

Electrical Characterization of Nanocrystalline CdS Thin Films in PVA Matrix.

Ankita R. Karule
Dept. of Science and Humanities,
Government Polytechnic,
Amravati, India.
e-mail: ankita.karule@gmail.com

Shrikrishna P. Yawale
Dept. of Physics,
Government Vidharbha Institute of
Science and Humanities.
Amravati, India.
e-mail: spyawale@rediffmail.com

Abstract— The Cadmium Sulphide (CdS) thin films in Polyvinyl Alcohol (PVA) matrix solution were prepared by chemical bath deposition method in alkaline medium and their electrical and optical properties were studied. The various characterization techniques such as DC electrical conductivity measurement, photoconductivity study and scanning electron microscopy have been carried out to characterize sample. DC conductivity measurement shows that, electrical conductivity increases with molar concentration of CdS. Electrical conductivity is maximum at 0.75M CdS and with further increasing concentration electrical conductivity decreases. Also activation energy for different molar concentration is different. Photoconductivity of chemically deposited CdS films changes with molar concentration of CdS. It is maximum for 1 M CdS concentration. The observation is supported from the changes in grain size and rise and decay curves. The values of crystallite size of CdS thin films are determined from SEM and are found to vary from 499.5 to 833nm. This shows that increase of molarity of CdS decreases the grain size which in turn increases the band gap.

Keywords- CdS thin film; PVA matrix; electrical conductivity; photoconductivity; nanometer grain size.

I. INTRODUCTION

In recent years, there is an increasing interest in developing the thin film solar cells as one of the alternative energy sources because they use less polluted solar energy. Cadmium Sulphide (CdS) and Nickel Sulphide (NiS) are promising semiconducting materials in conversion of solar energy into electrical energy. Many investigations on photoconductivity of CdS have been carried out. Many attempts have been made to increase the photoconductive properties of CdS films by adding the impurities [1-5].

Cadmium sulphide (CdS) is one of the most promising compound because of its wide range of applications in various optoelectronic [6-8], piezo- electronic [9] and semi conducting devices.

They are also used in the fabrication of optical filters, multilayer LEDs, photodiodes, phototransistors etc. Heterojunction solar cells with a wide band gap absorber are currently becoming the focus of intensive research in order to develop efficient, stable and low cost cells. Cadmium sulphide, with a band gap of 2.43 eV, is an ideal material for use as the window layer of heterojunction solar cells.

A wide variety of techniques have been employed for the deposition of CdS thin films. In this work CdS films were deposited by chemical bath deposition technique in polymer matrix which is relatively simple, cost effective and suitable for deposition of film on large area substrate [10].

II. EXPERIMENTAL

The deposition of CdS thin film was carried out in mixture of matrix solution and thiourea. The matrix solution was prepared by adding Cadmium Chloride to an aqueous solution (2%) of PVA with constant stirring at a constant temperature (70°C) maintained for 90 min. Five different concentrations of Cadmium Chloride (0.1, 0.25, 0.5, 0.75 and 1M) were used to get five different matrix solutions. The solution was then left for 24 hours to get a transparent liquid indicating complete dissolution of cadmium chloride. The pH of the solution was

maintained at around 11 by slowly adding NH₄OH solution. Then the equimolar solution of thiourea was added to the mixture solution and glass substrates were introduced vertically into the solution. After sometime colour of the solution changed to yellow and yellow CdS films are obtained. The overall chemical reaction is as follows –



When reaction is completed, due to excess precipitation, powder was formed. Then powder was pressed on the pellet machine having a pressure of 6 ton in at room temperature in circular shapes of 1cm diameter.

Thickness of all the samples was measured by using Digimatic Micrometer (Mitutoyo Make, Japan) with least count $\pm 1\mu\text{m}$.

Surface morphological study of optimized CdS thin films was done by using scanning electron microscope, (JEOL-JSM-6380A), operating with an accelerating voltage of 15KV at Vishveshwarya National Institute of Technology, Nagpur. Grain size was determined from SEM photograph at different magnifications.

The dc conductivity of the samples was measured by two probe method, in which resistance of the sample was measured. Samples under test were sandwiched between two electrodes of the sample holder. A constant dc voltage (5V) was applied to the sample and corresponding current was noted at different temperatures (313 to 423K).

