

Study of Photocurrent and Dark Current in ZnO Nano Particles Prepared by Sol – Gel Method

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Abstract: In present work an attempt has been made to study photoconductivity and dark conductivity in ZnO nano particles synthesized by sol-gel method. Voltage dependence and intensity dependence of photocurrent has been measured at room temperature under visible illumination. Rise and decay curve of photo current exhibits almost constant photocurrent during steady illumination. Structural study has been performed using XRD and SEM.

Keywords: Nano, ZnO, Photoconductivity, Sol-gel method, XRD, SEM.

1. Introduction

From the last few decades II- VI compound semiconductor with the dimensions in the nanometer has generated much interest for the researchers. In II-VI semiconductor materials such as ZnO, CdS, CdO researchers has shown great interest in the investigation of transport properties. As an important II- VI Semiconductor with a wide and direct band gap (3.37) and a large exciton binding energy (60 meV), ZnO has attracted much interest, owing to its specific electrical, catalytic, photochemical and optoelectric properties¹⁻⁵. Particle morphology plays a vital role in the reactivity of the ZnO surface⁶⁻⁷. ZnO NPs can be synthesized by different methods such precipitation method, sol-gel method, solid state reaction method, heat combustion method, thermal decomposition method. In this paper ZnO NPs were synthesized by sol-gel method and have been characterized for their photoconductivity and dark conductivity properties.

2. Experimental Section

2.1 Chemicals: Zinc acetate ($\text{Zn}(\text{CH}_3\text{COOH})_2 \cdot 2\text{H}_2\text{O}$), and Diethanolamine (DEA) were purchased from E. Merk Ltd. Mumbai. The chemicals were directly used without any special treatment.

2.2 Sample Preparation: In 50 ml of double distilled water 1.0975 gm of Zinc acetate was mixed and stirred for 24 hours. The solution was then placed in furnace at 90°C for 30 hours. The obtained powder was ground to get fine powder. That is again placed in furnace at 400°C for 4 hours. The final product is ground to get fine power.

2.3 Instrumentation: The crystal structure of ZnO nanoparticles were characterized by X-Ray Diffraction using Rigaku D/MAX -2200H/PC with Cu $K\alpha$ radiation ($\lambda = 1.54178 \text{ \AA}$). For measuring photoconductivity and dark conductivity, a cell is formed by spreading a thick layer of powdered sample in between two Cu electrodes etched on a Cu plate (PCB), having a spacing of 1 mm. The powdered layer was pressed with transparent glass plate. This glass plate has slit for providing illumination area of 0.25 cm^2 . In this cell type device, the direction of illumination is normal to the field across the electrodes. The cell was mounted in a dark chamber with a slit where from the light is allowed to fall over the cell. The visible photo response was measured using commercial bulb of 200 W as a photo excitation source. A stabilized dc field (50 V/cm to 500 V/cm) was applied across the cell to which a digital dc nano meter for measurement of current and Rish multi 18S with adapter were connected in series. The light intensity over the surface was changed by varying the distance between slit and the light source. The cell is kept in dark till it attains equilibrium before measuring the photoconductivity.

3. Results & Discussion

3.1 Structural Study: The Fig. 2 shows the XRD pattern of ZnO nano particles (NPs) synthesized by precipitation method at room temperature. The obtained peaks are well matched with that of standard cubic ZnO. The peak broadening in XRD pattern indicates that nano particles have been formed. The average crystallite size is calculated from the Scherer formula⁸⁻⁹.

$$(3.1) \quad D = 0.9 \lambda / \beta \cos(\theta),$$

where D is the crystallite size, λ is the wavelength of radiation used, θ is the Bragg angle and β is the full-width at half-maximum (FWHM) measured in radian. The average crystallite size of sample lies in the range of 45.63 nm.

