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# Spray Deposited Thin Film Metal Oxide Based Heterojunction for Solar Cell Application

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**Abstract:** In the present study, thin film heterojunction based on n-CdO/p-NiO was fabricated on glass substrate by home built spray pyrolysis technique under optimized condition. Cadmium acetate dihydrate and Nickel chloride were used as precursors. Structural, surface morphology, optical and photovoltaic properties were analyzed and reported.

**Key words:** Thin film, heterojunction, spray pyrolysis, solar cell

## INTRODUCTION

Solar energy is becoming a vital source of renewable energy. The principal photovoltaic material market today is silicon. Although, silicon is an abundant element, their large-scale production is highly expensive. Materials selection for future photovoltaics should satisfy several important criteria. The fore most is that the materials should be comprised of abundant and inexpensive elements. Metal oxide semiconductor is a good alternate one. Cadmium Oxide (CdO) is an n-type semiconductor with band gap of 2.2 eV (Ortega *et al*., 2000). Due to its high optical transparency and atmosphere dependent electrical conductivity, it is used in optoelectronic devise and as gas sensor (Ferro and Rodriguez, 2000). Nickel oxide (NiO) is a p-type transparent conductive oxide with an energy gap of 3.15 to 4.0 eV (Sato *et al*., 1993). It also possess magnetism (Fujii *et al*., 1996) and abundant in nature. Thin film of above compound can be prepared from various techniques. Spray pyrolysis is one such chemical solution technique to obtain thin films. It is essentially a thermal reaction between clusters of liquid/vapor atoms of different chemical species. The technique involves spraying of solution, usually aqueous, in mist form containing solvable salts of the constituent atoms. (Mishra *et al*., 2009). This method is used to develop various metallic oxide, semi-conducting oxides, binary and ternary chalcogenides and superconducting thin films of various materials (Godbole *et al*., 2009. In this study, a thin film heterojunction consisting of n-type CdO and p-type NiO materials was fabricated using home built spray pyrolysis technique (Jeyaprakash *et al*., 2011). The structural, optical, photovoltaic properties of the developed heterojunction were studied.

## MATERIALS AND METHODS

The n-type CdO thin films were spray deposited on ultrasonically cleaned glass substrates at 250°C. A 0.5 M Cadmium acetate dehydrate ($Cd(CH_3COO)_2.2H_2O$) dissolved in deionised water was used as precursor solution. The p-type NiO film was deposited above CdO film covering 50% of surface area. Nickel chloride ($NiCl_2.4H_2O$) dissolved in deionised water was used as precursor solution and film was deposited at 320°C. The nozzle was kept 30 cm away from the substrate. Aluminium contacts were developed using pressure contacts. The schematic of developed n-CdO/p-NiO heterojunction is shown in Fig. 1. Microstructural data were studied using X-ray diffraction method from

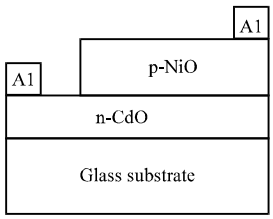


Fig. 1: Schematic of n-CdO/p-NiO heterojunction

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PANalytical X-ray diffractometer (Model D/MAX ULTIMA III). HITACHI makes (Model S-3000H) Scanning Electron Microscope was utilized to observe the surface morphology. The optical studies were carried out using ELICO SL 159 UV-Vis Spectrophotometer. Photovoltaic measurements were carried out using picoammeter and tungsten halogen lamp.

## RESULTS AND DISCUSSION

**Structural and micro structural characterization:** X-ray diffraction (XRD) patterns of the CdO film shown in Fig. 2 has well-defined peaks of (111) (200) (220) (311) and (222) plane at 2θ angle of 33.23°, 38.54°, 55.62°, 66.1°, 69.1° which were well matched with standard JCPDS card No. 05-0640. It indicates the film is of face-centered cubic (FCC) crystal structure. Also the presence of different oriented peaks indicates polycrystalline nature of film. The average grain size of 48 nm was determined by using well known Scherer's formula. Figure 3 shows the XRD pattern of NiO thin film which exhibits polycrystalline in nature with preferential orientation along (111) (200) and (220) plane at 2θ angle of 37.20, 43.25, 62.78. However the film grains were highly oriented along (111) plane. The peaks position indicates the hexagonal crystal structure which was well matched with standard JCPDS (78-0643) and grain size was found to be 21 nm.