For photoconductivity study 100 W lamp was used. The intensity of incident light was measured with the help of Lux meter (Lutron Make). Filters of different wavelengths were used so that light of suitable wavelength incident on a thin film

III. RESULTS AND DISCUSSION

A. Surface Morphology

Scanning electron microscopy is convenient method for studying surface morphology of thin films. The samples were scanned at different magnification. The SEM photographs of CdS thin films of 0.1, 0.25, 0.5 molarity are as shown in Fig. 1(a to c). It is observed from micrograph that CdS film is homogeneous, fine grained and well covered with overgrowth of some particles. The increase in molar concentration of CdS decreases the crystallite size. The values of crystallite size for CdS thin films having molarities 0.1, 0.25, 0.5 at 3000x magnification are found to be 833, 729.6 and 499.5nm. The crystallite size is found to be less for 0.5M CdS film.

From the SEM photographs it is observed that the films are partially crystalline and the crystallites are connected with each other forming small pores and voids. As the concentration of CdS increases the regularity in the crystallite formation increases.

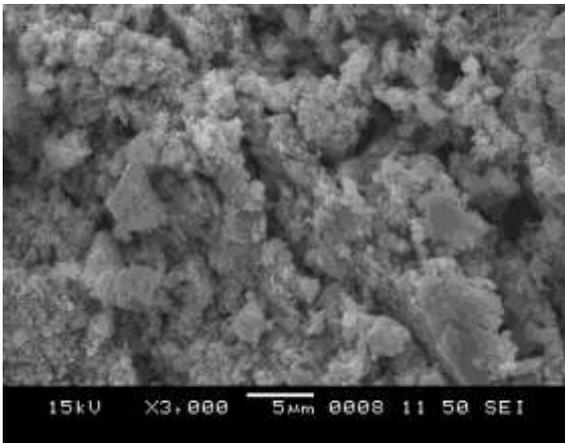


Figure1 (a): SEM photograph of 0.1M CdS thin film at 3000X magnification

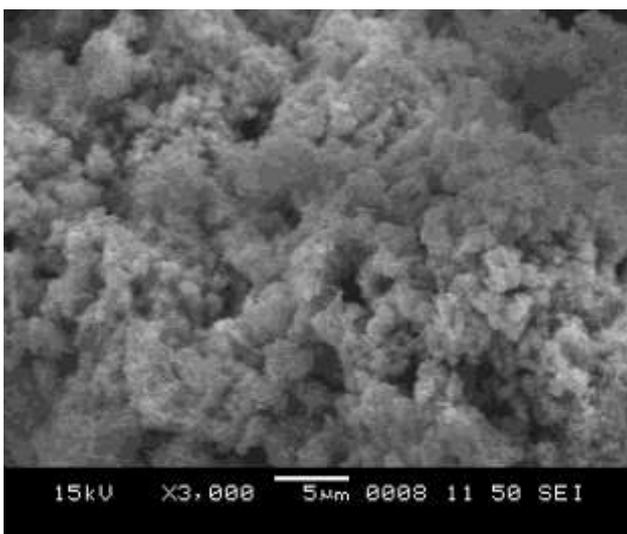


Figure1 (b): SEM photograph of 0.25M CdS thin film at 3000X magnification

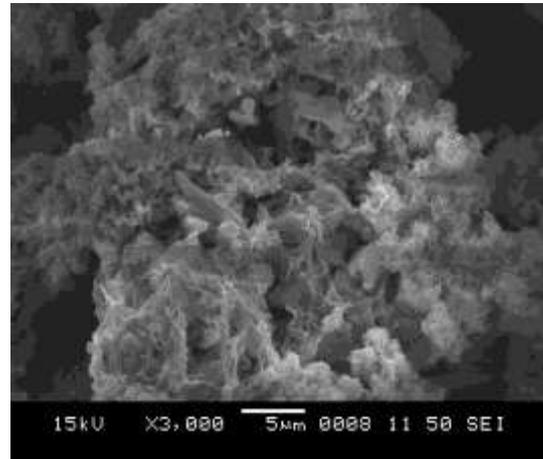


Figure1 (c): SEM photograph of 0.5M CdS thin film at 3000X magnification

B. DC Conductivity

DC conductivity of the films of different CdS molar concentration was measured in the temperature range 313 to 423K by measuring the resistance of the samples. It was observed that the value of resistance depends on composition as well as on temperature.