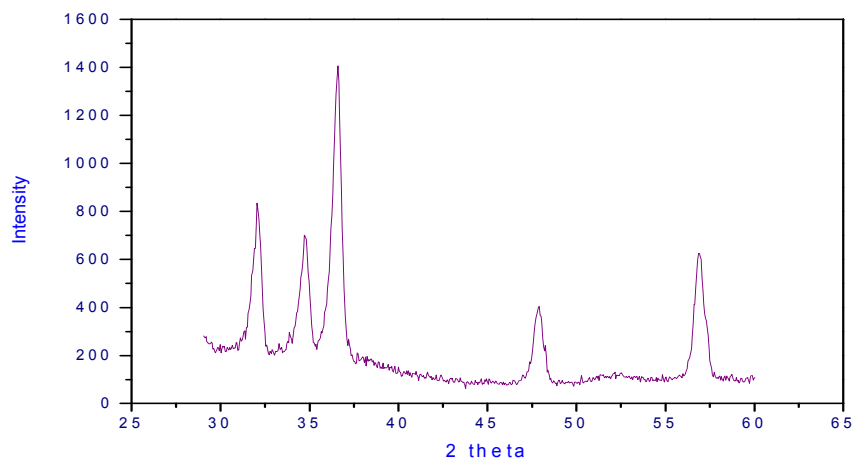


Fig. 1 XRD of ZnO Nanoparticles prepared by sol-gel method

3.2 Morphology Study

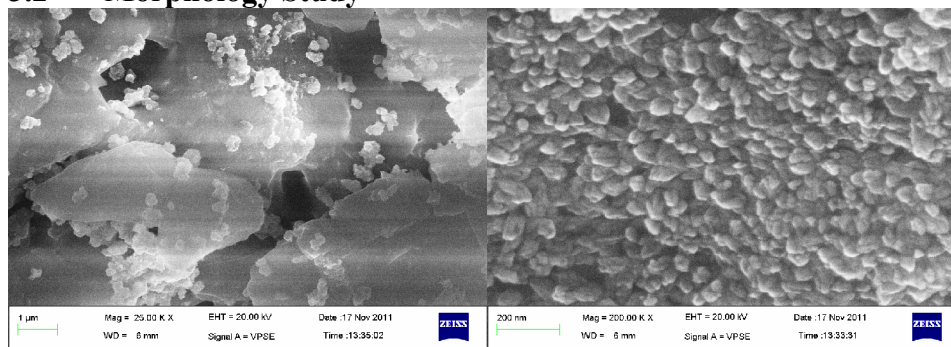


Fig.2 SEM images of ZnO at different resolution prepared by sol-gel method

Fig. 2 shows the SEM of ZnO NPs. The NPs are spherical in nature. The particle size lies in the range of 40 – 55 nm.

3.3 Photoconductivity Study

3.3.1. Voltage Dependence of Dark Current

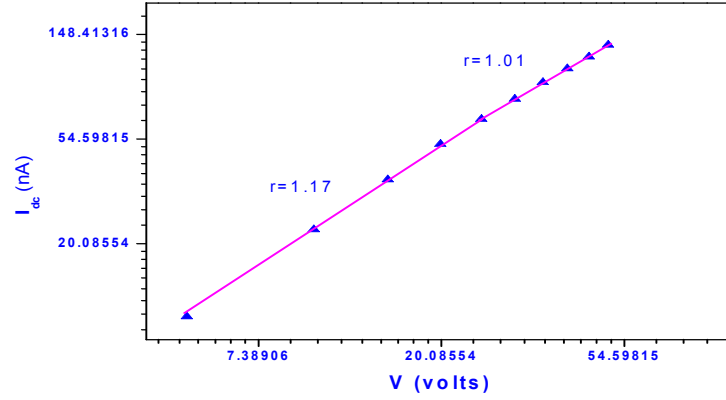


Fig. 3 Variation of dark current with applied voltage on ln-ln scale

Figure 3 shows the variation of dark current (I_{dc}) with applied voltage for ZnO nano particles (NPs) on ln-ln scale. The $\ln(I_{dc})$ versus $\ln(V)$ curve is straight line with two segments. The variation of dark current may be expressed by power law, i.e. $(I_{dc}) \propto V^r$, The super linear behavior suggests that additional charge carriers are injected into the sample from one of the electrodes¹⁰.

3.3.2 Voltage Dependence of Photo Current

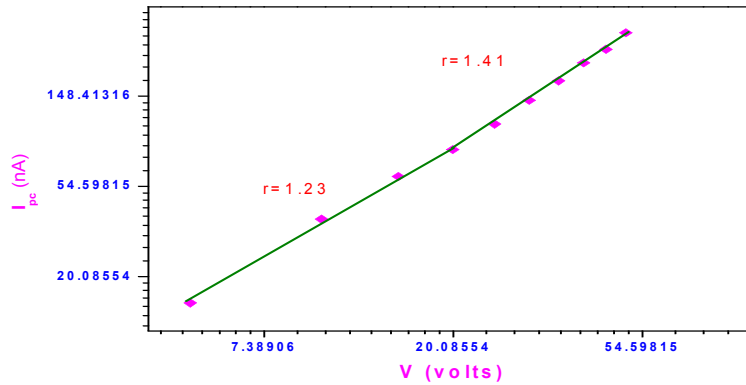


Fig. 4 Variation of photo current with applied voltage on ln-ln scale

Figure 4 shows variation of photo current (I_{pc}) with applied voltage (V) for ZnO (NPs) on ln-ln scale. The $\ln(I_{pc})$ versus $\ln(V)$ for the photo current curve is straight line with two segments with different slopes. The superlinear behavior of ZnO NPs may be due to injection of some additional charge carriers into the sample from one of the electrodes¹⁰.

