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Effect of Growth Layer Solution Reactant Concentration on the Structural and Optical Properties of Hydrothermally Grown ZnO Nano Rods for Solar Applications

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Abstract

The research provides a systematic study of structural and optical properties of ZnO nano rods. Zinc acetate dihydrate and ethanol were used as a starting material and solvent respectively. Zinc oxide (ZnO) thin films were deposited on an ordinary glass substrate by dip coating technique. The crystal structure and orientation of the ZnO nano rods were investigated by X-ray diffraction (XRD) patterns. X-ray diffraction patterns indicated that the grain size increased with increasing annealing temperature. The optical absorbance and transmittance measurements were recorded by using a UV visible spectrophotometer. The UV visible is absorption spectra showed that the band edge absorption at the ZnO band edge was strong, and the band gap of the films annealed at 500^{o}c. The Effect of Growth Layer Solution Reactant Concentration on the Structural and Optical Properties of Hydrothermally Grown ZnO Nano Rods were prepared and investigated for Solar Applications.

Keywords: **ZnO Nano Rods, Dip Coating, Hydrothermal, Solar Cell, Thin Films**

I. INTRODUCTION

Zinc oxide (ZnO) Nano rods, with a wide band gap of 3.37eV and a wide excite on binding energy of 60 meV, are suggested promising applications in transparent electronics, solar cells and optoelectronics devices. In the recent few years, ZnO Nano rods have been synthesized with various methods including vapour-liquid-solid (VLS) epitaxial, chemical vapour deposition (CVD), pulse laser deposition (PLD), hydrothermal synthesis, and so on. The CVD and VLS techniques which are high temperature processes requiring costly equipment, the Sol-gel method has been found a simple process for growth of ZnO Nano rods due to its different growth temperature 500°C. Now a day's numerous efforts have been

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adopted in controlling the sizes and shapes of ZnO Nano rods, because it provides a better model for investigating the dependence of electronic and crystalline properties on the size confinement and dimensionality.

It had been reported that the size and growth of ZnO Nano rods could be controlled at different growth properties of ZnO Nano rods were dependent on substrate temperature in the PLD process. Our work provides controllable structural and optical properties of ZnO Nano rods prepared on ZnO thin films with different annealing conditions were systematically studied. Our investigations indicated that the thin film annealed at the temperature of 500°C amorphous, but the Nano rods were high quality single crystals growing along the various directions with a high consistent orientation perpendicular to the substrates. We brief the experiments including preparation and annealing treatment of ZnO sol-gel thin films and the growth of thereon ZnO Nano rods.

II. EXPERIMENTAL DETAILS

1. ZnO Seed layer Thin Film: Sol-Gel Method

The ZnO thin films served as the seed layers were deposited on glass substrates by a sol-gel method. A coating solution was prepared by dissolving Zinc Acetate dihydrate [Zn (OAc)2] (Nice, 99.0% purity) and equivalent 20 ml Ethanol [C2H5OH] in 0.25 mol of deionized water. The concentration of Zinc acetate was 0.1mol. The resulting solution was then stirred 2 hours at room temperature to yield a homogeneous and stable colloid solution, which served as the ZnO Growth Layer Nano Rods Thin Film. Then the solution was coated onto glass substrates by dipping method. All the glass substrates were dipped 5 times at room temperature. Then the 5-layer films were annealed in a furnace at the temperature 200°C for 1 hour. Fig.1 shows the Flow Diagram of the ZnO Growth Layer Nano Rods Thin Film prepared from sol gel process using the dip-coating method.

