Electrical Characterization of Undoped and Cu Doped ZnO Thin Films Using Physical Vapor Deposition Technique

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ABSTRACT

Undoped ZnO and Cu doped ZnO thin films were prepared by physical vapor deposition technique on alumina substrate and annealed at different temperatures. The temperature dependent electrical resistance was measured by half bridge method in air atmosphere. The temperature and voltage dependent current was measured for the same films. The increase of resistance with reciprocal temperature for both undoped and doped ZnO thin films show constant difference at higher temperature side, but at lower temperatures the metallic doping of Cu in ZnO shows more conductivity than undoped ZnO due to excess current carriers. The I-V Characteristics are almost linear for both undoped and doped ZnO with constant shift.

Keywords: ZnO, thin films, alumina substrate, temperature, TCR, current, voltage.

INTRODUCTION:

Zinc oxide is a wide direct band gap (3.37 eV) semiconductor with a large excitation binding energy (60 meV), has received much attention due to its potential applications in the optoelectronic field [1–3]. One-dimensional ZnO nanostructures such as nanowires have been extensively studied for other applications including chemical sensors [4], solar cells [5], blue and ultraviolet (UV) light-emitting diodes [6]. Many techniques have been successfully used to synthesize ZnO thin films, including sol-gel [7], pulsed laser deposition (PLD) [8], thermal evaporation [9], chemical vapor deposition (CVD) [10] *etc.* Another method to prepare ZnO thin films is thermal oxidation of metallic Zn thin films [11] reported the production of high quality ZnO films by thermal oxidation of metallic Zn. Pure and qualified ZnO films have been prepared by thermal oxidation of metallic Zinc films in air [12,13]. Tae-Won Kim *et al.* have grown ZnO nanowires with an average diameter of 20 nm by thermal oxidation of pre-deposited hexagonal Zn nanoplates on a CaF2 (111) substrate [14].

In this paper, the pure ZnO and Cu doped ZnO thin films were prepared on alumina substrates by physical vapor deposition technique. The films were annealed at different temperatures and electrical characterization was predicted.

EXPERIMENTAL TECHNIQUE:

Substrate Cleaning

The alumina substrates were cleaned using liquid detergent, then they kept in potassium dichromate and HCL solution. After this, they were cleaned using distilled water and agitated ultrasonically in acetone. Then the substrates were dried under IR lamp.

Preparation ofZnO thin films

Pure ZnO and Cu doped ZnO thin films were deposited onto the alumina substrates by physical vapor deposition technique. Thesubstrateswere cleaned and mounted onto the stand placed nearly 10 cm above the tungstenfilament. The material to be deposited was placed in tungsten basket. In this method, themetalZinc and Copper material were vaporized by passing appropriate current through spiral basket. The Vacuum used for the deposition was 10^{-5}torr. When the material heated in vacuum, it undergoes sublimation and atoms get transported towards the substrates where they get deposited. The undoped and Cu doped ZnOsampleswere placed in a muffle furnace for 6hrs at different temperatures for allowing oxidation and stoichiometry of the films

RESULTS AND DISCUSSION:

Fig.1: Plot of log R verses 1/T of undoped and Cu doped ZnO thin films annealed at 723 K

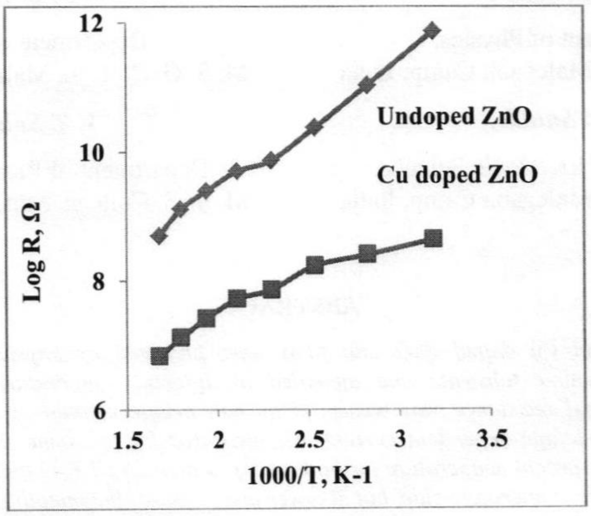
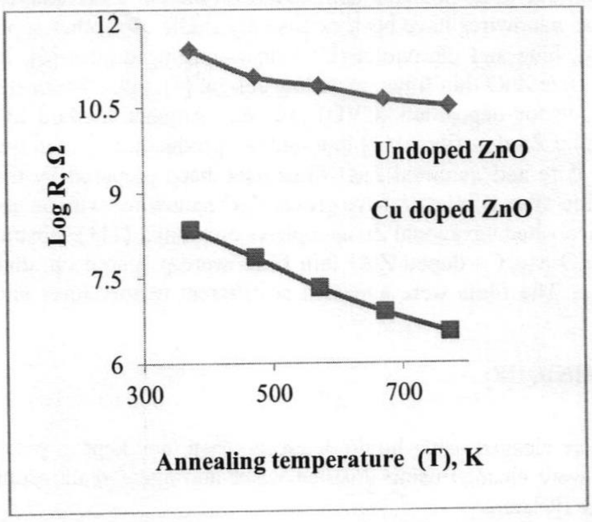


