ZnO 酸化物半導體를 利用한 紫外線 光센서에 관한 研究

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Photoresponsivity of ZnO Schottky barrier diodes

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要　約

分子線에피택시法으로 成長한 ZnO 酸化物半導體를 移用하여 製作한 쇼트키배리어 다이오드에 대하여 紫外線 光센서로서의 光特性을 調査한다. 첫째, 白色光 照射時 飽和電流値가 100倍 以上 增加하는 光여기 特性을 나타낸다. 둘째, 照射하는 빛의 波長에 대하 390nm의 遮斷長波長을 갖으며 195nm 以上의 밴드폭을 갖는 波長感度特性을 나타낸다. 셋째, 紫外線에 대해 0.36msec의 時定數 갖는 것으로 評價된다. 따라서, ZnO 酸化物半導體는 向後 紫外線 光센서소자의 材料로서 期待되어진다.

1. Introduction

ZnO has emerged to gain increasing attention in optoelectronic applications such as light-emitting diodes and white light sources, because of several advantages compared to GaN in the same energy bandgap region of ~ 3.4 eV.[1,2] First, ZnO has an exciton binding energy of 60 meV, 3 times larger than 21 meV in GaN. Second, larger size ZnO substrates are commercially available. Third, wet-chemical processing is feasible. Fourth, ZnO shows higher radiation hardness.

Recently, ZnO is becoming one hot issue in ultraviolet (UV) photodetecting devices such as furnace-plot-flame sensing, missile-plume detection, and astronomical appli -cation,[3,4] because the most common UV detectors currently in use are photomultiplier tubes and Si photodetectors, which are not solar-blind and require costly filters to attenuate unwanted visible and infrared radiations.

In this work, first, we fabricate ZnO Schottky barrier diodes using Plasma-assisted molecular-beam epitaxy (P-MBE). Second, we investigate the photoresponsivity of ZnO Schottky barrier diodes and discuss their possibility.

2. Experiment

ZnO layers were grown on Ga-polar GaN templates by P-MBE, equipped with a Zn solid source, an O rf-plasma source, and a N rf-plasma source. The GaN template used in this work was predeposited by Metal-organic chemical-vapor deposition (MOCVD) on a (0001) Al_2O_3 substrate[3]. First, a low-temperature ZnO buffer at 500°C was grown on the GaN template, followed by high -temperature annealing at 800°C. Subsequently, a ZnO layer was grown at 700°C under a Zn-rich growth condition. Finally, a ZnO:N capping layer was grown at 300°C for the formation of Schottky contact.

ZnO Schottky barriers diodes were fabricated by depositing semitransparent Au electrodes (~ 5 nm) on ZnO surfaces and In electrodes on GaN surfaces after etching away ZnO:N and ZnO layers. The Au Schottky electrode had a diameter of 1 mm andthe sample size was 5 mm by 10 mm. The electrodes were evaporated in a vacuum chamber, immediately after organic cleaning, in order to remove contaminants from sample surface.

3. Results

First, we investigate the current-voltage (*I-V*) characteristics of ZnO Schottky barrier diodes with and without UV radiation from a 100 W Halogen lamp at room temperature. Fig. 1 shows that Schottky barrier diodes in the dark present a reverse saturation current of ~ 10^{-8} A in the range up to 3 V and a breakdown voltage above 5 V. The small reverse saturation current and the large breakdown voltage indicate that good Schottky contacts are formed at the Au/ZnO:N interface. Moreover, it is found that the ZnO Schottky barrier diodes exhibit a large increase of reverse saturation current up to 10^{-5} ~ 10^{-6} A with maintaining stable diode characteristics, as the illumination intensity of a UV lamp increases to 25%, 50%, and 100%. The large current buildup of more than two orders of magnitude by photoexcitation and the stable diode characteristics make it possible to use the ZnO Schottky barrier diodes in photoresponse measurements.[3,4]