2. ZnO Growth Layer Thin Film: Hydrothermal Method

After uniformly coating the glass substrates with ZnO thin films, hydrothermal growth of ZnO Nano rod was achieved by suspending these ZnO seed-coated glass substrates upside-down in a glass beaker filled with aqueous solution of 0.02 mol of Zinc Nitrate dihydrate (Sigma Aldrich, 98% purity) and 0.2 mol of Hexamethylenetetramine (HMT) (Sigma Aldrich,99.5% purity). During the growth, the glass beaker was heated with a laboratory oven and maintained at temperature 100°C for 4 hours. At the end of the growth period, the substrates were removed from the solution, then immediately rinsed with de-ionized water to remove any residual salt from the surface, and dried in air at room temperature. Then the ZnO grown films were annealed in a furnace at the temperature 500°C for 1 hour.

Here we report the effect of three different precursor concentrations on the grown ZnO Nano rods with constant annealing temperature. Concentrations of 0.02mol of Zinc Nitrate dihydrate Zn $(CH_3C0_2)_2$ and 0.2 mol hexamethylenetetramine (HMT) $C_6H_{12}N_4$, were taken in the ratio of 1:10. The other two ratios were 2:10 and 3:10. ZnO Nano rods were grown in above three concentrations, annealed at same temperature of 500°C for 1 hour. The properties of grown ZnO Nano rods were investigated by X-ray diffraction (XRD) on XPERT-PRO X-ray diffractometer with Cu K_radiation (λ = 1.54060 nm) at a scanning rate of 0.05◦ s−1in the 2θ range from 10◦ to 80◦. To investigate the optical properties, the absorption and transmittance spectra were recorded by UV–Vis spectra on a JASCO Corp., V-570 spectrophotometer at room temperature.

