human existence and development. Meanwhile, a leakage of flammable and explosive gases such as Acetylene, ammonia, hydrogen, propane, propylene and methane that may result in loss of life and property damage. So, real-time and effective detection of those harmful gases via using gas sensors is in pressing need at present and future [3]

There are so many materials used as sensing gasses such as many semiconducting metal oxide s material, carbon based materials and some conducting polymers this have shown great potential for the detection of inflammable, flammable and toxic gases



Semiconducting Metal Oxide:

The extremely common sensing materials are metal oxide semiconductors, which give sensors with several advantages such as low cost and high sensitivity. Metal oxides, such as TiO_2, CuO, ZnO,Cr_2O_3, Mn_2O_3, Co_3O_4, NiO, CuO, MgO, SrO, In_2O_3, WO_3, V_2O_3, Fe_2O_3, GeO_2, Nb_2O_5, MoO_3, Ta_2O_5, La_2O_3, CeO_2, Nd_2O_3 V_2O_5, and SnO_2, can be utilized to detect flammable, oxidizing, or reducing gases with sensors which are mainly based on the resistance change responses to the target gases [2]. Metal oxides selected for gas sensors can be determined from their electronic structure. The scale of electronic structures of oxides is so wide that metal oxides were divided into two the following categories:

(1) Transition-metal oxides (Fe_2O_3, NiO, Cr_2O_3, etc.)

(2) Non-transition-metal oxides, which include (a) pre-transition-metal oxides (Al_2O_3, etc.) and (b) post-transition-metal oxides (ZnO, SnO_2, etc.).Pre-transition-metal oxides (MgO, etc.[4] transition-metal oxides obtained various oxidation states on the surface; hence metal oxide semiconductors are promising sensing materials compared to the non- transition ones. Transition-metal oxides with d0 and d10 electronic configurations could be used in gas sensing applications . The d0 configuration could be found in transition metal oxides (e.g., TiO_2, V_2O_5, WO_3), and d10 appears in post-transition-metal oxides (e.g., SnO_2 and ZnO)[2] Only transition metal oxides with electronic configurations d0 and d10 are actually used as gas sensors. The d0 configuration exists in binary transition metal oxides, such as TiO_2, V_2O_5, WO_3. The d10 configuration is found in later transition metal oxides, such as ZnO and SnO_2.[4]

These metal oxide semiconductors generally have a wider band gap and a lower surface/interface state density, so they can work at higher temperatures, and the change in surface work function effectively controls the space charge layer.[5] Semiconductor metal oxide (SMO) gas sensors are the most well-researched group of gas sensors and recently SMOs with a size of 1 nm to 100 nm have been increasingly used for the detection of gases due to their size-dependent properties. . Gas sensors using inorganic metal oxides, such as, zinc oxide, tungsten oxide, titanium oxide, tin oxide, iron oxide, silicon oxide,etc , show superior detecting qualities because of changing oxygen stoichi- ometry and electrically active surface charge[6] Nanomaterials are unique because of their mechanical, optical, electrical, catalytic, and magnetic properties; In addition, these materials also have a high surface area per unit mass; In addition, new physical and chemical properties arise when the particles are in the nanometer range. The surface and the ratio between surface and volume increases dramatically with decreasing material size. In addition, the movement of holes and electron in semiconductor nanomaterials is influenced by the size and geometry of the materials[7] Research on sensors based on semiconductors made of metal oxides should find new solutions to overcome their shortcomings. Research on metal oxide nanostructures shows that nanostructures (such as semiconductor nanowires) can improve the sensitivity and response time of gas sensors.[2]

Carbon based materials :

In the last few year researcher are very much interested in study of carbon based nanomaterial's, because of their unique electrical , optical , mechanical properties which makes them very interesting materials for development of gas sensor. Such carbon based materials such as carbon black, Graphene, carbon nanotube , Florence Some carbon based nanomaterial's such as Graphene and carbon nanotube have high quality crystal lattices and show high carrier mobility and low noise.

Geaphene:

Graphene is composed of a two-dimensional matrix of carbon atoms covalently linked by sp2 bonds to form a honeycomb sheet.it discovered in 2003,an allotrope of carbon and single layer of graphite. Structure of graphene is honeycomb like structure and 2D carbon nanomaterial having atomic thickness is 0.345nm. Graphene was considered part of the crystalline structure of graphite until 2004, when Novoselov and others first demonstrated some of the amazing electrical properties of graphene layers that they possessed[8] Graphene has very high surface area and electron mobility making it an attractive material for photocatalysis and gas sensing applications [9] graphene has high quality crystal structure that shows high-mobility, ballistic conduction. Its electronic bandgap, carrier type and densities.[7]. Being a strictly two-dimensional material, all graphene atoms are exposed to the environment, which results in the highest surface area per unit volume. It is a highly conductive material exhibiting metallic conductivity and, hence, low Johnson noise even in the limit of no charge carriers, where a few extra electrons can result in notable relative changes in carrier concentration. Graphene has few crystal defects, and thus exhibits low level of 1/f noise caused by their thermal switching. A few of its properties make this material very interesting for developing gas sensors[7]

