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Role of Hetero Junction as Gas Sensor

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ABSTRACT

In the modern industry, it has become more important to measure compositions of gas mixtures. Due to this requirement, the need of gas sensing systems with lower price and good quality has increased. These gas sensing systems are able to detect the inorganic gases and volatile organic compounds.

Semiconductor gas sensors are becoming so important in this area. It is also observed that from the past few years the performance of sensing the gases with the help of these kinds of systems has been increased significantly. With the passage of time and increase in the technology level, the sensitivity and stability of these sensors have enhanced rapidly. The current article highlights the role of hetero-junctions as sensors. The proposed hetero-junctions are made from several n-type semiconductor metal oxides.

KEYWORDS:

Semiconductor, Metal, Oxide, Gas, Sensor, Performance, Sensitivity

INTRODUCTION

In some of the cases, it is found that the sensitivity of these sensors tends to be lower. To minimize this kind of problem, multi-layer structures are investigated. The main usage of the additional layers is for active or passive filters to enhance the quality of the sensors.

These filers are placed over the sensing layer so as to reduce the impact of cross selectivity by securing against unnecessary compounds that can influence the response of sensor. In some cases, it is observed that an interface is used between two single-phase metal oxide semiconductors so as to enhance the performance of sensors.

The metals like Zinc, Aluminium etc. are used to form layers and works as simple resistors in conventional semiconductor gas sensors and their resistance is based on the proposition of ambient environment. Surface and volume of the gas sensing layer play an important role in changing the conductance of the system.

Other changes; found at the interface of electrode and gas sensor ; play a secondary role in this kind of mechanism. The sensor response carries the information about the interaction of destination gas molecules in hetero-junctions.

In the current study, the behavior of the prepared hetero-junction gas sensors was investigated.

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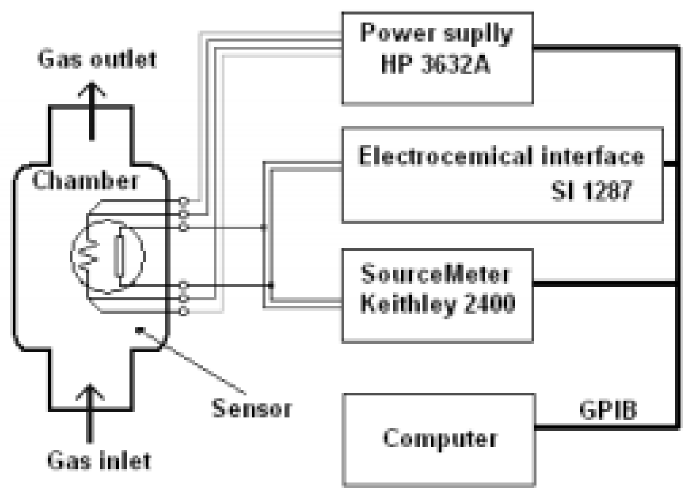

Fig. 2. Sensor test setup.

Temperature stimulated conductance (TSC) was used to measure the performance of the sensors. The above diagram shows the sensor test setup. Chamber were built to keep sensors. It was observed that a composition of clean air and isopropyl alcohol was used to measure atmospheres.

HP 3632A power supply was used to measure the measurements of TSC which was further used in controlling the temperature of the sensor heater. The temperature of hetero-junctions was varied from 250 to 700^{0}C. Bias voltages in several directions were polarized with the structures so as to investigate the impact of polarization voltage.

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METHODOLOGY

A thick film was built over the alumina substrate to prepare the hetero junction gas sensors. The integrated heater and the sensing structure were deposited on the opposite sides of the substrate. Gold and Platinum plates were used for the materials of electrode and heater.

