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Short Communication

Fabrication and Material Analysis of Zinc Oxide Nanorods Grown on Gallium Nitride Substrate

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Abstract: *In this study, we address process how the ZnO nanorods were deposited on GaN substrates with spin-coating by using the hydrothermal methods. After ZnO was spin coated, the samples were annealed with different temperatures to incorporate with Au nano particles. Multiple material analyses, such as the field emission scanning electron microscopy (FESEM), the energy dispersive X-ray spectroscopy (EDX) and the X-ray diffraction (XRD) analyses were carried out to characterize the Au nanoparticles/ZnO nanorods/GaN nanocomposites.*

Keywords: ZnO nanorods, nanorods, substrate, GaN substrate, annealing, particles

1. INTRODUCTION

ZnO nanorods are one dimensional (1D) nanomaterials with excellent properties. These include the short wavelength electroluminescence with a large bandgap (3.37eV) and the enormous excitation binding energy(60 meV) [1]. ZnO related nanostructures could be used for multiple applications such as gas sensors, transparent conductive layers and antibacterial agent, etc. Because of its symmetrical structure, ZnO-based semiconductor devices can tolerate high-voltage operations. Due to its large excitation binding energy, ZnO is stable on chemical reaction and good on optical properties sothat ZnO has a good luminous efficacy. In addition, fabrication of ZnO nanorods cost less than some other nanostructures. With these benefit, it is believed that the ZnO nanorods will attract growing attention for industrial applications in the future. In the past decade, researchers reveal that high-quality ZnO nanorods can be grown with a seed layer with hydrothermal methods. Furthermore, various deposition parameters and annealing conditions can have great influences on the film quality of the nanorods [2]. To characterize the material properties of the nanorods, multiple material analyses such as the field emission scanning electron microscopy (FESEM), the energy dispersive X-ray spectroscopy (EDX) and the X-ray diffraction (XRD) analyses were used to examine the morphologies, element compositions, and crystalline structures.

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2. EXPERIMENTAL METHODS

Isopropanol, D.I water and acetone were first used to clean GaN substrates. The ZnO nanorods seed layer was spin-coated with ZnAc, Ethanol Ethanolamine, CH_3CH_2OH, $Zn(NO_3))_2$. H_2O and Hexa-methylenetetramine on top of the GaN substrate. Afterwards, the samples were annealed in 400 ºC and 500 ºC with nitrogen, respectively. Since the seed layer was grown by hydrothermal methods, the uniform ZnO nanorods could be deposited on the seed layer. The ZnO nanorods were grown with a solution consisting of $C_6H_{12}N_4$, $Zn(CH_3COO)_2$ at a temperature of 80 ºC. The deposition time is one hour. The nanorods were densely filled on the GaN substrate.

3. RESULTS AND DISCUSSION

To observe the influence caused by seed layer annealing with different annealing temperatures, FESEM was used to observe the surface morphology, as shown in Fig. 1 (a) and (b). The FESEM images reveal that ZnO nanorods were more densely and compact grown with a seed layer at annealing temperature of 400 ºC than 500 ºC. Moreover, ZnO nanorods with seed layer annealing at 400ºC obtained higher directivity than 500ºC. Compared with ZnO nanorods on Si substrates, the ZnO nanorods were more compact. Especially for the ZnO nanorods with seed layer annealing at 400ºC, few gaps or spacings could be found between the nanorods, showing that high-quality densely ZnO nanorods could be grown on the GaN substrate [4, 5]. Furthermore, the element composi-

