Original Research Article

Growth of CdS nanoparticles to fabricate Schottky barrier

.

.

ABSTRACT

CdS nanoparticles have been grown by a simple cost effective chemical reduction method and a Schottky barrier of gold/ nano CdS is fabricated. The grown nanoparticles are structurally characterized by transmission electron microscopy and x ray diffraction. The optical properties of nano CdS is characterized by optical absorption, photoluminescence study. The band gap of the CdS nanoparticles is increased as compared to CdS bulk form. Capacitance–voltage and current–voltage characteristics of gold /nano CdS Schottky barrier junction have been studied. It is found that these characteristics are influenced by surface or interface traps. The values of barrier height, ideality factor, donor concentration and series resistance are obtained from the reverse bias capacitance–voltage measurements.

Keywords: CdS nanoparticles; structural properties; optical properties; Au/n-CdSSchottky barrier

1. INTRODUCTION

Semiconductor nanoparticles are promising material in electrical and optoelectronic devices. Properties of nanostructures such as structural, electrical, optical etc. are different from their bulk form due to mainly quantum confinement effect and surface to volume ratio [1-3].Cadmium Sulphide a group II - group VI semiconductor having characteristic band gap 2.42 eV in bulk form has been used in different optoelectronic devices e.g. Solar cell, LED, Laser etc[4-7]. CdS nanostructures based hetero junctions, Schottky barriers are important for application in such devices [8-11]. The electrical properties of Schottky devices are affected by interface or surface properties [12-14]. There are various physical and chemical methods to prepare CdS nanoparticles [15-18]. We have followed a simple chemical reduction method which is cost effective also [19].

In the present work CdS nanoparticles are synthesized by a simple cost effective chemical reduction method. The prepared sample is characterized structurally and optically. Schottky junction of gold (Au)/n-CdS has been fabricated. The electrical properties of Au/n-CdSSchottky junction have been studied by current-voltage and capacitance – voltage measurements. From measurements, the values of barrier height, donor concentration are obtained.

2. EXPERIMENTAL DETAILS

The CdS nanoparticles are grown by a chemical reduction method at room temperature. Cadmium chloride, sulphur powder and sodium borohydride are used to grow CdS nanoparticles. The structure of grown nanoparticles are characterized TEM JEOL JEM200 at 200 kV.Optical absorption of the grown nanoparticles is performed by Shimadzu-Pharmaspec-1700 UV-VIS. Photoluminescence spectra of sample are observed by Perkin Elmer spectrophotometer. The procedure to grow CdS nanoparticles, structural, optical characterization of as prepared CdS nanoparticles is described elsewhere [19, 20].

To fabricate Schottky junction a film of the CdS nanoparticles on ITO coated glass has been grown from the dispersed CdS nanoparticles. The pre-cleaned ITO coated glass substrate has been dipped in to the dispersed solution of CdS nanoparticles at least for 6 hrs. Uniformly thin film of CdS nanoparticles has been deposited on the glass substrate. Schottky junction is fabricated by evaporating gold (Au) dots of 2 mm diameter through a mask on CdS film.

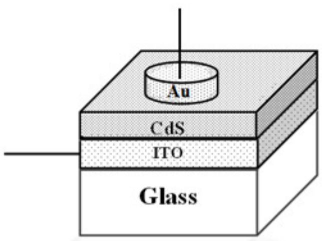

Fig.1 Schematic diagram of fabricated Au/nanoCdSSchottky device

Current-voltage and capacitance-voltage measurements of Au/n-CdSSchottky junction are performed using HP4284A LCR meter and Keithley electrometer.

3. RESULTS AND DISCUSSION

The TEM image of grown CdS nanoparticles is shown in Fig.2 and SAD pattern of the same is shown inset. The TEM image confirms that CdS nanoparticles are formed. The size of the as prepared nanoparticles is of the order of 11-14 nm.

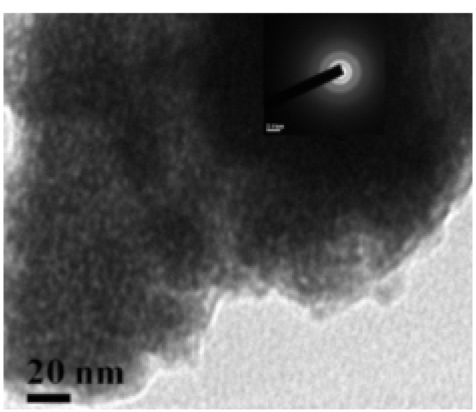

Fig. 2 TEM image and SAD pattern (inset) of as synthesized CdS nanoparticles

Fig. 3 shows the XRD pattern of the as prepared sample. The XRD pattern shows that nanoCdS sample is in hexagonal phase [20].

