

Photoconductivity and Darkconductivity in ZnO: Cu, Br

Ravi Shankar, Rajneesh K. Srivastava and S. G. Prakash

Department of Electronics and Communication
University of Allahabad, Allahabad-211002, India
Email: rkumarsau@gmail.com

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Abstract: In the present work, ZnO: Cu (0.15%), Br (0.50%) was prepared by heat treatment technique at 800 °C for one hour. The synthesized powder is investigated for photoconductivity and dark conductivity properties. Variation of photocurrent with voltage and with time (Rise and Decay) has been studied under UV illumination. Super-linear variation of photo and dark current with voltage may be attributed to injection of additional charge carriers from one of the electrodes.

Keywords: Photoconductivity, XRD, ZnO

1. Introduction

Among wideband semiconductors, oxide semiconductors has been studied widely because of their use in photonic and optoelectronic devices. ZnO is one of the wide band semiconductors having band gap of 3.2 eV and exciton binding energy 60 meV at room temperature, Wide band gap exhibits optical transparency in visible region, band gap of ZnO can be reduced by dopants for actual applications. Since last few decades zinc oxide (ZnO) witnessed much attention since it shows wide range of applications such as ultraviolet absorbents, Photo catalyst, Photo detectors, Transistors, Solar cells, sensors, Optoelectronic devices¹⁻⁵ etc.

Photoconductivity is an important characteristic to study semiconducting materials that provides information regarding nature of photo-excitation. The photoconductivity arises in semiconducting materials due to generation of electron hole pairs as result of interaction of photons with bound electron of lattice atoms. The photoconductivity of material mainly depends on carrier density, carrier lifetime and carrier generation, trapping and recombination. Photoconductivity properties are also function of temperature, applied field, intensity of light and energy of radiation⁶⁻⁸. In this paper we have prepare ZnO bulk material doped with Cu and Br using heat treatment method.

2. Experimental Section

The Zinc Oxide (ZnO) (AR grade), Cupric Sulphate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$) and Ammonium Bromide (NH_4Br) are directly used without special treatment. First, 2 gm of Zinc Oxide and aqueous solutions of Cupric Sulphate and Ammonium Bromide are mixed and the slurry is heated at 80°C . The dried mixture is ground and is fired in furnace for one hour at 800°C . Further it was ground in a mortar to make fine powder.

3. Results & Discussion

3.1 Structural study: The figure 1 shows the XRD pattern for ZnO: Cu, Br bulk material prepared by heat treatment method. The obtained result are very well matched with that of standard wurzite hexagonal structure. Furthermore, it can be seen that the diffraction peaks have no broadening which implies that the ZnO: Cu, Br bulk material have crystalline in nature.

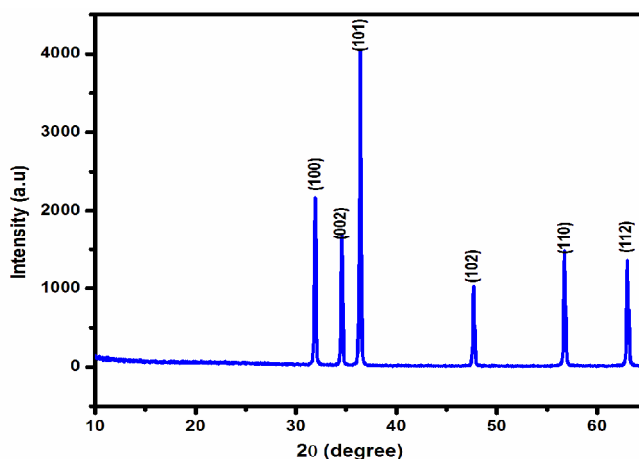


Fig.1. XRD Pattern of ZnO: Cu, Br Bulk Material Prepared by Heat Treatment Method

3.2 Morphological characteristics: Figure 2a and 2b shows the SEM image of ZnO: Cu, Br prepared by heat treatment method at 800°C . The particles are spherical and agglomerated. The size of these spherical bulk materials found to be 200 to 300 nm.

