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Synthesis of 1-Dimensional CdO Nanostructures and its Heterojunction Diode Characteristics

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Abstract

1-Dimentional nanostrutured Cadmium Oxide (CdO) thinfilms were prepared on p-type silicon (100) substrates by Chemical Bath Deposition (CBD). Deposition time was varied form 6 hrs to 12 hrs to tune the 1-Dimensitonal nanostructures. CdO thin films deposited for 6 hrs show needle like structures whereas film deposited for 12 hrs show nanowire structure. The XRD pattern confirms the polycrystalline nature of the film. EDAX pattern confirms the elemental species with right stoichiometry. PL spectra show strong emission peak at 511nm in all the samples. n-CdO/p-Si heterojunction diode was fabricated and its characteristics were studied. Ideality factor was estimated from I-V measurements and found to be 3.5 and 3.3. This high value of ideality factor arises due to the presence of interface states and series resistance effect.

Keywords: Chemical Bath Deposition, Heterojunction Diode, Nanoneedles, Nanowires

1. Introduction

Metal-oxide- transparent semiconductors like SnO_2, In_2O_3, ITO, FTO, and CdO have been used extensively for optoelectronic applications such as solar cells, smart windows, flat panel display and light emitting diodes[1]. One of the elementary devices of modern electronic industry is diode. Hence it is important to fabricate high performance diode for electronic and optoelectronic applications. Cadmium Oxide (CdO) is an II-VI compound n-type degenerate semiconductor with a simple cubic structure and having a direct band gap of 2.3 eV [2]. Intrinsic CdO show very low electrical resistivity of about 10^{-2} – 10^{-4} Ω-cm [3]. 1-Dimensional transparent metal oxide nanostructures with transparency and high electrical conductivity provide wide opportunities in transparent electronic applications. Mostly Heterojunction diodes are fabricated using 1-D ZnO/p-Si(100) which has high transparency, but electrical conductivity is at the order of few MΩ [4]. CdO has both visible transmission and high electrical conductivity. Hence heterojunction diode with 1-D CdO nanostructures would provide better performance in electronic and optoelectronic devices. 1-D CdO nanostructures were prepared by wet chemical prepcipitation [5], hydrothermal [6], chemical vapor deposition [7], chemical bath deposition [8] etc. Among the above chemical bath deposition is a simple, cost effective technique and large scale production is also possible.

In this work maiden attempt has been made to prepare 1-D CdO nanostructures by simple chemical bath deposition method and its heterojunction characteristics were studied. To the best of our knowledge there is no report on the Heterojunction diode characteristics are discussed in detail.

2. Experimental Procedure

2.1 Preparation CdO Nanostructures by Chemical Bath Deposition Method

For the synthesis of cadmium oxide thin films, the used precursors are cadmium nitrate tetra dehydrate and aqueous ammonia. 0.1M cadmium nitrate was first dissolved in the deionized water and then 5M of aqueous ammonia

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solution was added. Immediately, the solution turns into turbid white. Excess addition of ammonia to the above, the solution becomes colorless and transparent. Then the cleaned silicon substrates were dipped into the above complex solution for 6 hours and 12 hours at 70°C temperature. Then the substrates were taken and rinsed in DI water. Then the samples were annealed at 400°C for 1 hour to remove the hydroxide phase if any.

The structural analysis of CdO thin films were carried out by XRD using Shimadzu-6000 with CuKα radiation (λ = 0.154 nm). The surface morphology of the thin films was investigated using JEOL-600 Scanning electron microscopy (SEM) and Compositional analysis was done using EDS. Photolumisecnce spectra was obtained using Flurong. I–V characteristics were studied using 2612A Keithley Source Meter.

3. Fabrication of Heterojunction Diode

Figure 1 depicts the schematic diagram of n-CdO/p-Si heterojunction diode. After depositing n-CdO nanostructured thin film on p-Si(100) substrate, The ohmic contacts of these device was formed by Silver(Ag) paint onto the CdO thin film and to the back surface of silicon, respectively. I–V characteristics of the diode are analyzed using 2612A Keithley Source Meter in the voltage range −20V to +20V.