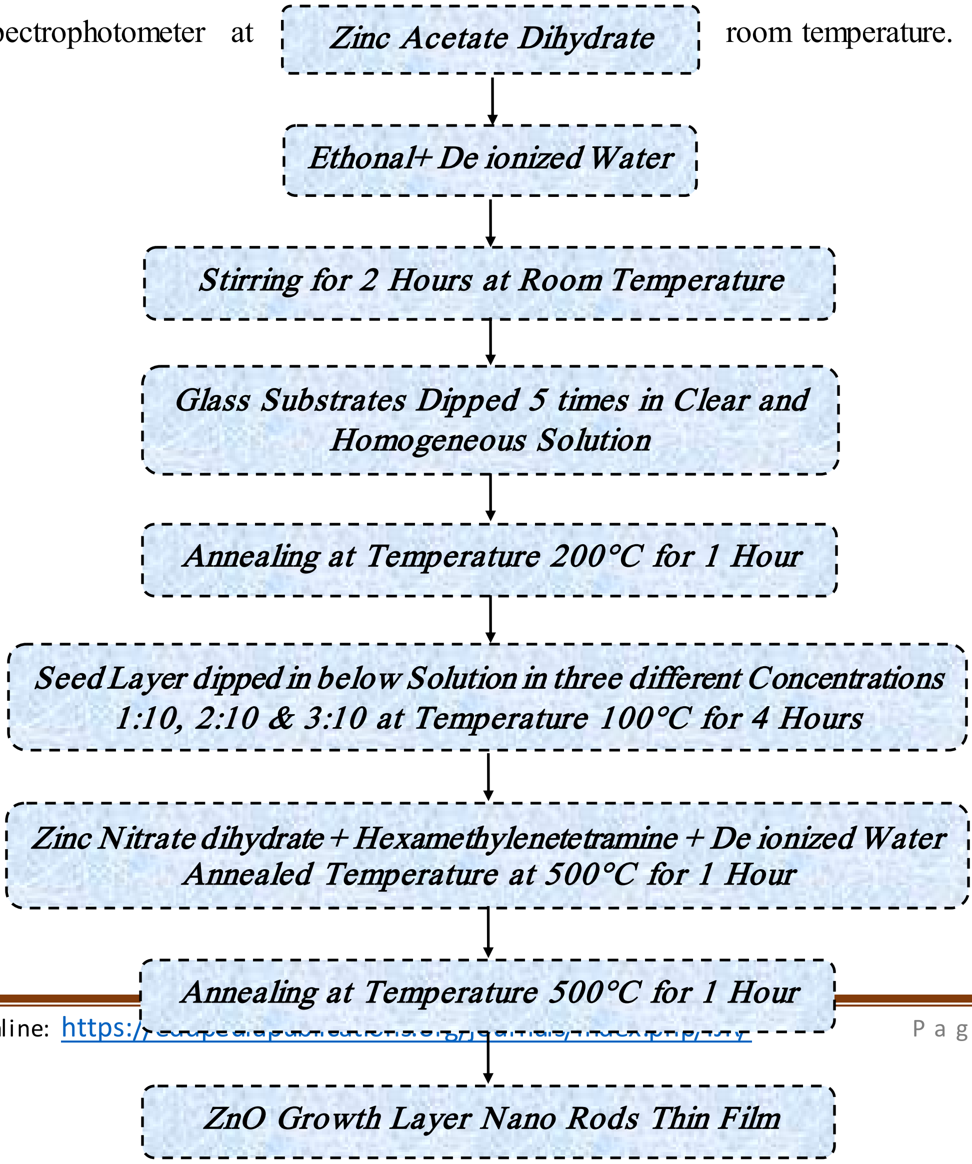

Fig.1 Flow Diagram of the ZnO Growth Layer Nano Rods Thin Film

III. RESULTS AND DISCUSSION

1. Structural Analysis

XRD patterns of the ZnO Nano rod samples are shown in Fig.2. It reveals that the well-aligned Nano rods have a hexagonal wurtzite crystal structure with a c-axis (002) preferential orientation.

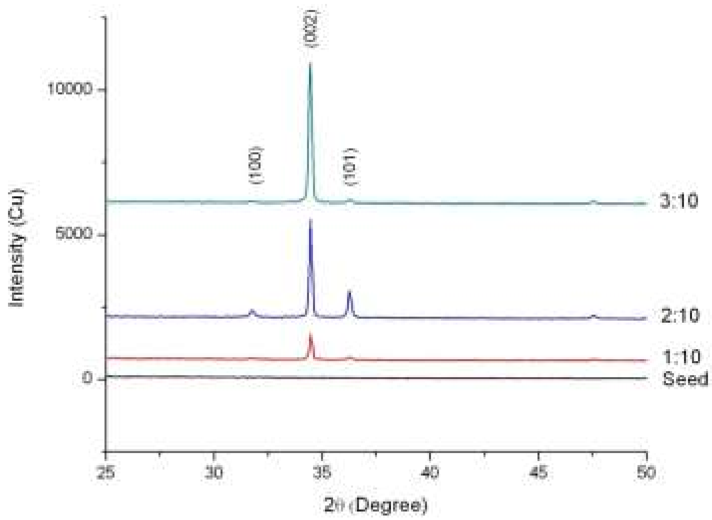

Fig.2 XRD pattern of ZnO growth layers on different growth solution concentrations at 500°C with Seed Layer

The XRD pattern of the growth concentration of 1:10 and 2:10 shows typical polycrystalline characteristics with relatively comparable intensity for the (100), (002) and (101) peaks. When concentration of 1:10 and 2:10 is compared, the 2:10 concentration is better than 1:10 concentration, which is seen in the XRD pattern, where (002) peak is stronger. The XRD pattern of growth concentration of 3:10 displays only the (002) diffraction

