Research on the Performance of ZnO/Mg$_{0.2}$Zn$_{0.8}$O Flexible Ultraviolet Photodetector

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Abstract. The ZnO/Mg$_{0.2}$Zn$_{0.8}$O/Au flexible ultraviolet photodetector (UV PD) with a polyethylene terephthalate (PET) substrate was successfully prepared at room temperature, which is compared with Mg$_{0.2}$Zn$_{0.8}$O/Au without a ZnO buffer layer. ZnO/Mg$_{0.2}$Zn$_{0.8}$O/Au double-layer film is biased at low operating voltage, the spectral responsivity is improved by 2.77 times. This result provides a way to grow a buffer layer on PET to improve the responsivity of the device. After 0/50/100/200 bending times and storage for more than 90 days, the pet substrate maintains excellent mechanical stability and repeatability, which is suitable for practical applications.

1. Introduction

ZnO is a direct band gap compound material of group II-IV, with a band-gap width of 3.37 eV, which has attracted widespread attention due to its superior photoelectric properties. MgZnO is a promising semiconductor material and is expected to be an ideal choice for UV detectors[1-3].

The MgZnO heterogeneous interface structure is superior to a single junction structure composed of a single type of semiconductor, for example, such as higher sensitivity, faster response speed and better rectification characteristics. In addition, MgZnO is a good choice for photodetector due to its physical and chemical properties, high excitation binding energy (60 mV), chemical stability, transparency and electron mobility.

ZnO/MgZnO heterostructure is a more excellent detector material. This is due to the band shift between the two films and the strong piezoelectric and spontaneous polarization effects. The polarization field is caused by [4-8]. Therefore, the photodetector based on ZnO/MgZnO heterogeneous interface exhibits excellent optical response gain, which enables it to detect weak signals at low bias. Most studies focus more on Mg content [9], doping, film thickness or structure [10]. Lack of analysis of gain theory formed by ZnO effect in devices.
In this work, we studied the Mg$_{0.2}$Zn$_{0.8}$O of ZnO buffer layer grown on PET. And tested the responsivity. At the same time, tested the mechanical stability and repeatability of the device after different bending cycles of 0/50/100/200 and stored for more than 90 days.

2.Experimental
The PET is ultrasonically cleaned with acetone, ethanol and deionized water in sequence. Using RF magnetron sputtering technology to grow ZnO film on PET, grow for 10 minutes at the pressure of 0.6 Pa, a sputtering power of 150 W and the O$_2$/Ar flow ratio is 10:40. The Mg$_{0.2}$Zn$_{0.8}$O film was grown on the ZnO film, the total pressure was 4 Pa, the sputtering power was 150 W, and the O$_2$/Ar flow ratio was 10:40 for 3 h.

Finally, Au interdigital electrodes are prepared by conventional photolithography and wet etching to produce UV PD with a metal-semiconductor-metal (MSM) structure. The width of the golden finger is 5 μm, the length is 500 μm, and the interval is 8 μm. ZnO/Mg$_{0.2}$Zn$_{0.8}$O film (PD-A), where 10 minutes of ZnO serves as a buffer layer and pure Mg$_{0.2}$Zn$_{0.8}$O film (PD-B) were designed for comparison. The crystallinity of the film was studied by using Rigaku Ultima VI X-ray diffractometer (XRD) at 40 kV and Cu Kα radiation (λ=1.543 Å). PerkinElmer Lambda 950 ultraviolet/visible spectrometer was used to record the 320-600nm absorption spectrum. The morphology of the film was characterized by JEOL JSM-6701F cold field emission scanning electron microscope.

3.Results and Discussion
Figure 1 shows the XRD patterns of PD-B and PD-A films grown on PET substrates. The two diffraction peaks (002; 2θ=34.2°). Only strong and weak (002) diffractions were observed, indicating that all the samples had hexagonal wurtzite structures with a high c-axis orientation. Compared with the pure PD-B film, the intensity (002) of the PD-A films increased slightly.

![Figure 1. XRD spectra of the PD-B films and PD-A films grown on PET substrates.](image)

Compared with the PD-B film, the PD-A film shows a clearer (330 nm) and softer (365 nm) absorption edge, indicating that the device with a buffer layer has a stronger absorption intensity. The next step is to increase the concentration of photogenerated carriers and build UV PD with excellent performance.
Figure 2. UV–visible absorption spectra of two films.

With 10 V bias applied, the measured maximum responsivity for PD-B and PD-A is 0.00284 A/W and 0.00787 A/W, respectively. The greater responsivity observed from PD-A can again be attributed to the insertion of high resistance ZnO buffer layer. In order to further evaluate the responsivity of the PD, we performed a spectrum analysis calculation on the EQE.

\[ \text{EQE}(\lambda) = \frac{R \omega \hbar c}{q \lambda} \]  \hspace{1cm} (1)

Where R is responsivity, \( \hbar \) is Planck's constant, \( c \) is the speed of light, \( q \) is the charge of electrons, and \( \lambda \) is the wavelength of light.

Figure 3. The responsivity graphs of the PD-B film and the PD-A film under bias conditions.

The EQE of PD-B and PD-A at 10 V is shown in Figure 4. With 10 V bias, the value of PD-A increases, which further supports the idea that gains already exists in PD-A.
Figure 4. EQEs of PD-B and PD-A.

Figure 5(a) shows the surface morphology of the PD-A film in the presence of the ZnO buffer layer. It can be seen from the SEM image that the grain distribution is uniform and compact. Figure 5(b) is the surface morphology of the PD-A film after bending test. The film has microcracks, most of which are intact.

4. Conclusions

In short, PD-A interface grown on PET substrate using convenient radio frequency magnetron sputtering system. Compared with the PD-B without the ZnO buffer layer, the PD-A double-layer film is not only under the low operating voltage bias, the spectral responsivity, the photodetector The external quantum efficiency (EQE) reaches a fairly high gain at 10 V. The PET device maintains excellent mechanical stability and repeatability, which is beneficial for practical applications.
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