Synthesis of Gallium (Ga) Doped $CdO/p-Si$ Heterojunction and Evaluation of Junction parameters

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Abstract

In this work, $CdO:Ga/p-Si$ heterojunctions were fabricated by depositing Gallium (Ga) doped CdO ($CdO:Ga$) thin film on a p-type single crystal silicon wafer by spray pyrolysis technique. The characteristics of heterojunction and junction parameters were evaluated by Current-Voltage ($I-V$) and Capacitance-Voltage ($C-V$) study. The XRD study showed that the prepared $CdO:Ga$ films on Si substrate are polycrystalline in nature and the crystal structure is identified as face-centered cubic (FCC). SEM images are found smooth and spherical shape grains of almost even sizes are distributed uniformly over the film surface for the film prepared on Si wafer. The room temperature PL study of $CdO:Ga$ films grown on p-Si substrate showed emission peaks due to the band-to-band and defect states. From the Hall measurement, $CdO:Ga$ is found as n-type semiconductor with carrier concentration of the order of ~10^{20} cm^3. The Current-Voltage ($I-V$) characteristics confirmed the rectifying diode behavior of the $CdO:Ga/p-Si$ heterojunction. The magnitude of the ideality factor and the $C-V$ response of the fabricated heterostructure at different oscillation frequencies reveal the good diode characteristics.

Key words: Heterojunction, photoluminescence, ideality factor, built-in potential.

Methodology

Precursor solution preparation:

Step 1:

$Cd(CH_3CO_2)_2$ (powder) + H_2O → (Stirring at RT, 2 hrs.) → $Cd(CH_3CO_2)_2$ 0.1 M

Step 2:

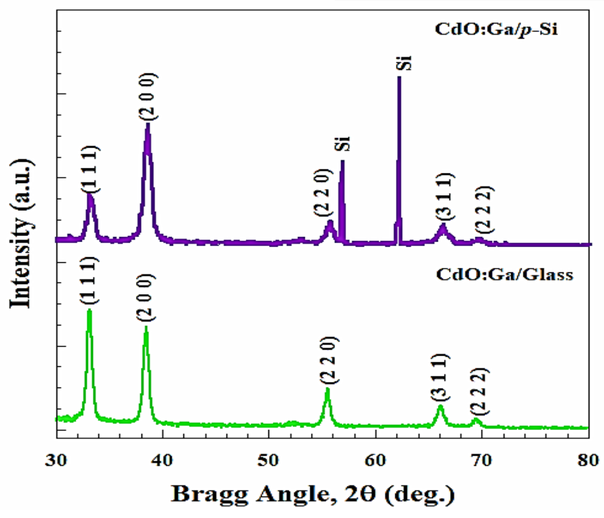
$Cd(CH_3CO_2)_2$ 0.1 M + $GaCl_3$ → (Stirring, 1 hrs.) → $Cd(CH_3CO_2)_2 .2H_2O$ +5% $GaCl_3$

Deposition:

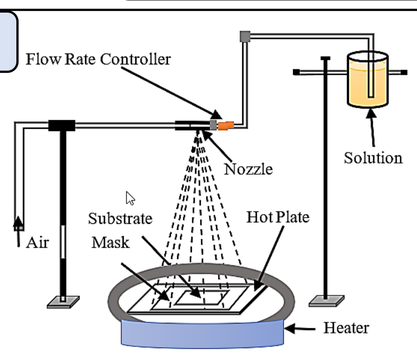
$Cd(CH_3CO_2)_2 .2H_2O$ +5% $GaCl_3$ → (280 ℃, Decomposes to) → $CdO:Ga$ + $Cl_2\uparrow$ + $CO_2\uparrow$ + $CH_4\uparrow$ + Steam ↑

Results and Discussion

Structural Property (XRD)