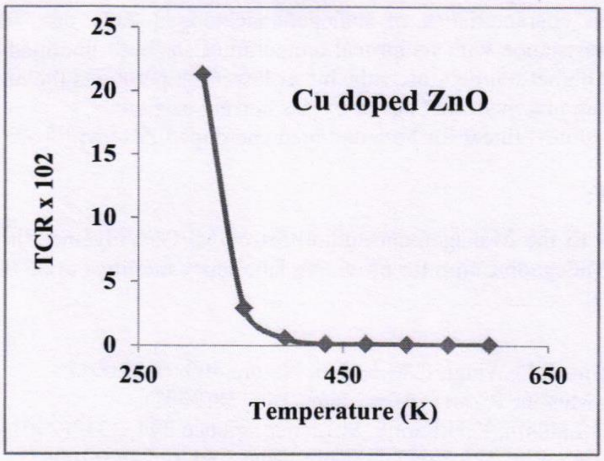
Fig.1 shows plot of log R verses 1/T of undoped and Cu doped ZnO thin films. It is observed that the films are pure semiconducting in the temperature range 313K to 523K. The increase of resistance with reciprocal temperature for both undoped and doped ZnO thin films show constant difference at higher temperature side, but at lower temperatures the metallic doping of Cu in ZnO lowers the resistivity than undoped ZnO due to excess of current carriers.

Fig.2: Plot of Log R verses annealing temperature (T) of undoped and 5% Cu doped ZnO thin films



From fig.2, it is observed that the resistance of thin films is temperature dependent. The decrease of resistance with increase of annealing temperature for undoped and Cu doped ZnO thin films is due to removal of defects. Similarly due to addition of metallic dopant the resistivity ultimately decreases.

Fig.3: Plot of TCR verses temperature (T) of Cu doped ZnO thin films



T.C.R.= (1/R) (ΔR/ΔT), K-1-------------------------(1)

The temperature coefficient of resistance (T.C.R.) of Cu doped ZnO thin films is shown in fig. 3, from fig. It is found that the T.C.R.is negative and it exponentially decreases with increase of temperature.

The decrease of negative TCR with increase of temperature can be explained on the basis of the island structure concept proposed by Neugebauer and Webb [15] and later developed by Neugebauer [16] to explain semiconducting behaviour of very thin films. The expression for negative TCR is given by,

Negative TCR= (-d (t)/dt) [{4π (2mϕ)**1/2**/ h**2**}-1/t]+ C/Γ^2]-------------------(2)

Where C= [(2e2 / ευ) + ΔEg] / 2K

'*t*' is the average distance between islands, 'e' electronic charge, 'm'mass of electron, 'K' Boltzmann constant, 'Γ' the average radius of islands,'Φ'the potential barrier between islands,'h' Planks constant,'ε' dielectric constant of the substrateand'ΔEg' Energy band gap. In the present investigation, negative TCR continuously decreases. It can be said that the contribution towards TCR due to first term in above expression is more predominant compared to the second factor.

Fig.4: Plot of Current verses Voltage of undoped and 5% Cu doped ZnO thin films

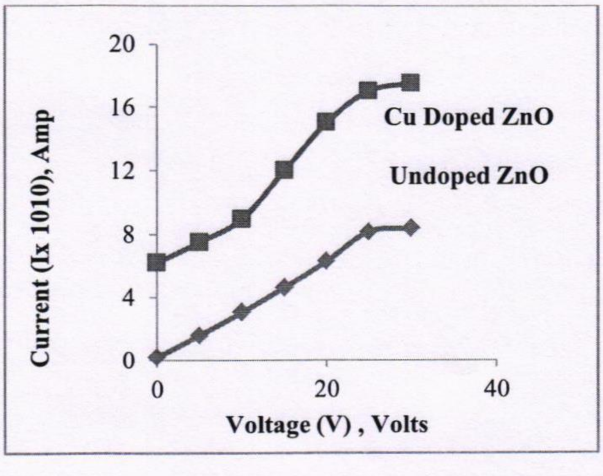


Fig 4 shows I-V characteristics of thin films having same thickness. It is seen that for undoped and Cu doped films, each curve starts with ohmic region (I αV) and then changes to nonohmic region ($I \alpha V^n$). The observed ohmic dependence ofcurrent on voltage at low fields can be explained on the basis of the sample studied, bulk limited currentexceeds the space charge limited current (SCLC). At higher fields, the observed value of n ($I \alpha V^n$) which isless than two, for both curves, rejects the possibility of an explanation of nonohmic region on the basis of Rose[17] theory of SCLC in defect insulators containing exponential distribution of traps or shallow traps.

CONCLUSION:

The temperature dependent characteristics of undopedandCudoped ZnO thin films show semiconducting behavior. The increase of resistance with reciprocal temperature for both undoped and doped ZnO thin films show constant difference at higher temperature side, but at lower temperatures the metallic doping of Cu in ZnO shows more conductivity than undoped ZnO due to excess current carriers.
The I-V Characteristics are almost linear for both undoped and doped ZnO with constant shift explained above.

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