

## SYNTHESIS AND CHARACTERIZATION OF Ag-CdS NANOSTRUCTURES

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### ABSTRACT:

*The synthesis and characterization of pure CdS and CdS-Ag hybrid nanostructures have been reported. The nanostructures are obtained by the combination of co-precipitation and solvothermal techniques. The synthesis of pure CdS nanoparticles has been carried out using solvothermal route. The CdS powder obtained by solvothermal process has been used directly for the synthesis of CdS-Ag nanoparticles. The synthesized nanomaterials are characterized by X-ray diffraction (XRD), Field Emission Scanning Electron Microscopy (FESEM) and Photoluminescence (PL) spectroscopy. The XRD analysis revealed the formation of hexagonal phase of CdS and cubic phase of CdS-Ag and after carefully matching the JCPDS cards, formation of pure CdS and CdS-Ag hybrid nanostructures have been observed. The FESEM images of CdS and CdS-Ag nanomaterials confirms the existence of tiny crystalline nanoparticles. The optical study (PL) reveals drastic changes in the energy band gap due to the presence of Ag in CdS-Ag hybrid nanostructure.*

**KEYWORDS:** CdS, Silver doping, XRD, FESEM, Photoluminescence, Nanostructures and Nanomaterials

### I. INTRODUCTION

Semiconductor nanostructures have attracted considerable interest of today's research work [1] owing to their potential applications especially in nanoscale electronic and optoelectronic devices [2]. When the particle dimensions are in the range 1-100 nm, the materials exhibit unique electrical and optical properties which are different from those of their counterpart bulk materials [3-4]. CdS is an interesting and widely used material for optoelectronic devices [5-10] and shows excellent physical properties with a wide energy band gap of 2.4 eV. CdS in its bulk form has hexagonal structure [11] at room temperature. However, CdS nanoparticles exhibit size dependent properties and it has been observed that the CdS nanostructure changes from hexagonal to cubic phase [12].

In recent years, particularly, hybrid nanostructures have received significant attention as these are having unique optical, electrical, magnetic and chemical properties [13]. In particular, doped CdS hybrid nanostructures such as CdS-Co [14], Li & Cu doped CdS [15-21], CdS-Mn [22], CdS-ZnO [23], CdS-Ag [24], CdS-CdSe [25], and CdS-HgS [26] have promising materials which are attracted not only because of their tunable optical and electrical properties but also due to their inherent potential for many technological applications such as photoconductor [27], solar cell [28], LED [29], and the wavelength controlled lasers [30]. There are several materials such as In, Mn, Cu, Ag [31-32] which have been used for doping into CdS by various methods. The electrical and optical properties of polycrystalline Ag doped CdS thin films have been reported by M.A. Khalid *et al.* [33]. D. Peter *et al.* [34] have reported the influence of Cu doping on the optoelectronic properties of chemically deposited CdS thin film. X. Li *et al.* [35] studied the effect of Ag on the crystal structure of CdS. The

effect of Ag doping on the optical and photovoltaic properties of CdS/PVA thin film has been reported by D.Saikia *et al.* [24]. V. Lekhya Subhashini *et al.* [23] studied the photoconductivity in a photoconductor fabricated using CdS doped ZnO.

In this article, with an aim for fabrication and exploration of hybrid nanostructures, pure CdS and Cds-Ag hybrid nanostructures have been synthesized using combination of co-precipitation and solvothermal technique and crystallographic, morphological and optical studies of pure CdS and Ag doped CdS have been reported. The pure CdS and Ag doped CdS samples were characterized by X-ray diffraction (XRD), Field Emission Scanning Electron Microscopy (FESEM) and Photoluminescence (PL) spectroscopy.

## II. EXPERIMENTAL WORK

### 2.1. Synthesis of Nanostructures

Synthesis of pure CdS has been carried out using solvothermal route, whereas synthesis of CdS-Ag has been accomplished by two step solvothermal route.

#### 2.1.1. Materials

Cadmium Acetate ( $Cd(CH_3CO_2)_2$ ), Thiourea ( $SC(NH_2)_2$ ), Silver Nitrate ( $AgNO_3$ ), Poly-vinyl Pyrrolidone, Sodium Citrate have been used as precursors. All the chemicals were of analytical grade and have been used as received without further purification. Deionized water has been used throughout the experiment.

