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GaN Metal-Organic-Metal Ultraviolet Sensors with Fullerene Organic Layers

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Abstract

GaN metal-organic-metal (MOM) ultraviolet (UV) sensors with a fullerene (C60) organic layer were proposed and successfully faricated. The dark current was substantially reduced and the UV-to-visible contrast ratio was enhanced by inserting the C60 organic layer. With incident light of 320 nm and 5 V applied bias, it was found that measured responsivities were 67 mA/W for the GaN MOM UV sensor with a C60 organic layer. The large UV-to-visible rejection ratio was achieved by inserting a C60 organic layer.

1. Introduction

GaN-based materials have attracted much attention with large direct bandgap energy and high saturation electron drift velocity. For sensor applications, various types of GaN-based sensors have been reported [1-3]. Among them, GaN-based metal-semiconductor-metal (MSM) sensors can be operated with high speed. To achieve high performance MSM sensors, 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 sensors with this insulating layer was called metal-insulator-semiconductors (MOM) sensors. To our knowledge, GaN-based MOM sensors with various insulating materials, such as oxides and nitrides were reported [6,7]. Previously, it has been shown that one can significantly reduce leakage current and enhance UV-to-visible rejection ratio by utilizing a organic based insulators such as C60 or m-MTDATA [8,9]. Using this technique can also decrease low-frequency noise (LFN), such as a noise-equivalent power (NEP) and a detectivity (D^*) in GaN metal-organic-metal (MOM) ultraviolet (UV) sensors. To achieve this purpose, the fullerene (C60) with a bandgap of 1.7 eV and good stability was introduced as an insulating layer between the Schottky contact and a high-quality GaN film in the MOM structure. In this study, we report the fabrication of GaN MOM sensors with C60 organic layers. The optical and electrical properties of the fabricated MOM sensors will be also discussed.

2. Experimental

The GaN-based MOM photodetectors in this experiment were all epitaxial grown on c-face (0001) sapphire substrates by 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 at 560 ℃. After the nucleation layer was grown, the temperature was raised to 1060℃ to grow a 2-μm-thick unintentionally doped GaN epitaxial layer. For the growth of undoped GaN layers, trimethylgallium (TMGa) and NH_3 were used as source materials. The MOM Sensors were then fabricated. The C60 organic insulating layer was deposited on GaN MOM Sensors by thermal evaporation at a pressure of 1x 10^{-6} Pa in a vacuum chamber. The deposited rate of the C60 layer was controlled to be 1 Å/s. The thickness of the organic thin film was approximately from 20 to 40 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 65 μm wide and 1150 μm long with a spacing of 85 μm. The schematic structure of the fabricated GaN MOM Sensors with the C60 organic layer is shown in Fig. 1. An Agilent E5270B semiconductor parameter analyzer was then used to measure dark current-voltage (I-V) characteristics of this GaN MOM detector. The spectral responses were measured by using monochromatic light source 300 W Xe lamp and calibration equipment.

3. Results and discussion

Figure 2 shows room temperature current-voltage (I-V) characteristics of the fabricated MOM Sensors with the C60 layer in dark ambient.With a 5 V applied bias, it was found that leakage current of the fabricated MOM Sensors with the C60 layer of 20-nm-thickness was 2.52 x 10^{-10} A. The effective Schottky barrier height from this device is approximate 0.729 eV. It was also found that the dark currents were 1.16×10^{-10} and 4.77×10^{-10} A for the fabricated sensors with C60 of 30-nm-thickness and 40-nm-thickness, respectively under a 5V bias voltage. The low dark current measured from the sensors with a 30-nm-thickness C60 layer could be due to the effective insertion of the C60 organic layer between GaN and the metal electrode. It will lead to the large Schottky barrier height between GaN and the metal electrode, and thus reduce the metal to the semiconductor thermionic emission. As the result, the effective Schottky barrier height from this device can increase to be 0.763 eV. Figure 3 shows the photo-to-dark current contrast ratios for these fabricated GaN MOM UV sensors with a C60 organic layer. With a 5 V applied bias, the photo-to-dark current contrast ratios were 1923, 8200, and 662 for the fabricated sensors with C60 of 20-nm-thickness, 30-nm-thickness and 40-nm-thickness, respectively. We achieved the highest photo-to-dark current contrast ratio for the GaN MOM sensors with a 30-nm-thick C60 organic layer. This case indicates that the insertion of the C60 organic layer considerably enhances the performance of GaN MOM UV sensors.

The spectral response of the GaN MOM detector with the C60 layer was shown in Fig. 4. The photoresponses were relatively flat in the short wavelength region when cutoff occurred at approximately 360 nm, which corresponds to the bandgap of GaN. With incident light of 320 nm and an applied bias of 5V, the measured responsivity was 67 mA/W for GaN MOM Sensors with the 30-nm-thickness C60 layer. Therefore, we could acquire a reasonably good performance by using the thin C60 layer as the insulator of GaN MOM UV Sensors. Here, we defined UV to visible rejection ratio as the responsivity measured at 320 nm divided by that at 420 nm. With a 5 V applied bias, it was found that UV to visible rejection ratio was 670. This finding indicates a reasonable UV to visible rejection ratio as result of inserting a C60 layer into the fabricated Sensors.

