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**Poondi– 613 503, Thanjavur-Dt, Tamilnadu**

*(Affiliated to Bharathidasan University, Tiruchirappalli – 620 024)*

## **3.7.2 Functional MoUs**

**Thanthai Hans**

**RoeverCollege(Autonomous),**

**Perambalur-621220,Tamil Nadu, India.**



# MEMORANDUM OF UNDERSTANDING

Dated 11<sup>th</sup> August, 2016  
Between



**Department of Physics,  
A.V.V.M Sri Pushpam College (Autonomous),  
Poondi – 613 503, Thanjavur (Dt),  
TamilNadu, India.**

**Department of Physics,  
Thanthai Hans Roever College (Autonomous),  
Perambalur-621 220,  
TamilNadu, India.**

Department of Physics, A.V.V.M Sri Pushpam College (Autonomous), Poondi, Thanjavur (Dt)-613503, TamilNadu, India and Department of Physics, Thanthai Hans Roever College (Autonomous), Perambalur-621220, TamilNadu, India hereby enter into this General Agreement to foster International Cooperation in Education and Research.

1. Both parties agree to encourage the following exchange activities based on their respective academic and educational needs.

- |                                    |                            |
|------------------------------------|----------------------------|
| a. Exchange of Scholars            | b. Exchange of Students    |
| c. Exchange of Research facilities | d. Joint Research Programs |
| e. Joint Conferences               | f. Joint Online Programs   |

g. Other academic exchange programs as may be agreed to by both the parties from time to time

2. The implementation of each exchange program referred above will follow the guidelines established on mutual agreement by both the parties. Efforts will be made by both the parties to find financial resources for carrying out the activities listed above.

3. Nothing shall diminish the full autonomy of either institution nor will any constraints be imposed by either upon the other in carrying out the agreement.

4. This agreement shall be in force for a period of FIVE YEARS from the date of the last signing and is subject to revision or modification by mutual consent. It is also understood that this agreement may serve as the basis for the specific agreements to be developed at a later date. It is further understood that either institution may terminate the agreement at any time, upon one year written notification to the partner institution, although such action will only be taken after mutual consultation in order to avoid any possible inconvenience to either party.

  
The Principal,

A.V.V.M Sri Pushpam College (Autonomous),  
Poondi – 613 503, Thanjavur (Dt),  
Tamil Nadu, India.

  
The Principal,

Thanthai Hans Roever college (Autonomous),  
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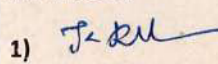
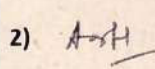
5. Amendment to MOU:


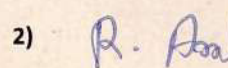
The Memorandum of Understanding may be amended in writing by mutual consent between both parties, IN WITNESS WHEREOF, the undersigned parties have agreed and executed this document in English in two originals.

For A.V.V.M Sri Pushpam College

For Thanthai Hans Roever College

WITNESSES:

- 1)  (Dr. K. Ravichandran).  
2)  (Dr. A. R. BALU)  
Asst. Prof of Physics

- 1)  (Dr. G. SELVAN)  
2)  (Dr. R. ANBARASU)





# Structural, optical and electrical properties of Cl-doped ternary CdZnS thin films towards optoelectronic applications



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## ABSTRACT

This paper reports the effect of chlorine doping on the structural, morphological, optical and electrical properties of spray deposited ternary CdZnS thin films. Cadmium chloride ( $\text{CdCl}_2 \cdot 2\text{H}_2\text{O}$ ), thiourea ( $\text{SC}(\text{NH}_2)_2$ ) and  $\text{ZnCl}_2 \cdot 6\text{H}_2\text{O}$  were used as precursors to prepare CdZnS thin films. Cl doping is achieved by adding NaCl with concentrations 0, 2, 4, 6 and 8 at.%. XRD analysis showed that the CdZnS and Cl-doped CdZnS films exhibit hexagonal crystal structure with a (002) preferential orientation. Film transparency increased with Cl doping and the band gap values exhibit a blue shift from 2.55 eV to 2.78 eV. Electrical studies showed that the CdZnS film resistivity decreased from  $4.96 \times 10^{-3} \text{ ohm-cm}$  to  $0.614 \times 10^{-3} \text{ ohm-cm}$  with Cl doping. The Raman studies confirmed the presence of defects in samples. Improved transparency, widened band gap and decreased resistivity values observed for the Cl-doped CdZnS films confirm that chlorine might be a suitable anionic dopant which can enhance the physical properties of CdZnS thin films.