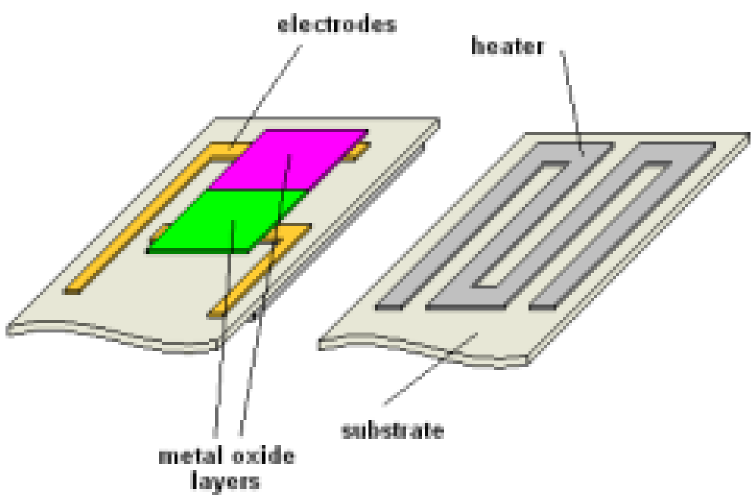

Fig. 1. Schematic view of the hetero junction gas sensor with the integrated heater

The powder of metal oxide and an organic binder were used to form a paste of thick films. Modified Okazaky method was used to prepare the SnO_2. $Zn(NO_3)_2$ precursor was used to obtain the ZnO powder. Silicotungstic acid ($H_6[Si(W_2O_7)_6] \cdot nH_2O$) was decomposed to get Wo_3 when it was heated for about 5 hours at a temperature of 650 degree.

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The powders of metal oxides and a paste of gold were mixed together to perform the doping process resulting in producing a composition of 0.8% wt gold. At last, the obtained thick film pastes for the structure of hetero-junction were printed at the electrodes and heated at 850^0c for about 2 hours.

RESULTS AND DISCUSSION

To identify the optimal working temperature for the detection of isopropyl alcohol, the characterization of the structures was started with the TSC method. The obtained characteristics of conductance as a function of the heater temperature changes (G=f(T)) were used to calculate the sensitivity of the sensors for the presence of isopropyl alcohol. This parameter is defined by the equation (1) as a ratio of the sensor conductance measured in the atmosphere of isopropyl alcohol to the conductance measured in the reference atmosphere:

$$S = \frac{G_{gas}(T)}{G_{air}(T)} \quad (1)$$

The achieved S=f(T) characteristics for the three samples exhibit several maxima in the investigated range of temperatures. As is shown in figure

3, the maximum sensitivity to isopropyl alcohol and the temperature T_{opt} at which the maximum is located depend on the polarization direction of the structures.

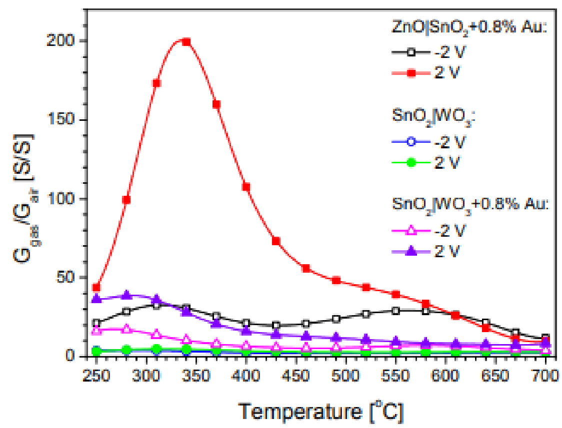

Fig. 3. Temperature dependence of sensor sensitivity to the presence of 200 ppm isopropyl alcohol in target atmosphere plotted for different polarization directions.

The influence of the voltage polarization on the sensing performance was investigated using cyclic voltammetry. The obtained currentvoltage (I-V) curves (fig. 4a,b,c) shows, that sensors behave like a Schottky diode. The current density flowing through the structure depend on the polarization direction. Such relation explain the different sensitivity level obtained from TSC.