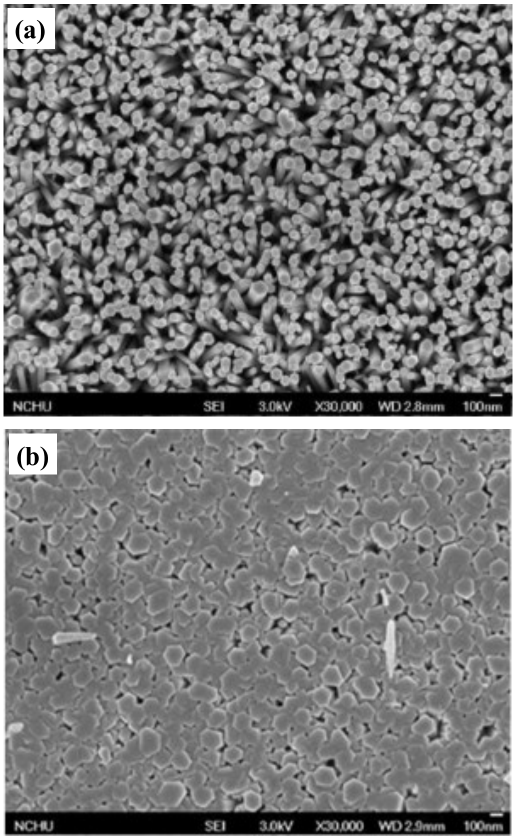

Figure 1. The FESEM figure of ZnO nanorods, figure (a) 500 ºC, figure (b) 400 ºC

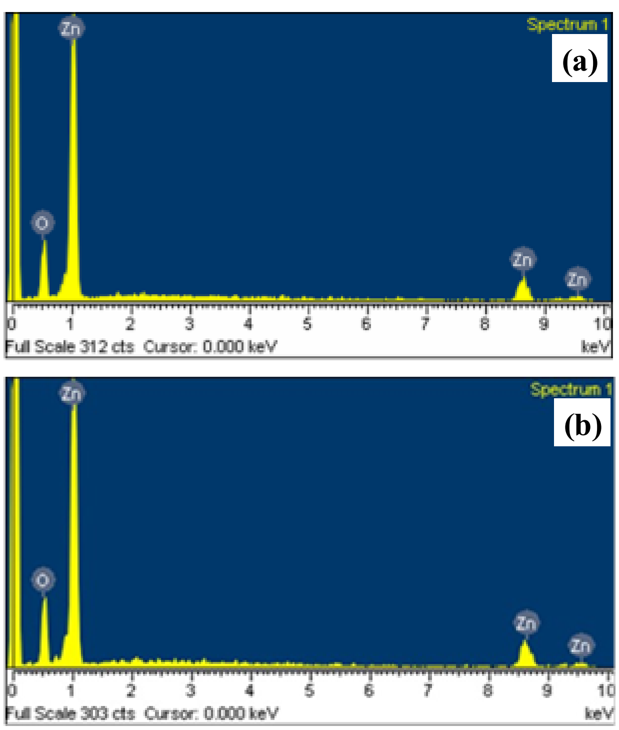

Figure 2. The EDX figure of ZnO nanorods, figure (a) 500 ºC, figure (b) 400 ºC

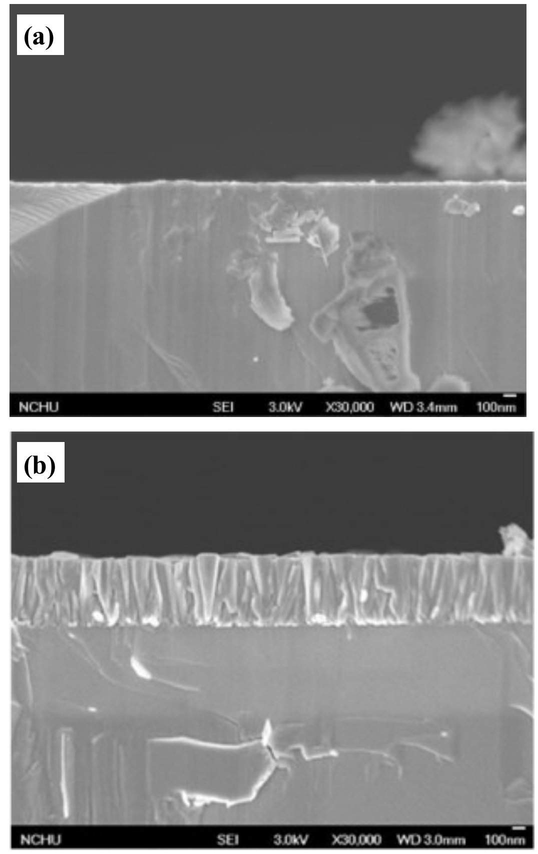

Figure 3. The FESEM figure of ZnO nanorods, figure (a) 500 ºC, figure (b) 400 ºC

tions were analyzed by EDX as shown in Fig. 2 (a) and (b). The chemical compositions show no observable difference with different seed layer annealing temperatures. Since ZnO nanorods were densely grown on the GaN substrates, Ga and N signals might be hindered by the nanorods. Moreover, to monitor the crossection of ZnO nanorods, side-view FESEM images were taken as shown in Fig. 3. Consistent with the top- view FESEM images, the nanorods with a seed layer annealing temperature of 400 ºC were vertically grown and densely filled on top of the GaN surface.

In addition, Au nanoparticles were incorporated into ZnO nanorods[4-6]. The 20 nm Au nanoparticles were spread on top of the ZnO nanorods by dripping colloidal solutions with Au nanoparticles. To confirm the presence of the Au nanoparticles, XRD was used to evaluate the ZnO nanorods and Au nanoparticles, as shown in Fig. 4 (a) and (b). From both Fig. 4(a) and (b), high (002) peaks can be seen on the spectra, indicating high-quality ZnO nanorods were grown perpendicular to the GaN c-axis (0001) plane. Compared with the XRD patterns of Fig. 4 (a) and (b), Au nanoparticles can be seen at 2 theta around 38.5º. The gold peak can be found in the XRD pattern. To investigate the surface morphology of the Au nanoparticles/ZnO nanorods/ GaN substrate [7], FESEM was used to observe the surface of the nanocomposite. Au nanoparticles were agglomerated on top of the ZnO as shown in Fig. 5 (a) and (b). The nanoparticles can be attached to the surface of the ZnO nanorods well.