#### 2.1.2. Synthesis of CdS Nanoparticles

A 22.5 ml aqueous solution of cadmium acetate (mM) and thiourea (mM) have been prepared separately using deionized (DI) water for the preparation of the cadmium sulphide. Thiourea solution is added drop wise to the cadmium acetate solution at the rate of 10 ml/min under constant magnetic stirring at 500rpm. A 5 ml aqueous ammonium hydroxide solution, added to the above admixture, changed the colour of the transparent solution to yellow colour. The resultant admixture is then transferred to Teflon lined stainless steel container of total capacity of 100 ml. It was subsequently heated at  $200^\circ C$  for 24 hours in a furnace and then was allowed to cool down to room temperature. Finally, the resultant yellow colored mass was washed several times with DI water followed by ethanol and dried overnight at  $55^\circ C$  to obtain yellow colored powder. The yellow color indicates the formation of the CdS nanoparticles.

#### 2.1.3. Synthesis of CdS-Ag Nanoparticles

For the synthesis of CdS-Ag hybrid nanoparticles, CdS nanopowder prepared by solvothermal technique has been used directly. In a typical reaction, a 50 ml aqueous solution of silver nitrate was prepared in 50 ml DI water at room temperature in a beaker using magnetic stirring at 500 rpm and PVP (0.1%) and 5 ml sodium citrate was added drop wise to it to obtain white colloidal solution. This solution was stirred for another ten minutes and then, CdS nanopowder of 0.5 mg was added to it to produce the light yellow color solution which was transferred to Teflon lined stainless steel container of total volume capacity of 100 ml. The container was sealed properly and kept in the furnace at  $200^\circ C$  for 24 hours and subsequently cooled down to room temperature. Finally, the resultant yellow colored mass was washed several times with DI water followed by ethanol and dried overnight at  $55^\circ C$  to obtain yellow colored powder.

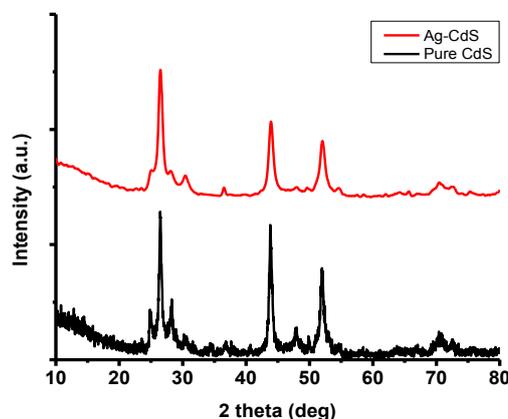
## III. CHARACTERIZATION

The structural characterization of the two samples were made by X-ray diffraction technique with a Model-D8, advance Bruker AXS, having Ni-filtered Cu  $K_\alpha$  radiation of wavelength  $\lambda = 1.543\text{\AA}$ . The morphological study was done with FESEM (Hitachi S4800). A small quantity of prepared powder was dispersed in ethanol and a drop of it is casted on aluminum foil followed by gold sputtering and the sample thus prepared is used for XRD studies. The characteristic XRD graph is presented in the figures 1.

## IV. RESULTS AND DISCUSSIONS

### 4.1. X-Ray Diffraction

Figure.1 shows the XRD diffraction pattern of the synthesized pure CdS and CdS-Ag hybrid powders. The observed diffraction peaks are carefully compared with the JCPDS (Joint Committee on Powder Diffraction Standards) cards.



