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Different Properties of CdS nanocrystalline material: A Review

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Abstract: This article provides a focused review on different properties of Cadmium Sulfide (CdS) nano material. CdS is an important II–VI semiconductor compound having potential applications in light-emitting diodes, thin film transistors, solar cells and photoconductive devices. As compared to bulk materials, CdS nano particles also have unique electrical and optical properties. Keeping this in view, researchers have explored several new substrates and methods for synthesis of CdS material. Some recent contributions of authors about new techniques and properties of CdS nano material and their use in a variety of fields are discussed.
Keywords: CdS, synthesis, nanomaterials

I. Introduction

Nano crystalline materials have attracted many material researchers due to its enhanced thermal, electrical and optical properties when compared to that of bulk materials. These materials are becoming increasingly interesting for optoelectronics and photonics. The electronic and electrical properties of such materials show a remarkable change as the particle size approaches that of its excitonic Bohr radius and then electrons and holes are subject to quantum confinement effects [1, 2] due to their large surface to volume ratios resulting in high density of surface states. Nanoscale semiconductors show interesting electro-optical properties and catalytic behavior [3]. As nanocrystal size increases, the energy of the first excited state decreases, qualitatively following a particle-in-a-box behaviour. This size dependence and the emergence of a discrete electronic structure from a continuum of levels in the valence and conduction bands of the bulk semiconductor result from quantum confinement. [4]

CdS is a wide band gap semiconductor with E_g = 2.4 eV at 300 K. As compared to bulk materials and the melting point, electronic absorption spectra, band gap energy, crystal structure, and other properties of these nano particles (CdS-NP) are also affected by size [5-7]. These nano particles with tailored physical properties have potential application in the fields of molecular level electronic and photovoltaic devices [8], [9], catalysis, molecular diagnostics and interfacial electron transfer [10] CdS is one of the most studied materials because it has a well established relationship between the optical absorption and the size of the particle, the first investigations in this area were focused in the improvement of the synthesis method [11-13].

This comprehensive review indicates some areas, which are not adequately addressed so far. This study may be listed as different synthesis techniques, properties and their applications in various fields. Various synthesis routes have been developed over the past few years to prepare these nanostructures. They can be prepared with customized properties such as increased stability, surface area, magnetic, optical and catalytic properties. A review of their synthesis techniques, properties and applications is given here.

II. Different properties of CdS material:

(a) Optical properties:

Recently in 2013 CH. Ashok and coauthors reported work on CdS material which is synthesized by spray pyrolysis method and found result that CdS thin films were in hexagonal phase. Using UV – Visible absorption spectrometry, the optical properties were examined and found that the absorbance decreased with decrease in substrate temperature and the band gap values increased [14]. P.E. Agbo et al. reported work on synthesis of CdS material by SILAR method in 2014 and the films were then doped with zinc and annealed at different annealing temperatures. The optical properties were studied using UV- VIS spectrophotometer and band gap was calculated. Both methods are suitable for solar cell applications.[15]

Room Temperature is also another technique for synthesis of cadmium sulfide material. Result of this method is fine and uniform particle using cadmium complex compounds and thioacetamide which is reported by A. Dumbrava et.al [16]

Recently in 2013 by sol-gel spin coating method using different thiourea concentrations, preparation of CdS nano structures is reported. The thiourea concentration effect for CdS nanostructures deposited on quartz

substrate was also studied by Ghosh et al [17]. It is a simple, economical method and the material showed good structural and optical properties which are desirable for photovoltaic applications.

(b) Structural properties:

Cadmium sulfide and cadmium oxide is synthesized by chemical route technique. This is reported in 2008 by K. Manickathai and coworkers. They study structural and morphological properties of CdS material.[18]. Using a simple aqueous method under ambient conditions G. A. Martínez-Castañón presents paper in 2010. This method enables us to obtain nano particles with different particle size with varying the Cd^{2+} to S^{2-}molar ratio with capping agents because of their nanometric dimensions, luminescence signal and their fictionalization with organic molecules which have functional groups that can attach them to biomolecules or cells.[19]

Hasnat and J. Podder reported work on CdS and Al doped CdS material in 2012 synthesized by spray pyrolysis method. characterization shows that uniform, smooth and compact particle were formed. Comparison of both CdS and Al doped CdS found that there is no significant effect on the surface morphology of the CdS thin film but in the CdS films, Al concentration increasing with Hall mobility and carrier concentration are increased [20]

A systematic study has been carried out to understand the influence of Ag doping on the structural and optical properties of CdS nano particles in 2013. Both undoped and Ag doped CdS material exhibited, hexagonal structures on XRD analysis. Ag doped CdS nano particles also exhibit red shift with respect to that of CdS nano particle. [21] Again in 2013, M. Penchal Reddy reported work on a one-pot non injection route method for getting homogeneous CdS nanoparticles from Cadmium Chloride and Thiourea, using mercaptopropionic acid as capping agent. Cubic structure and spherical shape is observed. This is used in research area and industrial application.[22]

Olumide Akinwunmi and coworkers presented a paper in 2014 in which they prepared sulfides embedded in polystyrene to form nano-composites. The colloidal form of Cadmium Sulfide, Zinc Sulfide and Cadmium Zinc Sulfide were prepared by modified metathesis reaction. The optical properties show that there is quantum confinement of the nanoparticles. They also determined particle size obtained from HRTEM [23].

(c) Luminescence property:

In 2006 P. P. Favero and coworkers studied about surface property of CdS material in which they observed photoluminescence property in which cubic CdS nanoparticles present a strong structural deformation and hexagonal reconstructed structures preserve their lattice behavior [24]

Ramamurthy. N et.al in 2011 showed that CdS nano composite material would have potential use as photo catalyst, novel luminescent and photoelectron transfer devices. With the help of PVP and SPP capped particle they observed photoluminescence emission. [25] CdS material showed photoluminescence property which is reported by A. I. IORGU in 2013. CdS material is doped with different ions and its structural, morphological, chemical and photoluminescence property is investigated [26].

(d) Electrical property:

P. Samarasekara and coworkers studies structural and electrical properties of CdS material which is synthesized by spin coating technique and they observed that after annealing ,efficiency may improve because of bond formation and improvement of particle size. Due to this phenomenon photo voltage is higher and photocurrent is lower and they also studied ZnO films and obtained higher band gap. [27]

In 2008 K.Manickathai et al. published a paper which described that CdS is one of the most promising materials as its bandgap corresponds closely to the visible spectra and also band to band transitions occur in these materials, making it suitable for applications in many electro-optic devices [18].Recently in 2015 Salunke Pooja presented a work on the preparation of CdS nano particle using chemical precipitation and green chemical route method and the measurement of conductivity is done by TDS digital meter. [28]

(e) Dielectric property

Sagadevan Suresh presents article on the dielectric properties of CdS nanoparticles in 2013. This CdS material was synthesized by wet chemical method. In the frequency range of 50 Hz–5 MHz at different temperatures, the dielectric properties of CdS nanoparticles were studied. He found that at different temperatures, with increase in frequency, dielectric loss decreases. When CdS material is in nano range due to confinement in low frequency range, dielectric property significantly improves. [29]

Conclusion

A review on different properties of CdS nanomaterial is briefly presented in this article. Various types of techniques used in synthesis of cadmium sulfide and the different properties reported are also discussed.

There are a variety of applications of CdS material like solar cells, as pigment, antireflection coating etc which are of considerable interest. Different synthesis techniques and properties of CdS nanomaterial have been reported by many researchers and this brief review would help in further investigations on this material.

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