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Synthesis of dendrite – like petals of CdO nanostructure

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Cadmium oxide nanostructure was synthesized by solid-vapor deposition without catalyst. CdO powder was heated to 1320 K in a tube furnace, and the resultant vapor was carried to the silicon substrate zone by an argon flow. Field emission scanning electron microscopy revealed that the product was dendrite –like petals of CdO nanostructure. X-ray diffraction and energy dispersive X-ray techniques were used to characterize structural properties. The grown nanostructure had random orientations and a grain size of 30 nm. Photoluminescence spectroscopy was conducted to investigate the optical properties of the nanostructure. The red-shift direct band gap energy of CdO nanostructure was at 548 nm (2.26 eV), whereas that of CdO bulk was at 491 nm (2.5 eV). High-quality CdO nanostructure was grown on a Si substrate and then investigated.

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1. Introduction

Nanoparticles materials have attracted great interest in recent years because of their unique chemical and physical properties which are different from those of the bulk materials or single atoms [1]. Cadmium oxide has a cubic crystal structure [NaCl] with face centered cubic type (fcc) and lattice constant (a) = 0.469 nm, it is an n-type with alternating Cd and oxygen atoms located at lattice scale [2]. CdO has distinguished properties and is widely used as a transparent conductive oxide (TCO) in optoelectronic devices, especially in solar cells [3]. Moreover, it has a narrower direct band gap of 2.2–2.5 eV [4] and it shows high transparency in the visible region of the solar spectrum [5].

Cadmium oxide nanostructures were directly synthesized and grown by evaporating CdO powder at 1000 °C [6]. Cadmium can be directly heated up to 900 °C in air or with a trace amount of oxygen in an argon flow [7]. In the present paper, CdO nanostructure was synthesized via the solid-vapor deposition technique at high temperature without a catalyst. Furthermore, the structural and optical properties of CdO nanostructure were characterized.

2. Experimental procedures

There are many methods on how to produce CdO nanostructure but we used the solid- vapor deposition method to yield CdO nanostructure due to lower cost and simplicity. This method is a physical one in which crystal grows from the vapor of the deposition material. The type of substrate is very important for growth of CdO nanostructure by solid-vapor deposition. The substrate used in the present paper was silicon.

We used the Radio Corporation of America process to remove the oxide layer from a P-type silicon (Si) wafer (1cm ×1cm × 283 μm) with a (111) orientation and a resistivity of 0.75 Ω cm. In this process, very purity CdO powder (99.99%, Aldrich) kept in a ceramic boat was placed at the center of a horizontal quartz tube furnace, and a Si substrate was placed downstream (5 cm from the boat) of the flowing gas. A flow of argon (Ar) gas was initially used to purify the tube. When temperature reached 1320 K inside the furnace, we put the CdO powder and Si substrate with the Ar flow of approximately 300 Sccm. The process ran for ninety minutes. A trace amount of Ar was necessary for good nanostructure growth. Afterward, the samples were cooled at room temperature for two hours. The products were obtained by controlling several parameters, such as temperature (T), reaction time (t), the gas flow rate (Ar), and the position of the substrate in the furnace.

The structural morphologic properties of the nanostructure were examined using X-ray diffraction (XRD) (PANalytical X'Pert PRO MRD PW3040), field emission scanning electron microscopy (FESEM), and energy dispersive X-ray (EDX) analysis (Leo Supra 50VP Carl Zeiss, Germany), and their optical properties were investigated using photoluminescence spectroscopy (PL) (Jobin Yvon HR 800UV, USA) at room temperature using an He–Cd laser (λ = 325 nm).

3. Results and discussion

The XRD patterns of the CdO nanostructure showed diffraction peaks absorbed at 2θ values (Fig. 1). The prominent peaks were used to calculate the grain size via the Scherrer equation [8], expressed as follows:

$$D = (0.94\,\lambda) / (\beta \cos\theta) \tag{1}$$

where λ is the wavelength (λ = 1.542 Å) (CuKα), β is the full width at half maximum (FWHM) of the line, and θ is the diffraction angle. The grain size of the CdO nanostructure was 30 nm [9], and the peaks were observed at the (200), (220), (311), and (400) planes. These peaks correspond to CdO. The evident reflections closely match the reference patterns of CdO (JCPDF File No.03-065-2908) [10]. The sharp XRD peaks indicate that the particles were of polycrystalline structure, and that the nanostructure grew with a random orientation.

Fig. 2 shows the FESEM image of the dendrite – like petals of Cadmium oxide nanostructure deposited on the Si substrate because of the high temperature (1320 K), the prolonged reaction time (90 min), and the gas flow (Ar) through the tube.

