Performance improvement of UV photodetectors using Cd-doped ZnO nanostructures

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ABSTRACT

The present research performed thermal decomposition to synthesize pure zinc oxide (ZnO) and cadmium-doped ZnO (ZnO:Cd) nanorods with ZnO-to-Cd weight ratios of 93:7, 95:5, and 97:3. Field emission scanning electron microscopy (FESEM), X-ray diffraction (XRD), and photoluminescence (PL) spectroscopy were performed, and current/voltage and current/time were measured to determine the optical, structural, and morphological characteristics of ZnO and ZnO:Cd. The XRD results suggested the hexagonal wurtzite structure of all the samples and the successful incorporation of Cd into the ZnO structures. This incorporation caused a spherical to rod-like change in the shape of the nanostructures. An intense and sharp peak was observed at 380 nm (3.26 eV) in the UV region of the PL spectra of all the samples. A UV photodetector fabricated on the basis of ZnO and ZnO:Cd nanorods with a metal–semiconductor–metal configuration showed the significant photocurrent and photosensitivity of the ZnO:Cd samples in the UV photodetection application. The sensitivity of the fabricated ZnO photodetectors with Cd percentages of 0, 3, 5, and 7% was, respectively, obtained as 110.62, 463.28, 762.40, and 920.30. The fastest photoresponse, with the rise and decay times of 2.5 and 4 s, respectively, was associated with the sample doped with 5% Cd.

1 Introduction

The military and civil applications of the ultraviolet (UV) technology include chemical and biological research, optical communication, and measuring UV radiation and radiation from artificial sources [1]. In addition to the early detection of missiles, UV applications are growing in astronomy in terms of distinguishing true from false targets. The band gap of the materials used in these UV detectors should be broad and their UV penetration depth and resistance to UV radiation be adequate. Specific precursors should be produced to construct this type of photodetector [1–4].

Given the large band gap of ZnO at the ambient temperature and its biocompatibility, mechanical and chemical stability, and exciton binding energy of as high as 60 meV, it can be used as an appropriate n-type semiconductor to produce UV photodetectors, the first generation of which included thin ZnO
layers and bulk materials [5]. The large surface-to-volume and aspect ratios of one-dimensional ZnO nanostructures make them appropriate for improving the performance of these detectors. The present findings suggest the high sensitivity of one-dimensional ZnO nanostructures to UV radiation and, therefore, changes in their conductivity. In addition to UV photodetection, ZnO can be applied to transparent electrodes, solar cells, laser, anti-reflection layers, and light-emitting diodes [5–8].

Various techniques have been utilized so far to improve the features of ZnO UV photodetectors, which include using composite materials, changing the morphology, resizing, and doping, which is a commonly used and efficient method in this regard [9–11]. Research suggests that doping transition metals, including cadmium, nickel, cobalt, manganese, and iron, into the ZnO lattice can enhance the electrical, magnetic, and optical features of UV photodetectors based on ZnO nanostructures [12, 13]. Impacts of employing chromium-doped ZnO nanorods on UV photodetection were investigated by Safa et al. [14]. Green/blue emissions and effects of copper doping on UV photosensitivity based on thin ZnO films were also investigated by Li et al. [15]. Shabannia employed cobalt-doped ZnO nanorods to fabricate highly sensitive UV photodetectors [11]. Moreover, Rajalakshmi et al. scrutinized the response of UV photodetectors based on ZnO nanostructures doped with transition metals such as manganese, nickel, and cobalt [16]. In addition, the impact of iron, nickel, and copper on UV photodetectors was investigated at various concentrations by Chu et al. [17–19].

These reports suggest the challenges facing the development of ZnO UV photodetectors which include fast relaxation and photocurrent saturation. The absorption and desorption of oxygen on the surface of ZnO nanostructures can decrease dark current and raise the sensitivity of ZnO photodetectors. This process, however, prolongs the rise and decay times of UV photodetectors and restricts the practical usage of ZnO nanostructures [20–22]. Cd was proposed as a dopant to solve the problem cited and raise the photosresponse of UV detectors.

