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Effect of gamma radiation on the optical and structural properties of ZnO nanowires with various diameters

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ABSTRACT

The effects of gamma-irradiation are studied on the morphology and structural properties of ZnO nanowire with various diameters. The ZnO nanowires are grown using Zn thin films at various initial thicknesses including 125, 250 and 500 nm in air ambient. The results illustrate dramatic effects of Gamma-irradiation on the deformation of ZnO nanowires. Thus, radiation induce ripple ZnO surfaces instead ZnO nanowires. Gamma-irradiation has also been effective on the optical and crystalline properties of the nanowires. X-ray diffraction attests that size of the ZnO nano-structures has changed and (l00) crystalline direction related to Zn metal has been created after irradiation. UV–Visible spectra display two areas for transmittance of irradiated ZnO nanowires, one in the Visible-light and the other in IR sub-region. In the Visible-light area, the layer gets thicker from 125 to 500 nm; the difference between the layer transmittance spectra is reduced before and after gamma irradiation. In the IR-light region, with increasing of ZnO initial thickness, the difference between the layer transmittance spectra is increased before and after gamma irradiation. The photoluminescence spectroscopy displays that intensity of green–yellow band improves in compared to near-band-edge emission due to formation of Zn metal and oxygen vacancies after gamma irradiation.

1. Introduction

Interaction of radiant energy with matter, especially γ radiation, is an extremely important from the view point of theory and practice [1–9]. Irradiation of solids with high energy radiation, like γ-rays, electrons or neutrons expected to affect their optical, electrical and physical properties [1–3,10]. The various researches illustrate that when solid state materials are exposed to ionizing radiation, their microstructural properties are altered [11–13]. Numerous efforts have recently been made to investigate the influence of gamma radiation on different metal oxides and polymers [14–21]. Recent experiments have demonstrated that irradiation of Carbon Nanostructures (CNSs) with gamma ray can be used to successfully modify properties of carbon nano-composites [17] and to form controlled defect structures on their surface [2].

On the other hand, Zinc oxide (ZnO) semiconductor with a wide direct band gap (3.37 eV) and large exciton binding energy (60 meV) in the balk, has received much attention due to its potential applications in the optoelectronic field [22,23]. One-dimensional ZnO nanostructures such as nanowires also have been extensively studied for various applications including chemical sensors, solar cells, blue and ultraviolet (UV) light-emitting diodes, transparent electrodes and hydrogen storage and batteries [24–34].

Here, low cost and non-catalytic growth method for the synthesis of ZnO nanowires is presented. The ZnO nanowires are grown on glass substrates by the thermal oxidation in air of metallic zinc thin films at 600 °C. The ZnO nanowires are irradiated with the absorbed doses of 100 kGy by the gamma-ray at room temperature. This study is carried out to investigate the effect of γ-rays radiation on the morphology, structure and optical properties of ZnO nanowires. Scanning electron microscopy (SEM), X-ray diffraction (XRD), photoluminescence (PL), UV–visible (UV–Vis) spectrophotometry are employed to assess the structure, quality, and optical properties of the ZnO nanowires before and after irradiation.

2. Materials and methods

Thin films of metallic zinc are deposited by thermal evaporation under vacuum on glass substrates. The source material is zinc metal

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granulate (Sigma-Aldrich, St. Louis, MO, USA) with a purity of 99.99%. Pressure of the growth chamber is on the order of 10^{-5} torr. The substrate is kept at room temperature during the coating process. The distance between the zinc source and the substrate is 20 cm. The Zn films are prepared with some different thickness of 125, 250 and 500 nm. To synthesize ZnO nanowires, Zn films are thermally oxidized in a conventional tube furnace at a temperature of 600 °C in air for 1 h. The ZnO nanowires are independently irradiated with the absorbed dose of 100 kGy by the gamma-ray flux at room temperature. The irradiations are performed by a cell-220 with the following properties: as activity, 19,171.0 ci; dose rate, 4.47 Gy/s and transit dose, 19.4 Gy.

The morphologies of the oxidized Zn films were characterized using a SEM (model Hitachi S-4160). The crystal structures of the samples are investigated using XRD (model Philips Pw 1800) technique. The optical properties are measured by UV–Vis spectrophotometer (model EPP2000) and the PL (model Cary Eclipse) spectra using xenon light with a wavelength of 325 nm as an excitation source.