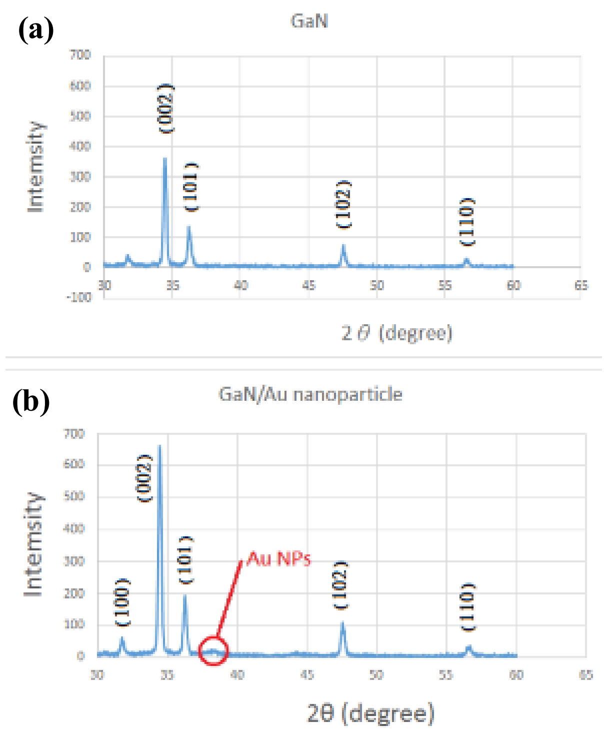

Figure 4. The XRD figure of ZnO nanorods with (a) no doped nano-gold particles (b) doped nano-gold particles

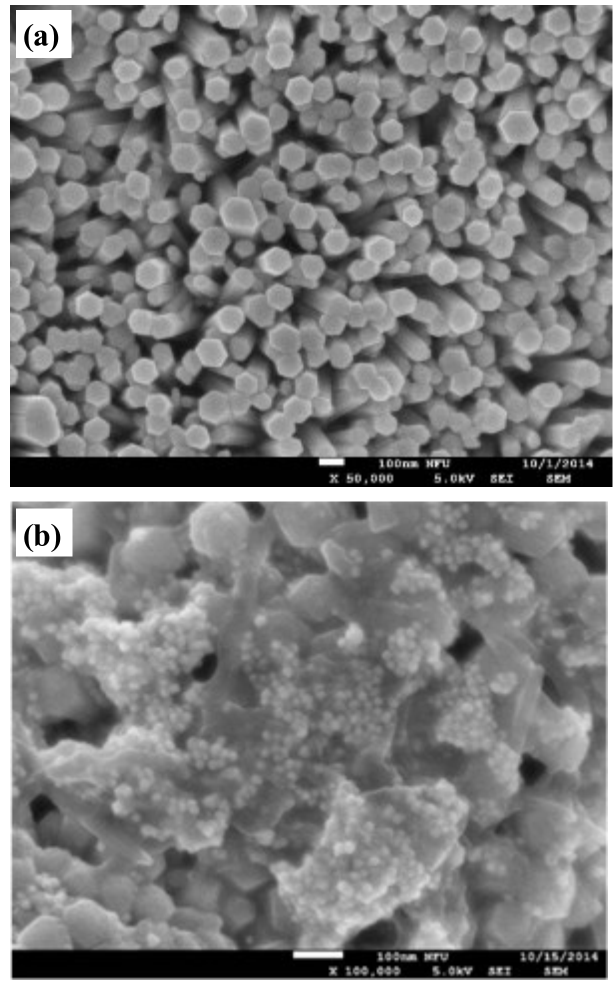

Figure 5. The FESEM figure of ZnO nanorod (a) without nano-gold particles (b) with nano-gold particles

4. CONCLUSION

In this research, we discover that high-quality ZnO nanorods can be grown with seed layer annealing temperature of 400 ºC. The ZnO nanorods were characterized by multiple material analysis including FESEM, EDX, and XRD. Furthermore, 20 nm Au nanoparticles were dripped and attached on the ZnO nanorods by the dripping method. The presence of the Au nanoparticles was confirmed by the XRD patterns and the profiles of the Au nanoparticles were observed by FESEM. The Au nanoparticles/ZnO nanorods/ GaN substrate nanocomposites are promising for future biomedical, optical, and electronic applications.

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