With promising optoelectronic properties, Cd can be utilized to fabricate devices based on ZnO given the increased absorption of oxygen molecules on the surface of nanostructures in the dark as the result of increased defects in the donor caused by replacing Zn$^{2+}$ with Cd$^{2+}$ [23, 24]. Increases in the number of holes trapped by oxygen ions under UV radiation also increase the number of free electrons that contribute to producing the photocurrent [22]. Given that incorporating Cd into pure ZnO improves its conductivity and carrier concentration, ZnO:Cd can be used in photovoltaic applications such as protective layers, sensors, and light-emitting diodes of a UV type. The photovoltaic benefits of ZnO:Cd for optoelectronic devices have been reported in the literature [25, 26]. Purusothaman et al. (2009) explored the impact of Cd doping on the characteristics of ZnO nanostructures and reported a higher donor content such as oxygen vacancy in Cd-doped ZnO nanorods than in pure ZnO. Replacing Zn$^{2+}$ with Cd$^{2+}$ raised defects in the donor, which increased the n-type carrier concentration of ZnO, Zn interstitial, and oxygen vacancy sites [24]. ZnO nanostructures may, therefore, enhance the features of the material and parameters of photodetectors using Cd dopants.

The approaches utilized to synthesize pure and doped ZnO nanostructures include sputtering, spray pyrolysis, sol-gel, pulse laser deposition, and hydrothermal and thermal decomposition [17, 24]. The simplicity of thermal decomposition and its high speed in producing pure cost-effective crystalline ZnO nanostructures using a single chemical agent and without employing a catalyst have turned this method into the most popular technique for ZnO production [27]. Given these excellent properties, the present experiments were conducted to synthesize ZnO nanostructures using thermal decomposition.

Developing ZnO UV photodetectors faces challenges such as photocurrent saturation and fast relaxation. The present research improved the performance of photodetectors by performing thermal decomposition based on Cd doping and synthesizing ZnO nanostructures with ZnO-to-Cd weight ratios of 93:7, 95:5, and 97:3. The doped samples had fast time responses than the undoped ZnO sample. The results of investigating the optical, structural, electrical, and morphological features of the samples were also presented.
2 Experimental

2.1 Powder products

Researchers seek to propose simple methods of developing one-dimensional zinc oxide nanostructures given that these techniques fundamentally require an accurately controlled synthesis environment, expensive equipment, and time-consuming methods. Lane et al. (2009) developed highly pure ZnO nanowires through simple thermal decomposition of zinc acetate at 300 °C [28]. This study performed thermal decomposition to develop Cd-doped ZnO nanostructures through decomposition, deposition, and evaporation. Not using catalysts differentiated thermal decomposition from the common vapor/liquid/solid mechanism. The ZnO: Cd nanostructures were synthesized using zinc acetate dehydrate (Zn(CH₃COO)₂·2(H₂O), Merck) and cadmium acetate dehydrate (Cd(CH₃COO)₂·2(H₂O), Merck) [22, 26]. Cadmium and zinc concentrations were the only growth factors that were not kept the same for all the samples. These nanostructures were synthesized by pouring 3 g of zinc acetate dehydrate with cadmium acetate dehydrate weight ratios of 93:7, 95:5, and 97:3 into alumina crucibles and mixing for 1 h. The crucibles were then kept in an electric furnace for 12 h. The temperature of the furnace increased to 300 °C with the rate of 2.5 °C/min, and it was then cooled down with the rate of 5 °C/min. The empirical processes were repeated eight times to confirm the findings.

2.2 Device fabrication

Thin films of ZnO: Cd were synthesized at diverse ZnO-to-Cd ratios to explore the application of ZnO: Cd nanostructures to UV photodetectors. Forty ml of deionized water was then added to separate containers, into which the powder produced by each crucible was poured, in a way that different solutions with the same concentration were obtained. To ensure the homogeneity of the solutions in the containers, they were kept in an ultrasonic tank for 20 min. In order to evaluate the applicability of the resulting powders for UV photodetector, the glass substrate was coated with a layer of aluminum by a physical vapor deposition method with the thickness of 200 nm. The dimensions of the glass substrate used for each sample were 1 x 15 x 15 mm³.

A gap was then made in the Al layer by using a sharp blade to cut the connection between the two sides. The resistance measurement was performed to ensure the complete scrubbing of Al layer and formation of an insulator ribbon between the two Al electrodes. Also, the length, width (gap between the two aluminum electrodes), and thickness of the active region were 15 mm³, 1 μm, and 200 nm, respectively.

The samples were dried by being kept in a 100 °C oven for 15 min. The experiment and fabrication conditions of the layers and fabrication conditions of the electrical connection were the same for all the samples.

According to Fig. 1, a UV photodetector was fabricated through thermal decomposition and incorporation of the synthesized nanostructures between the two conductive areas, i.e., aluminum and the glass substrate as the insulation zone.

