PREPARATION OF ZnO NANO STRUCTURE THIN FILMS BY SPIN COATING METHOD OF SPINTRONICS AND OPTICAL APPLICATIONS

UGC – MRP – FINAL REPORT

UGC FILE NO:- 41-933/2012(SR) dt 23/07/2012

SUBMITTED BY

Dr. G. RAVI M.Sc., M.Phil., Ph.D

PROFESSOR

DEPARTMENT OF PHYSICS

ALAGAPPA UNIVERSITY

(Re-accredited with "A" Grade by NAAC)

KARAIKUDI – 630 003

TAMIL NADU

JUNE – 2015

OBJECTIVES OF THE PROJECT:

Given the increasingly important role of electronic and optoelectronic devices, thin film materials that are transparent and show good electrical properties are in great demand. The salient features of ZnO preparation by sol-gel technique are its low cost, non-toxicity, ready availability, and high chemical stability in reduction environments. Recently, there has been intense search for ferromagnetic ordering in doped dilute magnetic semiconductors focusing on possible spin-transport properties, which have many potentially interesting device applications. The motivation of the project is to optimize the preparation conditions of pure and doped (Mn and Co) nano-crystalline ZnO films and explore the device characteristics with the following objectives.

- Preparation of pure and doped (Mn and Co) nano-crystalline ZnO thin films on glass, quartz, Al_2O_3, silicon, $PbTiO_3$, ZnO single crystal substrates by sol-gel spin coating technique.
- Determining the influence of precursor, solvent nature, coating and heat treatment conditions on the preferential orientation of films.
- Extensive analysis of the grown films for their composition and crystalline nature using EDAX and XRD.
- Magnetic property studies using SQUID magnetometer.
- Optical properties by optical transmittance, photoluminescence, etc.
- Morphology and domain structure studies by Atomic Force Microscopy.
- Evaluation of the device characteristics and finding possibility for the fabrication of proto-type devices like light emitting diodes.

ACHIEVEMENTS FROM THE PROJECT:

The hybrid structures of ZnO with other semiconductors could increase the performance of UV detectors. On the other hand, nickel oxide (NiO) has been under investigation for different technological applications due to its wide direct band gap (3.6 – 4.0 eV) and it is intrinsically p-type semiconductor. These properties make NiO a suitable candidate for the fabrication of p-NiO/n-ZnO heterojunction based UV photo-detectors. Evaluated on p/n junction based ZnO/NiO junction thin films were deposited on a glass substrate by using sol-gel spin coating method.

Structural investigation indicated that well aligned ZnO nanorods with hexagonal faces having a preferential orientation along the c-axis (002) have been achieved and that the ZnO thin film is covering all the NiO nanoparticles. The p-NiO/n-ZnO heterojunction device has an average transmittance of over 80% in the visible region. The luminescence properties variation was observed by photoluminescence (PL) spectroscopy. The optical response of the heterojunction diode was excellent regarding the photocurrent generation. The Hall mobility and carrier density were found from the deposited thin films.

SUMMARY OF THE FINDINGS:

Pure and doped (Mn, Co, Ni) ZnO thin films have been deposited on glass substrates by the sol-gel spin coating method. The effect of doped magnetic materials (3 wt % concentration) of ZnO thin films revealed that the improved structural, morphological, compositional, optical and magnetic properties. Powder XRD patterns showed that all films are having hexagonal wurtzite structure with no secondary phases. The preferred orientation of all the deposited films is along c-axis with (002) plane and variations of lattice parameters were identified from XRD patterns. From the VSM analysis, large coercivity and saturation magnetic moment was observed for TM: ZnO thin films. It is concluded that the ferromagnetic behavior at room temperature was induced due to the doping of magnetic ions. From these studies, it is concluded that Co-doped ZnO thin film produces better structural, morphological, optical and magnetic properties and cobalt addition in ZnO will be useful for various applications. And also, doped and co-doped elements of Al^{3+} and Cu^{2+} ions on the interstitial position of ZnO was confirmed from XPS. The room temperature ferromagnetism in Cu co-doped Al:ZnO thin films, $Zn_{0.80}Al_{0.10}Cu_{0.10}O$ thin films exhibited a higher magnetization than that of $Zn_{0.80}Al_{0.15}Cu_{0.05}O$. The ferromagnetic behavior can be ascribed to the exchange coupling between localized 'd' spin of Cu ion mediated by free delocalized carriers. The present work of Cu co-doped Al: ZnO has considerable low magnetization which could form useful DMSs for spintronic applications.

The p-NiO/n-ZnO heterojunction device has high transmittance of over 80% in the visible region. The luminescence properties variation was observed by photoluminescence (PL) spectroscopy. The optical response of the heterojunction diode was excellent regarding the photocurrent generation. Although other similar heterojunction diodes demonstrated lower threshold voltage, the rectification ratio and the sensitivity of the fabricated diode were superior in comparison to other similar heterojunctions thin films.

CONTRIBUTION TO THE SOCIETY:

ZnO nanorods have been used successfully in the development of short wavelength optoelectronic devices and biosensing including visible blind UV detector, nano-lasers, light emitting diodes, gas sensors, biosensors, as a photoluminescence material and ultraviolet (UV) photo-detectors. It is known that ZnO thin films have high surface to volume ratio and also have a capability of high charge capacity and excellent transport of charge bearer, therefore resulting in enhanced working performance of devices. The whole research work for the publication of 11 papers in internationally refereed journals and 11 international/national conferences.

Signature of the Principal Investigator

Dr.G.RAVI, M.Sc., M.Phil., Ph.D.,
Professor & Head
Department of Physics
Alagappa University, Karaikudi-630 003