Effect of Zno and Cdzno Thin Film Transistors on Solar Electrical and Optical Behaviour Characteristics Study

S L Lingeshwaran1, S Rajesh Kumar1, P Prakash1, C Ramesh1, M Karthick2,a), V Kaviarasan3, R Girimurugan4, T Sathish5, V Mohanavel6

1Department of Mechanical Engineering, K.S.Rangasamy College of Technology, Tiruchengode,

637215, Tamil Nadu, India.

2 Department of Mechanical Engineering, Erode Sengunthar Engineering College, Thuduppathi,

638057, Tamilnadu, India.

3 Department of Mechanical Engineering, Sona College of Technology, Salem,

636005, Tamil Nadu, India.

4 Department of Mechanical Engineering, Nandha College of Technology, Vailkaalmedu, Tamil

Nadu 638052, India.

5 Department of Mechanical Engineering, Vel Tech Multi Tech Dr.RangarajanDr.Sakunthala

Engineering College, Chennai, Tamil Nadu 600062, India.

6Department of Mechanical Engineering, Chandigarh University, Mohali 140413, Punjab, India

**Corresponding author: a)***mkarthickmech1992@gmail.com*

**Abstract.** The ZnO-based thin film transistors found significance in solar applications and developed via SCT (spin coating technique) found poor crystallized structure leads to low solar optical and electrical (O/E) properties. Due to this reason, this investigation is to prepare the cadmium (Cd) doped ZnO thin film transistor via plasma chemical vapour deposition route and its structure was evaluated by scanning electron microscope. The XRD tool records the variations in Cd doping over the ZnO. An Influence of the Cd layer on optical and electrical behaviour was evaluated and related to the ZnO film thin layer. The structure of Cd showed a uniform crystallized structure with homogenous particle distribution, and an X-ray diffraction pattern identified the Cd layer at 34.4º. The Cd-doped ZnO layer found a maximum current density of 2.04mA/cm2. Introducing a Cd layer over the ZnO film thin layer increases the transmittance and absorptance range.

# Introduction

In future, renewable energy will be the backbone for various applications due to its availability. Solar-based renewable energy was significant in various household, industrial, electrical vehicle, and heating/cooling applications due to their superior solar power conversion. The ZnO film enhanced made a transistor. The action of the ZnO thin film transistor, which enhanced thermal conductivity with increased heat flex, results in better solar power conversion. The Al and Mg-based composite materials were found to have good thermal behaviour. Based on this, researchers searched advanced doping materials like copper, Gallium, aluminium, magnesium, and cadmium [1]. Accordingly, solar collector, the thermal performance of solar was varied [2]. The non-fullerene polymer-based solar cell quality has to be enriched via zinc oxide introduction and prepared by the sol-gel process. Its structure observed by coarse uniform particle distributed crystallization structure results in improved solar cell performance [3]. Computational fluid dynamics analysis noted Effective solar thermal distribution [4].

The dye-prepared gallium-doped ZnO thin film and carbon monoxide (Co) thermal and electrical behaviours were experimentally evaluated and compared. The results showed that the Ga-doped ZnO significantly improved current density [5]. Most recently, the sol-gel derived bi and tri-layer film coatings (thin) were studied in various applications and found to increase current density compared to others [6]. Moreover, Al-doped ZnO and Cu-doped ZnO film were synthesized for solar applications and found to enhance solar power conversion compared to the layer of ZnO [7]. Yttrium doping over ITO film made via sol-gel spin coating. The yttrium ion offered lower electrogravity with an increased current rating [8]. The chemical vapour deposition developed ZnO film (thin) transistor behaviour was studied and found that the ZnCl2 precursor has high transmittance behaviour [9]. Recently, the solar thermal prepared Cd doped ZnO solar layer structure was analyzed by XRD & FESEM and UV-visible techniques and showed the even distribution of Cd particles over the ZnO layer [10-14]. However, the CVD method was suitable for thin film doping for solar thin film transistor applications [15-18]. Laser-assisted chemical vapour deposition developed Fe2O3 film in the solar application was studied, and its results showed homogenous particle distribution and good optical and electrical properties [19-22]. The chemical vapour technique formed the CdO, ZnO, and CdZnO doping layers, and it found that the SEM structure was distributed uniformly on the ZnO layer and offered good O/E behaviour related to the ZnO layer without doping material [23-27].

