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Characterization of the ZnO metal-semiconductor-metal ultraviolet photodetectors with Au contact electrodes

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1. Introduction

Short wavelength blue and ultraviolet (UV) photodetectors are important devices that can be used in space communications, ozone layer monitoring and flame detection. [1-2]. With the advent of optoelectronic devices fabricated on wide direct bandgap materials, it becomes possible to produce high performance solid-state photodetector arrays sensitive in the blue/UV region. It becomes possible to produce high performance GaN and ZnSe-based photodetectors.

Recently, there has been increasing interest in high quality ZnO films [5]-[8]. That is because it is an useful wide direct bandgap material [3],[4]. The large exciton binding energy of 60 meV and wide bandgap energy of 3.37 eV at room temperature make ZnO a promising photonic material for applications such as light emitting diodes (LEDs), laser diodes (LDs) and photodetectors.

There are many groups researched the contact on ZnO films, like Au, Ag, Pd, etc [9]. But there are few people use the Au metal on ZnO films to fabricate the MSM photodetectors. So we research the Au/ZnO MSM photodetector and discuss it's characteristics.

2. Experiment

ZnO samples were prepared on sapphire (0001) substrates using a rf plasma-assisted MBE system (Omni-Vac).The base pressure in the growth chamber was ~1x10-10 Torr. Zn with a purity of 99.9999% was evaporated from a commercial Knudsen cell (CreaTech)..Active oxygen and nitrogen radicals were produced by two rf-plasma systems (SVTA), respectively. The flow rate of oxygen/nitrogen gas was controlled by a mass flow controller (ROD-4, Aera). After degreased in trichloroethylene and acetone, the sapphire substrates were chemically etched for 30 min in a hot solution of H_2SO_4:H_3PO_4=3:1 at 110 °C and then rinsed with de-ionized water. A conventional two-step growth of ZnO, i.e., a low temperature buffer layer growth at 400 °C and a high temperature growth at 650 °C, was performed after nitridation. Oxygen termination will result in anion-polar film while aluminum termination the cation polarity. It is the coordination of Al atoms at the interface that makes the difference. In the case of oxygen termination, Al. When nitridation was performed on thermally cleaned sapphire surface at 800 °C for 1 h, we did obtain the Zn-polar ZnO films due to the ideal Al termination, which further justifies the atomistic view for polarity selection. It has been well established that nitridation involves the diffusion of nitrogen atoms into sapphire and substitution for oxygen, and AlN thin layer is formed as a result of the atom substitution.

Figs. 1 and 2 show the photoluminescence and x-ray diffraction spectra of our ZnO films. Those figures show our ZnO films have high quality.

After finish examining our ZnO sample's quality, we start to fabricate the MSM photodetectors. The area of active region was 200×200μm^2 with width and space of finger electrode were 10μm.

3. Results and discussion

Fig. 3 shows I-V characteristics of the fabricated ZnO MSM photodetectors with Au electrodes measured in dark (dark current) and under illumination (photocurrent). With 1 V applied bias, it was found that dark current and photocurrent of our ZnO MSM photodetectors were 1.22×10^{-8} and 1.26×10^{-4} A, respectively. We also use the thermionic emission theory to calculate the barrier height was 0.71 eV.

Fig. 4 shows the spectral responsivity as a function of wavelength on Au/ZnO MSM photodetectors. There is a sharp cutoff with a drop of 3 orders of magnitude at approximately 370 nm, and the response is nearly constant for wavelengths between 300 and 370 nm. With an incident wavelength of 370 nm, it was found that the maximum responsivities for the ZnO MSM photodetectors with Au contact electrode was 0.134 A/W as the bias at 1V, which corresponds to quantum efficiencies of 44.9 %.

The noise characteristics of ZnO MSM photodiodes were measured in the frequency range of 1 Hz~100 Hz using a low noise current preamplifier and a HP35670A fast Fourier transform (FFT) spectrum analyzer. The bias was varied from 1 V to 5 V and sample temperature was kept at room temperature. Fig. 5 shows measured noise power densities of the ZnO MSM photodetectors with Au contact electrode. In those figures, the low-frequency noise in ZnO MSM photodiodes is almost 1/f-type noise. The observation of such pure 1/f noise indicated that trapping states distributed uniformity in energy.

We also calculate the detector's noise equivalent power and detectivity (D*) and their values are 3.17×10^{-13} W and

2.23×10^{12} $cmHz^{0.5}W^{-1}$ as the bias at 1V.

