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Performance enhancement of MgZnO-based visible-blind photodetectors by Pt nanoparticles

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ABSTRACT

A series of ultraviolet photodetectors have been fabricated on MgZnO films, the molar ratio of Mg/Zn is about 18%, which grown by a radio frequency magnetron sputtering technique. Metal (Pt) nanoparticles are sputtered on the surface of the MgZnO film, embedded into the film and deposited on the substrate to improve the performances of the photodetectors, respectively. *I*–*V* characteristics under dark are improved by sputtering Pt nanoparticles on the surface of MgZnO film. Meanwhile, the photoresponse of the photodetectors with Pt nanoparticles are enhanced, especially when nanoparticles embedded into the MgZnO film, the peak responsivity is enhanced from 0.134 to 0.349 A/W at 30 V bias. It is demonstrated that the key role of Pt nanoparticles in the performance enhancement of MgZnO-based photodetectors, revealing the applicability of metal nanoparticles in ultraviolet photodetectors.

1. Introduction

MgZnO (MZO) materials with a direct band gap tuning from 3.3 to 7.8 eV, have been received more and more attention due to their well-known applications in optoelectronic devices, especially the ones in the ultraviolet (UV) range [1–7]. MZO-based UV photodetectors have been fabricated and reported, however, due to the difficulty of obtaining high-quality MZO, the responsivity of the metal-semiconductor-metal (MSM) structured devices based on MZO films are quite low [8–10]. As a consequence, improving the performance is still a key issue of the MZO-based MSM UV photodetectors, continuing efforts should be provided for this problem.

In recent years, a new method for thin-film solar cells, the use of metal nanoparticles, has been proposed and realized to improve the photoelectric conversion efficiency [11,12]. The thin-film materials with metal nanoparticles achieve more light trapping than the pristine, which provides a novel idea of enhancing the performance of MSM UV photodetectors based on MZO film.

In this letter, a series of MSM structured ultraviolet photodetectors, metal (Pt) nanoparticles deposited on the different situations of the MZO films, were fabricated on MZO films grown by a radio frequency (RF) magnetron sputtering technique. The electronic and optical properties were investigated. Meanwhile, we have also studied the photoresponse of the UV photodetectors based on MZO films with Pt nanoparticles.

2. Experimental

The schematic illustrations of the photodetectors with different structures are shown in Fig. 1. Pt nanoparticles were deposited on the different situations of the photodetectors for the same time (20 s), in which all the MZO films were prepared on the quartz substrates dividing into the two same steps, which thickness of each step is about 100 nm measured by ellipsometer. Sample MZO + Pt is Pt nanoparticles sputtering on the surface of films, sample MZO + Pt + MZO is Pt nanoparticles embedding in the MZO films, and sample Pt + MZO is with Pt nanoparticles on the substrate.

To fabricate the MSM structured MZO UV photodetectors, a thin layer of Au was sputtered onto the prepared MZO films to serve as the metal contact, kept a rate of deposition (~0.25 nm/s) for 10 min. The standard UV exposure and wet etching were then performed to define the interdigitated contact pattern.

A Rigaku Ultima VI X-ray diffractometer (XRD) with Cu Kα radiation (λ = ~1.543 Å) was used to make θ-2θ scans to evaluate the crystalline property of the MZO films. Both optical transmission and absorption spectra were recorded using a PerkinElmer Lambda 950

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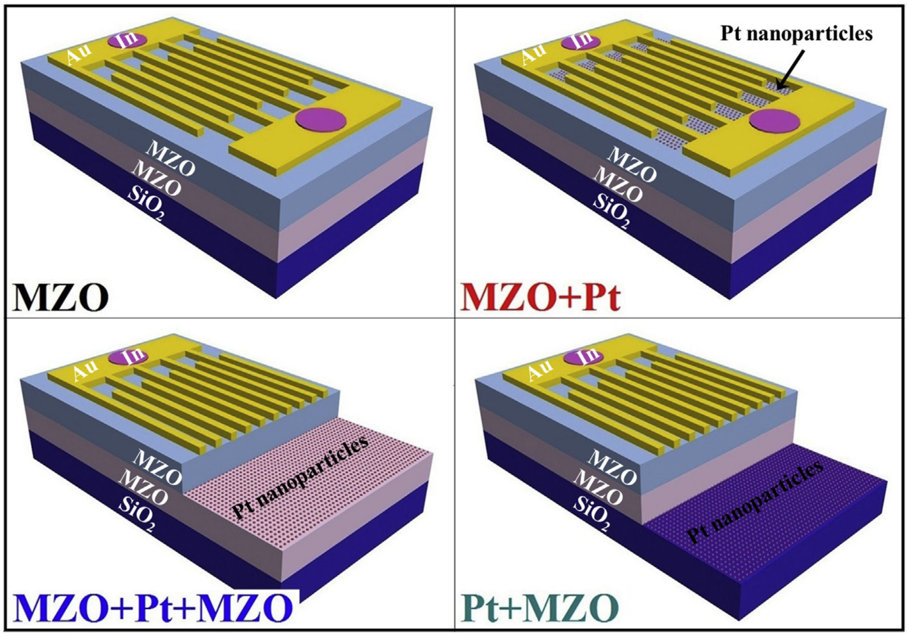

Fig. 1. The schematic illustrations of the photodetectors with Pt nanoparticles sputtering on the surface of MZO film (MZO + Pt), embedded into the film (MZO + Pt + MZO) and deposited on the substrate (Pt + MZO).