Carbonnanotube;

Carbon nanotubes (CNTs) are associates of the fullerene structural family and the ends of a nanotube may be covered. Their name is resulting from their long, hollow structure with the walls formed by graphene sheets. These sheets are rolled at specific and discrete angles, and the combination of the rolling angle and radius determines whether the individual nanotube shell is metallic or semiconducting[8]. Carbon nanotubes cylindrical carbon nanomaterial that can be classified into two types.1 single-walled CNTs (SWCNTs) and 2. Multi-walled CNTs (MWCNTs) according to the number of layers in the tube of wall. CNTs was observed in 1991 in the carbon soot of graphite electrodes during an arc discharge[7]. CNT has unique electrical properties mechanical stiffness, strength, and high thermal conductivity[10] Due to the well known and excellent properties of Nano scale materials, intensive research has been performed in various areas.

CONDUCTING POLYMER:

It is well recognized that the electrical conductivity of these conducting polymers is affected through exposure to various organic and inorganic gases. Conducting polymers that can be used as gas sensing materials include polypyrrole (PPy), polyaniline (PAni), polythiophene (PTh) and their derivatives[2] This Conducting polymers have a great importance among the researchers due to high mobility of the charge carriers and as excellent hosts for the tricking of metals and semiconducting nanoparticles.[11] Polyaniline (PANI) has been investigated as a potential material for gas sensing applications, due to its environmental stability, controllable electrical conductivity and interesting redox chemistry (or electroactivity), especially operating temperature to around at room temperature [12] Amongst the various conducting polymers, polyaniline (PANI) is a most studied polymer because of its relative ease in preparation, good environmental stability and tuneable conductivity

Tai and his team investigated NH3 gas-sensing behaviours of PANI/TiO2 Nano composite synthesized by an in-situ chemical oxidation polymerization approach, of which the sensitivity (S) and the recovery time (trec) were enhanced by the deposition of TiO2 NPs on the surface of PANI films [06].

Table gives an overall summary of materials

Mechanisms:

The surface of the semiconductor metal oxide adsorbs the gas molecules in case a sensor is exposed to a reducing gas. Adsorption of a gas molecule on the surface decreases the potential barrier by inserting electrons to the conduction band, allowing the electron to flow easily and thus reducing the electrical resistance. In this manner, the SMO gas sensors act as variable resistors whose value is a function of gas con-centration [6]. The response to reducing gases may be from reactions involving the utilization of the surface oxygen ion and replacement of the charge carrier density on the conduction band of the n type semiconductors, which is shown by reaction. The reverse development happens throughout exposure to oxidizing gases. Within the case of n-type semiconductors, the resistance of the gas sensors decreases after they are in touch with reducing gases or vapours Gas sensors for oxidizing and reducing gases are metal oxide sensors (MOS). The sensing materials is composed of one or more transition metal oxides. The detection of gasses this characteristic is based on the reaction between the material and the oxidizing or reducing gas in the atmosphere, which causes a change in electrical conductivity. Due to changes of electrical conductivity which is measured by a pair of electrodes embedded in material. The heating element is used to adjust the temperature of the sensor. The sensor should be heated to a temperature between 200 and 400 degrees Celsius to improve sensitivity and response time. Oxidizing and reducing agents are key terms used in describing the reactants in redox reactions that transfer electrons between reactants to form products.[13]

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Table 1 gives an overall summary in advantages, disadvantages and application fields for the mentioned gas sensing methods. Materials

Materials	Advantages	Disadvantages	Target gasses
Metal oxide Semiconductor	(a) Low cost; (b) Short response time; (c) Wide range of target gases; (d) Long lifetime.	Relatively low sensitivity and selectivity; (b) Sensitive to environmental factors; (c) High energy consumption. (a)	Industrial applications and civil use.
Carbon based materials	(c) Large surface- area-to-volume ratio; (d) Quick response time; (e) Low weight. (a)	a) Difficulties in fabrication and repeatability; (b) High cost.	Detection of partial discharge (PD)
Polymer	(a) High sensitivity; (b) Short response time; (c) Low cost of fabrication; (d) Simple and portable structure; (e) Low energy consumption	(a) Long-time instability; (b) Storage place of synthetic (c) Poor selectivity;	(a) Indoor air monitoring; (b) Irreversibility; products as paints, wax or fuels; (c) Workplaces like chemical industries.

Fig. Receptor and transducer functions as well as their physicochemical and material properties of metal oxide semiconductor gas sensor [06]