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RESEARCH ARTICLE

LPG sensing properties of spray deposited In doped ZnO Thin Films

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ABSTRACT

Indium doped ZnO thin films were prepared by simple and cost effective chemical spray pyrolysis technique. The effect of In doping (1 at% to 4 at %) on the liquefied petroleum gas (LPG) sensing properties were studied. the In: ZnO sensors shows different responses for different nanostructures. The LPG response is higher at an optimum operating temperature of the film and it is lower on either side of operating temperature. The response and recovery times of the Indium doped ZnO films were enhanced significantly compared to those reported for ZnO films. The response of 3% In doped ZnO film to LPG is considerable than that others.

Keywords: Spray pyrolysis; In-doped ZnO films; LPG sensing properties; response time.

INTRODUCTION

Zinc oxide (ZnO) is one of the most important metal-oxide semiconductors. It is an n-type semiconductor of hexagonal (wurtzite) structure with a direct energy wide-band gap of about 3.37 eV at room temperature. Because of its good electrical and optical properties, low cost and absence of toxicity, this material has got wide applications in electronic and optoelectronic devices such as transparent conductors, solar cell windows, gas sensors, heat mirrors, etc. [1–6]. For gas sensor purposes, this material has been investigated in various forms such as single crystals, sintered pellets, thick films, thin films and hetero-junctions [7–12].

Undoped and doped ZnO thin films have been investigated by several researchers for detection of toxic pollutant gases, combustible gases and organic vapours [13].Mitra et al. [13-16] have studied the LPG sensing properties of zinc oxide thin films sensitized with a Pd layer.

Most of the LPG sensors available at present make use of SnO_2 as sensing materials which operate at moderate temperatures of 300–400 ◦C. In the present article we report the development of thin film zinc oxide LPG sensors which have been doped with indium for improving their sensing performance.

METHODOLOGY

In-ZnO thin films were deposited on the pre-heated glass substrates by simple and cost effective spray pyrolysis technique at 400 ^{0}C, Spray rate 2.5 ml/min, substrate to nozzle distance 30 cm and molar concentration was 0.5 M. The precursor used was Zinc acetate dehydrated ($Zn(C_2H_3O_2)_2.2H_2O$). The Indium chloride was the doping source. The In percentage in the solution was varied from 1 at% to 4 at% in the starting solution. The prepared solution is then sprayed on the heated glass substrates which transforms the solution (mixture) to a stream formed with uniform and fine droplets.

The gas sensor was made by pressing the powder in the form of pellet. The gas sensing characteristics with reference to time at different operating temperatures and concentrations were recorded. The gas response (S) for a given test gas was calculated using following equation.

$$S(\%) = \frac{R_{air} - R_{gas}}{R_{air}} \times 100$$

Where, R_{air} and R_{gas} are the resistance of the sensor in air and in the test gas, respectively.

RESULTS

1 Effect of temperature

Fig. 1 depicts the LPG response as a function of operating temperature for In: ZnO thin films obtained at 500 ppm of LPG. The response study showed that increase in temperature gas response also increases up to 573 K and then decreased with further increase in temperature.. At low operation temperature, the low response can be expected because the gas molecules do not have enough thermal energy to react with the surface adsorbed oxygen species.

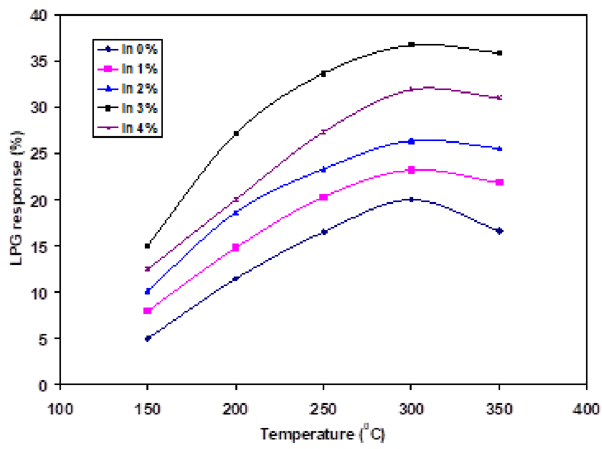

Figure 1: The variation of LPG response of In: ZnO film for various In at% to 500 ppm LPG at different temperatures.