3.3.3 Intensity Dependence of Photo Current

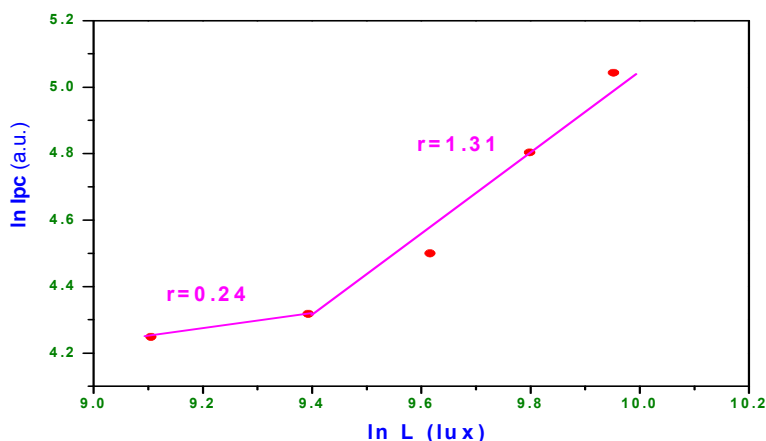


Fig. 5 Variation of photocurrent with Intensity

Figure 5 shows the photocurrent variation with intensity on ln-ln scale. The $\ln(I_{pc})$ versus $\ln(L)$ for the photo current curve is straight line with two segments with different slopes. At high intensity of illumination the photo current is found to vary super linearly. The sub-linear ($r < 1$) and super linear ($r > 1$) nature of photocurrent can be explained on the basis of class I and class II centers, respectively¹¹⁻¹². The sub-linear may be attributed to continuous and exponential distribution of of class centres between conduction and electron Fermi level. When the intensity of light increases, the electron Fermi level and hole- Fermi level are shifted towards conduction band valance band respectively¹³⁻¹⁴.

3.3.4 Rise and Decay of Photocurrent

Figure 6 shows the time - resolved rise and decay photocurrent spectra of ZnO nanoparticles (NPs). When the light is switched on, the photocurrent increases slowly and reaches to a peak value. When light is switched off, the photocurrent decreases slowly. The slow rise and decay may be due to large amount of recombination centers and to the presence of defect states and traps within the band gap¹⁵⁻¹⁶. The slow rise and decay may also be attributed to adsorption and desorption of O_2 and water molecules on the surface of ZnO NPs

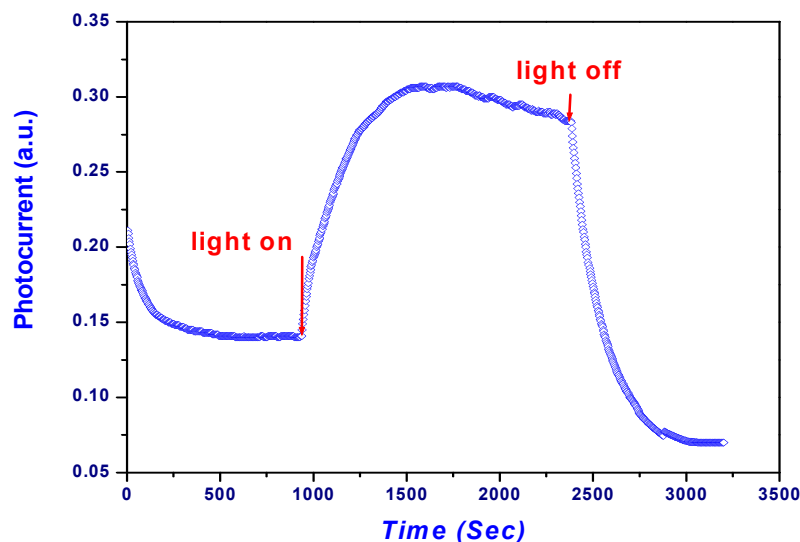


Fig. 4 Rise and Decay of photocurrent in ZnO nanoparticles (NPs)

4. Conclusions

ZnO NPs were synthesized by sol-gel method. XRD pattern indicates formation of hexagonal structure of ZnO NPs. The crystallite size is 45.63 nm. SEM exhibits formation of spherical ZnO NPs. Variation of photocurrent with voltage is superlinear under visible illumination. Dark current also varies with applied voltage super linearly at low as well as high voltage. The photocurrent varies super linearly with high intensity of illumination. Time - resolved rise and decay of photocurrent exhibits slow increase in photocurrent when light is switched on. When light is switched off, the photocurrent decreases slowly.

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