4. Results and Discussion

4.1 Structural Analysis

Figure 2(a-c) shows the XRD pattern of $Cd(OH)_2$ and CdO thin films prepared by simple chemical bath deposition method for 6 hrs and 12 hrs. $Cd(OH)_2$ samples show amorphous nature. CdO samples show polycrystalline nature exhibiting face centered cubic crystal structure. The characteristic peaks at 2θ = 33.04°, 38.3°, 55.33° corresponds to (111), (200) and (220) planes. Increase in deposition time from 6 hrs to 12 hrs the intensities of all the planes increases. The peak at 62°, correspond to the Si substrates. The crystallite size of sample were calculated from Debye Scherrer's formula; $D= 0.9\lambda/\beta\cos\theta$ where λ is X-ray wavelength, θ is the Bragg's angle and β is the full width of diffraction line (FWHM) at the half of maximum intensity and calculated crystallite size for the sample at 6 hrs was 30 nm and 12 hrs was 25 nm.

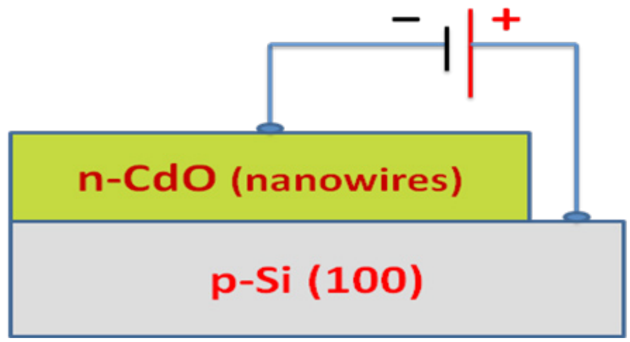

Figure 1. Schematic picture of Si(p)-CdO(n) Heterojunction diode.

4.2 Morphological Analysis

Figure 3(a-c) shows the morphological features of the chemical bath deposited $Cd(OH)_2$ and CdO thin films for 6 and 12 hrs. Figure 2(a) shows the nanoneedle of length few micrometers when films were deposited for 6 hrs duration. When increasing the deposition time to 12 hrs, the needles become smaller in size and align linear to form continuous nanowires. Figure 2 (d) EDAX Spectra of CdO thin films deposited for 12 hrs, its reveals that sample contains only Cd and O peaks, Si peak corresponds to p-Si(100) substrate of the samples.

4.3 Photoluminescence Spectra

Figure 4 shows the photoluminescence of CdO thin films deposited for 6 and 12 hrs. Both the samples show strong emission peak at 511 nm. 511 nm peak emitted by CdO nanowires is the near band edge emission of CdO. This clearly demonstrates that the samples are pure without impurity.

4.4 n-CdO/p-Si(100) Heterojunction Diode Characteristics

Figure 5 shows the diode characteristics of Heterojunction n-CdO/p-Si(100) prepared for 6 hrs and 12 hrs respectively. Both the samples show good rectifying behavior with forward-to-reverse current ratio in the range of −20 to 20 V. In forward bias current increases exponentially and for 6 hr deposited samples the threshold voltage is found to be 10 V and increase in deposition time from 6 to 12 hr, threshold energy of the diode decreases to 8.5 V.