Much literature on this investigation and poor crystallized structure during the SCT were addressed. This investigation prepares the Cd-doped ZnO film thin transistor to overcome the drawback via the PCVD technique. A Cd covered over the ZnO layer structure was studied and recorded by even-distributed particles with reduced particle distance and increased optical behaviour. The output behaviour was related to the conventional ZnO layer without doping material. Finally, the enhanced behaviour of the film was suggested for solar PV cell applications.

# Materials and Methods

Figure 1 illustrates the plasma chemical vapour deposition (PCVD) setup for Cd-integrated ZnO film preparation. It includes plasma coupler, gun, holding table, and control panel. Before the PCVD process, the structure of ZnO was studied and evaluated in the Cd doping process. In the cathode terminal, 25nm film thickness Cd was kept over the ZnO layer under 15 MHz voltages with applied sputtering pressure of 6x10-6 Mbar. This process helps to eliminate dust and other irrelevant particle over the ZnO layer. During the layer formation, a plasma gun focused on ZnO with effective particle distribution was made over the ZnO layer [28-30].

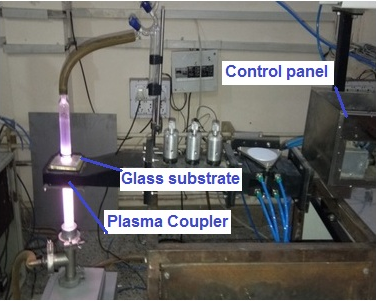


Fig. 1 Plasma chemical vapour deposition machine

It was formed and subjected to a structure analysis study to layer sequence. The sequence of layers is presented in Figure 2.

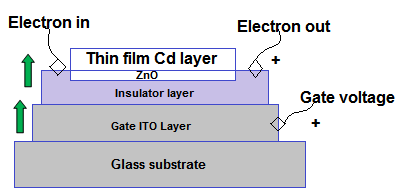


Fig. 2 Sequence of solar layer formation

# Results and Discussion

## Structure of ZnO and Cd-ZnO thin film

ZESIS make SEM adopted to identify the microstructure of the developed thin film. Fig. 3 and Fig. 4 show the SEM microstructure of ZnO & Cd integrated ZnO films. It was noted from Figure. 3(a) that the microstructure of ZnO showed cluster particle distribution with aggregated grain structure. It leads to variations in solar optical performance because of the impact of process parameters on the synthesis technique. The image was recorded by 3000X magnification and found a 50nm grain structure. The variations of grains were due to the effect of temperature difference and spin [31-34].

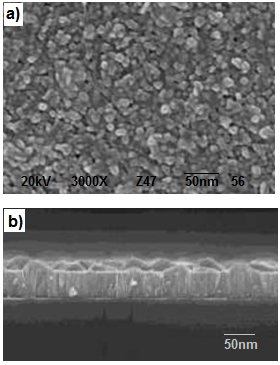


Fig. 3 Scanning electron microscope a) ZnO layer b) Cross-sectional SEM image ZnO thin film surface

Fig. 3(b) illustrates the cross-sectional microstructure view of the ZnO layer. It showed the variations in grains concerning layer formations. The waviness of the above surface of ZnO found small gas between the particles makes the cluster particle during the varied temperature process. The maximum temperature facilitates segregating the particle from the structure.

