Category: 'MEMS and Sensors

Optimization of MEMS based Gas Sensor Temperature for Sensing CO Gas using TiO_2 Film as a Sensing Material

T. Mudgal[1], A. Rani, M. Dwivedi, T. Dadhich, A. Balraj, V. Prakash, A.K. Sharma, J. Bhargava and G. Eranna[2]

Sensor and Nanotechnology Group
Central Electronics Engineering Research Institute (CEERI)
Council of Scientific and Industrial Research (CSIR)
Pilani -333031, Rajasthan, India
E-mail:-[1] traptimudgal@yahoo.com, [2]eranna@ceeri.ernet.in

***Abstract*--The miniaturization of gas sensors and the compatibility of their fabrication process with modern microelectronics technology are very important aspects for the development of gas sensing devices. The development of thin film gas sensor based on MEMS structure is a rapidly growing area, enabling fabrication of arrays of sensor elements coupled with reduced power consumption and enhanced sensitivity using microhotplates based on thin membranes (3-5 μm) due to low thermal mass. Thin film metal oxide materials, such as TiO_2, are preferred as gas sensing material due to certain advantages it offers. Utilization of these sensors requires higher temperature for their operation. In this paper titanium oxide is being used as a sensing element to detect carbon monoxide (CO) and selecting best operating temperature between 200 °C and 500 °C. It is observed that the sensor response is found to be highest at around 350 °C for sensing CO gas. The gas interact with the titanium oxide thin film and alter the conductivity of the surface. The change in conductivity is proportional to the concentration of gas under test. Suspended platform arrangement is fabricated by MEMS surface micromachining technique. In MEMS technology the reduction of power consumption minimizes not only thermal stresses but also enable to use battery operated sensor and smart sensors.**

***Index Terms*: - MEMS, Gas sensor, Micro hotplate, Titanium Oxide, CO gas.**

I. INTRODUCTION

The development of gas sensor devices with optimized selectivity and sensitivity has been achieving prominence in recent years. Because of their simplicity and low cost, semiconductor metal oxide gas sensors stand out among the other types of sensors. Nanostructure materials present new opportunities for enhancing the properties and performance of gas sensors because of the much higher surface-to-volume ratio compared to coarse grained materials. Sensitivity in these types of sensors is generally enhanced either by appropriate doping of an element that modifies the carrier concentration values or charge mobility or by micro structural changes such as reduction of the oxide particle grain size [1]. The effects of the thin film micro-structure, namely, ratio of surface to volume ratio, grain-size, and pore-size of the oxide, as well as film thickness play an important role in deciding the sensing behavior. The sensor detects a change in the gas atmosphere due to a change in the electrical properties of the sensing element. It was observed from the literature that gas sensing process involves surface adsorption and chemical reactions is analogous to catalytic reaction of the metal oxide gas sensing device, as both process involve surface adsorption and chemical reaction with the surrounding gas environment. Gas sensing process involves the interaction of O^-, O^{2-}, H^+ and OH^- and gaseous molecules to be detected. The electrical characteristic classifies the sensitivity of the sensing device [2].

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. For the fabrication of smaller device platforms have been to attain low power consumption when employing temperature control [3,4]. Among useful semiconducting metal oxides as sensing material, titanium oxide has been investigated for detection of toxic and inflammable gases such as NH_3, NO_2, H_2, CO. Here our consideration is focused on the detection of carbon monoxide (CO). CO gas is one of the most dangerous gases and is formed whenever incomplete combustion of carbonaceous products occurs.

2 TITANIUM OXIDE AS GAS SENSING LAYER

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, electrospinning, and hydrothermal methods. TiO_2 has three polymorphs: brookite (orthorhombic), anatase and rutile both tetragonal. It was oberserved that sensitivity of TiO_2 sensors can be enhanced by addition of dopants such as Nb, Cr, Sn, Pt, Zn, Al, La and Y [7].

