Optoelectronic Characteristics of n-CdO/p-Si Heterojunction Prepared by Spray Pyrolysis

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ABSTRACT

Photodetector made by deposition of n-CdO film using chemical spray pyrolysis (CSP) on clean monocrystalline p-type silicon substrate was investigated. The performance of the photodetector was evaluated by using I-V under dark and illumination conditions, C-V, and spectral responsivity. The experimental data confirm that the CdO-Si photodetector spectral response combines the effect of intrinsic absorption in both CdO and Si. Furthermore, the best photodetector exhibited current responsivity of 0.45 A/W around 800 nm under the presence of 3V bias voltage in the absence of additional post-deposition annealing.

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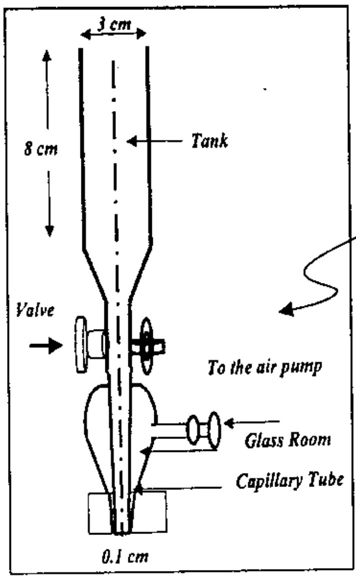
1. Introduction

Transparent conductive oxides (TCO's) are used extensively for a wide of applications including flat-panel displays, transparent electrodes, thin films photovoltaic, and heterojunctions **[Santana etal 1999, Ortega etal 2000, Gomez etal 2001, Dakhel and Henari 2003, Dewei etal 2003]**. Intrinsic cadmium oxide (CdO) is n-type semiconductor and it is transparent in the visible region with direct and indirect bandgaps of 2.5 eV and 1.98 eV respectively **[Dewei etal 2003]**. Many techniques were used to prepare CdO, one of the promising methods is the chemical spray pyrolysis (CSP) technique **[Uplane 2000]**. Growing a CdO on silicon to form a heterojunction is potentially attractive for PV applications. In this part of applications, little information are available in the literatures the CdO/c-Si heterojunction photodetectors **[Kunioka and Sakai 1968 , Ortega and Morales 1999]**. According to our knowledge, heterojunction devices prepared by deposition CdO thin film on Si by means of spray pyrolysis has not been reported. The main objective of present work is to fabricate and analyze the optoelectronic properties of the CdO-Si heterojunction photodetector made by CSP.

2. Experimental

In this study, (111)-oriented single crystal p-type Si wafers with dimensions (5 x 5 x 0.3 mm^3) having resistivity of 1–3 Ω.cm corresponding to doping concentration of ($4x10^{15}$ cm^{-3}) were used. The samples subjected to chemical etching using CP4-etchant before deposition of CdO layer. The intrinsic CdO films were deposited onto Si wafers by chemical spray pyrolysis technique. The description of experimental set-up of CSP system is presented in figure (1). CdO films were prepared by spraying an aqueous solution of cadmium nitrate [$Cd(NO_3)_2$] on hot glass and Si substrates kept at optimum temperature (400° C). The carrier gas used for spraying was compressed air. The thickness of the film was optimized to be 50 nm. Metallized ohmic contact was made on front layer (CdO) by deposition of high purity (5N) indium-film of (1000 nm) thick through special mask. In the case of Si substrate, contact was made by deposition of Ti (400 nm) and Al (500 nm) film over the surface. To investigate the transmission spectrum of CdO film deposited on a glass substrate , a double-beam spectrophotometer (Lambda 9 PERKIN-ELMER) was used. The conductivity type of CdO film was estimated using Hall effect measurements. The C-V measurements were obtained by an LCZ meter (HP/4192) at 10 kHz. Spectral photoresponse measurements were done in the (400 – 1100) nm range, using a single-pass monochromator with calibrated Si photodiode.



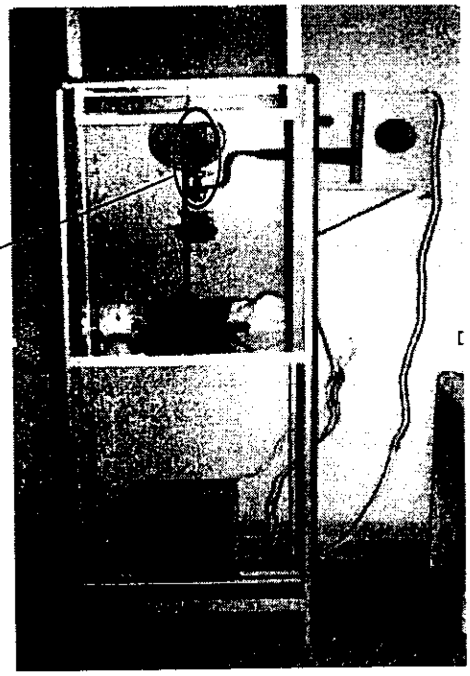


Fig.(1). Experimental Set-up of Spraying Apparatus (Right), and Layout of Enlarged Spraying Glass Nozzle (Left).