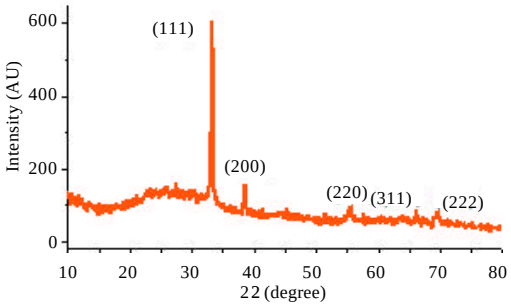


Fig. 2: XRD pattern of CdO thin film

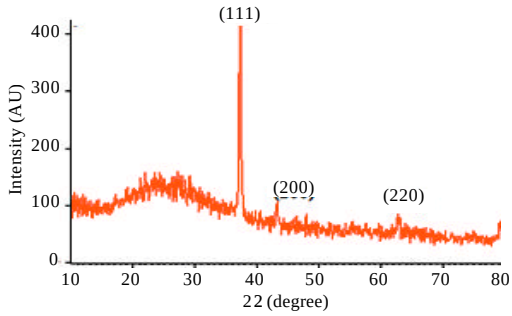


Fig. 3: XRD pattern of NiO thin film

The Field Emission Scanning Electron micrographs (FESEM) of CdO and NiO films were shown in Fig. 4 and 5. CdO film shows a cauliflower like grains morphology and is well connected to each other. Each larger grain has composed of smaller CdO grains of size lying between 10 to 20 nm. NiO surface shows continuous flakes like morphology.

**Optical characterization:** The variation of optical transmission with wavelength of CdO and NiO film is shown in Fig. 6. It shows that CdO is more transparent than NiO film.

Direct band to band transition in oxide films depends on the absorption coefficient (α) and photon energy (hν)by the relation:

$$(\alpha h\nu)^2 = A\,(h\nu - E_g) \qquad (1)$$

where, A is constant, hν and $E_g$ is the photon energy and optical band gap energy, respectively. The value $E_g$ is obtained by extrapolating the linear region of the curve between hν and $(\alpha h\nu)^2$. Figure 7 gives the band gap value for CdO film and is found to be 2.20 eV which is in