2.3 Characterization of powder and device

An X-ray diffractometer (Stoe, Germany) with a copper anticathode was employed to investigate the crystal structure using the Cu Kα wavelength of 1.54 Å at 20–90 °. FESEM (Hitachi S-4160) was performed to examine the powder morphology. A helium cadmium laser as an illumination source emitting at 325 nm was utilized to measure the photoluminescent (PL) properties of the nanostructures. Furthermore, a Keithley 2400 source meter was used to measure current–time (I–t) and current–voltage (I–V) characteristics under dark and ambient illumination (UV light at 350 nm) conditions at the ambient temperature and determine the impact of Cd doping on the performance of the UV photodetectors.

3 Results and discussions

3.1 Structural properties

The XRD spectra obtained at various Cd concentrations in Fig. 2 to explore the structural characteristics of the ZnO and ZnO: Cd powders showed the peaks at (100), (002), (101), (102), (110), (103), (200), (112), and (201) for all the samples to correspond to that of the ZnO reference card (0704-076-01). The XRD results showed the hexagonal wurtzite structure of all the samples with the orientation of (002) although the
most severe peak was related to (101) diffraction plates. No impurity and secondary phases associated with Cd, Cd oxide, and other compounds were observed in the samples less than 5% Cd, which suggested that Cd$^{2+}$ ions were completely dissolved in the ZnO lattice. Figure 2b shows that peaks (100), (002), and (101) were shifted to lower angles with increasing doping concentration. This is due to replacing larger ionic radius of Cd$^{2+}$ (0.97 Å) in Zn$^{2+}$ (0.74 Å) ionic site [24]. The shift in the diffraction peaks towards the lower angles indicated that Cd was embedded in the wurtzite lattice, also confirming the enhancement in the weight percentage of Cd in the ZnO nanostructures. In the case of higher Cd doping concentrations of 5 wt%, a second or impure phase appeared with low intensity, which indicated the formation of the CdCO$_3$ phase.

The c-axis strain ($\varepsilon_{zz}$) values were calculated using the following equation [30]:

$$\varepsilon_{zz} = \frac{c - c_0}{c_0} \times 100\%,$$  

(1)

where ‘c’ is the lattice parameter nanostructures calculated from the XRD data and ‘c$_0$’ is the unstrained lattice parameter of bulk ZnO. Table 1 presents the strain changes for the samples with different Cd concentrations. According to the above equation, the strain along c-axis can be tensile (positive) or compressive (negative).

The residual strain in the crystallite distorted the crystal lattice and, hence, led to broadening the diffraction peaks. In such cases, Eq. (2) (the Williamson Hall equation) was employed to calculate the mean crystallite size [31].

$$\beta \cos \theta = \frac{K \lambda}{D} + 4\varepsilon \sin \theta,$$

(2)

in which $\theta$ represents the Bragg diffraction angle, $D$ is the crystallite size, $\beta$ is the full width at half maximum, and $\lambda = 1.5406$ Å is the wavelength of the incident radiation. The X-ray patterns showed an increase in the crystallite size of the Cd-doped samples from 42.12 to 46.57 nm with increasing the dopant concentration. The expansion of the unit cell caused by the replacement of Cd$^{2+}$ ions exerted an internal strain on the growth of nanostructures and, thus, increased the crystallite size [24, 30]. Also, due to compressive strain along the c-axis, the lattice in x-y plane should be stretched (Poisson’s effect [30]), resulting in increased crystallite size [30].

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**Fig. 1** Schematic structure of the UV photodetector [29]

**Fig. 2** a XRD spectra of ZnO and ZnO:Cd nanostructures with different Cd concentration, b enlarged portion showing shifts in the peaks
Equation (3) was utilized to derive the hexagonal lattice constants, i.e., \( a \) and \( c \), of the ZnO:Cd and ZnO nanostructures [24].

\[
\frac{1}{d^2} = \frac{4}{3} \left[ \frac{h^2 + h k + k^2}{a^2} \right] + \frac{l^2}{c^2}
\]

in which \( h k l \) represents Miller indices and \( d \) is the distance between crystalline planes. Slight increases observed in the lattice constants with the Cd concentration can be explained by the larger radius of Cd\(^{2+}\) ions than that of Zn\(^{2+}\) ions (Table 1) [24]. The error margins of the measured lattice constants, \( 'a' \) and \( 'c' \), were 0.003 and 0.006, respectively.