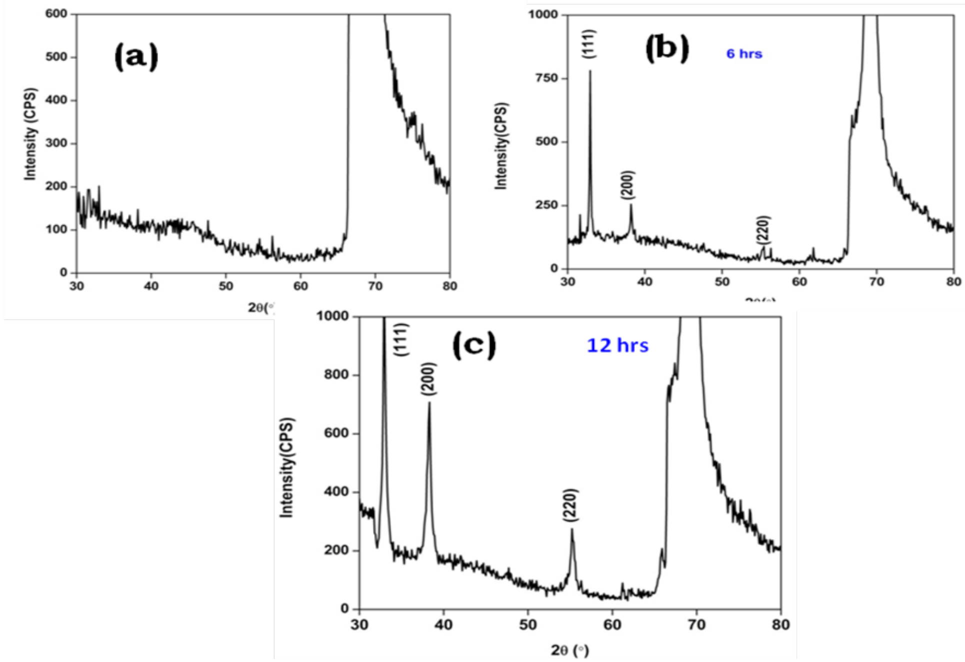

Figure 2. XRD pattern of (a) $Cd(OH)_2$ and CdO nanostructured thin films deposited for (b) 6 hrs and (c) 12 hrs.