The variation of electrical conductivity $\log \sigma$ versus $(1/T)$ for different concentration of CdS is as shown in Fig.2. From Fig.2 it is clear that, conductivity increases linearly with temperature thus it follows Arrhenius nature. The conductivity also varies with concentration of CdS.

The values of activation energy are calculated from the $\log \sigma$ Vs $1/T$ plot. The variation of activation energy with molar concentration of CdS is as shown in Fig.3. The activation energy is found to be maximum for 0.75 M of CdS and minimum for 0.25M of CdS samples.

Fig.4 shows the variation of conductivity with different molar concentration of CdS at 323K temperature. The maximum conductivity is found to be -11.6077 S/cm for 0.5M CdS film.

It is sometimes argued that ionic conduction is characterized by mobilities and high activation energies, while electronic conduction is associated with relatively higher mobilities and lower activation energies. It is also assumed as a general rule, that values for the activation energies less than 0.2 eV should be considered as indicating undoubtedly electronic mechanism and values more than 0.6 or 0.8 eV would normally be associated with ionic transport [11].

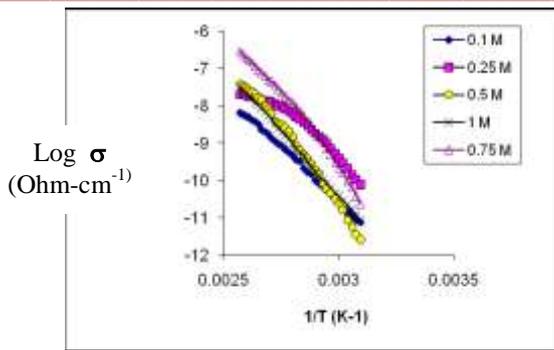


Fig. 2: Variation of electrical conductivity $\log\sigma$ with $1/T$ for different concentration of CdS

The rise and decay of the photoconductivity in different concentration of CdS films was studied for same light intensity i.e. 6050 Lux with an applied field 30V d.c. The rise (ON) and decay (OFF) time defined as time required for the photocurrent to rise 90% of the stationary value when light is ON and time required to decay 90% until the original dark current was reached when light is switched off.

The rise and decay of photoconductivity with time for different molar concentration of CdS at different wavelengths are as shown in following Fig. (5.1-5.5)

From the Fig. (5.1-5.5), ON time and OFF time for different concentration of CdS films at different wavelengths is calculated.

It is observed that ON time and OFF time for different concentration of CdS films is different. It is maximum for 1M CdS concentration and minimum for 0.1M CdS.

Fig.6 shows variation of photocurrent with wavelength of incident light for different molar concentration of CdS at room temperature. The decrease in photocurrent on longer wavelength side is attributed to the non-optimized thickness and the transition between defect levels. Decrease of photocurrent on short wavelength side might be due to the absorption of light in the electrolyte and high surface recombination of the photo generated carriers by surface states [16].