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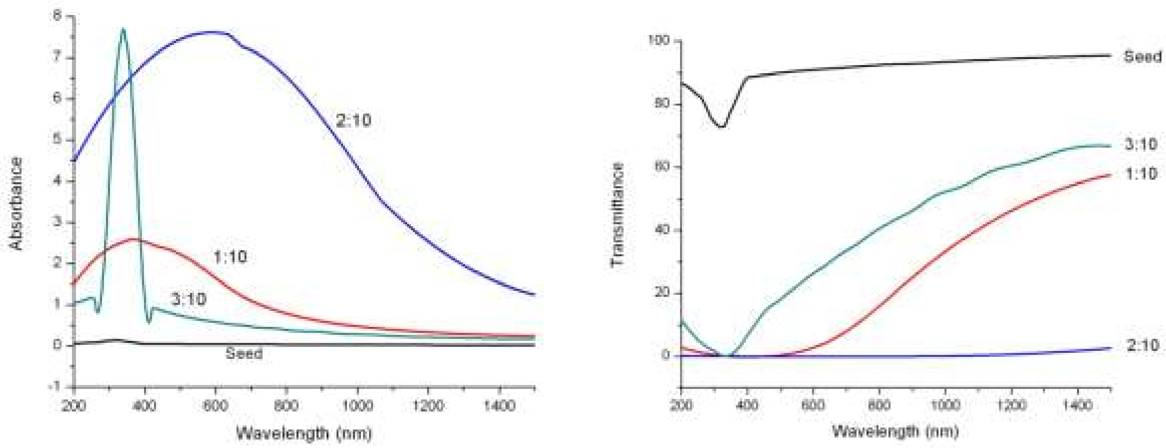
peak of the wurtzite ZnO, indicating the good orientation in the c-axis direction. The strong and narrow diffraction peaks indicate that the material has a good crystalline and size. From the above XRD patterns it is clearly seen that, as the growth concentration increases the diffraction peaks were oriented strongly along the (002) peak.

2. Optical Analysis

The Optical properties of ZnO Nano rods are important for many of their technological applications. In most cases the UV-Vis spectra of ZnO comprised of Absorption and Transmittance and the relationship between the two depends strongly on the preparation method and post-preparation treatment. The UV spectra in ZnO Nano rods are well accepted as the near-band-edge emission.



(a) (b)

Fig.3 shows the Absorption and Transmittance spectra at three different growth solution concentrations with Seed Layer

The optical absorption spectrum is shown in Fig.3 (a) is clearly indicates that, as growth solution concentration increases the optical absorption edge shift to a higher wavelength. The intensity of the absorption spectra increases considerably as growth solution concentration increases from 1:10 to 3:10. It is well known that the optical absorption determines the optical band gap and ZnO films have a direct band gap. The optical band gap of ZnO films was found to decrease as growth solution concentration increases from 1:10, 2:10 and 3:10 respectively. The decrease in band gap of ZnO films may be attributed to the improvement in the crystalline quality of the films and increase of grain size.

Fig.3 (b) shows the optical transmittance spectra from samples with three different growth solution mol concentrations of 1:10, 2:10 and 3:10, annealed at constant temperature of 500°C for 1 hour, which was obtained on a JASCO Corp., V-570 spectrophotometer. The transmittance spectra is in the visible range nearer to infrared wavelength region that is at 83%, which reveals the superior optical properties in the ZnO thin films produced by novel sol-gel method. The effect of change in the Nano rod molar concentration on the optical transmittance for samples was investigated.

A slight decrease in average transmission was observed with the increase of growth layer molar concentration and was attributed to the different of surface roughness. The optical transmittance of ZnO films was found to different from 58%, 05%, and 63% with the increase of growth layer molar concentration. The results indicated high optical quality ZnO Nano rods were successfully achieved via this low temperature chemical approach.

IV. CONCLUSION

ZnO Nano rod arrays have been successfully synthesized on glass substrate by hydrothermal method. The orientation mechanisms were elucidated. The structure and optical evolution of the layers was monitored by XRD and UV-vis measurements. The UV-Vis Absorption and Transmittance spectra measurements demonstrate that high optical quality ZnO Nano rods array could be achieved by this low temperature, low cost chemical approach. The results illuminate that the change in growth solution concentration, play crucial role in the growth rate, size and density of the layers. Growth layer Nano Rods with better properties are expected by further modifying the concentration of growth layer and annealing temperature.

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