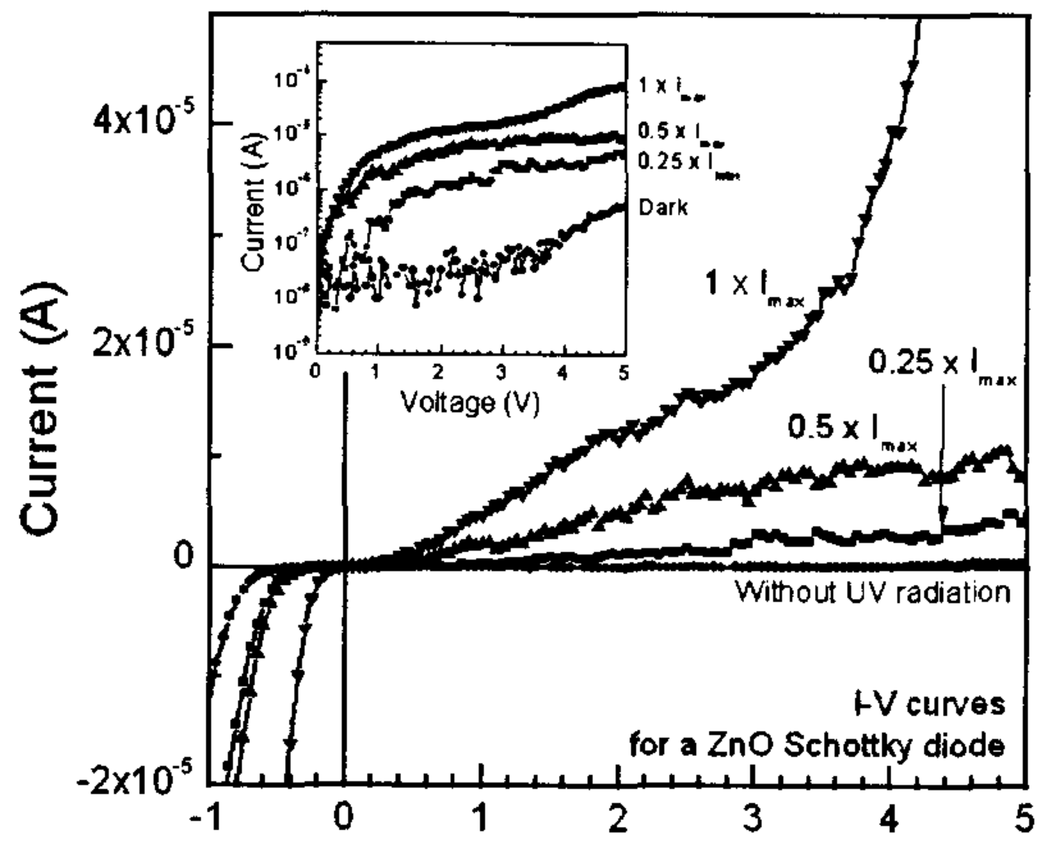

Fig. 1

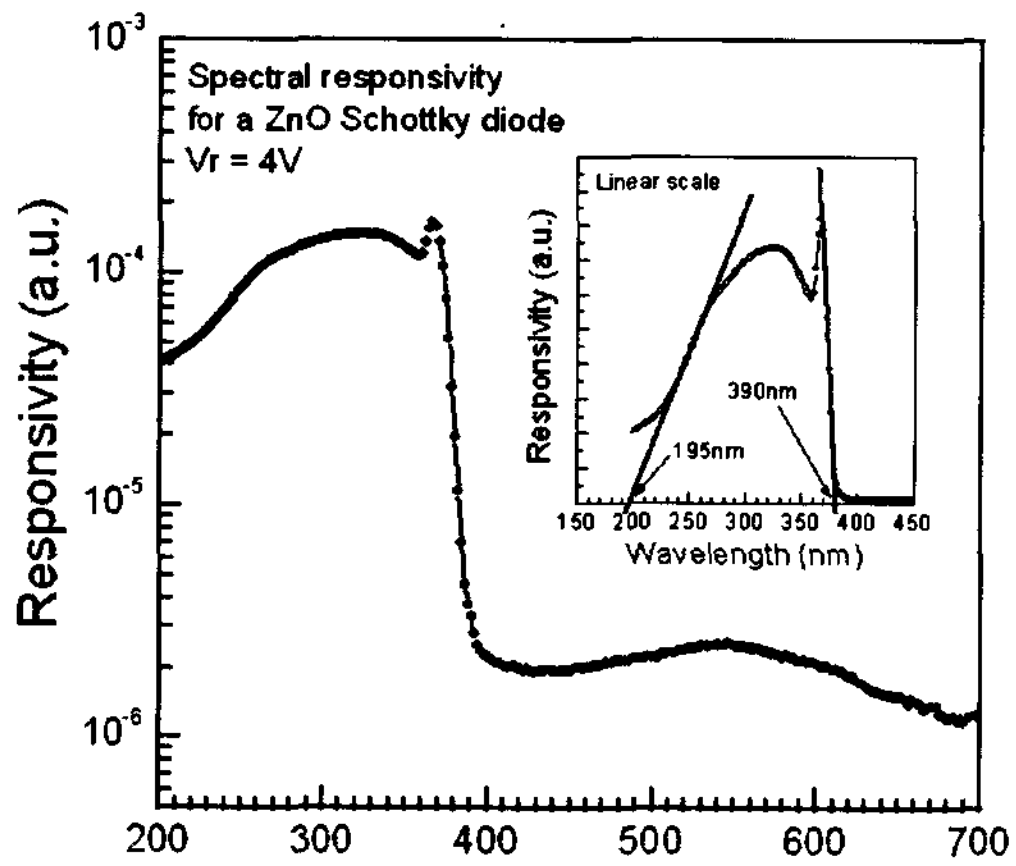

Fig. 2

Second, we investigate the spectral responsivity of ZnO Schottky barrier diodes as a function of wavelength. Fig. 2 shows that photocurrent increases very sharply at the band-edge cutoff, which indicates the intrinsic photoconductivity nature of ZnO.[3,4]. Moreover, it can be found that the short-wavelength cutoff and the long-wavelength cutoff of the spectral responsivity are 195 nm and 390 nm, respectively. (We should consider that the short-wavelength cutoff is limited by the emission of the Xe lamp and the spectral range of the monochromator.) Here, we note that the ZnO Schottky barrier diodes should have a bandwidth wider than 195 nm and show a large photocurrent increase of two orders at the long-wavelength cutoff.

Finally, we investigate the time response of ZnO Schottky barrier diodes. For this measurement, the diodes are connected to 100 Ω load resistors and operated at 3 V. The photocurrent change induced in the diode is obtained by measuring the variation of voltage drop in the resistor under an illumination condition. It is found that the photosignal rises and falls within 1 ~ 2 ms. Then, ZnO Schottky barrier diodes are estimated to have a time constant of 0.36 msec.

4. Conclusions

We fabricated ZnO Schottky barrier diodes and investigated their photoresponsivity. In the *I-V* characteristics with UV radiation, ZnO Schottky barrier diodes showed a large current build-up of more than two orders of magnitude. ZnO Schottky barrier diodes showed a rapid increase of photocurrent at the long-wavelength cutoff of 390 nm with a bandwidth of 195 nm. Moreover, ZnO Schottky barrier didoes exhibited a time constant of 0.35 msec in the time response measurements. It is suggested that ZnO Schottky barrier diodes are promising materials for ultraviolet photodetector applications.

References

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