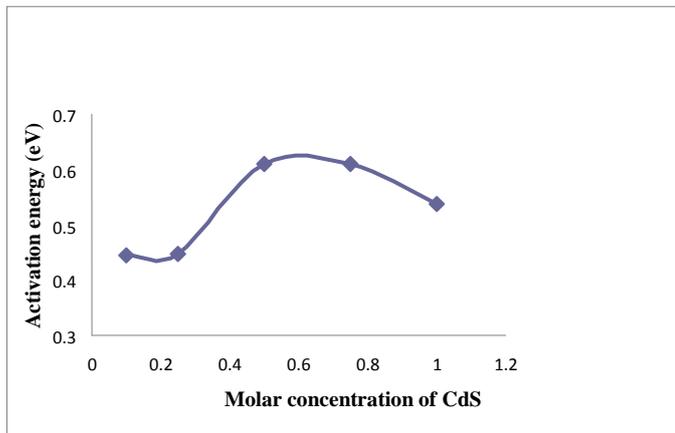


Fig. 3: Variation of activation energy with Molar Concentration of CdS

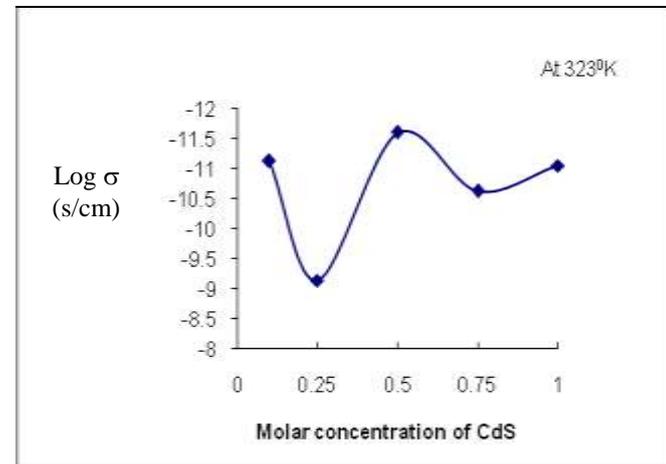


Fig. 4: Variation of electrical conductivity $\log\sigma$ with different molar concentration of CdS at constant temperature 323°K

C. Photoconductivity Study

To have ohmic contact to n-type semiconductor, the contact material should be of a lower work function than that of the semiconductor and can be chemically inert to it. Contacts to CdS films having different concentration were made by silver paste. The I-V characteristics has been found to be linear within the voltage range of study (up to 30V) shows that silver electrodes produce ohmic contact with CdS.