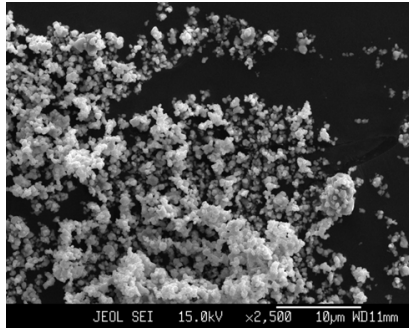


Fig.2a. SEM image of ZnO: Cu, Br

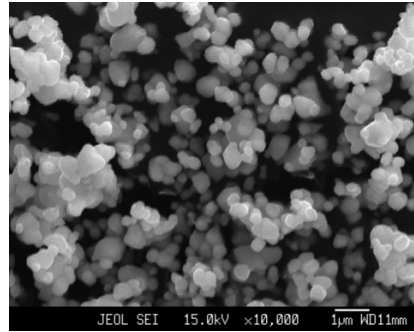


Fig.2b. SEM image of ZnO: Cu, Br

3.3 Study of Darkconductivity and Photoconductivity

3.3.1 Field dependence: Figure 3 shows variation of photocurrent and darkcurrent with voltage on log-log scale. Both are found to vary sub-linearly and follow power law I_{pc} (I_{dc}) $\propto V^r$ where r is the slope of the straight lines sublinear variation of photo and dark current with voltage is due to the to the formation of nonohmic contact which do not replenish the charge carriers completely once they are captured by electrodes as compared to that in dark. Under visible illumination conductivity is increased.

The increase in conductivity under visible illumination is due to generation of electron hole pairs as a result of absorption of photons. As the photons (visible) are not having sufficient energy to excite electrons from valance band to conduction band therefore increase in conductivity is not very significant

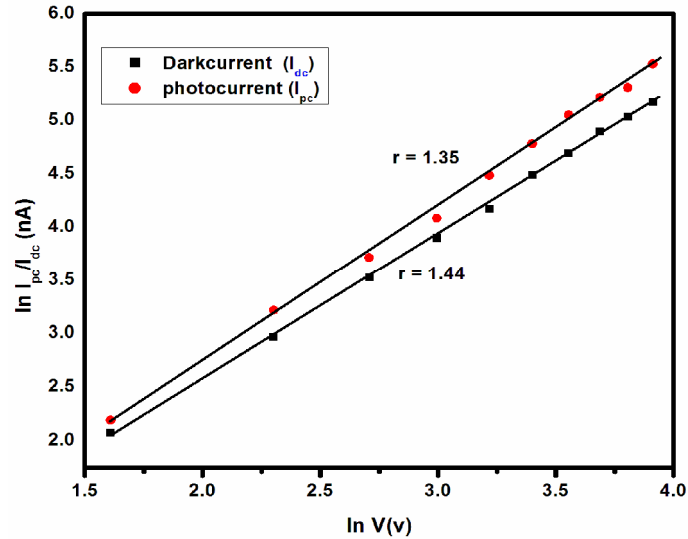


Fig.3. Variation of Photocurrent and Dark Current as a Function of Applied Voltage for ZnO: Cu, Br

3.3.2 Dependence of Intensity: Figure 4 illustrates the variation of photocurrent I_{pc} with the light intensity I_L for ZnO: Cu, Br bulk material on ln-ln scale. The I_{pc} versus I_L curves are straight lines with two segments have different slopes and the variation can be expressed by power law $I_{pc} \propto I_L^r$ where r is the slope. The value of $r = 0.12$ shows sublinear light intensity dependence of photocurrent due to defect state mechanism which includes both recombination and center traps at higher intensity value of $r = 1.9$ shows superlinear nature of photocurrent. The sublinear ($r < 1$) and superlinear ($r > 1$) nature of photocurrent could be explained on basis of class I and class II respectively⁹⁻¹¹. The sublinear behavior of segment indicates that continuous and exponential distribution of class I center between conduction band Fermi-level and electron band Fermi-level. The increase in intensity of illumination electron Fermi level are separated more and more converting class I center to recombination centers. This decrease the electron life time and the slow increase in photocurrent gives rise to observed sublinearity in photocurrent. When light increases, the electron Fermi level and hole Fermi level are shifted toward conduction bands respectively. Converting some of the class II states into recombination center and these recombination centers participate in recombination process which sensitizes ZnO: Cu, Br results in superlinearity in photocurrent versus illumination intensity curves.