According to Fig. 3, FESEM was conducted on the ZnO nanostructures to explore the impact of the Cd

![Fig. 3 FESEM images of the ZnO and ZnO:Cd nanostructures with (a) 0%, (b) 3%, (c) 5%, and (d) 7% Cd](image)
Table 2 The length and diameter of the Cd-doped nanorods

| Samples (%Cd) | Avg. diameter (nm) | Avg. length (nm) |
|---------------|--------------------|-----------------|
| 0%            | 50–60              | 300–400         |
| 3%            | 50–70              | 500–650         |
| 5%            | 40–60              | 600–700         |
| 7%            | 60–75              | 850–1000        |

dopant concentration on their morphology. The pure sample comprised nanorods and nanoparticles. Increases in the number and size of the nanorods with a rise in the Cd dopant concentration can be explained by larger radius of Cd$^{2+}$ (0.97 Å) than that of Zn$^{2+}$ (0.74 Å).

Table 2 presents the sizes of the nanostructures, suggesting that a rise in the doping levels of Cd increased the length of the nanorods. In addition, the morphological variations were explained by the point that the Cd–O bond energy was lower than the bond energy of Zn–O, which caused differences between the polar and non-polar planes in terms of the surface energy, raised the vertical growth, and prevented their sidelong growth [24]. Moreover, XRD and FESEM yielded consistent results.

3.2 Optical properties

Figure 4 illustrates the PL spectra of ZnO and ZnO:Cd, suggesting a sharp and highly intense peak at 380 nm (3.26 eV) in the UV zone for all the samples, which were excited at the room temperature and wavelength of 325 nm. Recombining excitons through an exciton–exciton collision process caused the emergence of an emission peak as large as the gap energy in the UV region. A second peak was observed in the so-called defect emission region at 430–600 nm. An increase in the Cd dopant concentration caused this defect emission to emerge, a phenomenon that is often reported in doped semiconductors [32].

A rise in the Cd concentration to more than 3% substituted larger size Cd$^{2+}$ ions for Zn$^{2+}$ ions caused the emergence of peaks at 443, 474, and 583 nm, created crystallite stress, and raised the number of defects, including Zn interstitials and oxygen vacancies [24].

The emission peak at 474 nm corresponded to structural defects of the product such as oxygen vacancies as the cause of visible green emissions [33, 34]. Emission peaks at 583 and 443 nm were, respectively, associated with the transition of oxygen vacancies and Zn interstitials [24]. The peaks were intensified as the Cd dopant concentration exceeded 3%, which also increased defects in the crystalline structure through developing surface defects, including Zn interstitials and oxygen vacancies. Doping, therefore, plays a key role in developing surface defects.

3.3 Electrical properties

Current–voltage characteristics were obtained in the dark and under UV radiation at 350 nm, – 10–10 V, and 15.5 mW/cm$^2$ to examine the UV photodetectors based on ZnO:Cd nanostructures. The photocurrent versus the voltage followed the Schottky curve, suggesting a Schottky contact between the nanostructures and the aluminum electrode. Although the dark current through the samples was as low as 0.29, 0.35, 0.42, and 0.50 nA at various Cd concentration, it increased in all the samples under UV radiation. The photocurrent of the samples ($I_{\text{illuminated}}-I_{\text{dark}}$) was derived as 32.08, 162.15, 320.21, and 460.10 nA at 5 V. The XRD results suggested variations in the growth direction of the ZnO:Cd nanostructures increased the photocurrent through the doped samples [35]. The I–V curve of the samples is compared in Fig. 5, showing the higher photocurrent of the Cd-doped samples than that of the pure sample. The superiority of the illumination current over the dark current indicated...
the sensitivity of the present study structures to UV radiation, which should be, therefore, used in UV photodetectors. The photocurrent increased to its maximum with an increase in Cd levels to 7%.

Doping ZnO with Cd enhanced its electrical conductivity through raising carrier concentrations in its structure [26]. Replacing Zn\(^{2+}\) with Cd\(^{2+}\) increased defects in the donor, which improved the n-type carrier concentration of ZnO and created more Zn interstitials and oxygen vacancies [24]. Increases in VO, i.e., oxygen vacancy, and n-type properties of the Zn-Cd-VO complex, with low ionization and formation energy, increased carrier concentrations and conductivity [26]. Figure 4 shows the results of the PL analysis, which confirmed these findings. In addition, incorporating Cd into ZnO raised the numbers of Cd interstitial and substitutional and sites as donors [26]. Increases in the number of donor defects, therefore, increased the number of oxygen molecules adsorbed on the nanostructure surface in the dark. UV radiation increased the number of holes trapped by oxygen ions and caused more free electrons to contribute to producing the photocurrent.

