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Synthesis of Nanostructured Cadmium Sulphide and Fabrication of High Response Photo Sensor

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Abstract*: The light dependent resistor (LDR) are prepared using bulk CdS material and using conventional thick film technique. But bulk CdS and this conventional thick film technique gives lower inter-electrode spacing resulting poor response. In the present work, the CdS nanostructure was synthesized using hydrothermal reaction technique and with the help of screen printing technique, the CdS pattern having lower inter-electrode spacing resulting larger length of the CdS was prepared. As the inter electrode spacing increases the photocurrent also increases resulting enhancement of the sensor response. The work reported in the present paper provides the photo-sensor having higher sensitivity.

Keywords* : Cadmium sulfide (CdS), nanomaterials, photosensor, optical sensor

I. INTRODUCTION

The semiconductor nanostructures have wide range of application in the area of light-emitting diodes, flat panel digital displays, solar cells, transistor, photocatalysis and many other optoelectronic devices.[1-5] The properties of semiconductors are strongly depends on their synthesis method, shape and size.[6] Among the studied semiconductor nanostructures, the CdS has been widely investigated semiconductor chalcogenides. The CdS represents II-VI semiconductor group having direct band gap of 2.4 eV, it can be prepared by various methods as well as techniques.[7] Each method has its own merits and demerits. Based on the targeted application, researchers are selecting the nanomaterials synthesis method. Various reports available mentioning the synthesis of CdS having quantum dots, one dimensional (1D), two dimensional (2D) and three dimensional nanostructures. One pot synthesis of CdS with nanorods, bipod and tetrapod like structures were reported by *Yong et al.*[8] *Arbuj et al* reported the hydrothermal synthesis of CdS nanoparticles as well as nanorods in presence of different capping agents and investigated its photocatalytic properties.[9] The shape of the nanoparticles are governed by the use of capping agents, solvents and reaction methods. *Xu et al* reported the synthesis of CdS nanowires and studied its formation mechanism also.[10] Further the uses of sulfur source also govern the structure and shape of the formed nanomaterials. Till today enormous amount of efforts has been taken by the researchers to find the best methods for synthesis of nanomaterials with ambient reaction conditions. In this regard herein, we have prepared the CdS nanostructures using ethylene glycol as a capping agent by solvothermal reaction technique at 150ºC for 2 h. The formed CdS nanomaterials were characterized with different spectroscopic techniques such as X-ray diffraction, Scanning electron microscopy, uv-visible and photoluminescence spectroscopy. The formed CdS nanostructure was used for the fabrication of photo-sensor and investigated its optical response. The available light dependent resistor (LDR) in the market are made up of bulk CdS having resistance around 20 MΩ in the dark and in light it minimizes to 5KΩ having response time in the order of 100 to 150 ms. For robotic and counter application we need to improve the response time in the range of 5 to 50 ms. The use of nanostructured CdS will help to reduce the response time of LDR, so that its applicability will be widen in the robotic eye as well as the other areas where faster response required. In this regard in the present paper, the efforts have been taken to synthesize the CdS nanostructures and to study its optoelectronic property.

II. EXPERIMENTAL

A. Chemicals

The cadmium nitrate ($Cd(NO_3)_2$ $4H_2O$), thiourea and ethylene glycol (EG) were used in the present study. All the chemical used were analytical grade and used as such without further purification.

B. Synthesis of CdS nanomaterial

CdS nanostructure was prepared by solvothermal reaction technique. For this purpose 10 mmol $Cd(NO_3)_2$ $4H_2O$ and 20 mmol Thiourea were dissolved separately in 30 mL of ethylene glycol and mixed together with constant stirring. The resultant reaction mass was mixed for 10 min and then transferred into teflon lined stainless steel autoclave further heated at 150 ºC for 2 hrs. CdS nanostructure was separated from ethylene glycol by centrifugation, washed with distilled water and ethanol. The washed CdS nanostructure was dried at 60ºC under vacuum oven for 10 h.

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C. Characterization

The crystal phase was studied using powder XRD technique (Bruker AXS model D-8, 10 to 70° range, scan rate = 1° min^{-1}) having a monochromator and Ni-filtered Cu Kα radiation. Crystallite size was studied using *Scherrer's* formula, $d = 0.9\lambda / \beta \cos\theta$ where λ is the x-ray wavelength (Cu Kα = 1.5406 A), β = FWHM and θ = angle of reflection. Diffuse reflectance UV-Visible absorbance spectra was investigated using Shimadzu UV-Vis-NIR spectrophotometer (Model UV-3600) wavelength range of 200 to 800 nm. The absorbance measured against the $BaSO_4$ as a reference. Photoluminescence analysis was performed on Shimadzu RF-5301PC spectrophotometer. BET surface area measurement was investigated using N_2 adsorption isotherms at liquid N_2 temperature using Quantachrome NOVA touch LX1 instrument. The morphological characterization of the samples was performed over HITACHI S-4800. The CdS nanostructure film was prepared by depositing powder on pre-patterned silver (IDE) inter-digited electrode printed on 98% alumina substrate having size around 10 mm x10 mm with inter-electrode spacing around 100 µm (±5) and the total photon catchment length was 25 mm long. The deposited sample was heated before measurement at 150°C in air in order to improve the electrical performance. The formed device was electrically measured using kelvin probe method connected to sample with spring loaded pressure gold coated contacts. The entire setup was maintained in the metal chamber in order to prevent electrical noise effect. Current – voltage (I-V) characteristics was carried out under solar simulator (PET, SS50AAA, Photo-emission, USA) having 1000W xenon lamp at 1.5AM (air-mass ratio). All the measurements were performed in air at room temperature with I-V system (Keithley SCS-4200 Semiconductor Characterisation System) connected with solar simulator utilized to record the photo induced effect.

