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Ultra-sensitive detection of H_2S with 2D ZnO nanostructures

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Abstract.
Detection of hazardous gases in the environment with excellent sensitivity is needed owing to their adverse effects on human health. Here, we report a 2D ZnO nanostructures based highly sensitive Hydrogen Sulfide (H_2S) gas sensor. It exhibited a response of 700% with a response time of a few minutes upon exposure of 4 ppm H_2S.

Keywords
Gas sensor, H_2S sensor, ZnO nanostructures

Introduction

The toxic gases released by industries and other sources have a significant impact on humans and other life on the earth [1-4]. H_2S is a poisonous gas, and as per the American Conference of Government Industrial Hygienists, its acceptable limit in the air is 10 ppm [5-7]. When the concentration exceeds 10 ppm, the human nose loses the ability to detect H_2S, which causes disastrous effects. Thus, the detection H_2S in the environment with good sensitivity is critical to save the lives. However, the low sensitivity of the existing sensors limits their usage in detecting toxic gases in the air. To address this, we report a highly sensitive Hydrogen Sulfide (H_2S) sensor with 2D ZnO.

Materials and Methods

The protocol for device fabrication and sensing experiments were explained in our previous reports [8,9].

Results and Discussion

The sensor was tested with the exposure of 500 ppb to 4 ppm H_2S, and it exhibited a response of ~700% upon exposure of 4 ppm H_2S at 250 ^{0}C. The response time varies between 162 to 256 s, whereas recovery time varies between 115 to 429 s. The principle of sensing can be explained using the ionosorption principle [10]. The interaction of gases with ZnO involves two steps.

(1) Ambient oxygen molecules adsorbed on n-type ZnO surface (Eq. (1) and Eq. (2)) immobilize the surface electrons of ZnO and subsequently, forms a thick space-charge layer and result in higher potential barrier (Figure 1(a)) [11]. Therefore, the sensor resistance increases as this process removes the free electrons from the conduction band of ZnO.

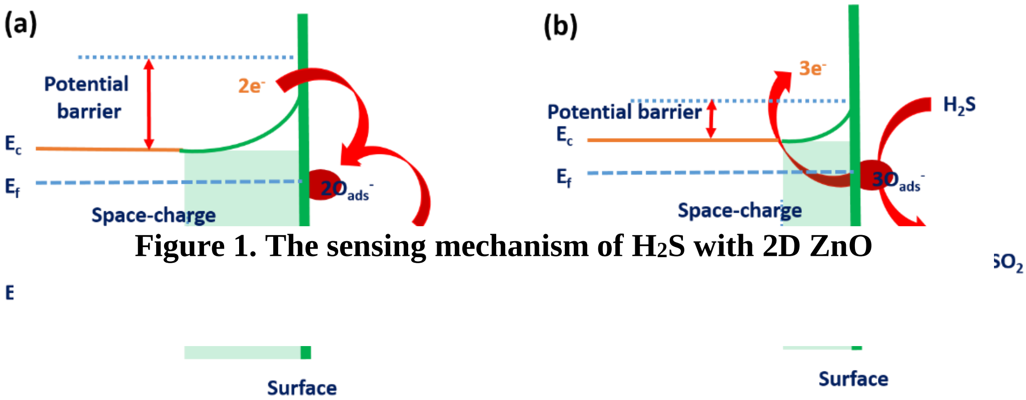

Figure 1. The sensing mechanism of H_2S with 2D ZnO

$$O_{2\,(gas)} \leftrightarrow O_{2\,(ads)} \qquad (1)$$

$$O_{2\,(ads)} + 2e^- \rightarrow 2O^-_{(ads)} \qquad (2)$$

(2) H_2S interacts with the adsorbed and releases the electrons to ZnO as shown with eq. (3) (Figure 1(b)). It results in a thin space charge layer and lower potential barrier, and thus, the sensor resistance decreases. [12].

$$H_2S + 3O^-_{(ads)} \rightarrow H_2O + SO_2 + 3e^- \quad (3)$$

Conclusions

In summary, an H_2S sensor is implemented with 2D ZnO nanostructures. Upon exposure of 4 ppm H_2S, the device exhibited a sensitivity of 700% with a response time of a few minutes.

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