3. Result and discussion

Fig. 1 shows SEM images of the ZnO nanowires prepared by oxidation of the Zn films with different thickness for 1 h at 600 °C before and after irradiation, respectively. They reveal that the samples contain ZnO nanowires before gamma radiation. As shown in Fig. 1, the nanowires are destroyed after the gamma irradiation. Fig. 2 shows the size distribution of the ZnO nanowires obtained by counting hundreds of nanowires over different fields of the ESEM images. ZnO nanowires form in the Zn film thickness of 125, 250 and 500 nm possess a mean diameter of 50, 75 and 83 nm. This result suggests that, with increasing thickness of Zn film, the mean diameter of ZnO nanowires has increased.

To study effect of the Gamma irradiation on the crystalline structure of ZnO nanowires XRD analysis is performed. Figs. 3 and 4 illustrates the XRD pattern of the ZnO nanowires ($\lambda = 1.54$ A) before and after gamma radiation, respectively. Tables 1and 2 show the diffraction peak position (2θ) for the crystal planes for un-irradiated and irradiated ZnO nanowires. All diffraction peaks in XRD patterns of the un-irradiated synthesized ZnO before can be labeled as ZnO crystals with a wurtzite structure. No impurity phases are observed in XRD spectra un-irradiated ZnO nano-wires. The sharp and strong peak (002) observe at $2\theta = 34.42$, 34.56 and 34.77° with thickness of 125, 250 and 500 nm for un-irradiated ZnO nano-wires and $2\theta = 34.41$and 34.62° for irradiated ZnO thin films with thickness of 125 and 500 nm, respectively. As shown in Fig. 4, the XRD pattern of ZnO nano-wires after irradiation includes peaks at $2\theta = 38.20$ and 38.38° related to (100) crystal planes of Zn metal which indicates

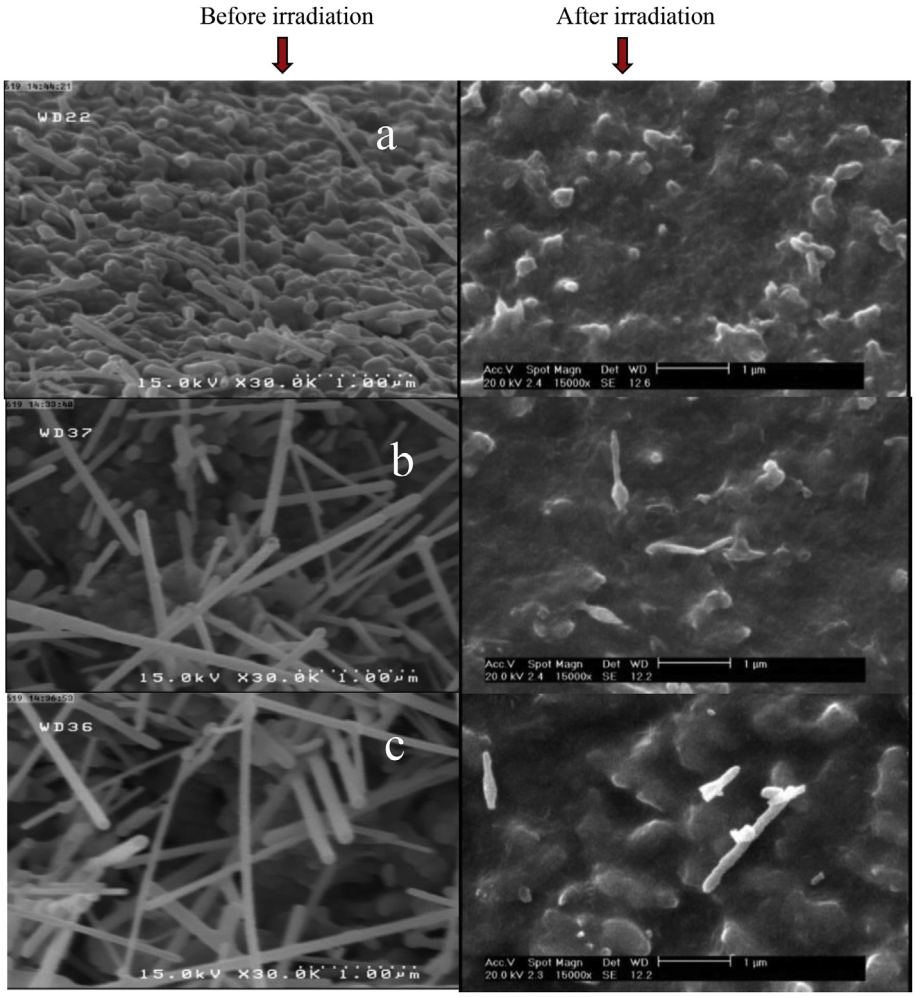

Fig. 1. SEM images of the ZnO nano-wires prepared by the oxidation of Zn thin films with initial Zn thickness of 125 (a), 250 (b) and 500 nm (c) before (left) and after gamma radiation (right).