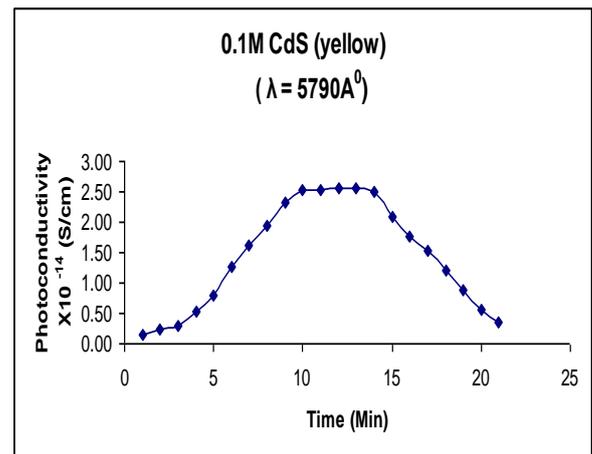


Fig. 5.1(a) At $\lambda = 5790 \text{ \AA}$

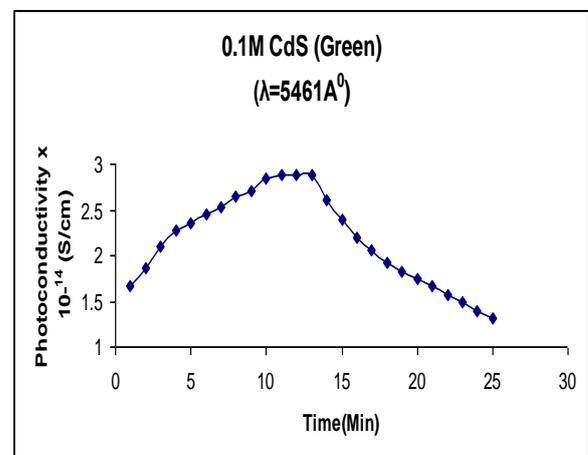


Fig. 5.1(b) At $\lambda = 5461 \text{ \AA}$

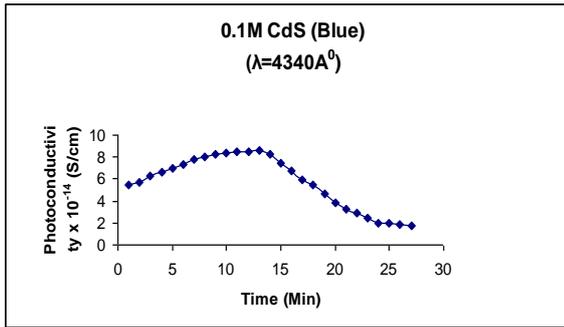


Fig 5.1(c) At $\lambda = 4340 \text{ \AA}$

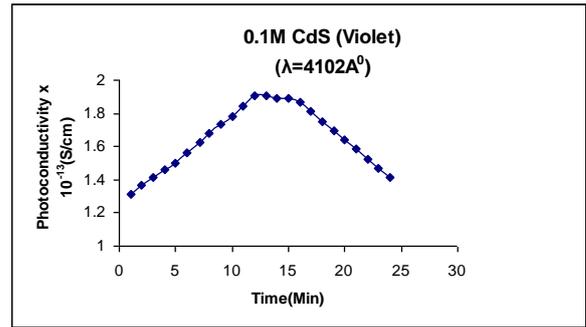


Fig 5.1(d) At $\lambda = 4102 \text{ \AA}$

Fig 5.1: The variation of photoconductivity with time for 0.1M CdS

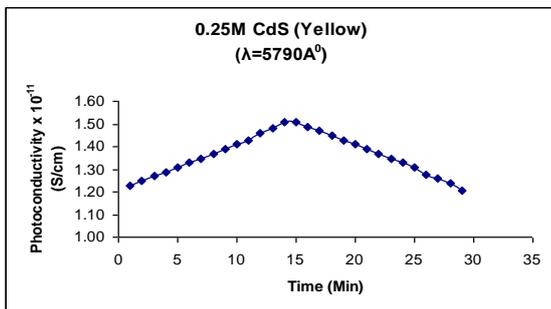


Fig 5.2(a) At $\lambda = 5790 \text{ \AA}$

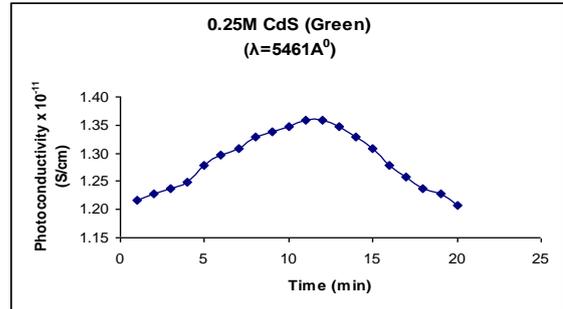


Fig 5.2(b) At $\lambda = 5461 \text{ \AA}$

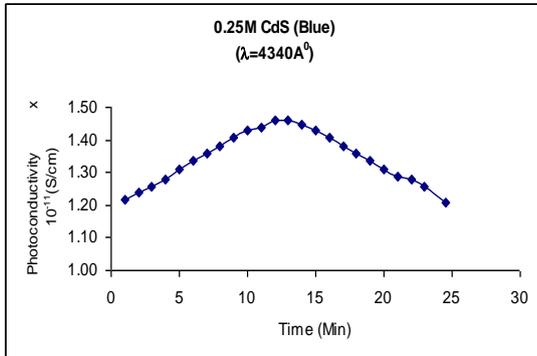


Fig 5.2(c) At $\lambda = 4340 \text{ \AA}$

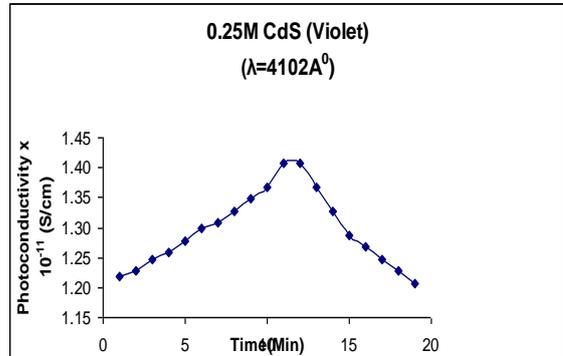


Fig 5.2(d) At $\lambda = 4102 \text{ \AA}$