3 . Results and Discussions

Figure (2) shows the optical transmission of intrinsic CdO thin film. It is obvious from the curve that transmission is so high (window) for wavelengths higher than 536 nm ($\lambda_{cut\text{-}off}$). After 900 nm wavelength, the transmittance is decreased due to the plasma edge.

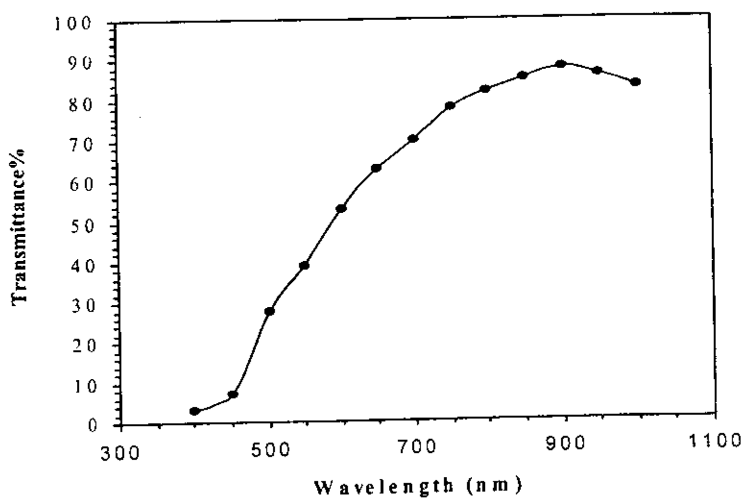


Fig. (2). Optical Transmittance of CdO Thin Film of 50 nm Thick.

The optical bandgap of CdO films was calculated from the transmission of absorption spectra by plotting $(\alpha h\nu)^2$ versus $h\nu$, the bandgap value of 2.3 eV was obtained which is in a good agreement with published results **[Dewei etal 2003]**. The CdO films made without any dopants (intrinsic) show a slight n-type character according to Hall measurement results,on the other hand the mobility of CdO film is around 50 $cm^2\ V^{-1}s^{-1}$.

The I-V characteristics in the dark and illumination condition of anisotype n-CdO/p-Si are presented in figure (3). The dark characteristics are of the form $\mathbf{I = I_S \exp(qV/nkT)}$ with $\mathbf{n = 2.5}$. The large value of ideality factor suggests that the recombination in these devices occurs primarily in the junction depletion region and/or at the junction interface, due to large value of lattice mismatch **[Song etal 2001]**. The I-V curve for the photodetector when illuminated with different intensity levels of white light is also shown in figure (3). Increasing light intensity leads to increase the photocurrent, i.e, the detector exhibits good linear characteristics. The ratio of the photocurrent to the dark current was about 47.5 at 3 V under illumination level of 150 mW/cm^2.

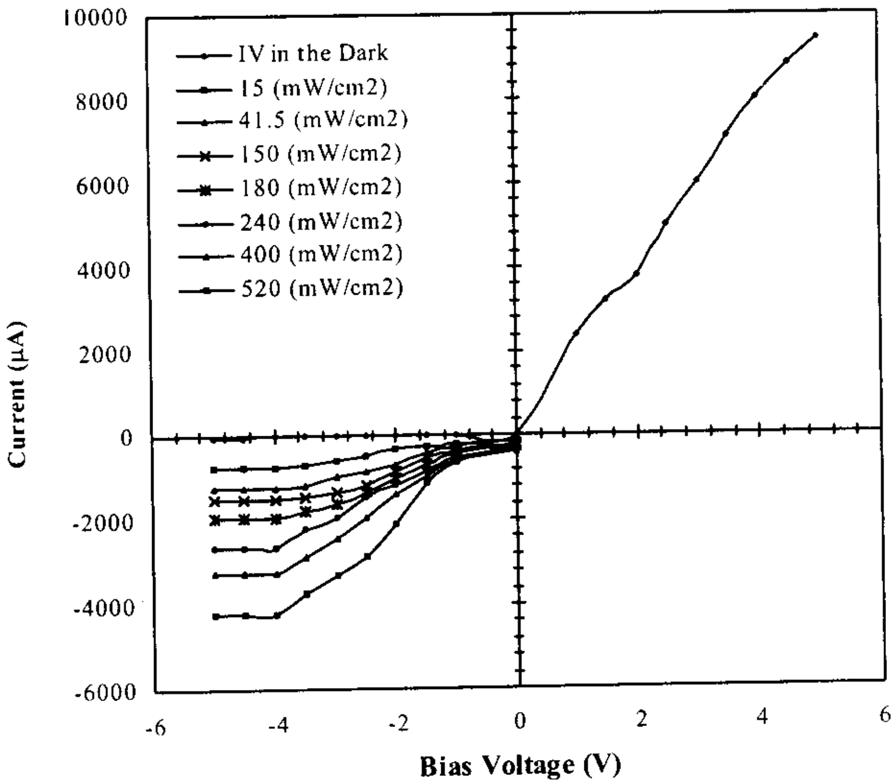


Fig. (3). I-V Characteristics in the dark and under illumination.