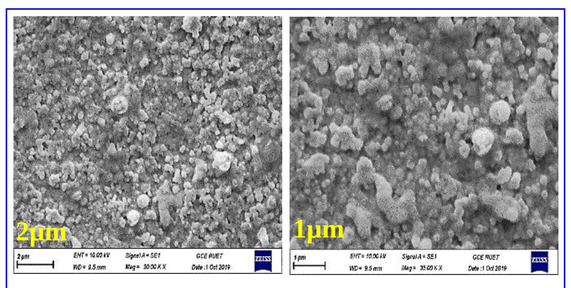
XRD pattern of $CdO:Ga$ thin films



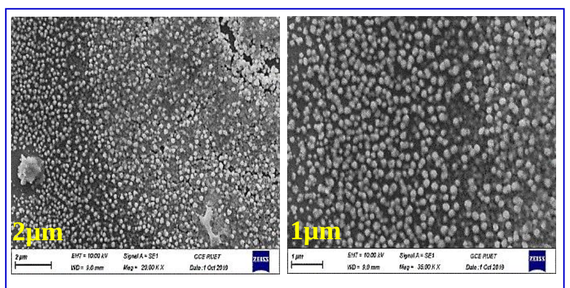
Experimental set-up of spray pyrolysis technique.

- (1 1 1),(2 0 0), (2 2 0),(3 1 1), and (2 2 2) planes confirms the polycrystalline, face-centered cubic structure without any impurity phases
- XRD patterns at 56.66° and 62.02° are originated from Si substrate

Surface Morphology (SEM)

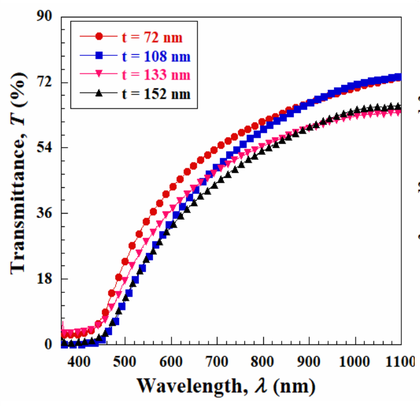


SEM micrograph of $CdO:Ga$ thin film deposited on glass substrate with magnification: (a) 20000 X and (b) 35000 X.

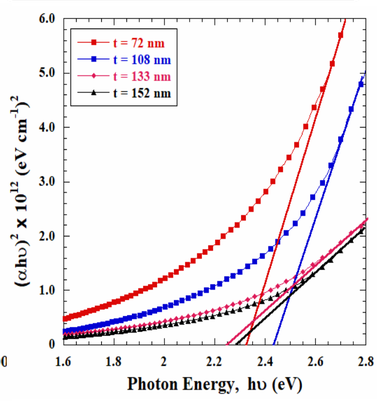


SEM micrograph of $CdO:Ga$ thin film deposited on $p-Si$ substrate with magnification: (a) 20000 X and (b) 35000 X

Optical Studies

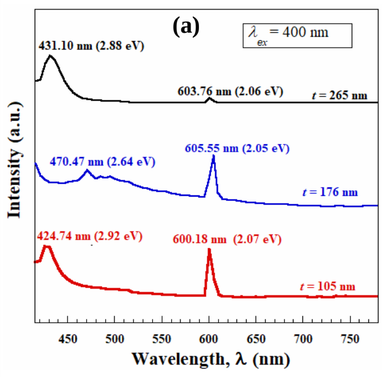


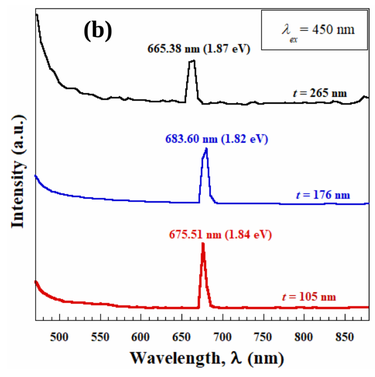
Variation of transmittance with wavelength for $CdO:Ga$ thin film deposited on glass substrate



Variation of direct band gap with photon energy for $CdO:Ga$ thin film deposited on glass substrate.