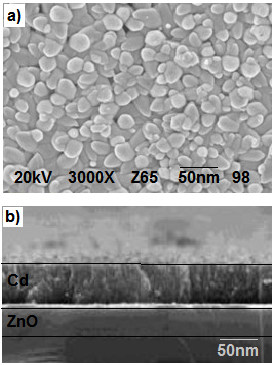


Fig. 4 Scanning electron microscope a) Cd-ZnO layer b) Cross-sectional SEM image Cd-ZnO thin film surface

Fig. 4(a-b) represents the Cd-doped ZnO layer microstructure and its cross-sectional view. From Fig. 4(a), the particles were distributed homogenously with a reduced band gap, offering enhanced optical and electrical characteristics compared to an enlarged band gap. Moreover, the solar performance fixed the particle distribution area, like the system's heat flux and thermal conductivity [35-39].

The PCVD-prepared Cd doped ZnO layer proved their presence in Fig. 4(b) and showed the fine bonded microstructure. It results in improved solar cell performance. Moreover, the effective plasma chemical vapour deposition showed enhanced particle distribution with good inertial bonding strength.

## X-ray diffraction pattern for ZnO & Cd integrated ZnO film.

Fig. 5 presents the XRD of different layers with highlighted ZnO and Cd integrated ZnO layers. According to the PCVD process, Cd-doped ZnO shows the variation in peaks and represents (100), (101), and (002). Moreover, the glass substrate showed a linear line with a slightly deviated structure [40-44]. This curve is represented in yellow, black, red, and green as a glass substrate, ITO, ZnO, and Cd-ZnO layers. The peaks (100, 101, and 002) showed equal space distribution. It results in improved optical performance.

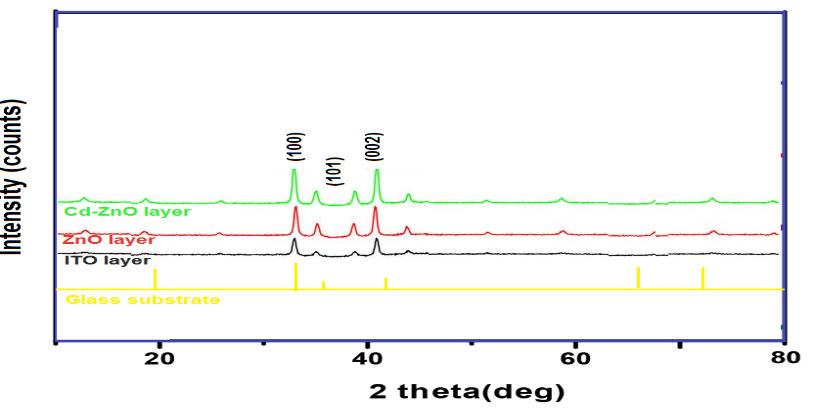


Fig. 5 X-ray diffraction pattern for ZnO, Al-ZnO, and Mg-ZnO layer

Based on the PVCD formed, Cd thin has proved its presence and distributed evenly. The effect of thin structure enhanced solar cell performance [3]. The efficient doped thin layer facilitated high current density [10]. However, the Cd was effectively doped with ZnO and found enhanced optical and electrical behaviour.

## Effect of Cd layer over the ZnO on the current density

The influence of the Cd thin layer over the ZnO on the current density of solar film is displayed in Figure 6. The current density of Cd-doped ZnO was superior to ZnO film. Current density of the ZnO film showed gradual improvement with an improved voltage from 0 to 0.72 volts. In the meantime, the implementations of the Cd thin layer over the ZnO recorded a higher value of 2.04mA/cm2 and improved by 41% compared to the ZnO thin film layer.

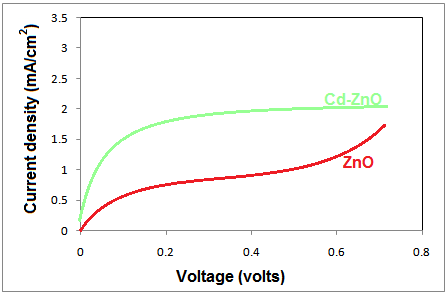


Fig. 6 Current density Cd doped ZnO thin film

The prime reason for enriching current density enhancement was the homogenous distribution of Cd particles over the ZnO layer. The uniform particle distribution with reduced particle space was found to have high solar thermal performance [11]. Based on the thin film processing, it was varied [49]. However, the enhancement of the ZnO layer with the Cd thin layer has shown superior current density. It results in high solar power conversion efficiency. In addition, the Cd has good thermal stability and offers superior heat absorption performance [45-48].