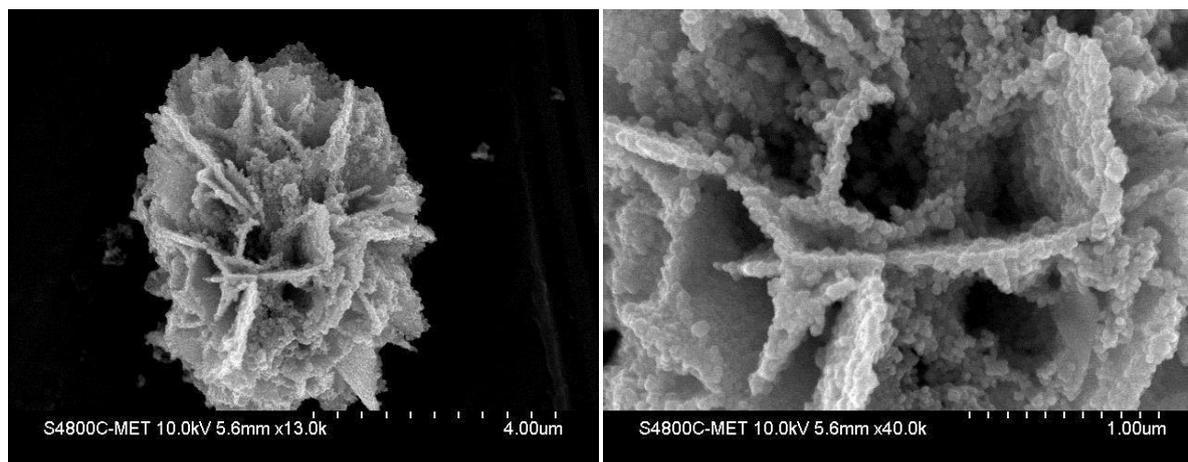
**Figure 1:** X-ray diffraction patterns of corresponding to pure CdS and Ag-CdS powders

The peaks are matched with the cubic phase with JCDPS card no: 80-0019 and cubic phase with JCPDS card no:43-0649 of individual CdS and Ag [36,37] respectively. The doping of Ag induces changing crystal from cubic to hexagonal [42]. The peaks occurred at  $2\theta = 25.143, 26.83, 27.21, 44.21, 52.30, 66.26, 73.06, 77.02$  correspond to hexagonal CdS and peaks at  $2\theta = 26.45, 43.81, 52.08$ , belongs to Ag. Thus XRD analysis confirms the purity of CdS and CdS-Ag and further, the broadening of peaks indicates that the formation of hybrid nanostructures.

### 4.2. Field Emission Scanning Electron Microscopy (FESEM)

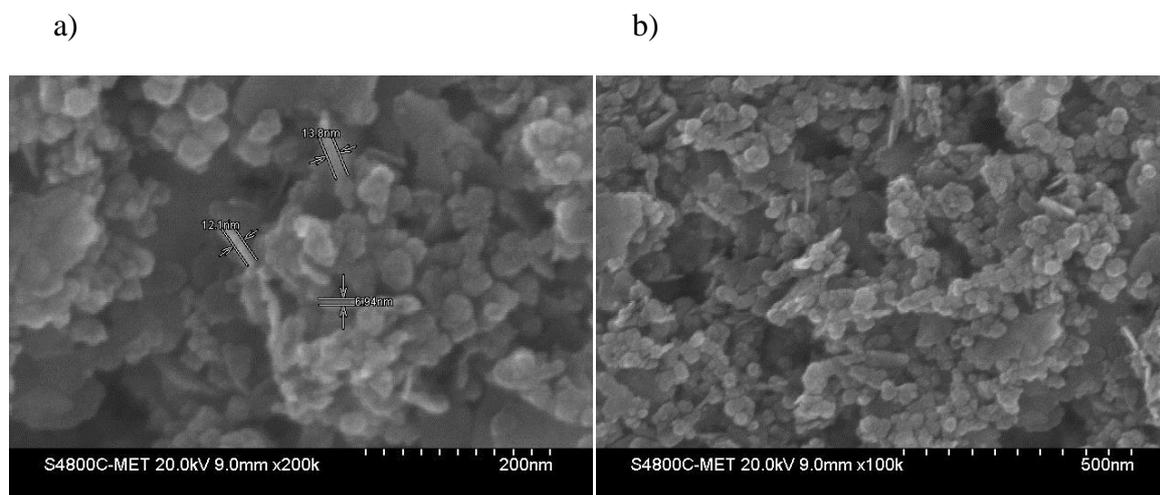
a)

b)



**Figure 2:** FESEM images corresponding to pure CdS powder at (a) low magnification and (b) high magnification.

FESEM images of pure CdS nanostructure are shown in the figure 2. Figure 2. (a) shows, at lower magnification, the formation of flower like hierarchal CdS nanostructures of  $6\mu\text{m}$  is observed. At higher magnification as shown in figure.2.(b) disclosed the feature of the petals. It is found that these petals are not made up of sheet like structures but are made up of spherical and faceted grown particles of size  $\sim 60 - 80\text{nm}$ .