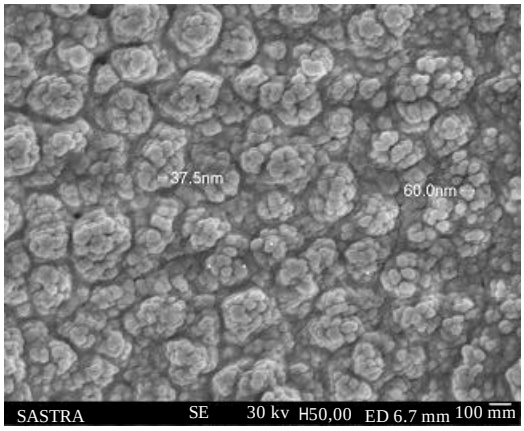


Fig. 4: Scanning electron micrograph of CdO thin film

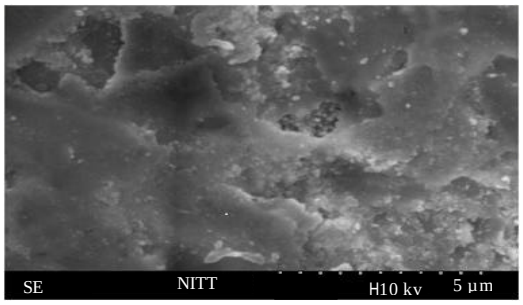


Fig. 5: Scanning electron micrograph of NiO thin film

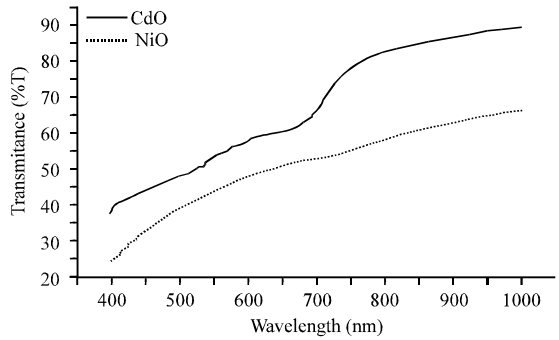


Fig. 6: Optical transmission spectrum of CdO and NiO thin film

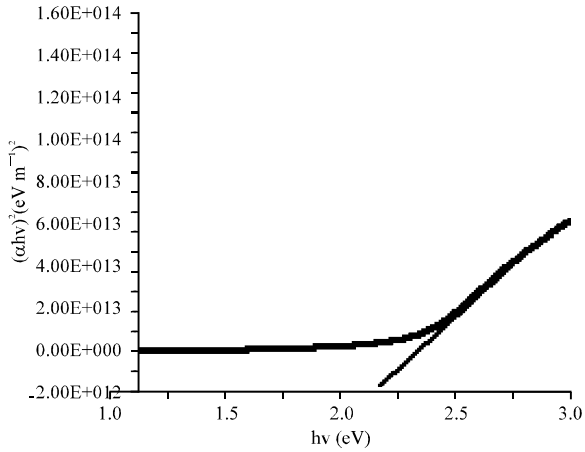


Fig. 7: Plot of hν vs. $(\alpha h\nu)^2$ for CdO thin film

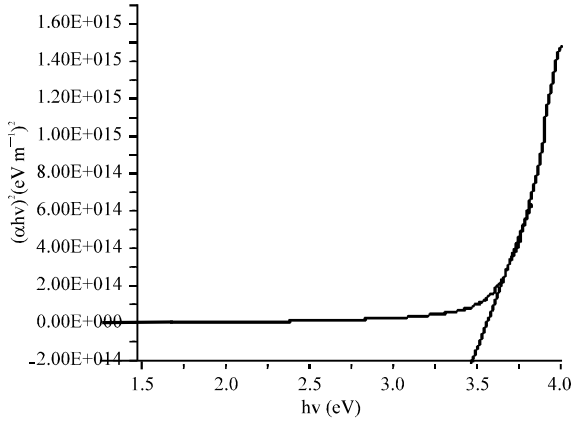


Fig. 8: Plot of hν vs. $(\alpha h\nu)^2$ for NiO thin film

good agreement with the reported result for CdO thin films (Ortega *et al.*, 2000). Figure 8 shows the plot for determining $E_g$ of NiO thin film. It was found to be 3.45 $(eV\ m^{-1})^2$ and is in good agreement with the reported result of NiO thin film (Sato *et al.*, 1993). Also NiO film exhibits a

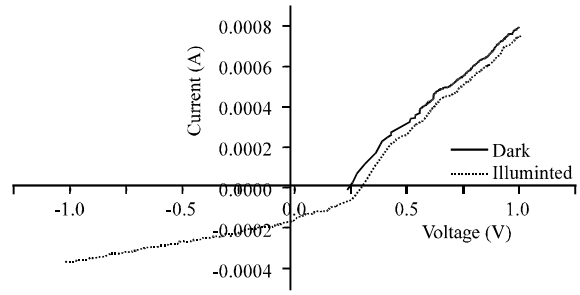


Fig. 9: I-V plot of n-CdO/p-NiO thin film

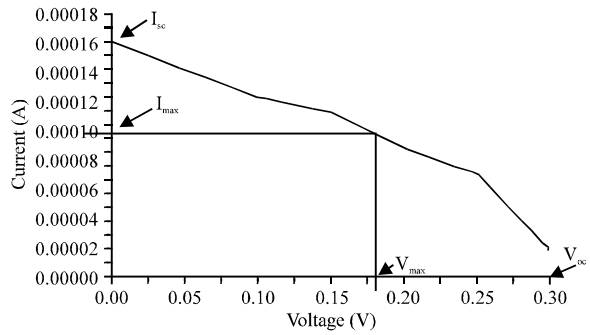


Fig. 10: Plot to determine fill factor and Efficiency, V: Voltage, I: Current

transmittance of 70% while CdO film exhibits transmittance up to 90%. This indicates that the developed heterojunction will have good photovoltaic property.

**Photovoltaic characterization:** Under dark condition the developed heterojunction shows a good rectifying behavior. The dark current increases with increase in applied voltage. In reverse bias condition the photocurrent exhibit almost flat dependence. In forward bias condition there was a rapid change in current with respect to the voltage. This could be observed from Fig. 9. Under an illumination of 50 mW $cm^{-2}$, photovoltaic studies were made on the n-CdO/p-NiO cells. From the Fig. 9, it was observed that the open circuit voltage ($V_{oc}$) was 0.3 V and the short circuit current ($I_{sc}$) was 0.16 mA. The Fill factor (ff) and Efficiency (η) were calculated from the Fig. 10 using the following relation (2) and (3):

$$ff = \frac{V_{max} I_{max}}{V_{oc} I_{Sc}} \quad (2)$$

$$\eta = \frac{V_{oc} I_{SC} ff}{P_{in}} \quad (3)$$

the maximum voltage ($V_{max}$) and the maximum current ($I_{max}$) values were found to be 0.18 V and 0.095 mA,

respectively. The fill factor and efficiency was found to be 0.35 and 1.34%. The calculated fill factor is very low due to presence of high series resistance.

## CONCLUSION

N-CdO/p-NiO thin film heterojunction were developed using home built spray pyrolysis technique and its structural, optical band gap and photovoltaic characteristics were studied. XRD peaks shows that the CdO and NiO film is oriented towards (111) orientation and exhibit polycrystalline nature. The grain size calculated is in good agreement with the SEM image. From the optical studies it was observed that CdO exhibit an optical band gap of 2.20 eV and NiO with 3.45 eV. Under the illuminated condition the developed heterojunction exhibits $V_{oc}$ of 0.3 V, $I_{sc}$ of 0.16 mA. It has a fill factor and efficiency of 0.35 and 1.34%, respectively. The efficiency found to be low; however it is encouraging to do further work on this abundant element and simple fabrication technique.

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