## Effect of Cd layer over the ZnO on optical behaviour of thin film

Fig. 7 and Fig. 8 illustrate the influences of the Cd thin layer over the ZnO on the optical behaviour of solar thin film. The transmittance range percentages on ZnO with and without the Cd thin layer are presented in Figure 7 and revealed progressive improvement in transmittance percentage. The cd-doped ZnO thin layer had a higher transmittance percentage than the thin layer. It was due to the effect of self-heating under varied solar radiations. Similarly, the Cd thin layer has better thermal behaviour than the ZnO material [54]. The transmittance percentage of ZnO was increased from 5 to 72% on an increased wavelength of solar film. Meanwhile, the Cd-ZnO thin film facilitates higher transmittance value due to its enhanced particle distribution, reduced particle space, and increased spread area. A similar mode of report was noted during the optical evaluation of Cd-ZnO prepared by sol-gel spin rotating [50-52]. Moreover, the transmittance of Cd-ZnO was found to be maximum and improved by 8% on 1350nm wavelength compared to ZnO film.

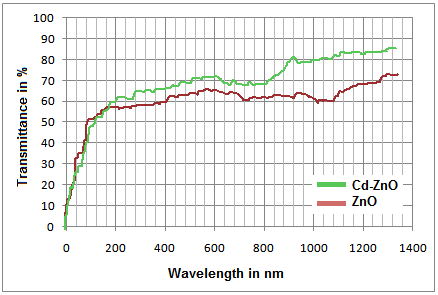


Fig. 7 Transmittance percentage of Cd doped ZnO thin film

Fig. 8 indicates the absorptance percentages of the ZnO layer doped with Cd thin film found to improve absorptance percentage. The Cd-ZnO thin film found higher absorptance than the ZnO thin film. It gradually decreased with an increase in wavelength.

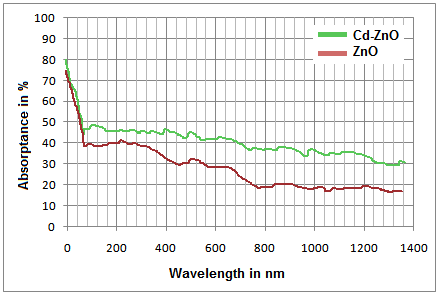


Fig. 8 Absorptance percentage of Cd integrated ZnO

It was noted from Fig. 8 that the Cd-doped ZnO layer was under a steady state between 400 to 800nm. In this limit, there was no major deviation.

ZnO's absorptance percentage gradually dressed 74% to 19% due to the cluster particle leading to poor heat dissipation. The cluster-phased ZnO layer is represented in Fig. 3(a). The implementations of the Cd layer over the ZnO film recorded a higher absorptance range of 30% for 1350nm. It was improved by 58% compared to the ZnO layer without a coat for the film as thin. Moreover, the enhancement of ZnO introduced a Cd thin layer and enhanced current density, resulting in better solar optical and electrical properties [53, 55].

# Conclusion

The plasma chemical vapour tool used Cd thin film successfully made over the ZnO and its structure was evaluated effectively. The structure revealed that the ZnO found cluster particle with varied particle space and Cd doped ZnO thin layer showed the even particle distribution offered good optical and electrical behaviour. Meanwhile, the view for a cross-sectional developed structure proved the Cd presence and has better solar thermal optical properties. The Cd-doped ZnO had the maximum current density and improved by 41% compared to the ZnO thin film without any coating material. Similarly, the Cd enhances the optical behaviour, such as transmittance and absorptance of ZnO solar film, using increased solar cell performance on varied current densities. The transmittance range of Cd doped thin film showed an 8% improvement at 1350nm wavelength, and its absorptance percentage was hiked by 58% compared to ZnO thin film without coating material.

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