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## 1. Introduction

Cadmium sulfide (CdS) is an extensively investigated II–VI metal chalcogenide thin film due to its application in solar cells, optical detectors and optoelectronic devices [1]. CdS thin film is used as window layer in heterojunction solar cells due to its high transparency, wide and direct band gap transition, high electron affinity and n-type conductivity [2]. However, polycrystalline CdS when used in solar cells have some adverse properties due to the creation of high defect density arising from its low band gap, thickness and lattice mismatch [3]. In order to decrease the defect density, the optical and electrical properties of CdS must be improved which can be achieved through doping. It has been reported earlier that when CdS is doped with certain cationic impurities such as Al, Ga, Mn, Zn, Cu, In and with certain anionic impurities such as F, Cl, B etc., its optoelectronic properties may be improved. In our previous work, we reported that Zn doping can improve the optical and electrical properties of pure CdS [4]. Improved optical and electrical properties in CdS through Mg incorporation have been reported earlier by Sivaraman et al. [5]. Besides these cationic impurities, there are earlier reports on anionic impurities influencing

the electrical and optical properties of pure CdS. Novruzov et al. [6] reported that boron doping reduces the electrical resistivity of pure CdS. Improved optical transparency, widened optical band gap and decreased electrical resistivity was reported for Cl-doped CdS thin films by Sivaraman et al. [7]. From their results, it is evident that Cl (an anionic dopant) can enhance the physical properties of CdS very much than the cationic dopants. So in the present work, ternary CdZnS thin film was prepared by spray technique using perfume atomizer with fixed concentration of zinc. Cl-doping has been performed by adding NaCl with 0, 2, 4, 6 and 8 at.% Cl concentrations and the effects of Cl doping on the structural, morphological, optical and electrical properties of the as deposited CdZnS thin films were investigated and the results are reported here. The use of perfume atomizer has some specific advantages over the conventional spray technique such as: low cost, non requirement of carrier gas, capable of forming powdered layers through fine atomization and no loss of the precursor to the surroundings [8].

## 2. Experimental details

Spray pyrolysis technique using perfume atomizer is used to fabricate CdZnS thin films on glass substrates maintained at  $400^\circ\text{C}$ . Cadmium chloride,  $[\text{CdCl}_2 \cdot 2\text{H}_2\text{O}]$  (0.05 M), thiourea,  $[\text{SC}(\text{NH}_2)_2]$  (0.05 M) and zinc chloride  $[\text{ZnCl}_2 \cdot 6\text{H}_2\text{O}]$  6 at.% were used as precursor salts to prepare CdZnS thin films. Zinc chloride concentration

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# Precursor aging effect on the properties of CdZnS films

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Nanostructured ternary Zn-doped CdS (CdZnS) thin films were fabricated from fresh and aged (1, 2, 3 and 4 days) starting solutions by the spray pyrolysis technique using a perfume atomizer. X-ray diffraction studies showed that the films are polycrystalline in nature exhibiting hexagonal crystal structure with a (0 0 2) preferential orientation. SEM images showed that the film prepared from 1 day aged solution possesses randomly oriented CdS crystallites of elongated needle shape. The optical band gap values exhibit a red shift with aging time of the precursor solution. A minimum resistivity of  $3.94 \times 10^{-3} \Omega \text{ cm}$  is obtained for the film prepared from 1 day aged solution. The obtained results infer that the CdZnS film prepared from 1 day aged solution exhibits better physical properties.

