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GaN-based MIS Ultra-violet Photodetectors with the CsF current suppressing Layer

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1. Introduction

GaN-based materials have attracted much attention with large direct bandgap energy and high saturation electron drift velocity. For photodetectors (PDs) applications, various types of GaN-based PDs have been reported [1-3]. Among them, GaN-based metal-semiconductor-metal (MSM) PDs can be operated with high speed. To achieve high performance MSM PDs, it is important to achieve a high Schottky barrier height at the metal-semiconductor (MS) interface. A large barrier height can lead to small leakage current and high breakdown voltage which could result in improved responsivity and photocurrent to dark current ratio. To reduce leakage current, it is possible to insert an insulating layer between metal and the underneath semiconductor [4-5]. The PDs with this insulating layer was called metal-insulator-semiconductors (MIS) PDs. Previously, caesium fluoride (CsF) and aluminum was utilized to be served as a composite electron injection layer in organic light-emitting diodes (OLEDs) in order to avoid the use of low work function metals and to enhance their reliability. In this study, we first reported the fabrication process and characteristics of GaN based metal-insulator-semiconductors (MIS) ultra-violet (UV) PDs using CsF as a current suppressing layer. The influence of inserting CsF layer on performance of MIS UV PDs will also be discussed.

2. Experimental and Result Discussions

Figure 1 shows the schematic structure of GaN MIS PDs with a CsF current suppressing layer. The GaN-based MIS photodetectors in this experiment were all epitaxial grown on c-face (0001) sapphire substrates by metalorganic chemical vapor deposition (MOCVD) system. Before epitaxial growth, the sapphire substrates were annealed at 1150℃ in H_2 ambient to remove surface contamination. A low temperature GaN nucleation layer was deposited as 550 ℃. After the nucleation layer was grown, the temperature was raised to 1060℃ to grow a 2-µm-thick unintentionally doped GaN epitaxial layer with a growth rate of 2µm/h. For the growth of undoped GaN layers, trimethylgallium (TMGa) and NH_3 were used as source materials. The MIS PDs were then fabricated. The CsF current suppressing layer was deposited on GaN MIS PDs by thermal evaporation, and annealed at high temperature (500℃) using the furnace. The thickness of CsF current suppressing layer is 50 nm. Ni/Au (5/5 nm) contact electrodes were subsequently deposited onto the samples. The contacts of the device form two inter-digitated contact electrodes. The fingers of the contact electrodes were 10 µm wide and 150 µm long with a spacing of 10 µm. An Agilent E5270B semiconductor parameter analyzer was then used to measure dark current-voltage (I-V) characteristics of this GaN MIS PD at room temperature. Spectral responses of these PDs were also measured. During spectral response measurements, a 300 W Xe arc lamp and a monochromator were used as the light source. The monochromatic light, calibrated with UV-enhanced Si photodetectors and an optical power meter, was collimated onto each photodetector via an optical fiber.

Figure 2 shows current-voltage (I-V) characteristics measured from the fabricated PD at dark and under illumination. With 5 V applied bias, it was found that dark current measured from the sample with a CsF current suppressing layer was 7.1×10^{-10} A. The small dark current measured from the PD is due to the use of a CsF current suppressing layer between GaN and metal. It should be noted that the inserted CsF current suppressing layer should form a high potential barrier between the metal electrode and GaN. As a result, we could significantly reduce dark current of the fabricated PDs. Furthermore, it was also found that photo current measured from the PD under illumination was 2.4×10^{-7} A with a 5 V applied bias. This small photocurrent also can be attributed to the fact that incident photons are partially absorbed by the CsF layer. With a 5V applied bias, the photocurrent-to-dark current contrast ratios were determined to be 3.12×10^{-2}.

Figure 3 also shows spectral responses measured from the fabricated PD. It should be noted that the photo responses were relative flat in the short-wavelength side while cutoff occur at around 360 nm, which corresponds to the bandgap of GaN for both two PDs. With incident light of 340 nm and 5 V applied bias, it was found that measured responsivities were 0.10027 A/W for the GaN MIS UV PD with a CsF current suppressing layer. With the inserted CsF layer, photo-generated current should become smaller again due to the insulating nature of CsF. As a result, the responsivities measured from the fabricated PD with a CsF current suppressing layer was also small, as compared to conventional PDs. Here, we defined UV-to-visible rejection ratio as the responsivity measured at 340 nm divided by that measured at 440 nm. With this definition, it was found that UV-to-visible rejection ratios were 6.349×10^1, and 1.562×10^1 for the fabricated PD with a CsF current suppressing layer with a 1V and 5V bias, respectively. These values also indicate that we can effectively enhance UV-to-visible rejection ratio by inserting the CsF layer. Such a result suggests the GaN MIS UV PDs with a CsF current suppressing layer are potentially useful for practical detector applications.