Fig 5.2: The variation of photoconductivity with time for 0.25M CdS

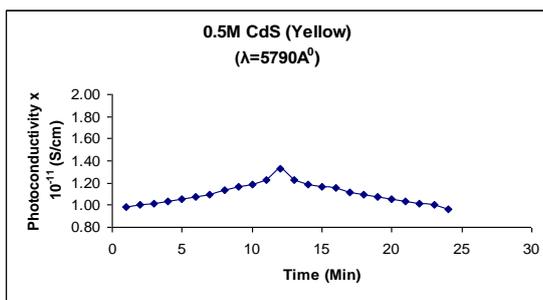


Fig 5.3(a) At $\lambda = 5790 \text{ \AA}$

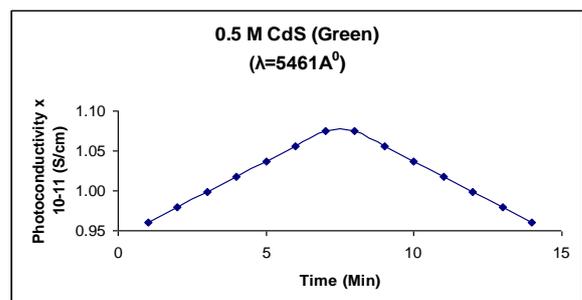


Fig 5.3(b) At $\lambda = 4340 \text{ \AA}$

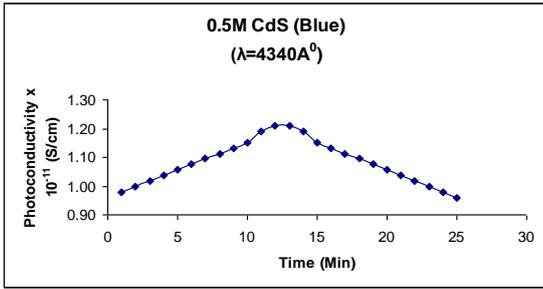


Fig 5.3(c) At $\lambda = 4340 \text{ A}^0$

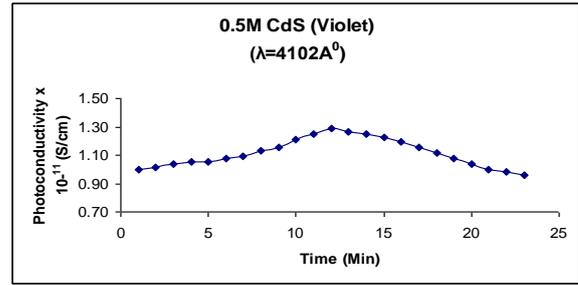


Fig 5.3(d) At $\lambda = 4102 \text{ A}^0$

Fig 5.3: The variation of photoconductivity with time for 0.5 M CdS

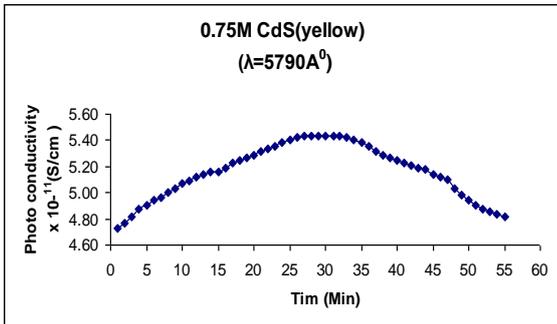


Fig 5.4(a) At $\lambda = 5790 \text{ A}^0$

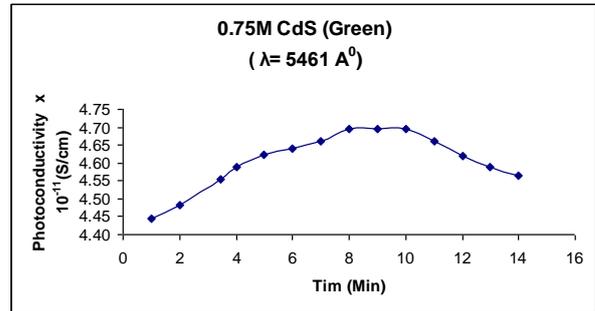


Fig 5.4(b) At $\lambda = 5461 \text{ A}^0$

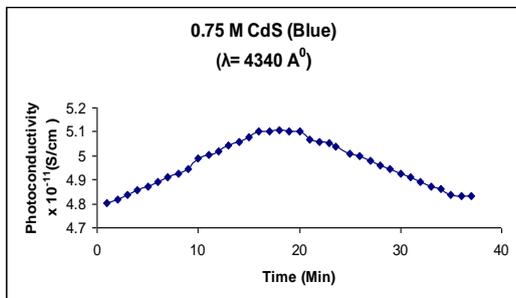


Fig 5.4(c) At $\lambda = 4340 \text{ A}^0$