Table 2 shows the highest photocurrent in the longest sample doped with 7% Cd. According to the UV photodetection mechanism, increasing the length of nanorods raised the number of oxygen molecules adsorbed on their surface in the dark. UV radiation, therefore, increased the number of holes, in which oxygen ions were trapped and the photocurrent produced through increasing the number of free electrons [36, 37].

Photodetectors can be appraised using parameters such as detectivity (\(D^*\)) and responsivity (\(R\)), which were obtained using Eqs. (4)–(5) [38].

\[
R = \frac{I_{ph}}{P_{inc}}, \tag{4}
\]

\[
D^* = \frac{R}{(2eI_{dark})^{1/2}}, \tag{5}
\]
in which \(I_{dark}\) represents the dark current, \(e\) is the unit charge, \(I_{ph}\) is the photocurrent, and \(P_{inc}\) is the

![Fig. 5 The I–V characteristics of ZnO and ZnO:Cd nanostructures for different Cd concentrations from -10 V to 10 V](image)

![Fig. 6 Sensitivity of ZnO and ZnO:Cd nanostructures as a function of Cd concentration](image)

| Samples (%Cd) | Photocurrent (nA) | Rise time (s) | Decay time (s) | Sensitivity (\(I_{ph}/I_{d}\)) | Responsivity (\(\mu A/W\)) | Detectivity (jones) |
|---------------|-------------------|---------------|---------------|--------------------------------|---------------------------|---------------------|
| 0%            | 32.08             | 18            | 13            | 110.62                         | 2.07                      | 0.22 \(\times 10^9\) |
| 3%            | 162.15            | 8             | 10            | 463.28                         | 10.46                     | 0.98 \(\times 10^9\)  |
| 5%            | 320.21            | 2.5           | 4             | 762.40                         | 20.66                     | 1.8 \(\times 10^9\)   |
| 7%            | 460.10            | 5             | 6             | 920.30                         | 29.68                     | 2.4 \(\times 10^9\)   |

Table 3 The sensitivity, responsivity, photocurrent, decay time, rise time, and detectivity of the ZnO and ZnO:Cd nanostructures measured at 5 V
incident optical power. Table 3 summarizes the detectivity and responsivity of the ZnO and ZnO:Cd nanostructures at different Cd concentrations a 0%, b 3%, c 5%, and d 7% measured with and without UV light illumination at 5 V.

Figure 6 shows the ratio of the photocurrent to dark current ($I_{ph}/I_{dark}$) as the sensitivity of the photodetectors, suggesting the sensitivity of 110.62, 463.28, 762.40, and 920.30 for the ZnO and ZnO:Cd photodetectors, respectively. The higher sensitivity observed in the samples doped with Cd compared to the pure ZnO can be explained by increases in the illumination current in the ZnO:Cd samples.

Response time was also used for the qualitative measurement of UV photodetectors. Figure 7 shows temporal variations in the photoresponse of the
samples under UV radiation at 350 nm, 15.5 mW/cm², and a 5 V on-off bias. The cycles were repeated for several times to measure the response time, i.e., they were exposed to UV radiation for 3 min and, then, placed in the dark for 3 min.

This study observed the fast reversibility of the photodetectors and their appropriate repeatability. Under UV radiation, the current rapidly increased to a certain level and, then, returned to its original state as the lamp was turned off. Oxygen molecules were released under UV radiation through combining the holes generated by oxygen ions and adsorbed on the detector’s surface. As discussed earlier, free electrons were trapped by oxygen molecules as UV lamp was turned off and oxygen molecules were re-adsorbed on the surface [36, 37]. UV radiation should be kept off for long enough to help the current through the detector return to its initial level, and oxygen ions were completely adsorbed on its surface.

The rise and decay times of a detector are, respectively, defined as the length of interval, during which its current increases from 10 to 90% of its peak and decreases from 90 to 10% [14]. 

Turn-on:

\[ I(t) = I_0(t) \left(1 - \exp\left(-\frac{t}{\tau_r}\right)\right) \beta \]  

Turn-off:

\[ I(t) = I_0(t) \left(1 - \exp\left(-\frac{t}{\tau_d}\right)\right) \beta \]

in which \( \tau_r, \beta, I_0(t), \) and \( t \), respectively, denote the time constant, decay exponent, transient current, and time passed after on/off. 