**Keywords:** Thin films, X-ray diffraction, Optical band gap, Electrical resistivity

## Introduction

Cadmium sulphide (CdS), a wide band gap (2.42 eV in cubic phase and 2.57 eV in hexagonal phase) II–VI semiconductor, is a promising material which has a number of applications in devices such as solar cells, photoconductors and sensors.<sup>1</sup> It is widely used to fabricate solar cells with p-type compounds, such as CdTe, Cu<sub>2</sub>S, CuInSe<sub>2</sub> and Cu(In,Ga)Se<sub>2</sub>.<sup>2</sup> However, polycrystalline CdS, when used in conventional solar cells, has some adverse properties arising from its low band gap, thickness and lattice mismatch, which create high defect density.<sup>3</sup> The physical properties of solar cell layers may fluctuate due to external factors such as environmental radiations, high frequency electromagnetic waves and UV rays from the sun.<sup>4</sup> Environmental stability strongly influences the lifetime and commercial viability of solar cells. As a window material, CdS which is not affected by environmental radiations show better performance on solar cell applications. Also, to improve the solar cell efficiency, a CdS window layer must have: (i) good uniformity to avoid electrical short-circuit effects, (ii) high conductivity and (iii) high transparency in the visible spectra region. It is well known that defects such as sulphur vacancies ( $V_s$ ) and cadmium interstitials ( $Cd_i$ ) play an important role in the conductivity of CdS thin films.<sup>5</sup> These defects act as electron donors which increase the free electron concentration thereby decreasing the film resistivity. So by controlling these defects, the

performance of the CdS window layer can be improved. In situ doping of CdS with group III elements such as Al, In and Ga and with group II elements such as Zn and Mg increases its conductivity to a large extent. In a previous work,<sup>6</sup> we have shown that Zn-doping can drastically alter the optical and electrical properties of CdS thin films. Sivaraman *et al.*<sup>7</sup> reported that incorporation of Mg into the CdS lattice can enhance its structural, optical and electrical properties. Due to high band gap values of ZnS and MgS as compared with CdS, it is assumed that doping Zn or Mg could increase the optical band gap of CdS. Also due to the occupancy of  $Zn^{2+}$  ions or  $Mg^{2+}$  ions in the CdS lattice substitutionally or interstitially can improve its electrical properties. Also, it has been reported earlier that the properties of doped CdS films can be influenced by other factors besides doping concentration such as thermal annealing,<sup>8</sup> film thickness,<sup>9</sup> deposition period<sup>10</sup> and substrate temperature<sup>11</sup>. Biswal *et al.*<sup>12</sup> reported that the aging period of the starting solution plays a phenomenal role in altering the properties of fluorine-doped ZnO thin films. But reports on the precursor aging period on the physical properties of metal chalcogenide thin films are very scarce in the literature that too for doped films. Hence in the present study, the effect of precursor aging period on the physical properties of sprayed CdZnS films is performed and the results are reported. Among the various deposition techniques used to prepare thin films, the spray pyrolysis technique is simple, inexpensive and it offers an extremely easy way to dope films. It required no high-quality targets and/or substrate or the use of vacuum at any stage.<sup>13</sup> The use of perfume atomizer adopted here has some specific advantages over the conventional spray technique such as fine atomisation, no need for carrier gas, etc.<sup>14</sup>

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# Influence of (Zn + F) double doping on the structural, morphological, photoluminescence, optoelectrical properties and antibacterial activity of CdS thin films

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**Abstract** The effects of (Zn + F) double doping on the structural, morphological, optical and electrical properties of CdS thin films is reported in this paper. Polycrystalline nature is observed for all the films. Zn-doped and (Zn + F) doubly doped CdS films exhibit a strong (0 0 2) preferential orientation similar to that of the undoped film. The (0 0 2) plane of the Zn-doped and (Zn + F) doubly doped films shift towards higher Bragg angles favoring a contraction in their lattice parameter values. Increased transparency and blue shift in optical band gap is observed for the doubly doped films. The electrical resistivity values of the undoped, Zn-doped, (Zn + F) doubly doped CdS thin films are found to be in the order of  $10^{-1} \Omega\text{-cm}$ . From the obtained results it is found that the physical properties of Zn-doped CdS films got enhanced when co-doped with fluorine, and the (Zn + F) doubly doped CdS thin films seem to be a potential candidate for future optoelectronic device applications. Antibacterial activity of the as deposited films were carried against *E. coli* gram negative bacteria and from the zone of inhibition it is confirmed that the (Zn + F) doubly doped CdS thin films can be used as a good antimicrobial agent against pathogenic microorganisms.

