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AlGaN MSM Photodetectors with SiN/GaN double buffer layers

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Abstract

GaN and related compounds semiconductors have a direct band gap and thus suitable for optical devices such as light-emitting diodes or photodiodes. To date, various types of GaN UV photodetectors have been demonstrated. Among these devices, MSM photodetectors have several advantages including an ultralow intrinsic capacitance and a fabrication process compatible with field-effect-transistor (FET)-based electronics. However, because of the lack of suitable substrates, the nitride-based optoelectronic devices were grown on sapphire substrates. The large lattice constant mismatches between GaN epitaxial layers and the sapphire substrate results in an epitaxial layer with poor quality. The threading dislocations reduced the efficiency of those optoelectronic devices operated in UV region to a greater degree than they do for visible region. In order to further reduce the dislocation density, techniques such epitaxial lateral overgrowth (ELO) has been used. For the ELO method, one needs to deposit a thick GaN epitaxial layer on sapphire substrate prior to the insulator patterning and second epitaxial growth. Such complicated procedures results in a low production yield. Recently, it has been reported that one can also reduce the defect density in nitride-based epitaxial layers using GaN/SiN as the nucleation layer [1-2]. It has been shown that there exist many nanometer-sized holes on the surface when SiN layer is deposited onto sapphire substrate [3]. A resulting porous SiN layer probably serves to enhance the lateral growth, which is quite similar to that in ELO. In this paper, nitride-based UV AlGaN MSM photodetector with SiN/GaN double buffer layer (sample A) or with LT GaN single buffer layer (sample B) were prepared. The optical and electrical properties of the fabricated UV photodetectors with different buffer layers will also be reported.

Figure 1 showed the room temperature I-V characteristics of sample A and sample B. It was found that the dark current of sample A was a constant around 1×10^{-12}A less than 10V and slightly increased to 3.8×10^{-11}A at 20V. In contrast, the dark current of sample B was increased from 3.3×10^{-11}A at 5V to 1.4×10^{-8}A at 20V. The much smaller and much less voltage dependent leakage current observed from sample A should be attributed to the use of SiN/GaN nucleation layer. Figure 2 showed the photocurrent to dark current contrast ratio of sample A and sample B. It was found that photocurrent to dark current ratio of the sample A was much larger than 3 orders of magnitude even at 20V. In contrast, the ratio of sample B was strongly decreased from 2×10^{3} to 5. With the insertion of the porous SiN layer, one should be able to reduce threading dislocation in the epitaxial layer and thus suppress the leakage current and improve device performance.

Figure 3 showed the spectral response of (a) sample A and (b) sample B. It was found that the responsivity of sample B increased significantly with biased voltage. The maximum responsivity of sample A and sample B were 0.09 A/W and 0.2 A/W, respectively. The large response of sample B suggests that there exists high photoconductive gain in sample B. Here, we define UV to visible rejection

ratio as the responsivity measured at 330 nm divided by the responsivity measured at 400 nm. The UV to visible rejection ratio was showed in fig. 4. It was found that the UV to visible rejection ratio of sample B was much smaller. This is due to the fact that the dark current of sample A was much smaller. In addition, the sub-bandgap response of sample B was much larger than that of sample A. This might be due to the higher surface density and dislocation density in sample B.

In summary, AlGaN MSM photodetectors with SiN/GaN double buffer was fabricated. The leakage current was much smaller and less bias dependent for the photodetectors with SiN/GaN buffer layer. It was found that the photocurrent to dark current contrast ratio was increased from 5 to 2.4×10^{3} at 20V. Furthermore, it was found that we can effectively suppress internal gain of the detector and enhance UV to visible rejection ratio by using the SiN/GaN nucleation layer.

References

[1] K. Uchida, K. Nishida, M. Kondo and H. Munekata, “Epitaxial growth of GaN layers with double-buffer layers”, J. Crystal Growth, Vol. 189-190, pp. 270-274, 1998
[2] T. Kachi, K. Tomita, K. Itoh and H. Trando, “A new buffer layer for high quality GaN growth by metalorganic vapor phase epitaxy”, Appl. Phys. Lett., Vol. 72, pp. 704-706, 1998
[3] S. Sakai, T. Wang, Y. Morishima and Y. Naoi, “A new method of reducing dislocation density in GaN layer grown on sapphire substrate by MOVPE”, J. Crystal Growth, Vol. 221, pp. 334-337, 2000

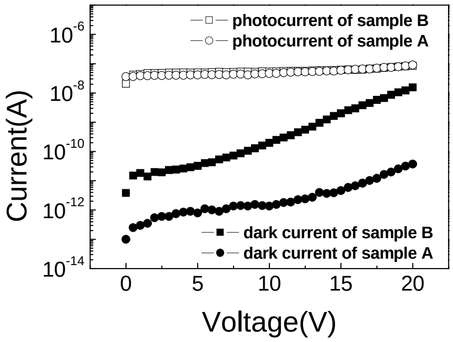

Fig. 1 I-V characteristics of sample A and sample B

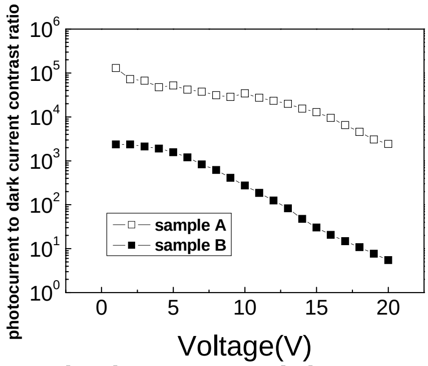

Fig. 2 the photocurrent to dark current contrast ratio of sample A and sample B

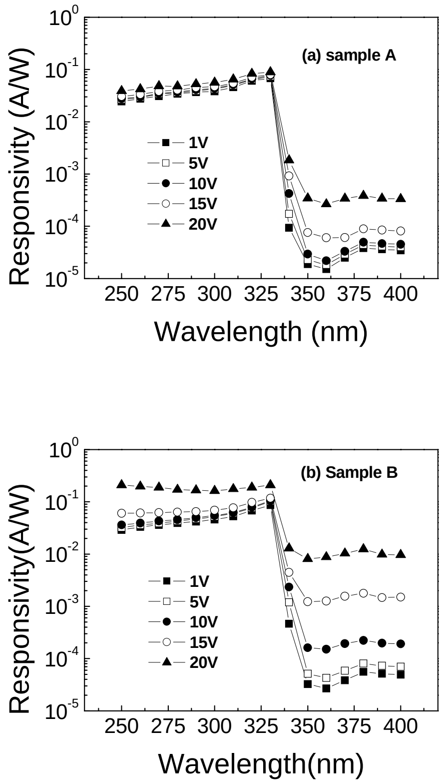

Fig. 3 spectral response of (a) sample A and (b) sample B

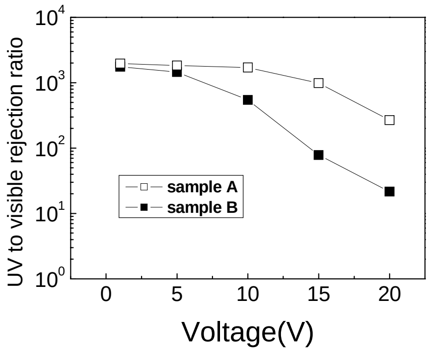

Fig. 4 UV to visible rejection ratio of sample A and sample B