D. Fabrication of sensor

The schematic of the fabrication of CdS photo-sensor is depicted in Fig.1. The detail fabrication approach is explained in the earlier paragraph

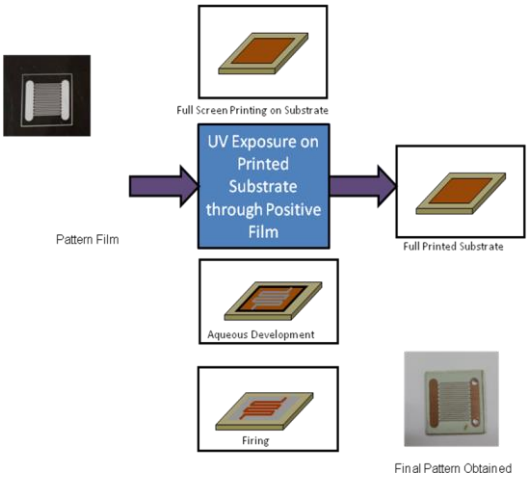

Fig.1. Schematic of fabrication of CdS photo sensor

III. RESULTS AND DISCUSSION

A. X-ray diffraction analysis

The as synthesized CdS nanostructure was analyzed by powder X-ray diffractometry to identify the crystalline phase. The XRD patterns of CdS reveal the formation of hexagonal phase (Fig. 2). The diffraction peaks at 2θ = 24.8, 26.5, 28.1, 36.6, 43.6, 47.8 and 51.8 can be indexed to (100), (002), (101), (102), (110), (103) and (112) crystal planes of hexagonal CdS. The XRD pattern clearly matches with the standard JCPDS data (PDF card 41-1049 JCPDS). The intense and sharp diffraction peaks indicates the formation of highly crystalline hexagonal phase of CdS. All the peaks are assigned to standard pattern and confirm the formation of pure hexagonal phase of CdS nanostructures.

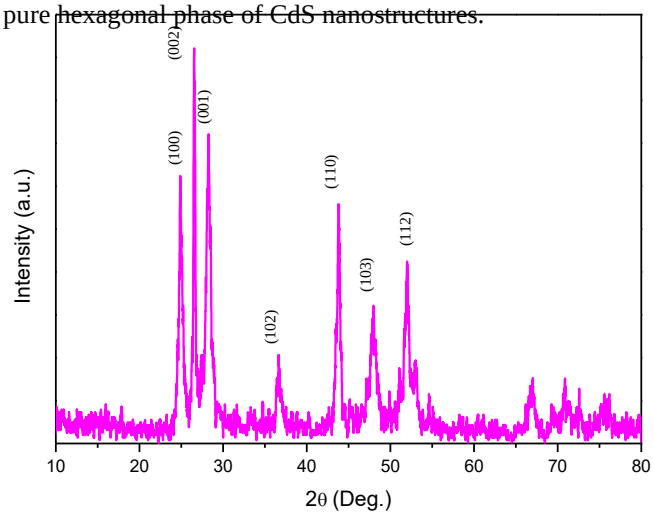

Fig. 2. XRD pattern of CdS nanostructure

B. UV-visible absorbance spectra

The diffuse reflectance UV-visible absorbance spectrum of CdS nanostructure is depicted in Fig. 3. It shows the absorption edge around 520 nm corresponds to band gap of 2.4 eV. The diffuse reflectance spectrums (DRS) indicate the absorbance in the range of 300 to 520 nm. The DRS provides vital information related absorbance of CdS at different wavelength and helpful for fabrication of optical sensor.

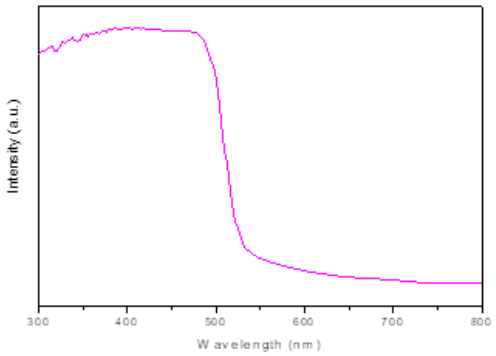

Fig. 3 Diffuse reflectance UV-visible absorbance spectra of CdS nanostructure

C. Photoluminescence spectra

The photoluminescence spectrum of prepared CdS nanostructure is depicted in Fig. 4. For the measurement of PL spectra the 1 mg of CdS nanostructure was disperse in 10 mL of DI water and sonicated for 5 min.
The dispersed solution was transfer to 5 mL, PL cuvette and excited with 400 nm light. The graphs of wavelength Vs Intensity indicate the strong band edge emission at 522 nm. Along with band edge emission peak very small humps at 600 nm also observed and indicate the presence of some surface defects.