3 TEMPERATURE OPTIMIZATION OF GAS SENSING LAYER

The Literature survey was carried out for the optimization of the sensing temperature and the approximation for specific species of gases were derived and plotted. It was found that the thin film of titanium oxide have good response range in between 200°C-500°C for CO gas detection as shown in Fig.-1. If the thin film of titanium oxide its doped with Pt, Ag, etc nanoparticles, the activation energy of thin film is reduced and the reduces the operating temperature in gas sensing. The experimental considerations are the minimum energy required by the sensing layer to sense the gas. This activation energy is obtained either by doping the material or by heating the material. Hence low temperature is suitable for impure thin films as the activation energy decrease with the impurity concentration and high temperature is required to attain the activation energy in pure thin film of TiO_2.

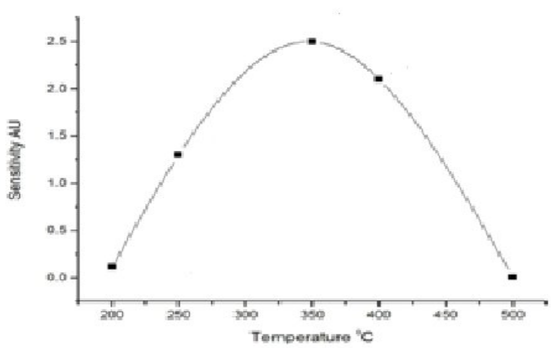

Fig.-1: Titanium oxide thin film response to CO gaseous species. Data from Ref [9-12].

4 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. TiO_2 has been studied as a CO gas sensor, which works at high temperature (>400°C).

5 ACKNOWLEDGEMENT

The authors would like to thank DIT, New Delhi, for project sponsorship and Director CSIR-CEERI Pilani for the support.

6. REFERENCES

1. G. Eranna, B. C. Joshi, D. P. Runthala, and R. P. Gupta, *Critical Review in Solid state and Materials Sciences* **29**, 111(2004).
2. S. V. Manorma, N. Izu, W. Shin, I. Matsubara, and N. Murayama, *Sens. Actuators,B* **89**, 299 (2003), and the references therein.
3. S. Semancik, R. E. Cavicchi, M. C. Whecler, J.E Tiffany, G. E. Poirier, R.M. Walton, J. S. Suehle, B. Panchapakisan, and D. L. Devoe, *Sens.Actuators, B* **77**,579-591 (2001).
4. M. Madon, Fundamentals of Microfabrication, CRC Press, Bocaraton, Fl, 1997.
5. A. Fujishima and K. Honda, Electrochemical Photolysis of water at a semiconductor electrode, Nature **238**, 37-38(1972).
6. Suman Pokhrel, Lihua Huo, Huizhuao, Shan Guo, *Sens.Actuators B*-**129**, 18-23 (2003).
7. Young Jinchoi, Zachary Seeley, Amit Bandhyopdhyay, Susmita Bose, Sheikh A. Akbar, *Sens & Actuators B*-**124**, 111-117 (2007).
8. Dr. Adawiya. J. Haider, Raad M. S. Al-Haddad, June (2010).
9. Youn-Ki, Hyun-Su Kim, Jong-heyn Lee, and Seong-hyeon Hong,*Sens & Actuators B*-**120**,69-73 (2006).
10. G. N. Chaudhari, A. M. Bodade, S.S. Patil, and V. S. Sapkal, *Sens.& Actuators B*-**115**,297-302 (2006).
11. E. Comini, V. Guidi, C. Frigeri, and G. Sberveglieri, *Sens & Actuators B*-**72**,16-21 (2001).
12. G. Sarala Devi, Takeo Hyodo, Yasuhiro Shimizu, Makoho Egashira, *Sens & Actuators B*-**87**, 122-129 (2002).
13. M.-H. Seo, M. Yuasa, T. Kida, J.-S. Huh, K. Shimanoe, and N. Yamazoe, *Sens. & Actuators B*-**137**,513-520 (2009).
14. A.M. Ruiz, A. Cornet, and J.R. Morante, *Sens. & Actuators B*-**100**,256-260 (2004).