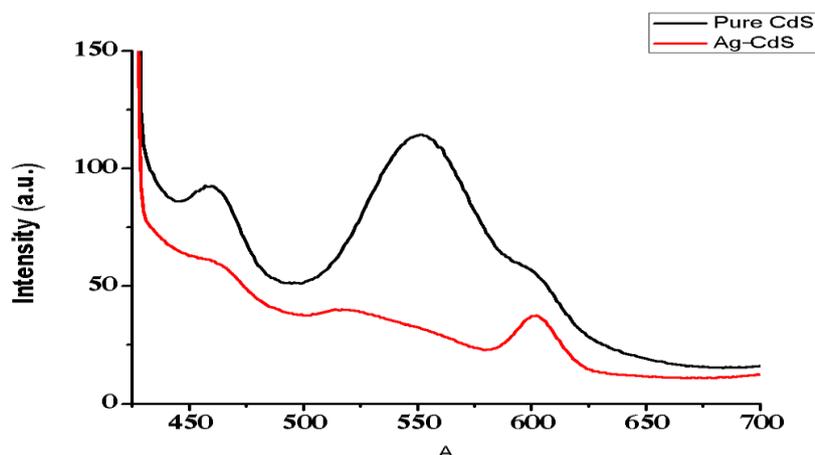
**Figure 3:** FESEM images corresponding to Ag-CdS hybrid powder at (a) high magnification and (b) low magnification.

The FESEM images at lower and higher magnification of CdS-Ag hybrid nanostructures are shown in figures 3.(a) and (b). It is observed from figures 3. (a) that the flower like structure is completely disintegrated into spherical and irregular shaped nanoparticles with many number of disc like structures. Figure. 3 (b) shows formation of spherical and irregular shaped nanoparticles having sizes in the range of 30-50 nm with many number of disc like structures whose thickness is in the range of 7-15 nm. The disc like shapes are actually the silver nanoparticles while the spherical and irregular shaped particles composed of CdS nanostructures.

### 4.3. Photoluminescence (PL) Spectroscopy

The PL spectrum of pure CdS and CdS-Ag hybrid nanostructures is shown in the figure 4. The spectrum of pure CdS shows one prominent peak at 550 nm and the other two small peaks in the region of 460 nm and 600 nm respectively. The small peak in the region of 600 nm may be attributed to the transition due to presence of defects, whereas the peak at 460 nm may be due to higher level transitions and the peak at 550 nm is due to the band gap transition of CdS[38].

The PL spectrum of CdS-Ag exhibits an interesting fact that the intensity of peaks for CdS-Ag hybrid nanostructure is lower than that of pure CdS nanostructure and also has three peaks at 460 nm, 515 nm and 600 nm respectively. But the peak 550 nm, which is predominant in pure CdS spectrum due to band gap transition, is appreciably suppressed. The absence of 550 nm peak in CdS-Ag is mainly attributed to the non-availability of space for the separation of electron-hole pairs which leads to zero photocurrent.



**Figure 4:** Photoluminescence spectra for CdS and CdS-Ag Hybrid nano structures

## V. CONCLUSIONS

The pure CdS and CdS-Ag hybrid nanostructures have been synthesized successfully by the combination of co-precipitation and solvothermal techniques. The structural characterization of these samples has been carried out with XRD, FESEM and Photoluminescence (PL) Spectroscopy. XRD diffraction pattern of pure CdS nanostructure indicated the cubic phase while the XRD diffraction pattern of CdS-Ag hybrid nanostructure revealed the hexagonal structure. Morphological studies on these samples show the flower like structure of pure CdS is disintegrated in the CdS-Ag hybrid nanostructure due to doping of Ag into pure CdS and forms spherical and irregular nanoparticles having size in the range of 30 -50 nm. As the direct band gap transition at 550 nm of pure CdS is not present, the optical studies of hybrid nanostructure of CdS-Ag reveals that there is no space for electron and hole separation, which leads to zero photocurrent and hence, photoconductivity studies are not performed for CdS-Ag hybrid nanostructure sample.

## VI. FUTURE WORK

In view of potential applications of CdS in the field of optoelectronic devices, there is a need for more detailed study of  $Cd_{1-x}Ag_xS$  hybrid nanostructures with different concentrations of  $x$ . These hybrid nanostructures can be characterized by XRD, FESEM, Photoluminescence (PL) Spectroscopy, Fourier Transformer Infrared (FT-IR) Spectroscopy and UV-Visible Spectroscopy.

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