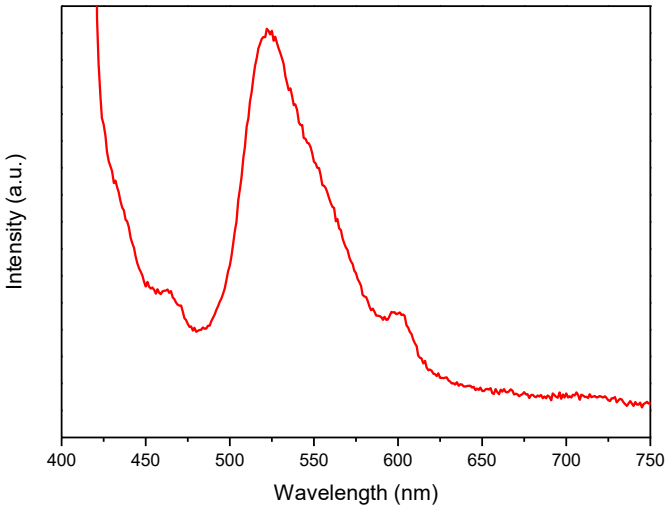

Fig.4 Photoluminescence spectrum of CdS nanostructure at excitation wavelength $\lambda_{Excitation}$=400 nm.

D. Field Emission Scanning Electron Microscopic analysis (FE-SEM):

The FESEM image of prepared CdS nanostructure is depicted in Fig. 5. The formation of homogeneously distributed CdS nanoparticles have been observed having size in the range of 10-15 nm. The CdS particles are giving slightly distorted shaped morphology.

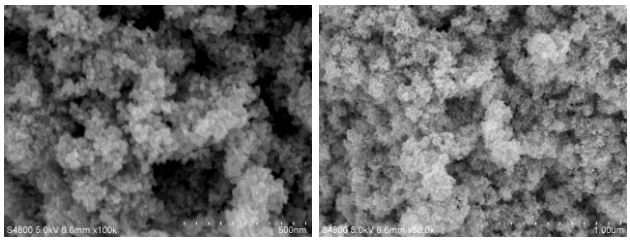

Fig. 5. FE-SEM of CdS nanostructure

The use of ethylene glycol as a capping agents provided the well separated particles with uniform size and shape.

E. Photo-sensor measurements

The current voltage measurement of the prepared CdS nanostructure is depicted in Fig. 6. The graph of I-V in dark shows almost negligible current whereas the current under light illumination is around 3.8 x 10^{-4} A. This enhanced current directly indicate the optical sensing behavior of prepared CdS nanostructures. The response time of the prepared photosensor is measured and depicted in Fig. 7. The observed photoresponse for prepared CdS photosensor is around 5- 40ms.

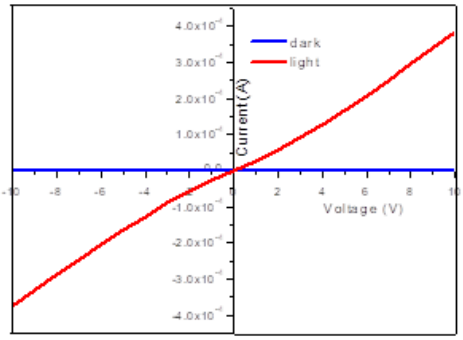

Fig. 6 The I-V measurement of photo-sensor fabricated using prepared CdS nanostructure at 6000lux

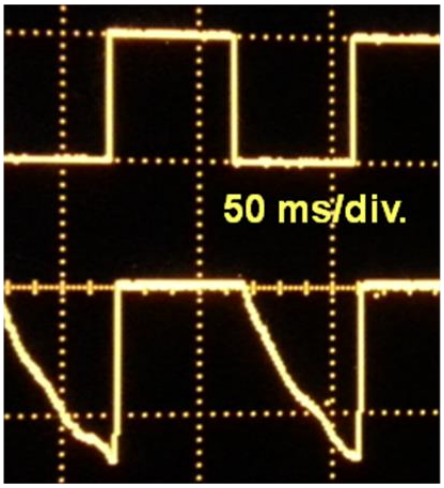

Fig. 7 Response time of prepared photo-sensor using synthesized CdS nanostructure.

IV. CONCLUSION

The nanostructured CdS was successfully prepared using hydrothermal reaction technique having hexagonal crystal structure and size in the range of 10-15 nm. The optical band gap observed to be around 2.37eV. The prepared optical sensor gives marginal IV response in dark and light having response time around 40 ms. Overall we have successfully prepared the CdS based optical sensor.

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