2 Dynamic gas response transients of In: ZnO film

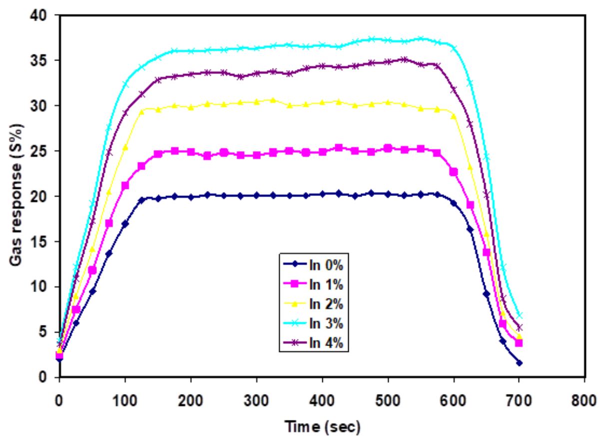

Figure 2: Dynamic LPG transient response of In doped ZnO films

Fig. 2 shows the dynamic gas response transients of In: ZnO films of different In concentrations upon exposure to 500 ppm of LPG at 573 K. The response went on increasing with In doping. The maximum response was obtained with film In 4 at%. The grain size and porosity of the film played an important role.

3 Response and recovery time periods

Fig. 3 and Fig. 4 shows the variation of response and recovery time, respectively, with film having different In doped ZnO thin films at 573 K for 500 ppm. It is observed that both the response and recovery times decrease first with increasing In percentage and again increase with the further increase in In concentration. The smallest response time of 120 s and the recovery time of 95 s obtained for sample with 3 at% might be due to non-spherical grains which are not able to trap gas molecules.

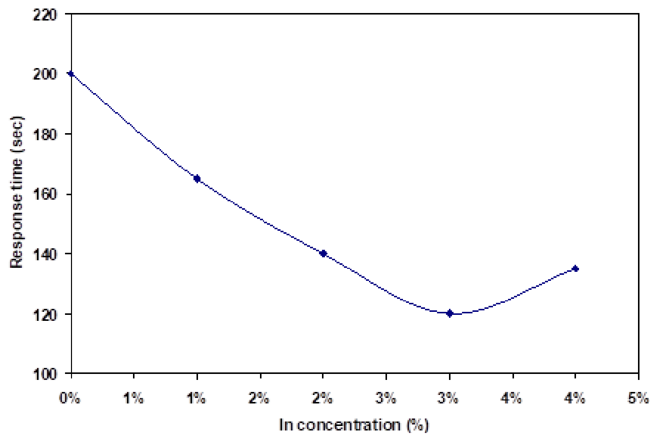

Figure 3: The variation of Response time of In doped ZnO films.

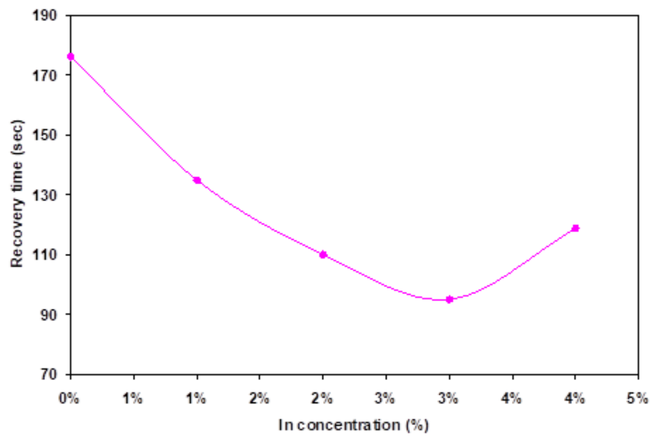

Figure 4: The variation of Recovery time of In doped ZnO films.

CONCLUSION

The effect of Indium doping (1 at% to 4 at%) on the LPG sensing properties were studied. The sensors response gradually increases up to 300 ^{o}C and then starts to saturate. The response and recovery times of the In: ZnO films were enhanced significantly. The response time of 120 s and corresponding recovery time is 95 s is observed for 3% In doped ZnO thin film

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