3. Conclusions

In summary, GaN MIS UV PDs with a CsF current suppressing layer were proposed and successfully fabricated. It was found that we can obtain a reduced dark current and an enhanced UV-to-visible contrast ratio by inserting the CsF current suppressing layer. With incident light of 340 nm and 5 V applied bias, it was found that measured responsivities were 0.10027 A/W for the GaN MIS UV PD with a CsF current suppressing layer. It was also found that we can achieve a large UV-to-visible rejection ratio for the fabricated PD with a CsF current suppressing layer.

Acknowledgements

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References

[1] S. S. Liu, P. W. Li, W. J. Lin, *Mater. Sci. Engineering B* **122** (2005) 196.

[2] J. Ohsawa, T. Kozawa, O. Ishiguro, and H. Itoh, *Jpn. J. Appl. Phys.* **45** (2006) L435.

[3] C. H. Chen, *Optical Review* **16** (2009) 371.

[4] A. Chini, J. Wittich, S. Heikman, S. Keller, S. P. DenBaars, and U. K. Mishra, *IEEE Electron Device Lett.* **25** (2004) 55.

[5] Y. Z. Chiou , Jpn. J. Appl. Phys. **45** (2006) 3045.

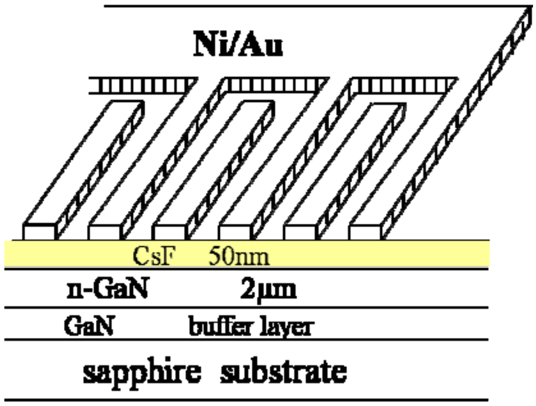

Fig. 1 The schematic structure of GaN MIS PDs with a CsF current suppressing layer

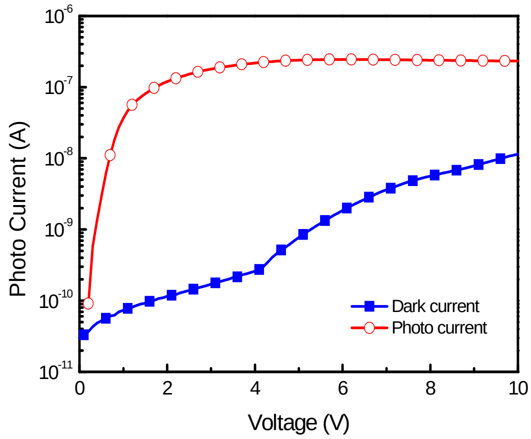

Fig. 2 I-V characteristics measured from the GaN MIS PDs with a CsF current suppressing layer at dark and under illumination.

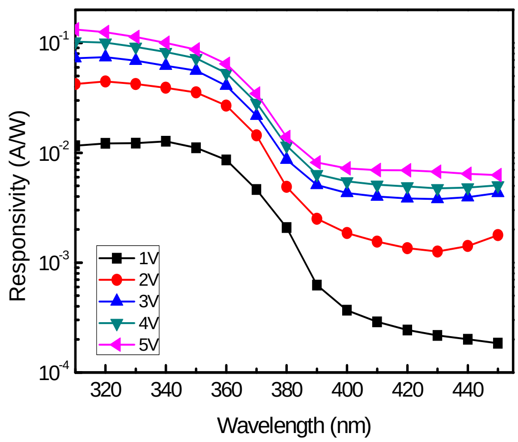

Fig. 3 Spectral responses measured from the GaN MIS PDs with a CsF current suppressing layer.