UV/vis Spectrometer in the wavelength range from 200 to 700 nm. Besides, the MZO films were characterized by energy-dispersive spectrometer (EDS). The current–voltage (*I*–*V*) (Agilent 16442A Test Fixture) in the dark and the responsivity (Zolix DR800-CUST) characteristics were measured, which applied voltage in *I*–*V* testing was tuned from −15 to +15 V and bias voltage in the responsivity testing was 30 V.

3. Results and discussion

Fig. 2 shows the XRD patterns of the MZO films with Pt nanoparticles depositing on the different situations, and only a diffraction peak located at about 34.9° can be observed, indicating that the films are hexagonal structured and highly *c*-axis oriented. Due to Pt nanoparticles depositing on the different situations of the films, the intensity of different MZO films is discrepant, which can prove that the existence of Pt has an effect on the crystal quality of films. As shown in Fig. 2, the full wave at half maximum (FWHM) of MZO with Pt nanoparticles are modest increased, which is in evidence that the decreasing of the crystal quality. Meanwhile, the MZO films were characterized by EDS, and the molar ratio of Mg/Zn is about 18%.

The absorption spectra of the MZO films with Pt nanoparticles depositing on the different situations are shown in Fig. 3, and the inset shows the UV–vis transmission spectra, which transmissions are more than 85% in the visible region. It is clear that Pt nanoparticles can enhance the light absorption of the MZO film, especially the structure of MZO + Pt + MZO performed the most obvious improvement, which indicates that the location of Pt nanoparticles is also concerned with light absorption. The phenomenon of

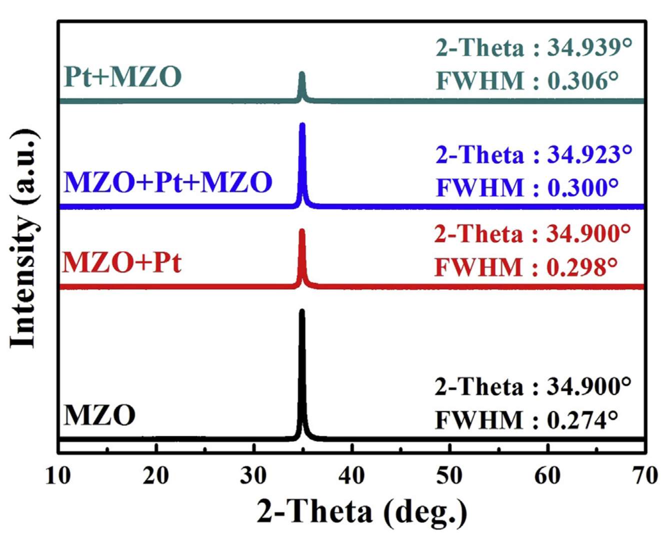

Fig. 2. XRD patterns of the MZO films with Pt nanoparticles depositing on the different situations.

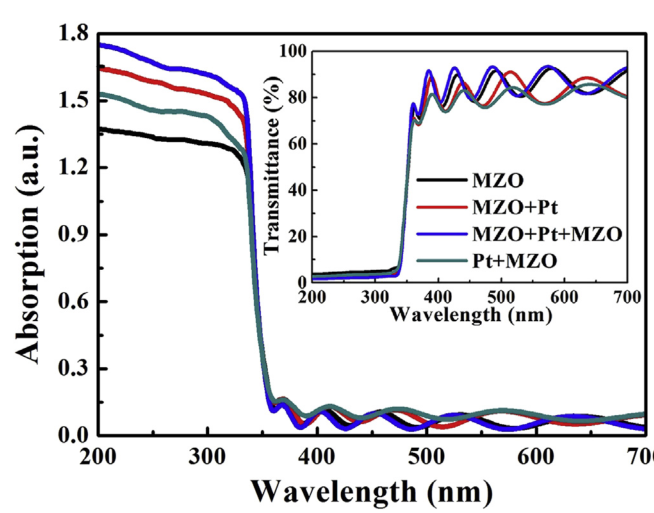

Fig. 3. The absorption spectra of the MZO films with Pt nanoparticles depositing on the different situations, and the inset shows the UV–vis transmission spectra.