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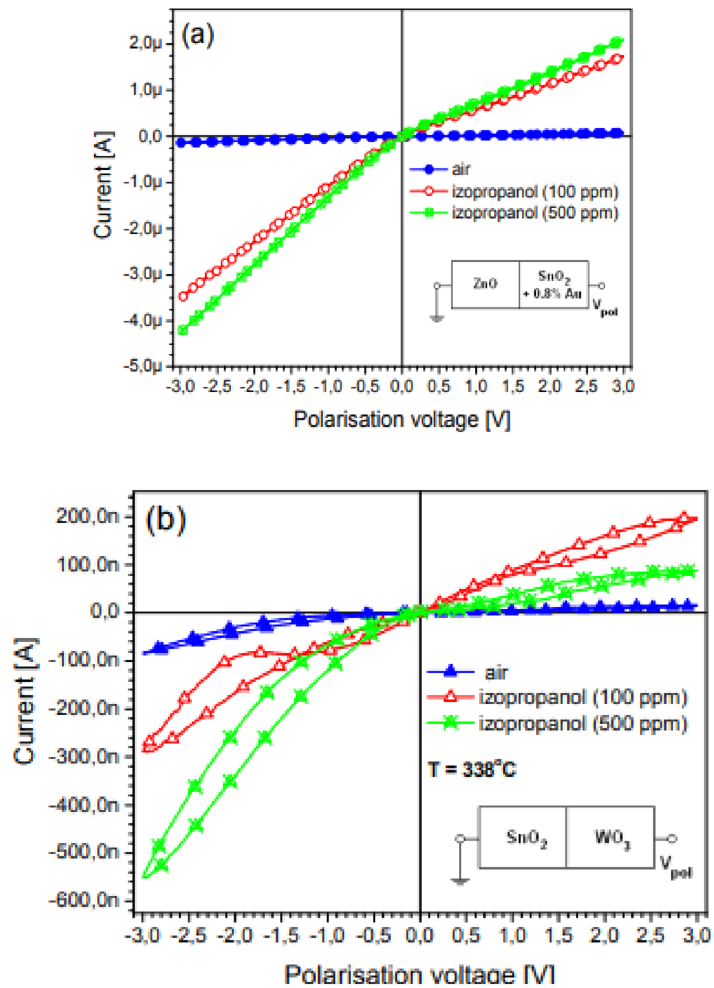

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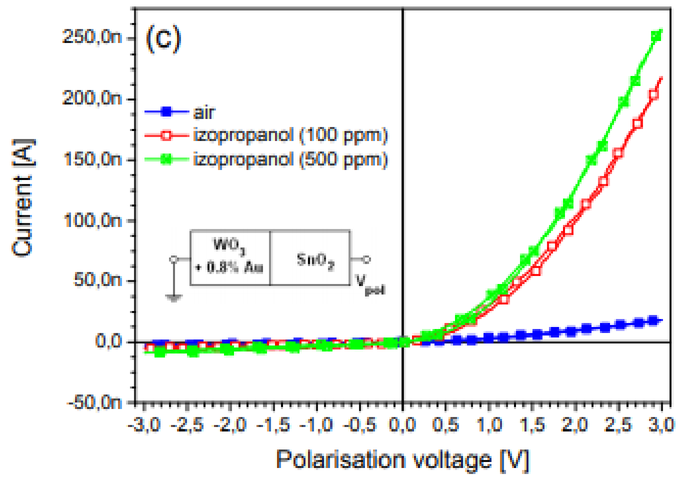

Fig. 4. Current-voltage characteristics measured in clean air and isopropyl alcohol by using the following structures: a) ZnO|SnO_2+0.8 wt. % Au, b) SnO_2|WO_3, c) SnO_2|WO_3+0.8 wt. % Au.