4. Conclusions

GaN MOM Sensors with a C60 layer were successfully fabricated and characterized. It was found that we can achieve a small dark current and large photocurrent to dark current contrast ratio from the proposed devices with the use of C60 layers. With a 5 V applied bias, the dark current of the fabricated GaN MOM Sensors with C60 insulating layers were 1.16×10^{-10} A. With incident light of 320 nm and 5 V applied bias, it was found that measured responsivities were 67 mA/W for the GaN MOM UV PD with a C60 layers. We also achieved large UV to visible rejection ratios from the photodetectors with C60 layers.

References

[1] S. S. Liu et al, *Mater. Sci. Engineering B* **122** (2005) 196.
[2] J. Ohsawa et al., *Jpn. J. Appl. Phys.* **45** (2006) L435.
[3] C. H. Chen, *Optical Review* **16** (2009) 371.
[4] A. Chini et al., *IEEE Electron Device Lett.* **25** (2004) 55.
[5] Y. Z. Chiou , Jpn. J. Appl. Phys. **45** (2006) 3045.
[6] W. Y. Weng et al., *IEEE Sens. J.* **11** (2011) 999.
[7] K. You et al., *Appl. Phys. Lett.* **100** (2012) 121109.
[8] C. H. Chen et al., *Lecture Notes in Electrical Engineering* **293** (2014) 1133.
[9] P. Y. Su et al., *Jpn. J. Appl. Phys.* **54** (2015) 04DK12.

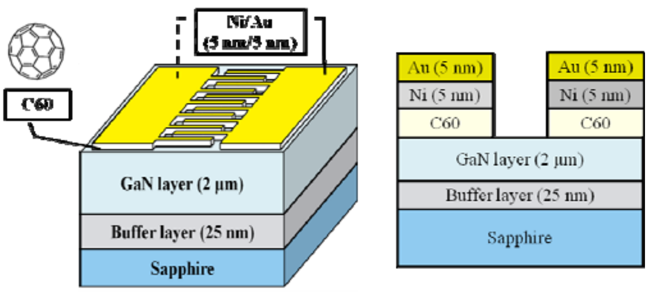

Fig. 1 The schematic structure of GaN MOM UV PD with a C60 layer.

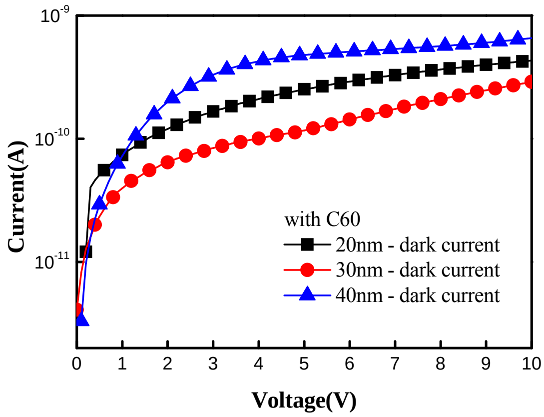

Fig. 2 I-V characteristics of GaN MOM Sensors with C60 layers.

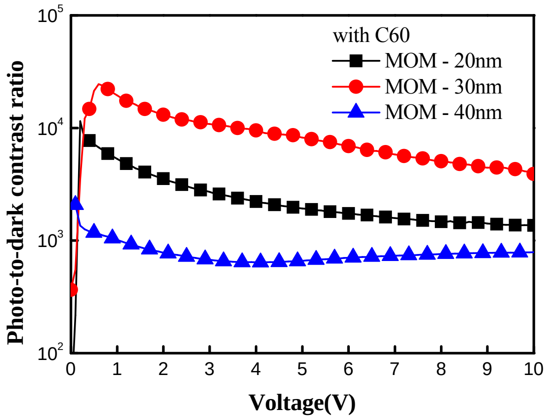

Fig. 3 Photocurrent-to-dark current ratios of GaN MOM Sensors with C60 layers.

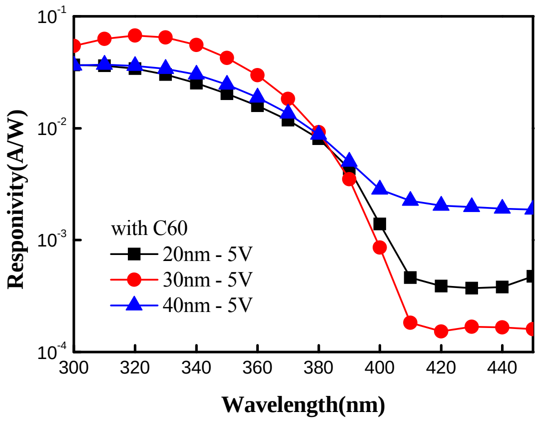

Fig. 4 Spectral responses of GaN MOM Sensors with C60 layers.