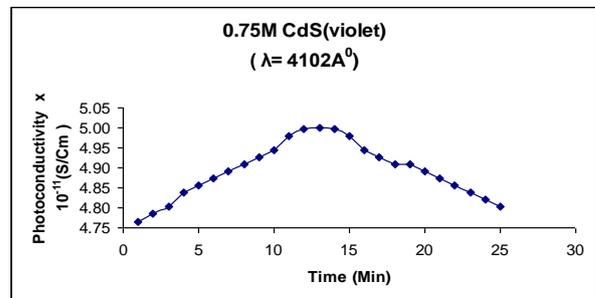


Fig 5.4(d) At $\lambda = 4102 \text{ A}^0$

Fig 5.4: The variation of photoconductivity with time for 0.75 M CdS

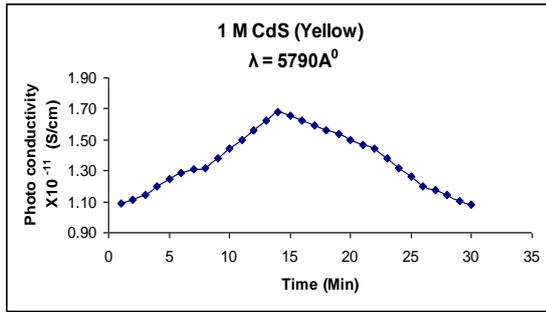


Fig 5.5(a) At $\lambda = 5790 \text{ \AA}$

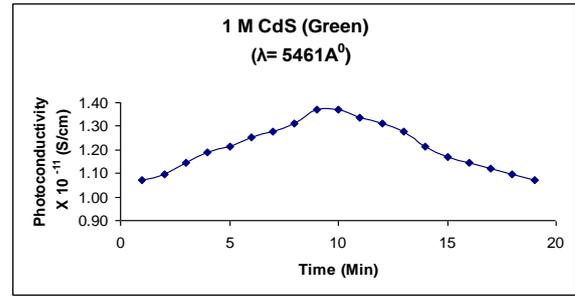


Fig 5.5(b) At $\lambda = 5461 \text{ \AA}$

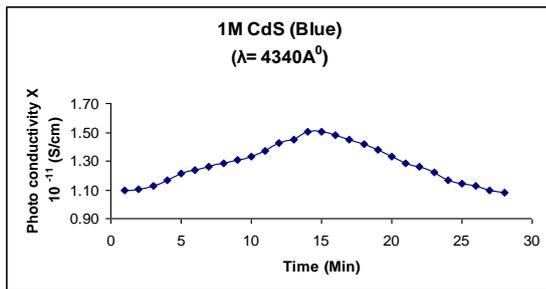


Fig 5.5(c) At $\lambda = 4340 \text{ \AA}$

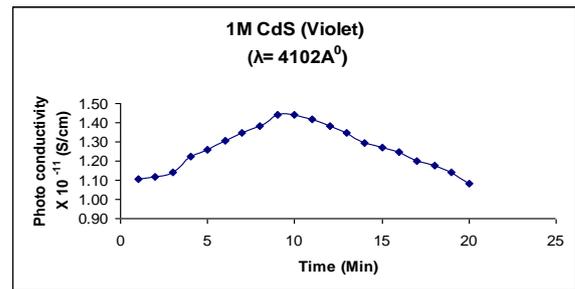


Fig 5.5(d) At $\lambda = 4102 \text{ \AA}$

Fig 5.5: The variation of photoconductivity with time for 1M CdS

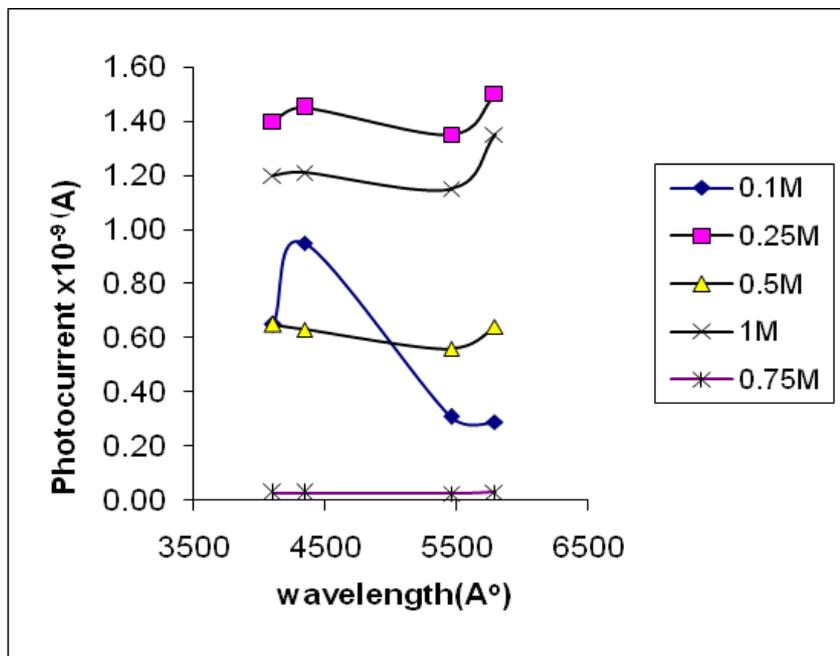


Fig 6: Photocurrent variation with varies Wavelengths of incident light at room temperature for different molar concentration of CdS.