## 1 Introduction

II–VI metal chalcogenide semiconductor thin films find applications in chemical sensors, surface acoustic wave devices, nanoscale electronic and optoelectronic devices due to their high transparency in the visible range, acoustic characteristics, high electrochemical stability and excellent electronic properties [1–3]. Among the n-type II–VI metal chalcogenide thin films, CdS due to its high transmittivity, low resistivity and excellent permeability is widely used as window layer for CdTe and CuInSe<sub>2</sub> based solar cells [4]. However due to low band gap, thickness and lattice mismatch its role in conventional solar cells is limited due to the creation of high defect density. It is well known that due to external impacts such as environmental radiation, high frequency electromagnetic waves and UV rays from the sun the efficiencies of solar cell layers (electrodes, windows and absorbers) reduces considerably [5]. To improve the performance of CdS based solar cells, it is essential to prepare CdS window layer which is not affected by external impacts. By altering the structural, morphological, optical and electrical properties through doping it is possible to improve the performance of CdS window layer. It has been experimentally proved that doping CdS with metallic ions such as Zn [6], Mg [7], Al [8] and with non-metallic ions such as B [5], Cl [9] and F [10] improved its physical properties. Recently it has been reported that simultaneous doping of CdS with both metallic and non-metallic ions drastically alters its optical and electrical properties [11]. In this work, double doping is performed on CdS with zinc and fluorine. Zn-doped CdS thin film is formed with fixed concentration of zinc (6 at.%) and to achieve double doping fluorine with concentrations (1, 2 and 3 wt%) is added and the enhancement in the properties of CdS through double doping is observed

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## Optoelectronic, magnetic and antifungal properties of CdS thin films co-doped with zinc and bromine

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**Abstract** This paper reports the results obtained on the optical, electrical, magnetic and antifungal properties of CdS thin films co-doped with zinc and bromine. XRD studies reveal that all the films exhibit hexagonal crystal structure of pure CdS. The undoped, Zn-doped and (Zn, Br) co-doped CdS thin films have a strong (0 0 2) preferential growth. Nanosized grains are evinced from the SEM images of all the samples. Optical transparency of undoped CdS increases from 76 to 81% for the Zn-doped film and to 90% for the co-doped films. Decreased electrical resistivity is observed for the co-doped films. Room temperature ferromagnetic orderings in the form of S-shaped loops are observed for all the films. Antifungal activity was performed against *A. niger* fungus strain and from the zones of inhibition developed around the samples it was observed that the Zn-doped and (Zn, Br) co-doped CdS thin films exhibit better antifungal efficiency.

### 1 Introduction

Cadmium sulfide (CdS) is a potentially important II–VI group metal chalcogenide semiconductor which plays an important role in visible-light driven optoelectronic applications due to its smaller band gap of 2.4 eV, high transparency and high electron affinity [1]. It is widely