The potential barrier of the heterojunction can be measured from C^{-2}-V plot [Fig. (4)], since the band bending is on the CdO side. The C^{-2}-V intercept of 1.5 V is essentially equal to the diffusion potential within CdO.

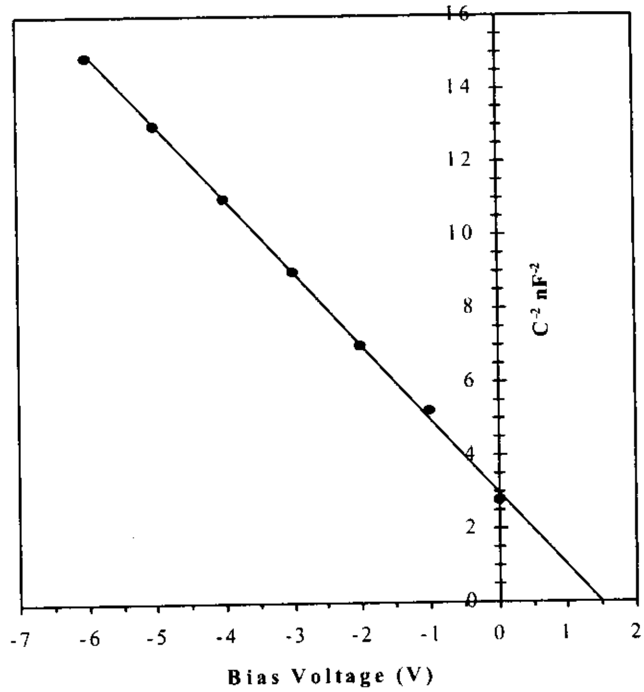


Fig. (4). Reciprocal of Square Capacitance against Reverse Voltage.

The spectral responsivity plot in the presence and absence of reverse bias voltage is depicted in figure (5). It is evident that there are two peaks of response, the first one is due to the intrinsic absorption of CdO (around 600 nm) since beyond λ = 600 nm the curve shows pronounced minima which can be attributed to the traps defect. The second peak located at 800 nm due to intrinsic absorption of Si, i.e, the photodiode shows window effect between 650 – 1000 nm. On the other hand, applying bias voltage resulted in greatly enhancment in the responsivity of photodetection. A peak responsivity of 0.46 A/W at 800 nm was obtained when the detector biased to 3 Volts. This result is in competition to that obtained by**Ortega and Morales [1999]** for doped-CdO-Si prepared by chemical bath deposition (CBD) . No significant increment in responsivity is noted at bias voltage greater than 3 V. Also no shifting in peak response occurs under effect of bias condition has been noticed.

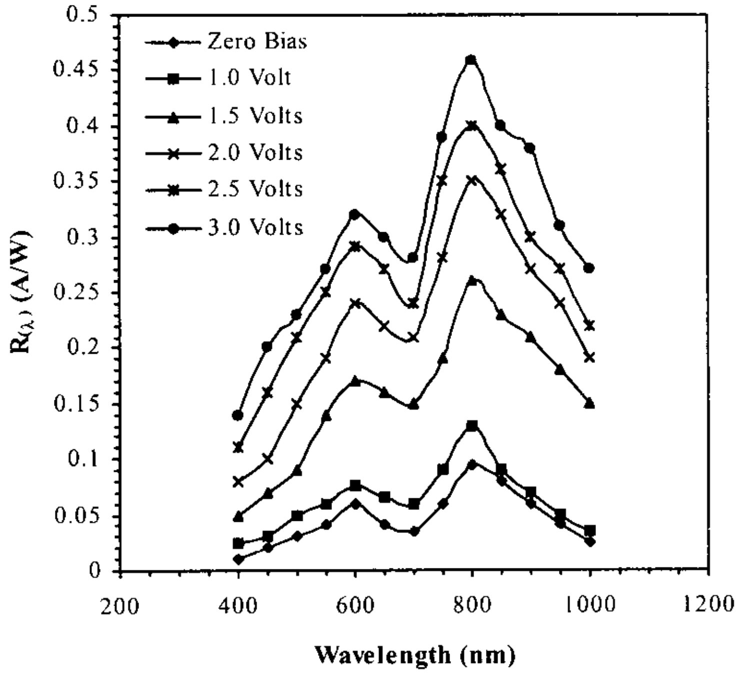


Fig. (5). Spectral Responsivity of CdO/Si Heterojunction.

4. Conclusions

The anisotype CdO/Si heterojunctions made by simple and inexpensive CSP were fully characterized without using any heat treatment process. The high value of responsivity at a small bias voltage suggests the use of such photodetectors instead of homojunction for blue line and NIR region. Influence of CdO doping and post-deposition annealing on PV characteristics of CdO/Si heterojunction is underway.

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