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Gas Sensing Properties of Nanostructured ZnO : A Review

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ABSTRACT

In this communication, I present the review on the reported work on gas sensing properties of nanostructured Zinc Oxide (ZnO) thin films and particles. Effect of sintering temperature on structure and granular morphology of nanoparticles is discussed in the context of gas sensing. In case of thin films, effect of 'In' doping on structural, optical and eventually on acetone sensing properties is elaborated.

Keywords : Zinc Oxide, Heterostructures, Nanostructured, Granular Morphology

I. INTRODUCTION

Transition metal oxides such as ZnO, V_2O_5, CeO_2 and TiO_2, etc. have been vastly studied for their advanced applications and functional properties. ZnO with stable wurtzite structure is a wide room temperature II-VI semiconductor with a band gap ~ 3.4eV and high exciton binding energy ~ 60MeV, shows various fascinating properties such as optical response, appropriate resistance, easy device fabrication and high records of safety. ZnO is one of the most attractive materials for gas sensing due to thermal and chemical stability, large availability in nature, low cost and absence of toxicity. ZnO has been widely studied in various forms such as nanoparticles, thick films, thin films and heterostructures [1 - 4].

Besides the large number of practical applications, many reports are available on its sensing capability of various gases, such as H_2, NO_2, acetone etc [1, 5]. Many reports are available on the acetone gas sensing behavior of ZnO [6, 7] while only few reports are available on the granual morphology dependent gas sensing behavior of ZnO and other oxide nanostructures. Keeping in mind all the above important aspects and results of the studies on gas sensing properties of ZnO based nanostructures and devices in this communication, I report the overview on gas sensing properties and its dependence on doping, structural changes, and granular morphology of various nanostructures and devices made-up of ZnO.

II. MATERIALS

In this review article, two different published articles have been discussed in detail. First article covers the sol – gel grown nanostructured ZnO and sintering temperature effect on grain morphology, resulting into the change in gas sensing behavior [1]. Second article is based on the experimental results obtained for gas sensing propertied of 'In' doped nanoparticulate thin films of ZnO. [7].

III. REVIEW

Rajyaguru et al [1] have synthesized successfully nanostructured ZnO and sintered them at different temperatures in the smaller temperature window, i.e. at 600°C, 700°C, 800°C, since; sintering / annealing temperature and time are the key factors to modify the physical properties of nanoparticles of metal oxides [8]. From XRD measurements they identified that all the samples were single phasic in nature without any detectable impurities. They also confirmed the hexagonal wurtzite unit cell structure. From FWHM, they calculated crystallite size and it is

found to increase from 11.53nm to 15.33nm and 20.96nm with increase in sintering temperature. They made responsible agglomeration effect to form larger crystallite as increasing temperature. Acetone gas was used for the gas sensing measurements; they performed measurements by filling the chamber with ~ 400ppm acetone gas and measure the resistance prior to gas filling and after gas filling at every 50sec. They observed that room temperature resistance increased with increase in sintering temperature, because of increment in crystallite size with sintering temperature. All mechanism of gas sensing by measuring the resistance is explained by adsorption and desorption of gas molecules on the surface of sensing particles. Oxygen species adsorbed on surface gives high resistance and less oxygen species increases the carrier concentration and hence resistance decreases. The exponential increasing nature of gas sensing response is understood by time dependency: at lower time scale reactions were rapid and higher time scale reaction reaches to saturation. At last they concluded that, the sensing mechanism depends upon the crystallite size, crystal boundary density and defect density. Variation in gas sensing capability was discussed in the context of crystal boundary density and chemical reaction between gas species and oxygen content available at surface.

Prajapati et al [7] have deposited nanoparticle thin films on glass substrates by spray pyrolysis technique using zinc acetate dihydrate as a host precursor and indium chloride as a dopant; thin films made by this technique were found to be having hexagonal wurtzite structure. Upon 'In' doping, they found that thin films exhibit reduced crystallinity as compared with the undoped film. From optical studies they found that optical band gap of samples are in the range of 3.23 – 3.27 eV, and In 'In' doped films normal dispersion is observed in wavelength range 450 – 550 nm. Among all the films investigated, the 1 at% In – doped film shows the maximum response 96.8% to 100ppm of acetone in air at the operating temperature of 300 ºC, at lower concentration of 25 ppm of acetone, the response is more than 90% at same temperature. Higher response at low concentration was explained by smaller crystallite size of the film, leading to sufficient adsorption of oxygen on the surface if film. A possible mechanism to understand the acetone sensing is explained as follows; at higher temperatures oxygen is absorbed on the film surface, at higher temperatures increased proportion of electrons in conduction band slows the gas detection process. The oxygen adsorption and desorption process plays a very vital role in detection of acetone molecules.

IV. CONCLUSION

In conclusion, nanostructured ZnO was grown by simple sol-gel technique and effect of sintering temperature is studied in the context of change in granular morphology or crystallite size. Thin film of ZnO and 'In' doped ZnO was grown by spray pyrolysis technique. Higher response is observed in thin films at low concentration also. The possible mechanism for gas detection is explained.

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