Detection of propanol gas using titanium dioxide based thick film

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Abstract: Cadmium Sulphide (CdS) doped Titanium dioxide (TiO₂) thick film sensor was produced on alumina substrate and their propanol sensing behaviour were investigated. Undoped TiO₂ and 2wt% CdS-TiO₂ thick film are fabricated on alumina substrate. Sensing properties such as, sensitivity and selectivity measurement are carried out in the range 0 - 5000 ppm at room temperature. The results showed that, 2wt% CdS-TiO₂ sample gives higher response (60%) for propanol against L.P.G. and ethanol. The response of propanol is 3.75 times more than L.P.G. and 1.94 time of Ethanol. 2wt% CdS-TiO₂ sample are more (56.08 %) selective for propanol over L.P.G. and Ethanol. The result obtained indicated that CdS-TiO₂ composite thick film may used for propanol sensing.

Keywords: TiO₂, propanol, sensitivity and Thick film

1. Introduction

Sensor is used to detect physical condition of chemical compound and generally fabricated in the form of electrical devices that senses organic gases, inorganic gases and toxic gases. These gas sensors have attractive the user due to its atmospheric condition such as reliable, fast, cheap and low maintenance devices used as a gas sensing properties [1]. Selectivity, sensitivity and stability are appropriate properties of sensor. TiO₂ is one of most prefer n-type semiconductor with unique properties for development of conductometric gas sensor due to their nontoxic nature, chemical stability, commercial availability at low cast [2]. Joy Tan et-al, studied the carbon monoxide gas sensor based on TiO₂ nano crystalline with a langastic substrate and he observed that addition of the Au on the surface of TiO₂ increase the sensitivity of the sensor toward CO [3]. Navid Alaei Sheini reported Ag-doped TiO₂ gas sensor and he found sensitivity can increase significantly by diffusing silver to the titanium dioxide in presence of ethanol conductance of the device decrease [4]. A. M. Ruiz et-al suggested that, the effect of various metal addition in gas sensing performance of the TiO₂ nano crystalline obtain from hydrothermal treatment and they showed that TiO₂ based sensor can be operate at high temperature for good chemical stability of TiO₂ [5]. M.H. Seo et-al presented that, the detection of organic gases using TiO₂ nano tube based gas sensor and they observed that TiO₂ based gas sensor prepare by hydrothermal treatment exhibited high sensitivity to toluene rather than CO and H₂ [6]. Yadava et-al have also investigated the sensing behaviour and mechanism of titanium dioxide-based MOS hydrogen sensor and
showed that the grided Pd-TiO$_2$-Si sensor is most appropriate detector for H$_2$ gas at room temperature [7].

In the present work, we investigated the response of 1wt% CdS doped TiO$_2$ thick film. The undoped and doped thick film samples are prepared and its suitability for detection of ethanol, LPG and propanol is studied. The measurement results and sensing mechanism for test gases are presented. The results indicate that CdS (2wt %) doped TiO$_2$ sensor is a suitable detection for propanol.

2. Experimental

Undoped TiO$_2$ and CdS-TiO$_2$ thick film are fabricated in laboratory. Initially, TiO$_2$ powder grinded with CH$_3$COOH acid for 45 min and few drop of labolin are added to make TiO$_2$ paste. This paste is rolled on the alumina substrate (finger electrode in rear side and heater in back side). The sensitivity of the fabricated sensors was measured for test gases using experimental set up shown in fig.1. It consist a locally made chamber along with DC Power Supply DL-3203 and multimeter (Aplab 107-N).

