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Ni-doped ZnO sensors for highly selective detection of acetone

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Abstract

In this research, gas sensing performance of Ni-doped ZnO sensors were measured for detection of 300 ppm ethanol, CO and acetone in the temperature range from 200 to 400°C. Ni-doped and single phase hexagonal ZnO plates have been synthesized by a low temperature hydrothermal method using D-ribose as a template. The response of Ni-doped ZnO sensors to acetone has been greatly improved in comparison with the response of pure ZnO and the optimal doping concentration was 5 mol% (mole ratio of Ni to Zn is 0.05). 1 and 5 mol% Ni-doped ZnO sensors showed remarkably higher sensing response to acetone compared to other gasses, making them highly selective to acetone. The highest response of 230 to 300 ppm acetone at 300°C was obtained for a doping concentration of 5 mol% Ni in ZnO. Sensitivity of pure ZnO to CO was effectively decreased by increasing the concentration of Ni.

Key words: Semiconductor Sensor, Zinc oxide, Ni-doping, Selective, Acetone

Introduction

Acetone is one of the hazardous gases that is widely used in industry and can harm human health and safety. Given the development of industry and increasing use of acetone, research on selective and rapid detection of acetone by gas sensors has attracted attention [1].

Recently, advantageous features of zinc oxide have made it one of the most important semi-conducting materials used for different technological applications, including sensors [2]. In addition, doping modification with various metallic elements, for example transition metal has been proven to be an effective strategy to enhance the sensing properties of metal oxide semiconductor gas sensors, improving thermal stability, reliability and selectivity of them [3].

For instance, Niu et. Al reported that using Fe, Co, and Cr as dopants improves the gas sensing property of undoped ZnO. Darvishnejad et. Al found that Ni and Mn doped ZnO sensors exhibitedenhanced response to 300 ppm acetone at a temperature of 300°C and were selective to acetone [4].

In this study, we present a high performance of Ni-doped ZnO sensor for detection of acetone.

Experimental

Ni-doped ZnO sensors were synthesized by a simple hydrothermal method. The mixture of 5 mmol $Zn(Ac)_2 \cdot 2H_2O$ and 10 mmol ribose which were dissolved in 50 ml distilled water was stirred for 30 min at room temperature. Then 0, 0.05, 0.25, 0.5 mmol of Ni acetate were added to solution, respectively. After being stirred for another 30 min 10mmol NaOH was added to solution and obtained solution was transferred to a Teflon lined autoclave, and sealed and heated up to 90 °C for 2 h. The prepared powders were rinsed several times serially with deionized water and dried at room temperature. In order to investigate gas sensor properties, the sensors were sintered at 400°C for 4h, and then located in a quartz reactor in a furnace. The electrical resistance of the sensors was measured in air and in test gases (ethanol, CO and acetone) in the temperature range from

200°C to 400°C.The sensor response (S) is expressed as the ratio of the electrical resistance of the sensing material in air (Ra) to that in the target gas (Rg).

Results and Discussion

Figure 1 shows the response of Ni-doped ZnO sensors to 300 ppm acetone in the temperature range of 200-400. According to the figure 1, sensor response to acetone improves with the increase of Ni doping percentage, reaches a maximum value, at 5 mol %, and then falls with further increase in doping percentage. In contrast, the sensor responce to CO continuously decreases with the increase of doping percentage (Fig. 2). The effect of Ni doping in ZnO on the selectivity of the sensors are observed in Fig. 3 (a, b). As shown in Fig. 3, the sensor with 5 mol % Ni doped ZnO is much more selective toward acetone compared to undoped ZnO.

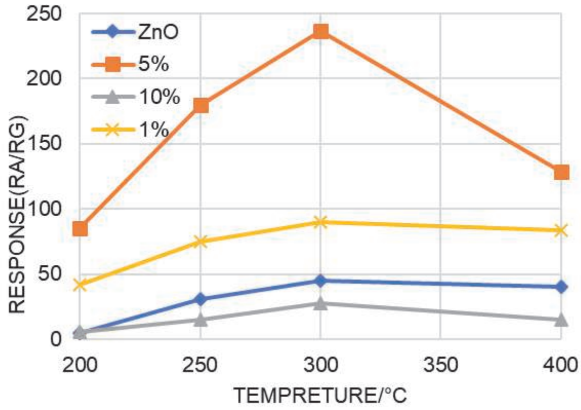

Fig. 1. response of Ni-doped sensors to 300 ppm acetone.

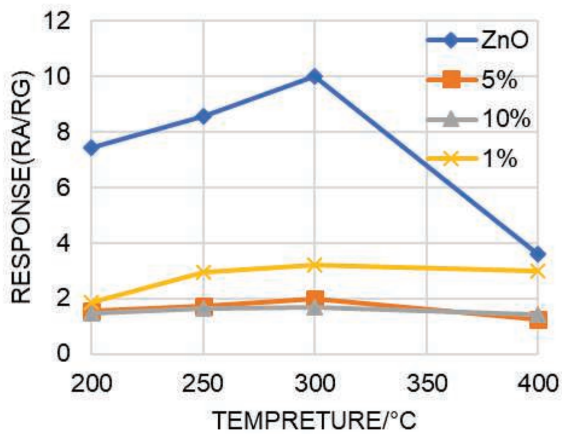

Fig. 2. response of Ni-doped sensors to 300 ppm Co.

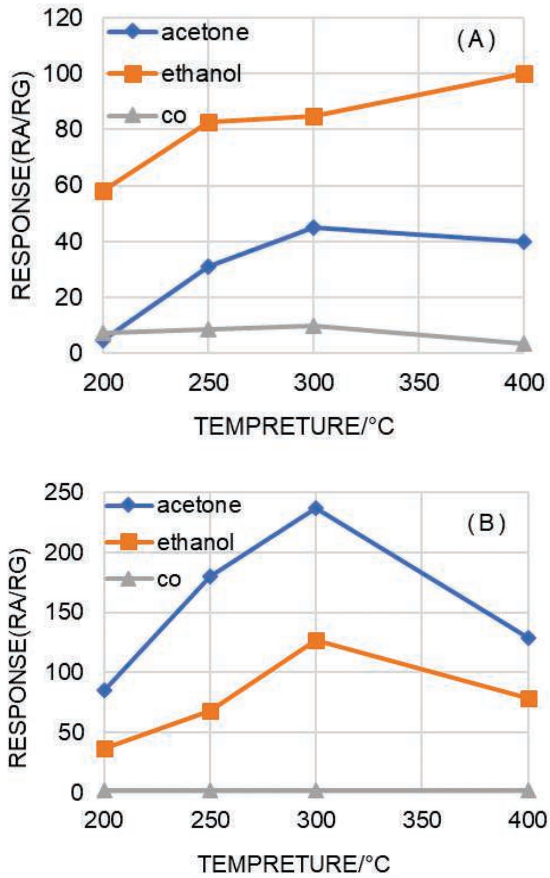

Fig. 3. response of (A) undoped ZnO sensor and (B) 5 mol% Ni-doped sensor to 300 ppm target gases.

As a result, the doping of the ZnO with Ni creates electronic defects which cause the variation in the adsorbed oxygen and adsorbed gas. It develops a potential barrier which changes the resistance of the materials, sensor response and selectivity.

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