Sample	Thickness, t (nm) ± 10 (nm)	Optical band gap, E_g (eV)
CdO	81	2.28
	113	2.34
	142	2.38
	162	2.37
$CdO:Ga$	72	2.32
	108	2.43
	133	2.25
	152	2.29



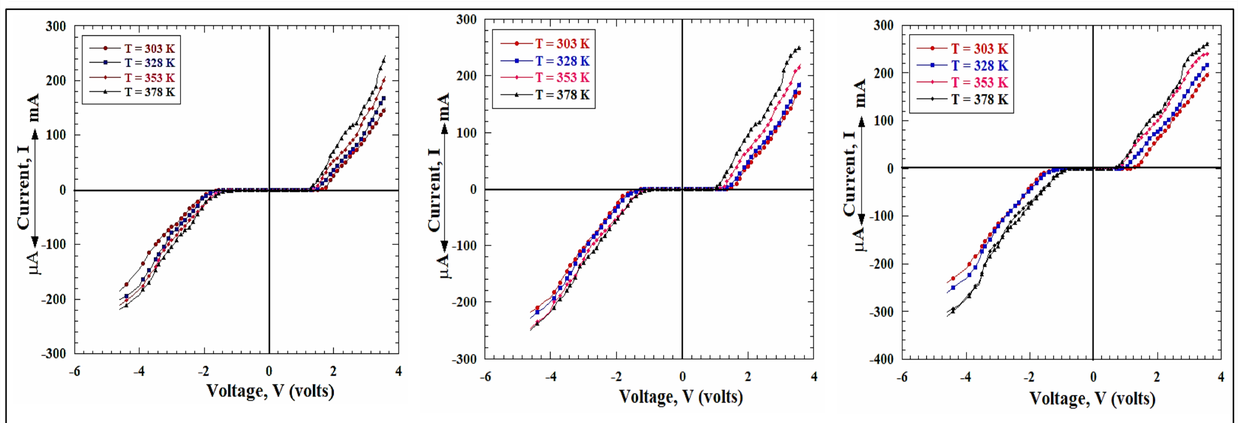


RTPL spectra of $CdO:Ga$ thin film deposited on $p-Si$ substrate for different thickness at excitation wavelength of (a) 400 nm, (b) 450 nm.

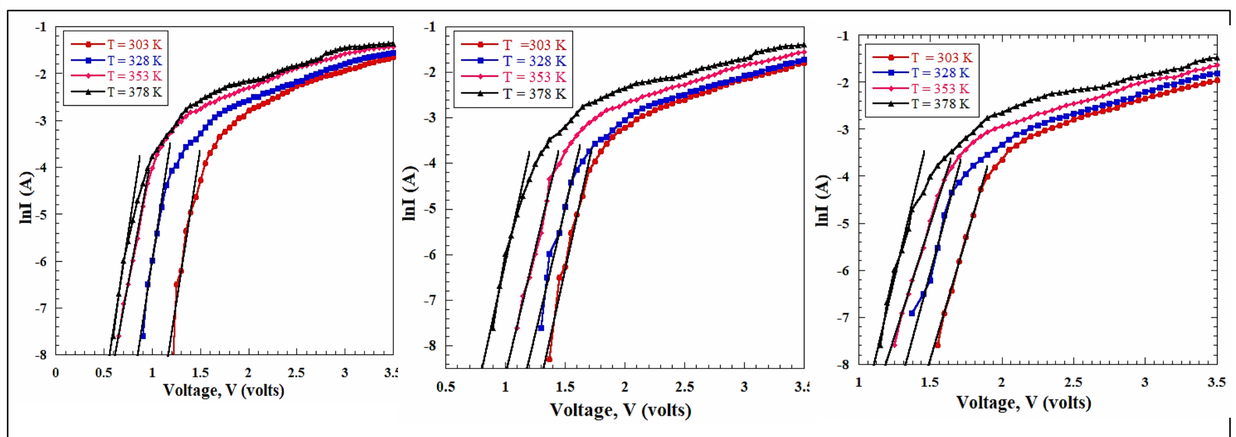
The spectrum shows two peaks for each film: the first peak at 424.74, 470.47 and 431.10 nm for the films having thickness of 105, 176 and $265 \pm 20\ nm$ respectively which can be referred to the band to band transition. The second peak at 600.18, 605.55 and 603.76 nm for films having thickness 105, 176 and $265 \pm 20\ nm$ respectively which is due to the exciton emission.

