# Fabrication and Characterization of Nanocrystalline CdSe/ZnSe Heterojunctions

**Charita Mehta[1], G.S.S. Saini[2], S.K. Tripathi[3]**
[1, 2, 3] Department of Physics
[1] GGN Khalsa College Ludhiana-141004 India
[2, 3] Panjab University, Chandigarh-160 014 (INDIA)

***Abstract-*** *This paper presents the diode preparation and characterization of multijunction between ZnSe and CdSe. Nanocrystalline thin film of ZnSe has been prepared by chemical bath deposition technique while CdSe thin film has been prepared by physical vapour deposition method. The X-ray diffraction studies show that the deposited ZnSe thin films are nanocrystalline with a mixture of cubical and hexagonal phase, while CdSe films are having cubical phase. The response of heterojunction between CdSe and Znse has been investigated using forward bias current measurements at room temperature. Accordingly, ideality factor (n), built-in voltage ($V_{Bi}$), breakdown voltage ($V_{BD}$), saturation current ($I_o$) and breakdown current ($I_{BD}$) of the diode made of ZnSe/CdSe has been calculated.*

***Keywords-*** Nanocrystals, Heterojunction, XRD, Diode.

## I. INTRODUCTION

Heterojunction devices are playing an increasingly important role in optoelectronics [1,2]. They are produced by combining semiconductors that have differing band gap energies but closely matching lattice parameters. Semiconductor heterojunction is an idealized interface between two semiconductors. For device applications such an interface has to be free of contaminants and the two SCs much generally be lattice matched so that no distortion of epitaxial layers occurs to give rise to unwanted defects within the layer. In these very special circumstances, the band diagrams of the separate materials can be joined continuously and engineered to produce some desired heterojunction behaviour. This band gap engineering has provided a medium for understanding of semiconductor interface physics. Recently it has been investigated that devices fabricated from nanoparticles (NPs) have fundamental advantage over current bulk materials like ease of fabrication for large area and conformal combined with transparent, flexible and low cost [3]. This is because of the reason that as compared to higher dimensional quantum well and bulk active regions, NPs are advantageous for photo detection due to the effects of three dimensional quantum confinement effect. The heterojunction of ZnSe/CdSe is of particular interest due to a highly efficient charge separation across the interface. The wide band gap ZnSe layer has been used as a window layer while CdSe as an absorber layer. Also, the lattice match between the CdSe and overlayer ZnSe is very important. ZnSe has either a sphalerite structure with lattice parameter a = 5.67 ´ or a wurtzite structure with lattice parameters a = 3.82 ´ and c = 6.62 ´. Electron affinity of ZnSe is about 4.1 eV. The lattice constant value of cubic CdSe is reported as 6.05 ´ and electron affinity of about 4.56 eV. Lattice mismatch between these two materials is around 6.5%. The value of optical band gap ($E_g$) of ZnSe nanocrystalline thin films is 3.5 eV while for CdSe thin films $E_g$ is 2.2 eV.

## II. EXPERIMENTAL

The fabrication of heterojunction diode includes following steps: evaporation of semitransparent In electrode on clean glass slides by physical vapour deposition (PVD). Then ZnSe thin film is deposited over it by chemical bath deposition (CBD) method. Over this system, $Cd_{30}Se_{70}$ thin film is deposited by PVD to form a multijunction. This is followed by thick aluminium layer over CdSe film. There should not be any contact between the two electrodes. The structure of the diode is shown below in Fig. 1.

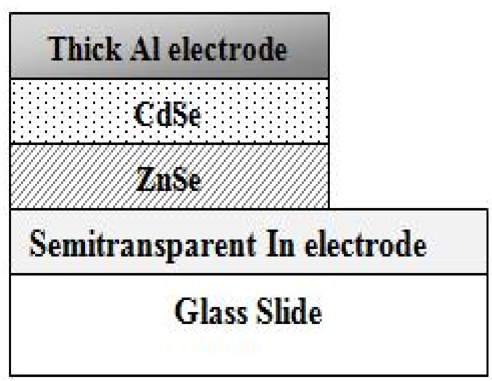


Figure 1: Structure of CdSe/ZnSe diode

Both CdSe and ZnSe are of n-type semiconductors. But carrier concentration of as-deposited ZnSe nanocrystalline thin films (~ $1.7 \times 10^{16}$ $cm^{-3}$) is greater than as deposited CdSe thin films (~$1.4 \times 10^{12}$ $cm^{-3}$). So, we consign ZnSe as $n^+$ and CdSe as n-type semiconductor. The deposition details of ZnSe thin films by CBD have been described elsewhere [4] while deposition of $Cd_{30}Se_{70}$ have also been described in the reference [5]. Crystallographic study is carried out in a Spinner 3064 XPERT-PRO X-ray diffractometer using CuKα radiation in the 2θ range from $10^o$ to $60^o$. Transmission electron microscopy (TEM) has been done using Hitachi H7500 electron microscope, operating at 90 kV.