IV. CONCLUSION

In present work CdS thin films in PVA matrix were prepared by chemical bath deposition method in alkaline medium and their electrical and optical properties are studied.

The samples were scanned at different magnification using SEM for determination of surface morphology. The values of crystallite size at 3,000x magnification are found to be within 499.5 to 833 nm.

DC conductivity measurement shows that, electrical conductivity increases with molar concentration of CdS. Electrical conductivity is maximum at 0.25M CdS and with further increasing concentration, electrical conductivity decreases. The activation energy for different molar concentration is different and it is maximum for 0.75M CdS i.e. 0.617eV and it is minimum for 0.1M CdS i.e. 0.443 eV.

It is concluded that the photoconductivity of chemically deposited CdS films changes with molar concentration of CdS. It is maximum for 1M CdS concentration. The observation is supported from the changes in grain size and rise and decay curves.

In the present investigation, as the films were prepared by the chemical bath deposition method, oxygen molecules are assumed to be physically adsorbed on to the surface of cadmium sulphide. They then become chemisorbed having captured a conduction electron, which binds them to the surface. The energy levels of such bound electrons are sufficiently below the conduction band that in the dark, the rate of escape of electrons from the surface to the conduction band is negligible. Holes move to the surface under illumination and are captured by negatively charged oxygen molecules, giving neutral molecules which are weakly bound and can escape from the surface [13].

When the film is illuminated by light, the conductivity of the film may enhance due to the increase in excess carriers and / or decrease in barrier height depending upon the incident photon energy [14]. In the present work the number of photons falling per second on an effective film area between the electrodes, which are expected to be strong enough to cause a partial depletion of grains. Thus the change in conductivity due to carrier modulation from the excess photogenerated carriers is insignificant relative to those remaining thermally generated carriers. Hence the conductivity under illumination increases primarily due to the enhancement of carrier mobility resulting from barrier modulation [15].

ACKNOWLEDGMENT

Authors are thankful to Director, Professor and Head of the Physics Department, both from Government Vidarbha Institute of Science and Humanities, Amravati for providing laboratory facilities.

REFERENCES

- [1] A.U. Warad, M. D. Uplane and S. H. Pawar, Mater. Chem. Phys. 13 (1985)91.
- [2] N. R Pavaskar, C.A. Menzes and A. P. B Sinha, *J. Electrochem. Soc.*124(1977) 743.
- [3] B.B.Bargale, Ph.D Thesis, Shivaji University, Kolhapur, 1977
- [4] T.S.Moss, Optical properties of semiconductor, Butterworths, London.1961.
- [5] S.Bhushan and S.K.Sharma, *J.Phys.D.Appl.Phys* 28(1980)909
- [6] Iyechika Y, Winger G, Jager D, Witt A & Klingshirn C 1988 SPIE Opt.

Comput.88 103.

- [7] Dhumure S S & Lokhande C D 1993 Indian J. Pure & Appl Phys. 31 512.
- [8] Lee Jae – Hyeong et al 2003 Thin solid films 344 431.
- [9] Kerk J de and Kelly E F 1964 Appl. Phys. Lett.52; Stefko V V 1991 Sov. J. Commun. Technol. Electron.36.
- [10] R. Devi, P. Purkayastha, P. K. Kalita and B. K. Sharma, Bull. Mater Sci., 30 (2) (2007) 123-128.
- [11] V. K. Jain, C. L. Gupta and R. K. Jain, Solid State Physics Laboratory, Lucknow Road, Delhi, 110007 (1977).
- [12] Sayer M. and Mansingh A. Phys. Rev., B6, 4626(1972).
- [13] S. J. Lade, M. D. Uplane, C. D. Lokhande, Materials Chemistry and Physics 68(2001) 36-41.
- [14] J. Dutta, D. Bhattacharyya, S. Chaudhary and A. K. Pal, Sol. Energy Mater. Sol. Cells 36, 357 (1995).
- [15] P. K. Kalita, PRAMANA –Phy, 60(6) (2003) 1247-1257.
- [16] S. J. Lade, M. D. Uplane, C. D. Lokhande, Mate Chem and Phy 68(2001) 36-41.