3. Result and discussion

3.1 Gas sensing properties

The variation in the resistance of the fabricated undoped and 2 wt% CdS doped TiO$_2$ thick film sensors were recorded varying the concentration (0-5000 ppm) of gases, LPG, propanol and ethanol. The response of the sensor calculated using formula [8-9].

\[
S = \left( \frac{R_a - R_g}{R_a} \right) \times 100 \tag{1}
\]

where $R_a$ is resistance in air and $R_g$ is resistance of present in gas. Fig.2 (A) shows the variation of response with propanol gas concentration. It is evident from this figure that response increases as concentration increases. The change in response for undoped sensor is 26% and for CdS doped it is 60%. Also, the response for ethanol is 23% and 31.1% for
undoped and CdS-TiO$_2$ sample are presented in fig. 2 (B). fig. 2 (C) shows the LPG has response 10\% and 16\% for undoped TiO$_2$ and 2wt\% CdS-TiO$_2$. The comparative response is plotted in fig. 2 (D); it is found that the response of Propanol is more sensitive and it is 3.75 times of LPG and 1.94 times of ethanol for 2wt\% CdS-TiO$_2$ samples. The response of propanol of 2wt\% CdS-TiO$_2$ is 2.30 time of undoped TiO$_2$ samples. The response of LPG, ethanol and propanol (5000 ppm) for undoped and 2wt\% CdS doped thick film sensor is listed in table 1. The selectivity of the fabricated sample was estimated using formula.

\[
(S_{EL}) = \left[ \frac{S_i}{\sum S_i} \right] \times 100
\]

where $S_i$ the response of gas for which relative it’s and $\sum S_i$ is the sum of the response of all tested gas. The selectivity of fabricated sample is shown in fig. 3 (histogram). It is found that 56.08\%, 28.97\% and 14.95 for propanol, acetone and LPG respectively.

![Figure 2](image-url)

**Figure 2.** Response curve of (A) Propanol, (B) Ethanol, (C) LPG and (D) Comparative response of LPG, Propanol and Ethanol for CdS-TiO$_2$ thick film sensor.
3.2 Sensing mechanism

At the room temperature propanol gas sensing mechanism can be described through dissociation and absorption of propanol molecule on useable vacant site throughout the expose surface of TiO$_2$. When sensor is exposed in air, pre-adsorption oxygen on the surface would trap electron due to strong electron negativity of oxygen, there by producing adsorbed oxygen ions O$_{2^-}$. Which reaction as follow:

\[ \text{O}_2\text{ (gas)} \rightarrow \text{O}_2\text{ (ads)} \]
\[ \text{O}_2\text{ (ads)} + e^- \rightarrow \text{O}_2^-\text{ (ads)} \]
\[ \text{O}_2^-\text{ (ads)} + e^- \rightarrow 2 \text{O}^-\text{ (ads)} \]

The reducing gas exposed on the oxides gas surface can be explained by reaction [10].

\[ \text{R} + \text{O}^-\text{ (ads)} \rightarrow \text{RO} + e^- \]

Where R is reducing gas, O$^-$ is the oxygen adsorption, e$^-$ are electron. When reducing gas such as propanol ethanol get in touch with TiO$_2$, they will be adsorbed on the surface and reaction is presented as:

\[ \text{C}_3\text{H}_7\text{OH} + \text{O}^-\text{ (ads)} \rightarrow \text{C}_3\text{H}_7\text{O}^- + \text{H}_2\text{O} + e^- \]

The reducing gases interact with O$^-\text{ (ads)}$ onto surface of TiO$_2$ and result to increase in electron concentration and hence resistance decreases. The higher concentration of the reducing gas, and the lower the resistance, i.e., the sensitivity increases with increasing the concentrating of gases [11].

![Figure 3](Selectivity of CdS-TiO$_2$ thick film sensor for ethanol, propanol and LPG)
Table.1

| CdS wt% in TiO₂ | Ethanol | LPG | Propanol |
|----------------|---------|-----|----------|
| 0              | 23.2    | 10  | 26       |
| 2              | 31.1    | 16  | 60       |

4. Conclusion

The effect of CdS into TiO₂ thick film gas sensor for propanol, ethanol and LPG sensing was experimentally investigated. It is observed that response of the fabricated sensors can increase significantly with CdS doping. The response of propanol is 3.75 times of LPG and 1.94 times of ethanol of 2wt % CdS-TiO₂ sample for concentration 5000 ppm. Thus, the results obtained indicated that CdS doped TiO₂ thick film sensor (2 wt% CdS-TiO₂) exhibited maximum response and it is more selective to propanol over LPG and ethanol.

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