OPTIMIZATION OF SENSOR TEMPERATURE FOR SENSING ETHANOL GAS USING TITANIUM OXIDE FILMS

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ABSTRACT:-

For the gas sensing application, semiconducting metal oxide material such as TiO_2, ZnO, WO_3 and SnO_2 etc. play an important, steadily increasing role in almost all fields of electronics, especially their application to gas sensors demand. The principle of operation of semiconductor gas sensors is based on the interaction of a gas molecule with the surface, which produces an interchange or trapping of free carriers. This sensing mechanism implies that the surface of the material is extremely important. Titanium dioxide (TiO_2) is used in a wide range of application such as sensor devices, catalysis and dye-sensitized solar cells etc. The material properties of TiO_2 are function of the crystal structure, particle size and morphology and strongly dependent on the method of synthesis. TiO_2 exits in three main phases: anatase, brookite and rutile .In this paper titanium dioxide as a sensing element is used to detect ethanol (C_2H_5OH) gas and varying the temperature between 200-500 °C. We can optimized the temperature where sensor response is maximum at around 350 °C for sensing ethanol gas, which is comparatively sense the other gases, by this temperature variation can be achieved using a heater arrangement suspended below titanium oxide. It has wide application in MEMS based gas sensor due to its stability with temperature and high surface volume ratios and electrical response of anatase TiO_2 films. In MEMS technology the reduction of power consumption minimizes not only thermal stresses but also enable to use battery operated sensor and smart sensors.

INTRODUCTION:-

Recently, solid-state gas sensors have played an important role in environment monitoring and chemical process controlling. Among the various solid-state sensors, semiconducting metal oxide sensors have been widely investigated due to their small dimensions and low cost. One of the most simple and reliable methods to detect gases is by measuring the change in electrical conductivity induced by the adsorption of gas molecules on the surface of a semiconductor. The adsorption and desorption gas sensing mechanism of semiconductor gas sensors is resistivity change, due to the desorption of surface oxygen adsorbets via reactions with reducing such as H_2, CH_4, C_2H_5OH, CO, LPG, NH_3 and H_2S. The reducing gas react with physisorbed oxygen increasing the electronic concentration in the material, thereby decreasing the electrical resistance [1,2]. Thin film technology, in particular, is being actively applied in the development of semiconducting gas sensors devices given such that sensors depend on the gas-surface interaction. Thin films exhibit unique properties that cannot be observed in bulk materials. The properties of film strongly depend on its thickness. An extremely thin film is characterized by a high surface-to-volume ratio, and its surface phenomena and one-dimensional quantum confinement effects. Thin film gas sensors have potential advantages of fast response time and potential for miniaturization via integration with IC-based technology leading to low power consumption, high reliability, improved selectivity and reduced cost [3]. The development of thin film gas sensor based on MEMS structure is a rapidly growing area, enabling fabrication of array of sensor of elements coupled with reduced power consumption and enhanced sensitivity using micro hotplate based on thin membrane due to low thermal mass. Micro hot plate elements include functionality for measuring and controlling temperature, and measuring the electrical properties of deposited films. As these effects can be important in producing response signal, temperature controlled platform have been used in gas sensors. Among useful semiconductor metal oxides as sensing material, titanium oxide has been investigated for detection of toxic and volatile organic gases.

SENSING LAYER:-TITANIUM OXIDE

TiO_2 thin films are extensively used in many areas as a sensing material because of its chemical, electrical, and optical properties, which are mainly correlated to different crystallographic phases [5,6]. Titanium oxide (TiO_2) is an n-type semiconductor and having suitable energy band gap (~3ev), and thermodynamically favorable phase, though titanium exhibits Ti^{3+} and Ti^{2+} oxidation states. Its chemical properties are based on surface interactions with reducing or oxidizing gases, as a resulting, affect the conductivity of the film. TiO_2 films are used as the active layer and gas sensing layer dielectric capacitors, optical coating layers, photo-catalyst. TiO_2 nanostructures are normally produced from solution-phase growth methods including surfactant, sol-gel, electro spinning, and hydrothermal. TiO_2 has three polymorphs: brookite (orthorhombic), anatase and rutile both tetragonal. It was observed that sensitivity of TiO_2 sensors can be enhanced by addition of dopants such as Nb, Cr, Sn, Pt, Zn, Al, La and Y [4].
Only anatase and rutile have been observed in the thin films. In addition, amorphous TiO_2 films are often observed if the substrate temperature is low during deposition.[5] These are three different phases as well as the grain size of the TiO_2 layers can be controlled by the process parameters Consequently, TiO_2 thin films with various properties can be prepared and the demand of different applications. In sensing mechanism the operation of the sensor is based on manipulation of the electrical resistance (conductance) of the oxide materials that results from the interactions between the target molecules and the active complexes on the oxide surface [6].

OPTIMIZATION OF TEMPERATURE:-

Titanium Oxide synthesized in thin film and the typical response curve for thin film, showing their response to ethanol (C_2H_5OH) gas when operated in the range of 200°C-500°C, and is maximum at around 350°C for sensing, which is comparatively sense the other gases shown in Fig-1. Various literature surveys have been carried out to get the optimized sensing temperature and approximate curve has been plotted. This graph shows the response of this gas at various temperatures and is based on the published literature. In general the sensitivity of sensors is affected by the operating temperature. The higher temperature enhances surfaces reactions of the thin films and gives higher sensitivity in a particular temperature range. The undoped films shows a good response in the range of 200°C-500°C and maximum response also obtained at particular temperature range. The optimized temperature can be lowered down by using doping material such as Pd, Pt, Ag etc addition of doping reduces the activation energy hence low temperature is required.

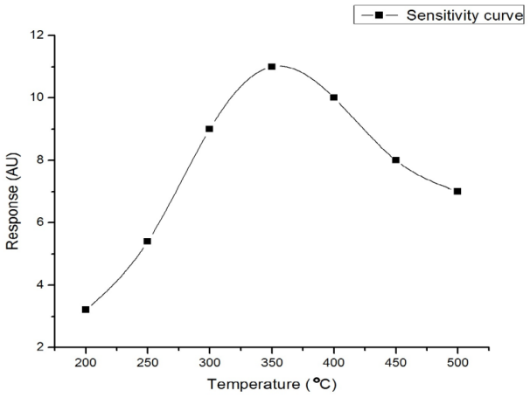

Fig.1 Titanium oxide thin film response for ethanol gas.

With the reference from this data the optimized temperature range for the sensing of ethanol gas is found to be sensitive but the maximum sensitivity is around 350°C. Beyond this temperature value the sensitivity decreases and the performance decreases.

CONCLUSION:-

MEMS based gas sensor with TiO_2 sensing layer has been studied and it has been observed that increasing the operating temperature increase the sensitivity of the gas sensors and make the rapid response for the gases raising the temperature beyond the optimized temperature. The sensitivity starts to decrease. It has been also observed that the phase of the material also determined the operating temperature of the sensor.

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