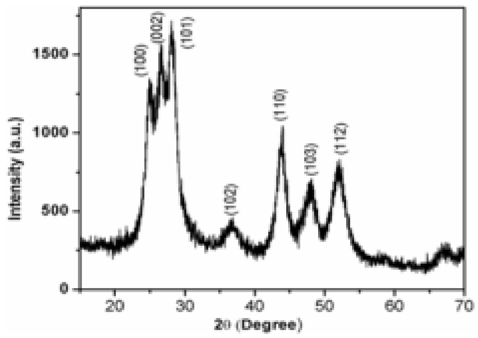

Fig. 3 The XRD pattern of the as grown CdS nanoparticles

The variation of optical absorbance of CdS nanoparticles with wavelength is shown in Fig. 4

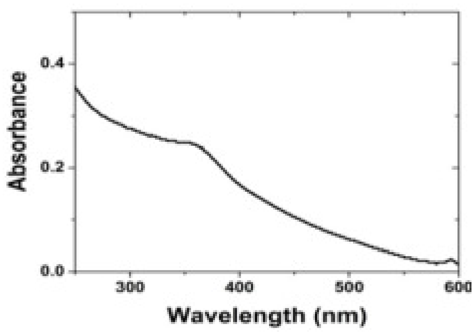

Fig. 4The optical absorption spectrum of as prepared sample

The band gaps of the as-prepared nanoparticles are determined from the Tauc relation [21]

$(\alpha hv)^2 = C\,(hv - E_g)$ (1)

Where C is a constant. Eg is the band gap of the semiconductor material and α is the absorption coefficient. (αhv)2 vs. hv plot is given in figure 5. The band gap is found to be 2.97 eV.

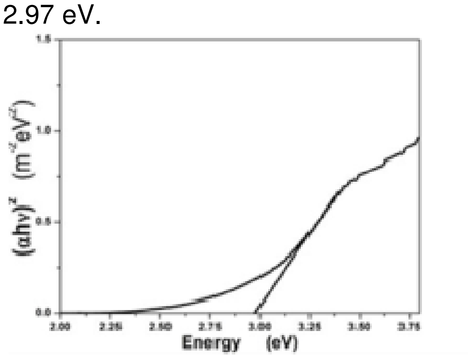

Fig. 5 The band gap determination curve for as prepared sample

The photoluminescence spectrum of as-prepared CdS sample is displayed in Fig. 6.

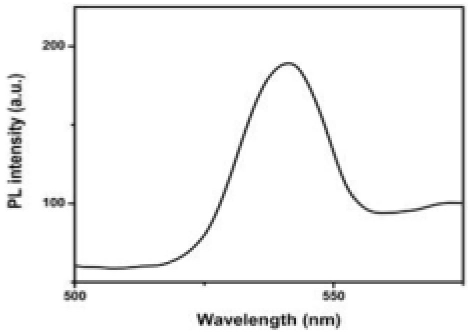

Fig.6 The photoluminescence spectra of as prepared sample

Photoluminescence spectrum displays peak around 530 nm due to presence of surface states [22].

Capacitance(C) –Voltage (V) Measurement

The C-V measurement of Au/n-CdS Schottky junction with reverse and forward biasing voltages at temperature 303 K is shown in Fig. 7.

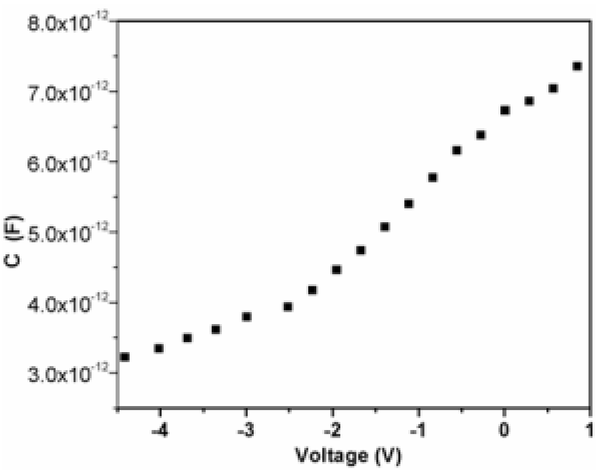

Fig. 7 The C-V characteristics of nano n-CdS /Au Schottky junction

The $1/C^2$ vs. V plot is given in figure 8. The carrier concentration, built-in-voltage is determined from the slope [25] and the intercept on the V axis of $1/C^2$ vs. V plot using the Mott-Schottky relation (2)

$$C^{-2} = \frac{2(V_b + V)}{q\varepsilon\varepsilon_{\circ} A^2 N_d}$$

where N_d is the donor concentration, V_b is the built-in potential, q is the electronic charge, ε_0 is the permittivity of free space, ε is the dielectric constant of the semiconductor. W is the width of the depletion region. A is the area of the device. In Mott-Schottky relation it is assumed that surface or interface traps are absent, no interfacial layer is present between metal and semiconductor [24].