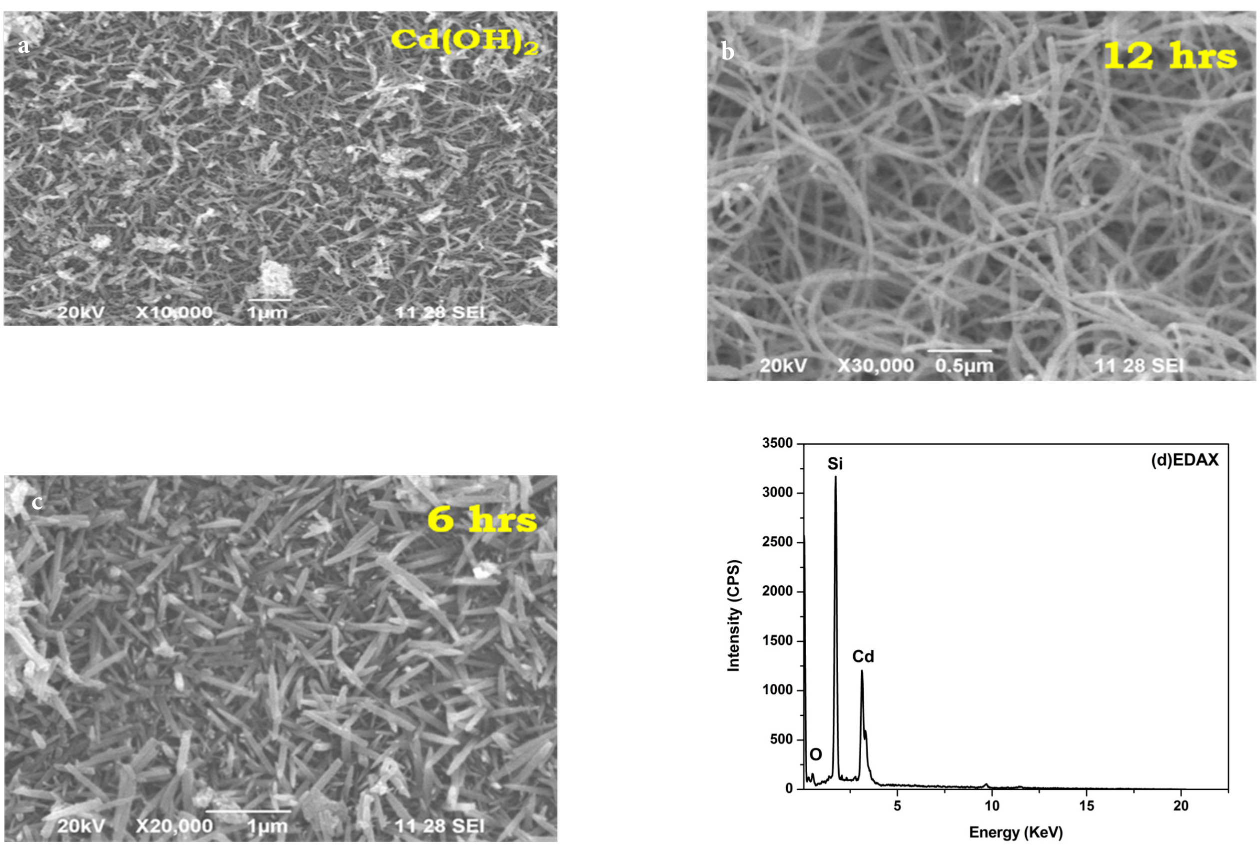

Figure 3. SEM images of (a) $Cd(OH)_2$ and (b)CdO nanostructure thin films deposited for 6 hrs (c) SEM images of CdO thin films deposited for 12 hrs (d) EDAX Spectra of CdO thin films deposited for 12 hrs.

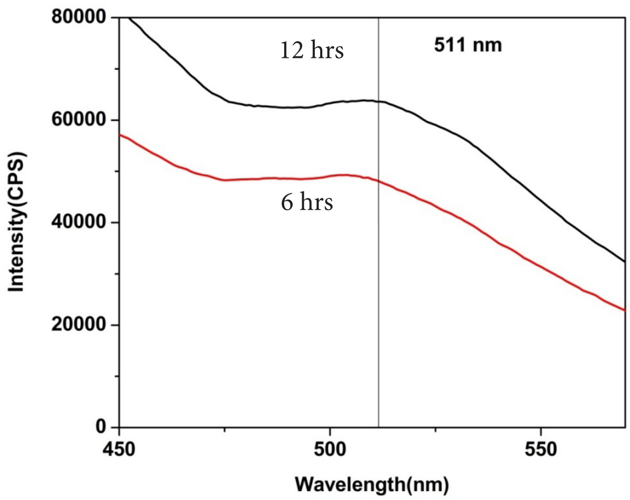

Figure 4. Photoluminescence Spectra of CdO thin films deposited for 6 and 12 hrs.

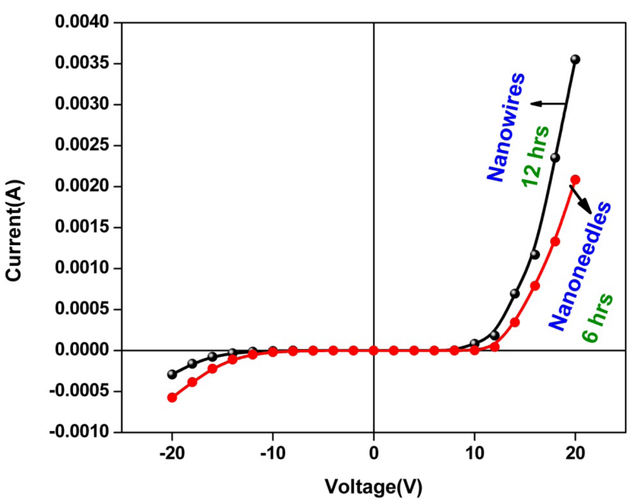

Figure 5. Heterojunction diode Charaterstics of n-CdO/p-Si(100) (12 hr deposition).

The diode ideality factor was determined from the slope of the forward bias lnI vs. V curve [9] using the equation given by

$$n = \frac{q}{kT}\frac{dV}{d\ln I}$$

where, k is the Boltzmann constant and $dV/d\ln I$ is the inverse slope of $\ln I$ vs. V curve.

The value of the ideality factor of the CdO/p-Si Heterojunction is determined from the slope of the straight line region of the forward bias log I–V characteristics The estimated ideality factor was found to be 3.5 and 3.3 for films deposited at 6 hr and 12 hr respectively. The higher value of ideality factor of the CdO/p-Si diode is attributed to the interface states and series resistance effects [10].

5. Conclusion

CdO nanoneedles and nanowires were prepared by simple chemical bath deposition method for the deposition time of 6 hr and 12 hr. XRD pattern shows the polycrystalline nature of CdO nanocrystalline thin films.Surface morphology is highly influenced by deposition time (i.e) film deposited 6 hrs shows nanoneedles where as film deposited 12 hrs shows nanowire. Heterojucntion diode was fabricated using n-CdO/p-Si(100) layers and ideality factor found to be 3.5 and 3.3 due to interface SiO_2 layer formed. The present value of Ideality factor is comparatively less than reported values. Hence it is highly suitable for heterojunction diode fabrication.

6. References

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