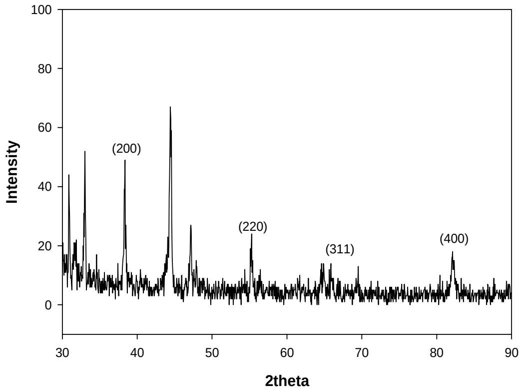

Fig. 1. XRD spectrum of CdO nanostructure grown on silicon substrate.

The CdO nanostructure generated by the solid-vapor deposition on the Si substrate was formed with an n-p junction. In this junction, the conduction and valence band edges of the wide-gap CdO semiconductor lie within the energy gap of the narrow-gap Si semiconductor to obtain a straddling-gap semiconductor [11].

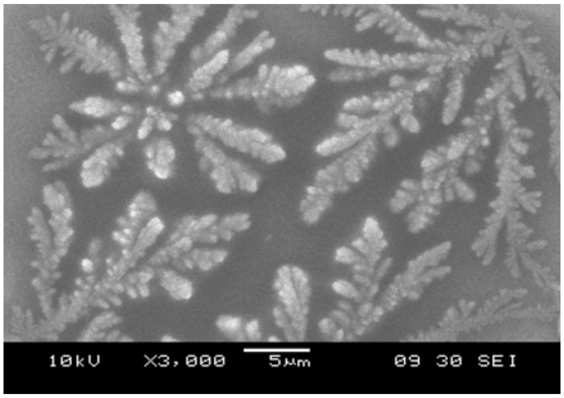

Fig. 2. FESEM image of CdO nanostructure grown on Si substrate.

Fig. 3 shows the EDX spectrum of the CdO nanostructure. The atomic percentages of Cd, O, and Si were 26.95%, 57%, and 16.05%, respectively. The results indicate the presence of Cadmium oxide nanostructure deposited on the Si substrate.

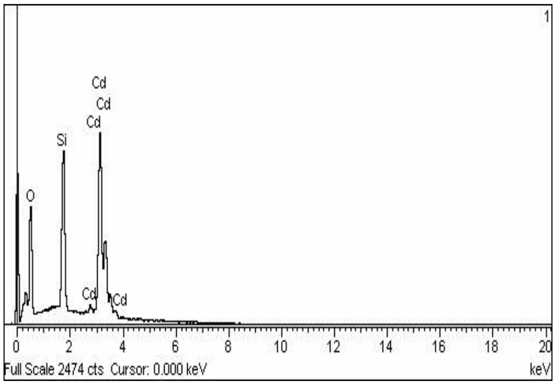

Fig. 3. EDX spectrum of CdO nanostructure.

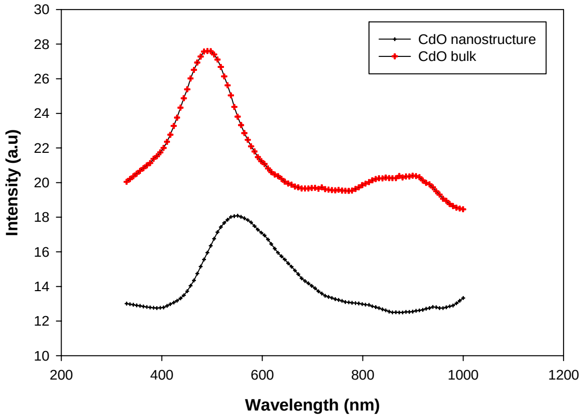

Fig. 4. Photoluminescence spectra of CdO nanostructure and CdO bulk.

Fig. 4 shows the photoluminescence spectra of the CdO bulk (tablet from CdO powder) and the CdO nanostructure. An emission peak for bulk CdO was noted at 491 nm (2.5 eV) with an FWHM of 9 eV. An emission peak for the CdO nanostructure was red-shifted at 563 nm (2.26 eV) with an FWHM of 10.5 eV, which agrees well with the reported value for CdO nanoparticles [10]. This red-shift from 2.26 to 2.5 eV was caused by the formation of donor levels (Fermi levels) near the conduction band of the CdO nanostructure.

4. Conclusion

CdO nanostructure was produced by solid-vapor deposition mechanism. The parameters used in the experiment were: high temperature, high gas flow (Ar), prolonged reaction time, and the absence of a catalyst. The sharp XRD peaks indicate that the particles have a polycrystalline structure and that the nanostructure grew with a random orientation. The generated CdO nanostructure on the Si substrate were formed with an n–p junction and can be used in optoelectronic devices, especially in solar cells.

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