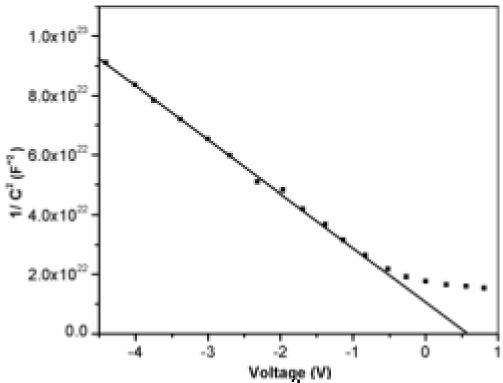

Fig. 8 Reverse bias 1/C^{2}vs V characteristics of Au/n-CdSSchottky barrier

The obtained values of N_d and V_b are given in Table 1. The value of barrier height φ_b is calculated by the following relation

$$\Phi_b = V_b + V_p \quad (3)$$

Where V_p is the potential difference between the Fermi level and the top of the valance band in CdS. V_p is calculated by knowing the donar concentration N_d and value of N_d is obtained from the following relation

$$V_p = KT \ln (N_c / N_d) \quad (4)$$

Where N_c= 1.5X10^{20} cm^{-3} is the density of states in the conduction band for CdS [14]. The calculated barrier height value for the Au/n-CdS Schottky junction is given in table 1.It is seen from the result that C-V characteristics of Au/n-CdS Schottky junction is influenced by surface traps. [26].

Current (I)–voltage (V) characteristics

The I-V characteristics of the Au/n-CdS device under forward and reverse biasing conditions at 303K is shown in Fig. 9.

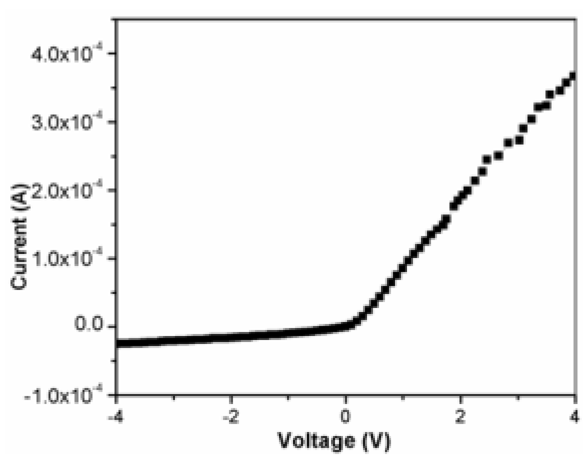

Fig. 9 The I-V characteristics of the Au/n-CdS device in forward and reverse biasing condition

The electron affinity of n-type CdS is 4.8 eV [27] while the work function of gold (Au) is about 5.25 eV [28]. So a Schottky barrier should be formed at the contact interfaces of Au/n-CdS. According to thermionic emission theory the current in metal semiconductor Schottky junction is given by

$$I=I_s\,[\exp(qV/\eta kT)-1] \qquad (5)$$

Where I_s is saturation current, V is applied voltage, η is the ideality factor, k is the Boltzmann constant, T is the absolute temperature in Kelvin. Taking into consideration of series resistance Rs the equation can be expressed as

$$I=I_s[\exp(q(V-IR_s)/\eta kT)-1] \qquad (6)$$

The equation can be differentiated as

$$dV/d(\ln I)= IR_s +\eta kT/q \qquad (7)$$

The plot associated with Eq. (8) $dV/d(\ln I)$ vs I is given in Fig. 10.

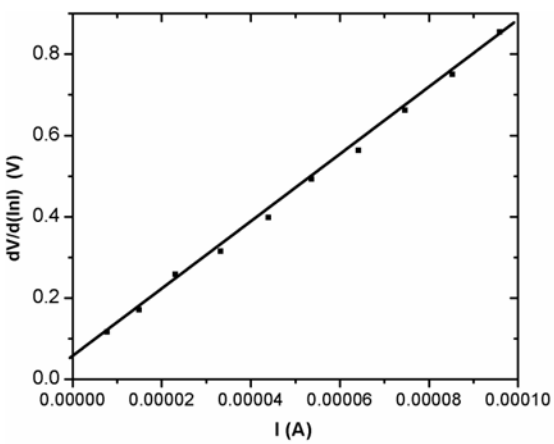

Fig. 10 dV/d (lnI) versus I plot for Au/n-CdS device.