Furthermore, \( \beta \) was estimated at 1 using the fitted exponential formula and \( \tau_r = 2.5 \) s was obtained as the rise time of the 5% Cd samples for turn-on and \( \tau_d = 4 \) s as the decay time of the 5% Cd samples for turn-off. The 5% Cd samples were, therefore, found to be excellent in terms of their photoresponse.

According to the FESEM results, incorporating Cd as a dopant changed the shape of the nanostructures from spherical to rod shaped. Using one-dimensional ZnO:Cd nanostructures increased the surface effects by increasing the ratio of the surface area to the volume. The rates of absorbing and desorbing oxygen molecules on the surface of the nanostructures and the response of the photodetectors were, therefore, increased [11, 37]. Decreases in the diameter of ZnO:Cd nanorods were found to narrow the conduction channel of charge carriers (electrons), which were closer to the surface effects and precipitated the re-absorption of oxygen molecules on the surface and increased the photoresponse speed of the detector [37]. The photoresponse of the 5% Cd nanorods with a relatively smaller diameter was also faster.

Table 3 presents the sensitivity, responsivity, photocurrent, decay time, rise time, and detectivity of the photodetectors.

Figure 8 illustrates a model of the mechanism of charge transport in the MSM photodetectors based on ZnO:Cd nanorods. The adsorption of oxygen molecules (O₂) onto the surface of ZnO as negatively charged ions through capturing free electrons from the n-type ZnO structure can generate a low-conductivity depletion layer near the surface of pure ZnO nanorods in the dark [\( \text{O}_2\text{(gas)} + e^- \rightarrow \text{O}_2\text{(adsorption)} \)]. Moreover, UV radiation (\( \hbar \nu > E_g \)) photogenerates electron–hole pairs and discharges the adsorbed oxygen (O₂) ions through surface electron–hole recombination on the pure ZnO nanorods [\( \hbar \nu \rightarrow e^- + h^+ \)]. The electrons of the pair remaining in the conduction band increase conductivity [\( \text{O}_2\text{(adsorption)} + h^+ \rightarrow \text{O}_2\text{(gas)} \)]. In contrast, the arrays of the ZnO:Cd nanorods with a large surface-to-volume ratio can cause their adsorption onto and desorption from the surface of ZnO:Cd [19, 24]. Their response rate and carrier concentration in the ZnO:Cd structure can be, therefore, significantly improved; they can further contribute to increasing the number of oxygen vacancies generated, which improves the photocurrent of ZnO:Cd.

Fig. 8 Schematic diagram of the ZnO:Cd nanorod photodetectors under UV radiation
photodetectors. \( \text{Zn}^{2+} \) ions in the ZnO lattice can be easily replaced with \( \text{Cd}^{2+} \) ions. The positive charge of the substituted \( \text{Zn}^{2+} \) site (formation of electron–donor defects \([\text{Cd}_{\text{Zn}}]\)) should be, however, compensated for through releasing electrons to keep its electrical neutrality. Cd doping introduces electrons into the conduction band of the sample and, therefore, increases the concentration of free electrons and lowers the resistivity of the ZnO:Cd material, which, thus, increases responsivity. According to Fig. 8 and the trapping mechanism of oxygen adsorption/desorption, ZnO:Cd nanorods are thoroughly recommended for UV detection.

Table 4 compares the results of doping ZnO with different materials in photodetectors, suggesting improvement in the characteristics of UV photodetectors through doping the ZnO structure with Cd. This device is, therefore, applicable to UV photodetection.

### 4 Conclusion

The present study performed thermal decomposition as a simple, fast, and cost-effective technique to synthesize ZnO and ZnO nanostructures doped with 3, 5, and 7% Cd. The XRD patterns showed the hexagonal wurtzite structure of the study samples and that (002) plane to be the preferred orientation in the nanostructures. According to the results of FESEM, variations in the Cd concentration can morphologically influence the ZnO nanostructures. The UV photodetectors were fabricated by employing the synthesized ZnO: Cd nanostructures. UV detection measurements showed that doping Cd improves photodetector parameter of ZnO nanostructures. Indeed, photocurrent and photoresponsivity of 5% Cd-doped sample were nearly ten times greater than those of the undoped ZnO nanostructures. Also, ZnO: Cd samples had fast time responses than the undoped ZnO sample. The sample doped with 5% Cd indicated the highest response rate (the rise and decay times were 2.5 s and 4 s, respectively).

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