Based on the achieved results, authors plot the relationship of the sensor conductance to the concentration of isopropyl alcohol at temperatures were the local sensitivity maxima was found (fig. 5a,b,c). In logarithmic scale the relation between those factors is linear, like in a conventional single layer semiconductor gas sensor and can be described by equation (2)

$$G = G_0 p_{gas}^n \quad (2)$$

where G is the measured conductance, p_{gas} is the partial pressure of the target gas, G0 and n are experimentally determined values, which are calculated by fitting the measured points with a linear equation (3)

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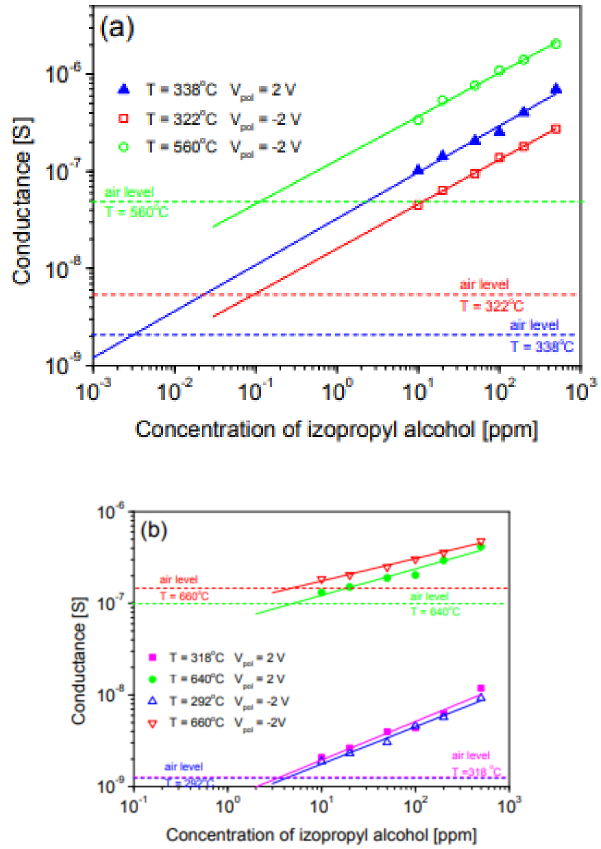
$$\log G = \log G_0 + n \log p_{gas} \qquad (3)$$



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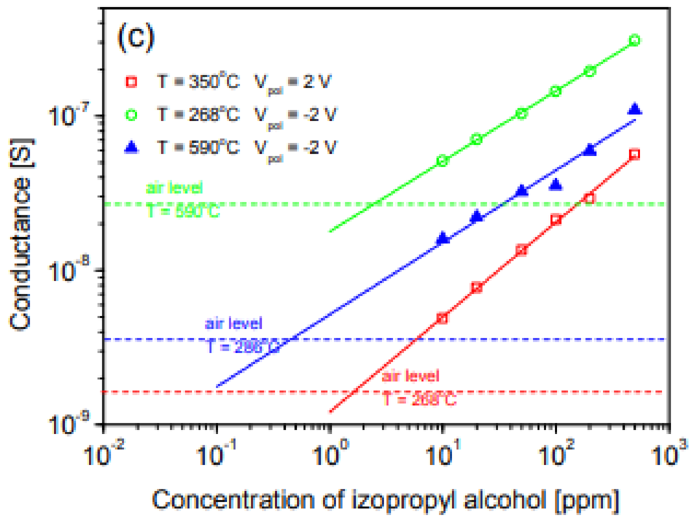

Fig. 5. Dependence of sensing structure conductance versus partial pressure of isopropyl alcohol: a) ZnO|SnO_2+0.8 Au, b) SnO_2|WO_3, c) SnO_2|WO_3+0.8 Au.

CONCLUSIONS

The sensing properties of thick film ZnO|SnO_2+0.8 wt. % Au, SnO_2|WO_3 and SnO_2|WO_3+0.8 wt. % Au hetero contact gas sensors were investigated. The response of the devices to the presence of isopropyl alcohol has been shown. The obtained current-voltage characteristics show rectifier properties for all three hetero junctions.

The highest sensitivity of about 200 was achieved by the ZnO|SnO_2+0.8 wt. % Au which work at a polarization voltage of 2 V and a temperature of 338°C. Its lower detection limit was estimated to be at about 3 ppb. The rectifying properties of such hetero junction gas sensors give a an additional degree of freedom for the manipulation of sensor parameters.

By combination of changes in polarization voltage with heater temperature modulation it is possible to control the sensor sensitivity and selectivity.

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