The series resistance R_s are calculated from the slope of *dV/d (ln I) vs I* characteristic according to equation (7) [29]. The series resistance R_s here includes the contact resistance. While η is determined from the dV/d(lnI) axis intercept of the line fit shown in Fig. 9. The series resistance is found to be 8.27 kΩ .The ideality factor in the room temperature is listed in Table 1.

Table 1 Different parameters of Au/n-CdS Schottky junction at temperature 303K

V_b (V)	N_d (cm^{-3})	Φ (eV)	η
0.56	5.41×10^{15}	.82	2.19

The obtained high series resistance of the Au/n-CdSschottky device may be attributed to the high resistance of the starting CdS material or to the interfacial layer created between the metal and CdS [4]. The high value of η may be due to large recombination within the interfacial layer [15, 30] which exists mainly in the semiconductor side

4. CONCLUSION

We have synthesized CdS nanoparticles. We have also fabricated a nanoCdS /Au Schottky junction. The C-V and I-V characteristics of the Au/n-CdS Schottky junction have been studied. The values of built in potential, barrier height, ideality factor, series resistance, the density of interface states have been calculated. It is found that the I-V and C-V characteristics of the Au/n-CdS Schottky junction are influenced by the surface states or interface traps.

REFERENCES

1. PengXG,MannaL,Yang WD, Wickham J,Scher E, Kadavanich A, Alivisatos AP, Nature 2000;404: 59

2. Trindade T, Brien PO', Pickett NL, Chem.Mater. 2001;13: 3843

3. Bawendi MG, Caroll PJ, Wilson WL, Brus LE, J.Chem.Phys. 1992;96:1335

4. Pal ., Bhattacharya D, Maity AB, Choudhury S., Pal A K, Nanostruct.Mater. 1994;4:329

5. Lin YF, Hsu YJ, Lu SY, Chen KT, Tseng TY, J. Phys. Chem. C 2007;111:13418

6. Law M, Greee L E, Johnson J C, Saykally R, Yang P, Nat. Mater. 2005;4: 455

7. Kang Y, Kim D, Sol. Energy Mater. Sol. Cells 2006;90:166

8. Ye Y, Dai L, Wu P C, Liu C., Sun T, Qin GG, Nanotechnology 2009;20:375202

9. Farag AAM, Yahia IS, Fadel M, Int.J.Hydro gen Energy 2009;34(11):4906

10. Mandal S K, Maity AB, Dutta J, Chaudhuri S, Pal A K, Phys. Stat. Sol. (a) 1997;163(2):433

11.. Wang X, Zhou J, Song J, Liu J, Lu N, Wang Z L, Adv. Mater. 2008;20,:3127

12. Chand S, Kumar J, J ApplPhys, 1997;82:5005

13. Didden A, Battjes H, Machunze R, Dam B, Krol R, J. Appl. Phys. 2011;110:033717

14. Maruska HP, Namavar F, and Kalkhoran N H, Appl. Phys. Lett. 1992 ;61:1338.

15. Chaure N B, Bordas S, Samantilleke AP, Chaure SN, Haig J and Dharmadasa IM, Thin Solid Films 2003;37:10

16. Yang Y, Chen H, Mei Y, Chen J, Wu X, Bao X, Actamaterilia 2002;50 :5085

17. Xu D, Xu Y, Chen D, Guo G, Gui L, Tang Y, Chem. Phys. Letters 2000;325:340

18. Shen XP, Yuan A H, Wang F, Hong J M, Xu Z, Solid State Commun. 2005;133:19

19. Wang W, Germanenko I, El-Shall MS, Chem. Matter. 14; 3028: 2002

20.Bhattacharya R, Das TK, Saha S.J Mater Sci: Mater .Electron 2011;22:1761

21. Ghobadi N, Int. Nano Lett. 2013;3:2

22. Okamoto S, Kanemitsu Y, Hosokawa H, Murakoshi K, Yanagida S., Solid StateCommun. 1998;105 (1): 7

23. SzeS.M.. Physics of semiconductor devices, 2nd ed (John Wiley & Sons, New York 1981), p. 249

24. Patel B K, Nanda K K, Sahu SN, J. Appl. Phys. 1999;85(7):366

25. Sahu S N, Chandra S, Sol. Cells 1987;22:163

26. Zhang ZY, Jin CH, Liang X L, Chen Q, Peng LM, Appl. Phys.Lett. 2006;88 :073102

27. Swank R K, Phys. Rev. 153, 844 1967

28. Rusu PC, Brocks G, J. Phys. Chem. B 2006;110 :22628

29Quan DT, Hbib H, Solid-State Electron 1993;36:339

30. Lao CS, Liu J, Gao P X, Zhang L Y, Davidovic D, Tummala R, Wang Z L, Nano Lett. 2006;2: 263