used as window layer in the fabrication of solar cells with various p-type materials such as CdTe and PbS [2, 3]. In these types of solar cells, it is essential to elaborate the conductivity of CdS as it decreases the sheet resistance of the solar cells. The conductivity of CdS could be improved by controlling its native defects such as Cd interstitials and S vacancies which can be achieved through doping. Properties (electrical, optical and magnetic) of CdS thin films are strongly modified by doping with isovalent metallic ions such as Ag<sup>+</sup> [4], equivalent metallic ions such as Fe<sup>2+</sup> [5], Ni<sup>2+</sup> [6] and trivalent metallic ions such as In<sup>3+</sup> [7] and B<sup>3+</sup> [8]. Besides these codoping CdS with a combination of (cationic, cationic) and (cationic, anionic) ions its physical properties could be improved to a large extent. Increased optical transparency and improved band gap value has been reported by Liu et al. [9] for Zn, Fe co-doped CdS thin films. Increased third-order nonlinear susceptibility, optical band gap and decreased electrical resistivity have been reported by Sivaraman et al. [10] for Mg, Cl co-doped CdS films. Selvan et al. [11] reported an enhancement in the optical and electrical properties of CdS thin films when they are co-doped with zinc and chlorine. In our earlier work we observed that bromine; an anionic dopant ion strongly enhanced the surface morphology, optical transparency and electrical properties of CdS thin films [12]. Motivated by the results obtained with Br doping, in this work CdS thin film is co-doped with zinc and bromine. Spray technique using perfume atomizer is adapted to coat (Zn, Br) co-doped CdS thin films. Zn concentration is kept fixed as 6 at.% and Br concentration is varied as 1, 2 and 3 at.% and the enhancement in the properties of (Zn, Br) co-doped CdS thin films are investigated and reported here. Magnetic studies were performed to investigate the suitability of CdS in magneto-optical devices

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# Magnetic and antibacterial properties of Zr-doped SnO<sub>2</sub> nanopowders

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**Abstract** Zirconium doped tin oxide (SnO<sub>2</sub>:Zr) nanopowders were synthesized by a simple soft chemical route adding various concentrations of zirconyl chloride (0, 5, 10 and 15 wt%). The samples were characterized by techniques like XRD, SEM, TEM, EDX, FTIR spectroscopy, UV–Vis–NIR spectroscopy and photoluminescence spectroscopy. XRD studies confirm that all the samples exhibit rutile tetragonal crystal structure with a strong (1 0 1) preferential growth texture. Hexagonal shaped grains were evinced from the SEM images. Nanosized grains are evinced from the TEM images and EDX spectra confirm the presence of Zr in the doped samples. The bands at 523 and 583 cm<sup>-1</sup> observed in the FTIR spectra which are attributed as the characteristics of γ (Sn–OH) terminal bond of the SnO<sub>2</sub> crystalline phase confirm the presence of Sn–O in the synthesized samples. The doped samples exhibit ferromagnetic behavior. Enhanced antibacterial activity was observed for the doped samples. The obtained results show that zirconium strongly influenced the structural, morphological, optical, magnetic and antibacterial properties of pure SnO<sub>2</sub> nanopowders.

## 1 Introduction

Metal oxide semiconductors in nanoregime are found to exhibit interesting structural, optical, electrical and

magnetic properties. The physical properties of these nanoparticles are strongly influenced by the nature of grain, grain boundaries, distribution of cations, oxygen deficiencies, etc. These nanoparticles currently find applications in microwave devices, sensors, bio processing, etc. [1]. Among the various metal oxides, tin oxide (SnO<sub>2</sub>) is a wide band gap (~3.6 eV) semiconductor which has high optical transparency and degenerate semiconducting electrical properties [2]. SnO<sub>2</sub> has many technological applications such as transparent electrodes in photoelectric conversion devices, liquid crystal displays, electrochromic displays and planar wave guides [3]. SnO<sub>2</sub> is considered as a promising material for the development of multifunctional magneto-optical devices due to its high optical transparency and room temperature ferromagnetism. However for each applications SnO<sub>2</sub> requires a specific set of output properties which are influenced by its structural, morphological and optoelectronic properties which can be relatively easily modified and controlled by doping it with various transition metal ions such as lithium (Li<sup>1+</sup>) [4], cobalt (Co<sup>3+</sup>) [5], copper (Cu<sup>1+</sup>) [6], magnesium (Mg<sup>2+</sup>) [7], etc. When doped with transition metal ions, SnO<sub>2</sub> can become a good candidate for ferromagnetic semiconductors because of its large number of structural geometries with an electronic structure that can have metallic, semiconductor or insulator character [8] and potential applications (magnetic devices, gas sensors, dye base solar cells, optoelectronic devices, electrode materials and catalysts). Zirconium is a very strong, malleable, ductile transition metal having chemical and physical properties similar to that of titanium. It is extremely resistant to heat and corrosion. It is used to make surgical instruments and is used in steel alloys as a hardening agent. Zr<sup>4+</sup> ion have ionic radius of 0.74 Å which is smaller than that of Sn<sup>2+</sup> (0.93 Å) ion. Hence when SnO<sub>2</sub> is doped with Zr, more Zr<sup>4+</sup> ions can be accommodated into