### III. RESULTS AND DISCUSSION

Fig. 2 shows the XRD pattern of as deposited CdSe and ZnSe thin films. By comparing the observed 'd' values of ZnSe crystals with the standard 'd' values [6], it is confirmed that obtained ZnSe nanocrystalline films have a mixture of hexagonal and cubical phase.

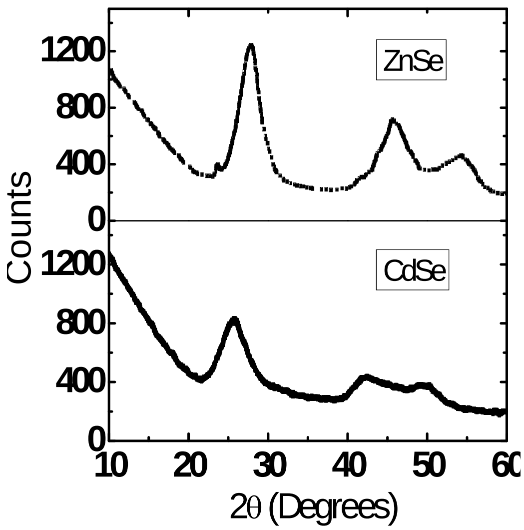


Figure 2: XRD pattern of CdSe and ZnSe nanocrystals

Comparison of 'd' values of CdSe thin films [7], confirms sphalerite cubical (zinc blende type) nanocrystalline structure of CdSe without impurities of hexagonal modification.

The p-n junction diode allows the current conduction in the forward direction and blocks the current flow in the other (reverse) direction. The ideal diode I-V characteristic is given by the following Eq.,

$$I = I_o\left(e^{qV_A/nkT} - 1\right) \qquad (1)$$

where, $I_o$ is the reverse saturation current, $V_A$ is the voltage applied across the diode terminals, $q$ is the electron charge, $k$ is Boltzmann's constant, $T$ is the ambient temperature in Kelvin, and $n$ is an ideality factor.

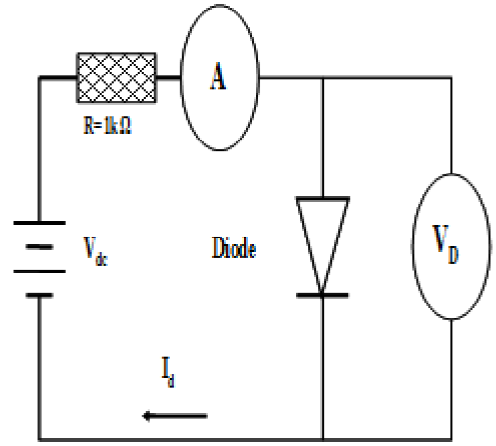


Figure 3: Schematic diagram for measuring the I-V characteristic of diode.

For the ideal p-n junction, $n$ is close to 1. In practice, it can vary anywhere from 1.2 to 2 or more. The setup of a p-n junction diode with power supply (Keithley 6517A) is shown in Fig. 3.

In forward bias, once the applied voltage is greater than a few ($kT/q$), we can neglect 1 in Eq. (1). Logarithms on both sides of the above equation, we get Eq. (2)

$$\ln(I) \cong \ln(I_o) + \left[\frac{qV_A}{nkT}\right] \qquad (2)$$

Fig. 4 represent the straight line plot of ln($I$) vs. $V_A$ with slope = $q/nkT$. The y- intercept gives the reverse saturation current ($I_o$). From the slopes, ideality factor ($n$) has been calculated [8].