4. Summary

ZnO epitaxial films were grown on sapphire substrates by molecular beam epitaxy. The sharp and strong excitonic related photoluminescence peak located at 3.31 eV indicates good crystal quality of our ZnO films. We fabricated the metal-semiconductor-metal (MSM) photodetector with Au electrodes. From the thermionic emission theory, we calculate the barrier height for electron was 0.71 eV. The photocurrent was larger three times than dark current. With an incident wavelength of 370 nm, it was found that the maximum responsivities for the ZnO MSM photodetectors with Au contact electrode was 0.134 A/W as the bias at 1 V, which corresponds to quantum efficiencies of 44.9 %. For a given bandwidth of 100 Hz and a given bias of 1V, it was found that the corresponding noise equivalent power of our

ZnO MSM photodetector with Au electrode was 3.17×10^{-13} W. Furthermore, it was found that the corresponding D* was 2.23×10^{12} $cmHz^{0.5}W^{-1}$.

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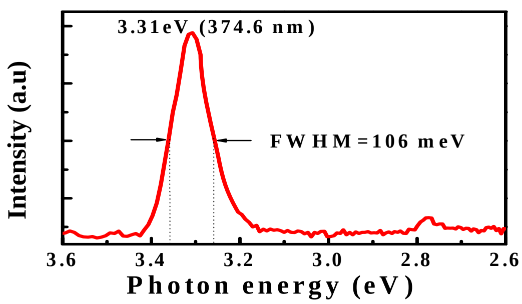

Fig. 1 Room temperature photoluminescence (PL) spectrum of epitaxial ZnO films.

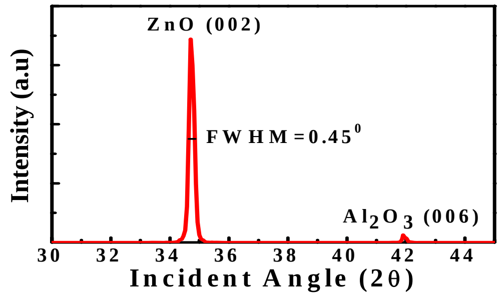

Fig. 2 High resolution X-ray diffraction (HRXRD) spectrum of epitaxial ZnO films on sapphire substrate

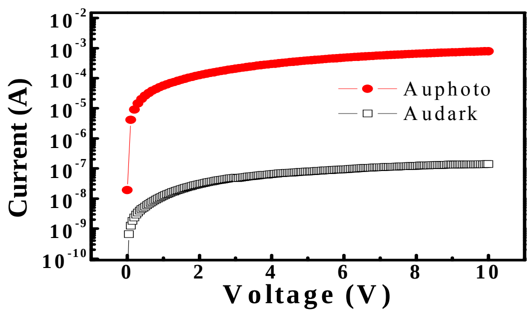

Fig. 3 I-V characteristics of the fabricated ZnO MSM photodetectors with Au electrodes measured in dark (dark current) and under illumination (photocurrent).

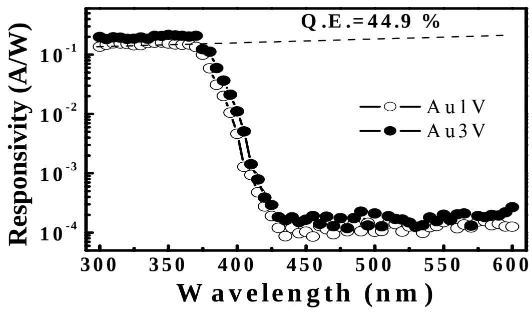

Fig. 4 The responsivity spectra of Au/ZnO MSM photodetector

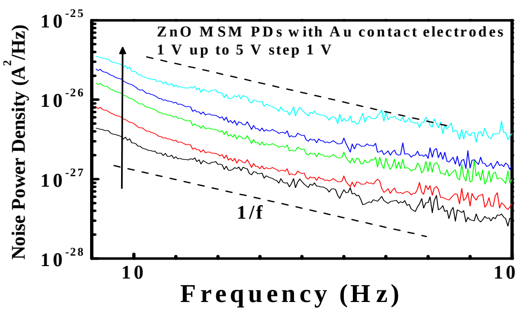

Fig. 5 The noise power density of the ZnO MSM photodetector with Au contact electrode.