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Nanostructured ZnO thin film based CO_2 sensor by RF sputtering technique

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Abstract
In this research we aim at developing a CO_2 sensor by depositing nanostructured ZnO over Au/Ti interdigitated electrodes using RF sputtering technique. Sensor is being developed, keeping in mind the hazards caused by sudden increase of CO_2 in mines, areas of volcanic activities, industries, spots of gas leakages, highly polluted cities around the world, etc. CO_2 being odourless and colourless cannot be easily sensed or detected by organisms until adverse effects in health condition such as suffocation, loss of conscious, uneasiness, etc. are observed. Latest researches in medical field also shows that few diseases can be detected by monitoring the amount of CO_2 exhaled during respiration. The deposited thin film was characterised for its structural, topographical and morphological studies. All the experiments carried out to detect the gas were performed at room temperature and under ambient conditions, with atmospheric air as carrier gas in order to detect only the increased amount of CO_2.

Sensor, Carbon-dioxide, Sputtering, Thin film, ZnO, Interdigitated electrode

1. Introduction

Carbon Dioxide (CO_2) is a well-known and commonly found gas in the atmosphere and also found dissolved in water bodies. Estimation of concentration of CO_2 along with few other gases is very important in wide variety of applications including industrial, environmental, clinical analysis, automobiles, etc. [1], [2], [3], [4], [5], [6], [7]. Carbon dioxide is a colorless and odorless gas, which is not harmful in lower or natural concentration in air (~404 ppm/~0.04% as per Earth System Research Laboratory, Hawaii, USA). But, for blackdamp, a gas mixture containing 5-20% CO_2, in enclosed spaces such as mines, sewers, wells, tunnels, industrial workspaces and ships (submarines) is required by safety regulations. Volcanic gases typically contain 10-40% of CO_2. Monitoring the variations in CO_2 levels in the gas mixtures released from dormant craters, hot springs, and seafloor "smoking chimneys" may help capture the early signs of a volcano, earthquake, or tsunami. Apart from these there have been many reported causalities due to sudden increase in amount of CO2 due to volcanic eruptions, accidental gas leakages, mine hazards, etc. To avoid the causalities in such occurrences a gas sensor can be made use of, to make people aware in order to evacuate the affected region. Available sensors are bulky, inflexible and less sensitive. So, we tried to develop a flexible and cheap ZnO thin film sensor that can be installed on skin or fabric and has fast response rate.

2. Experimental Procedure

Development of sensor started with selection of materials for substrate, electrodes, sensing film, etc. With the help of literature review and past experiences, PET for substrate, Au/Ti for electrodes and ZnO for sensing film was decided. Initially a parallel electrode type sensor was fabricated using the decided material, but due to its unstable and poor response the design was changed to indigitated type as it offered more surface area for sensing for very small electrode gap. The interdigitated electrode was made by ECR sputtering technique by using a photolithographic printed mask whereas a RF sputtering technique was used for deposition of ZnO sensing film. After the deposition of electrodes and thin film in a batch fabrication type of process, the sensor was tested for detecting excessively diffused CO_2 inside a gas chamber under ambient conditions. A DC potential of 5V was applied across the circuit which involved the fabricated sensor connected to a digital multimeter. Laser microscopy, XRD spectra and FESEM were used for structural, topographical and morphological analysis of thin film. Following image shows the laser microscopic image of our sensor with batch fabrication type method on top right corner.

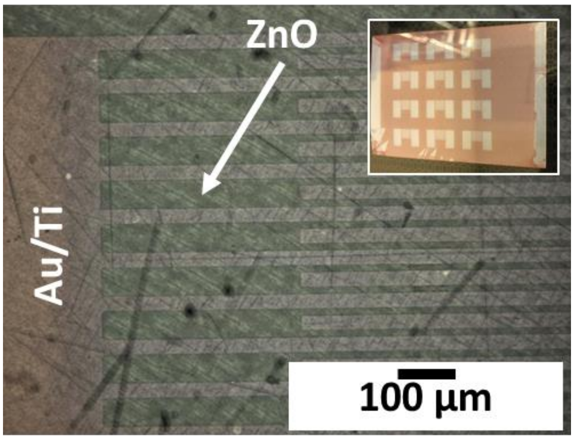

Figure 1: Laser microscope image of ZnO thin film on interdigitated electrode. Inset shows the batch of sensors prepared at the same time

3. Results

X-Ray Photoelectron Spectroscopy (XPS) showed that the formation of ZnO took place in its pure and fully oxidized state. No impurity was detected in any of the batch fabricated set of sensors. Also, the Field Emission Scanning Electron Microscope (FE-SEM) showed that the deposition of ZnO was uniformly deposited throughout with tiny spherical grains and no defects or cracks were present on the thin film. Apart from analysis of thin film, analysis of the sensing properties also showed a positive result. The sensor was able to detect the excessive amount CO_2 instantly and showed a decrease in resistance based on the amount of CO_2 injected. The sensor was also able to detect continuous diffusion of CO_2 in and out the chamber. Following figure shows graph of sensor`s resistance plotted against time. There are three arbitrariry chosen concentrations for intial testing purpose. Gas was transferred to tetra bag and then diffused in gas chamber. But exact quantity of gas inserted to resistance study is in progress.

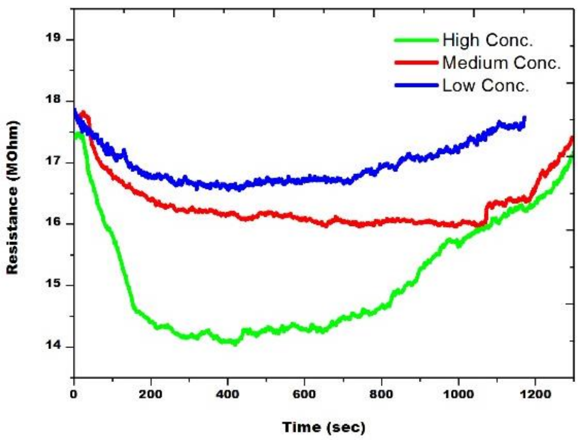

Figure 2: Graph showing resistance change of sensor with amount of introduced CO_2 gas

4. Summary and Conclusion

From the result it can be observed that the fabricated sensor can be used to detect the excessive CO2 caused due to some leakage or hazard instantly. Also due to batch fabrication it is cheap, easy to install on skin and fabric so can be economically and conveniently used by the target users. Sensitivity calculation of the sensors are being carried out, so that amount of CO2 can be also know along with its presence. As ZnO can sense other toxic gases like NH3, acetone, formaldehyde, ethanol vapours, etc. sensor can also be made use to detect these harmful gases with some modifications in the thin film.

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