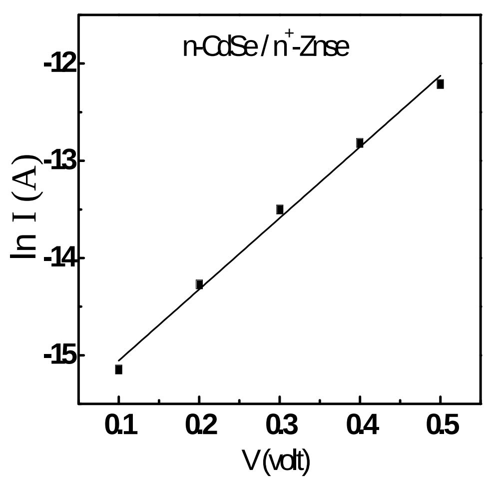


Figure 4: Plot of ln($I$) vs. $V_A$ for n-CdSe/$n^+$-ZnSe heterojunction.

The value of ideality factor for n-CdSe/$n^+$-ZnSe thin film heterojunction comes out to be 5 and its reverse saturation current is $1.39 \times 10^{-7}$ A.

Fig. 5 represents the current voltage curve of heterojunction between CdSe/ZnSe. The value of built-in voltage ($V_{bi}$) is calculated to be 0.4 V, forward resistance ($R_f$) is 10076 Ω. The value of breakdown voltage ($V_{BD}$) is -0.8 V and value of breakdown current comes out to be $-9.05 \times 10^{-6}$ A.

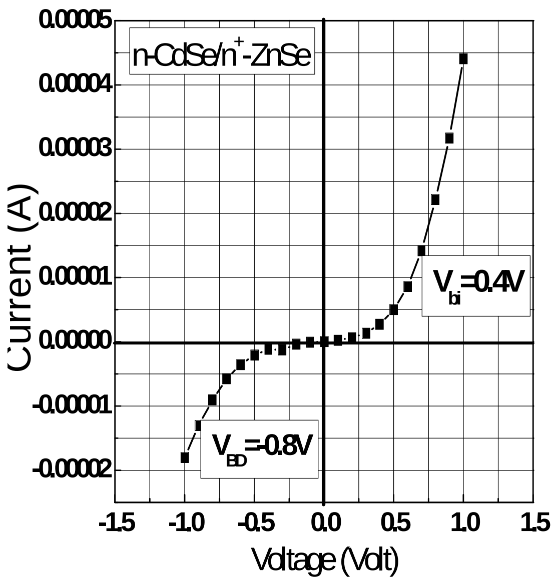


Figure 5: Current – Voltage curve of n - CdSe / $n^+$-ZnSe diode thin film

## IV. CONCLUSIONS

Nanocrystalline thin films of CdSe and ZnSe have been successfully utilized to fabricate a heterojunction diode between them. The ideality factor of the diode comes out to be 5, which is near to that of an ideal diode. From the current voltage characteristics, of the diode, built in voltage are calculated to be 0.4 V while breakdown voltage is -0.8 V. We believe that there is further scope for improving the diode characteristics of the bilayer device by optimizing synthesis and post-synthesis processing of the ZnSe nanocrystals, to use it in various optoelectronic devices. The ability to make multi-layer nanocrystal devices is an important step forward to inexpensive broadband photovoltaics.

## REFERENCES

[1] A. Stavrinadis, J.M. Smith, C.A. Cattley, A.G. Cook, P.S. Grant and A.A.R. Watt, SnS/PbS nanocrystal heterojunction photovoltaics, Nanotechnology 21, 185202, 2010.

[2] H. Lee, S.W. Yoon, J.P. Ahn, Y.D. Suh, J.S. Lee, H. Lim, and D. Kim, Synthesis of type II CdTe/CdSe heterostructure tetrapod nanocrystals for PV applications, Solar Energy Mat.Solar Cells 93, 779-782, 2009.

[3] B. Sun, A.T. Findikoglu, M. Sykora, D.J. Werder and V.I. Klimov, Hybrid photovoltaics based on semiconductor nanocrystals and amorphous silicon, Nano Lett., 9, 1235–1241, 2009.

[4] C. Mehta, G.S.S. Saini, J.M. Abbas, and S.K. Tripathi, Effect of deposition parameters on structural, optical and electrical properties of nanocrystalline ZnSe thin films, Appl. Surf. Sci., 256, 608-614, 2009.

[5] J. Sharma, G.S.S. Saini, N. Goyal, S.K. Tripathi, Thermally induced changes on the electrical and optical properties of nanocrystalline CdSe thin films, J. Optoelect. Adv. Mat., 9, 3194-3199 (2007).

[6] JCPDS data files, 37-1463 and 15-105.

[7] JCPDS Data File No. 8-459 and 19-191.

[8] J.J. Liou and J.S. Yuan, Semiconductor Device Physics and Simulation, Plenum Press, New York: (1998).