Electrical Analysis

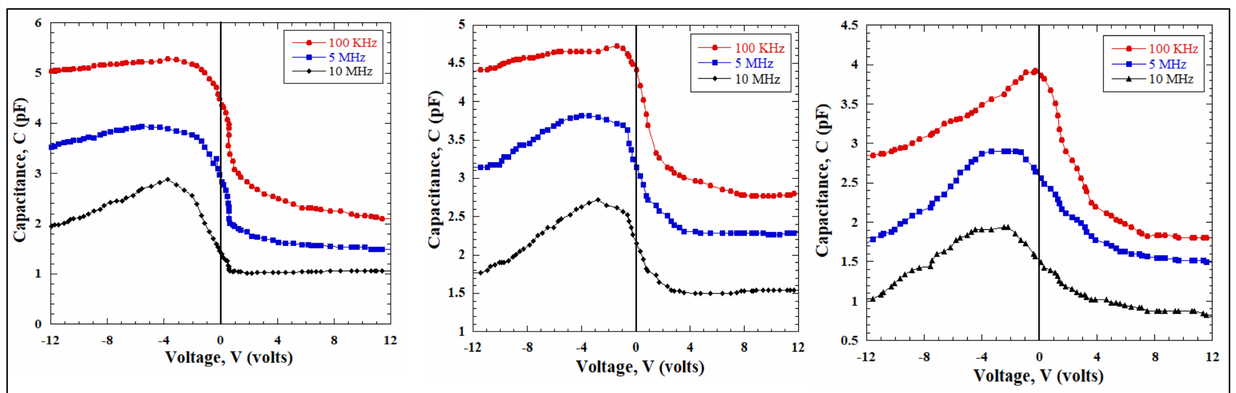
Hall Properties: $CdO:Ga$ thin films are found as n-type semiconductor with carrier concentrations of the order of 10^{20} (cm^{-3})



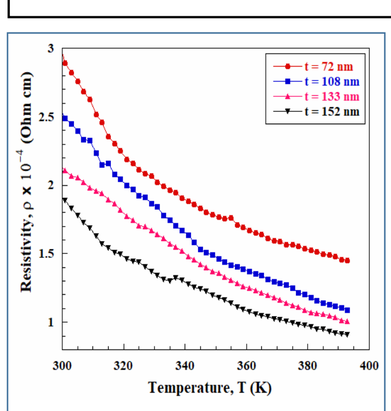
I-V characteristics of 5% Ga doped $CdO/p-Si$ heterojunction of thickness 265 nm at different temperature



Variation of forward current in logarithmic scale with voltage of 5% Ga doped CdO/p-Si heterojunction of thickness 105 nm at different temperature.



C-V characteristics of 5% Ga doped $CdO/p-Si$ heterojunction of thickness 265 nm at different oscillation frequencies.



Variation of resistivity (ρ) with temperature for $CdO:Ga$ thin films of different thickness.

Conclusions:

The XRD study confirms the cubic structure of the $CdO:Ga$ films. SEM images show moderately uniform surface morphology with spherical shape grains of the $CdO:Ga$ films. Optical study shows that CdO:Ga films are highly transparent in the visible range of electromagnetic radiation and the are direct band gap semiconductor. The room temperature PL study of $CdO:Ga/p-Si$ heterojunction confirms the ability of emission light of the diodes in the visible spectrum. The temperature dependent resistivity conforms the semiconducting behavior of the films. Hall measurement confirms the n-type nature and the carrier concentrations of the films were found of the order of 10^{20} cm^3. The temperature-dependent I-V characteristics of the fabricated $CdO:Ga/p-Si$ heterojunction confirm the rectifying diode behavior. The threshold voltage decreases with increasing thickness and temperature. The charge density varies with the bias voltage in both forward and reverse bias conditions and as well as for different frequencies.

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