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# Improved photodegradation activity of SnO<sub>2</sub> nanopowder against methyl orange dye through Ag doping

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## Abstract

Silver doped tin oxide (SnO<sub>2</sub>:Ag) nanopowders were synthesized by a simple soft chemical route with 0, 5, 10 and 15 wt% concentrations of Ag. The structural, morphological, optical, photoluminescence and photocatalytic properties of the synthesized samples were studied and the results obtained are reported in this paper. XRD studies confirm the polycrystalline nature of the synthesized samples. The undoped and doped samples exhibit a strong (1 0 1) preferential growth. Decreased crystallite size is observed with Ag doping. Nanosized grains were observed for the doped samples. Peak related to Sn–O–Sn lattice vibration is observed for both the undoped and doped samples in the FTIR spectra. Peaks related to oxygen vacancies were observed at 362 and 499 nm for all the samples in the PL spectra. Enhanced photocatalytic activity was observed for the doped samples and the SnO<sub>2</sub>:Ag nanopowder with 10 wt% Ag doping concentration exhibited maximum photodegradation efficiency against the degradation of methyl orange dye.

## 1 Introduction

In recent years, metal oxide semiconductor photocatalysts have attracted considerable attention due to their potential applications in hazardous waste remediation and energy problems with abundant solar light [1]. Among the metal oxide semiconductor photocatalysts, tin oxide (SnO<sub>2</sub>) is a wide band gap n-type semiconductor which has high optical transparency, electrical conductivity, high photosensitivity and chemical sensitivity [2]. Due to its good optical properties, chemical and mechanical stability, SnO<sub>2</sub> is used in many applications such as oxidation catalysis, gas sensors, solar cells, transparent conducting electrodes, lithium ion batteries, etc [3]. In the field of photocatalysis, SnO<sub>2</sub> seems to be an interesting material due to its different morphologies, high photochemical stability, strong oxidizing power and non-toxic nature [4]. The photocatalytic activity mainly relies on the generation of electron–hole (e<sup>−</sup>/h<sup>+</sup>)

pairs in semiconductor particles under illumination by visible/UV light. However, a quick recombination of the photo-generated electron and hole prevents augmentation of the photocatalytic efficiency. To counter this challenge many strategies such as semiconductors combination, transition metal doping and metal deposition has been adopted [5]. Eventhough, SnO<sub>2</sub> seems to be a promising semiconductor material for photovoltaic applications, its photocatalytic efficiency is often restricted because of poor quantum yield caused by the fast recombination rate and ineffective utilization of photo-generated electron–hole pairs [6]. To improve the photocatalytic efficiency of SnO<sub>2</sub>, doping has been performed as the dopant ions could introduce lattice defects which could lower its effective optical band gap, thus leading to a better photoactivity [7]. Silver is noble metal of group I which possess high electrical conductivity which facilitates fast electron transfer and low work function favoring the formation of good band alignment and Ag doped/loaded photocatalyst showed enhanced photocatalytic activity due to the surface plasmon resonance phenomenon under light irradiation [8]. Improved photocatalytic activity has been reported earlier for Ag-doped CdS thin films [9] and Ag-doped TiO<sub>2</sub> nanoparticles [10]. Motivated by these results, in the present work Ag-doped SnO<sub>2</sub> (SnO<sub>2</sub>:Ag) nanopowders were synthesized by a cost effective chemical method with different concentrations of Ag (0, 5, 10 and 15 wt%). Among the various chemical methods used to synthesize

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