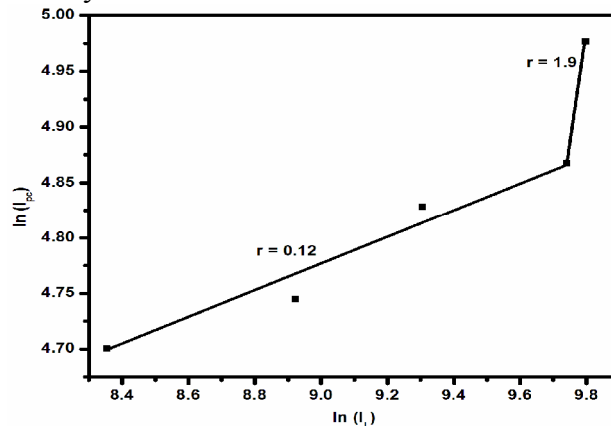


Fig.4. Variation of Photocurrent as a Function of Incident Illumination Intensity (Voltage 20 V and Room Temperature 25°C)

3.3.3 Rise and decay curve: The rise and decay time transient photoconductivity response measurements help to study the photoconductivity dynamics of ZnO: Cu, Br bulk material during which the light was abruptly on and off at room temperature. The figure 5 shows rise and decay curve of photocurrent under visible illumination with fixed photo flux and bias voltage. When the light is switched on the photocurrent

initially increases very fast due to generation of electron hole pairs as a result of absorption of photons then it gradually sets stabilized. When the light is switched off the photocurrent decreases exponentially as a result of recombination of electron and hole. The slow photoconductive rise and decay response may be attributed to a large amount of recombination centers and presence of trap levels and defect states within the band gap¹²⁻¹⁷.

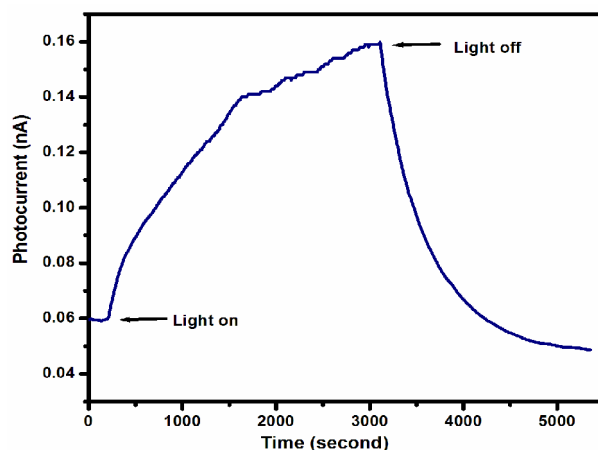


Fig.5. Rise & decay of ZnO: Cu(0.15%), Br(0.5%)

4. Conclusion

ZnO: Cu, Br bulk material prepared by heat treatment method. The SEM exhibits spherical structure of ZnO: Cu, Br. The size of bulk material is estimated to be 200 to 300nm. ZnO: Cu, Br bulk material found to exhibit photoconductivity measurement of ZnO: Cu, Br were perform under visible illumination and it shows that photoresponse under visible illumination is quite slow photoconductivity response may be attributed to presence of traps. The proposed works suggest very promising device application of solar cell, photoconductor and sensors, etc.

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