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AlGaN Ultraviolet Metal-Semiconductor-Metal Photodetectors with Low-Temperature-Grown Cap Layers

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1. Introduction

The III-V based material system is suitable for high-temperature and high-power operation due to the feasibility of tuning wide band gap and good chemical stability. As yet, GaN-based photodetectors included photoconductors [1], p-n junction detectors [2], metal-semiconductor-metal detectors [3] and Schottky barrier detectors [4] operated in solar blind UV region have been demonstrated. Besides, the applications such as UV astronomy, flame detection, pollution monitoring and space communications have also been growing significantly. However, having low leakage current is one of the challenges for high performance nitride-based photodetectors. Several reports [5] have shown that the leakage current is mainly ascribed to threading dislocation-assisted leakage path. In this study, we grown high-resistivity low-temperature-grown GaN and AlGaN cap layers on the top of undoped AlGaN layer to minimize the threading dislocations in AlGaN metal-semiconductor-metal (MSM) detectors.

2. Experiments

The AlGaN MSM photodetectors with low-temperature-grown cap layers used in this report were all epitaxially grown on c-face sapphire substrates by Nippon Sanso SR2000 metalorganic chemical vapor deposition (MOCVD) system. Trimenthylgallium (TMGa), trimethyaluminium (TMA), and ammonia (NH_3) were used as the sources of Ga, Al, and N, respectively. A 25nm-thick low temperature GaN nucleation layer was deposited at 500°C and followed by the growth of 1-μm-thick unintentional doped GaN. The nominally undoped 200nm-thick $Al_{0.16}Ga_{0.84}N$ was grown on the undoped GaN. Then, we fabricated the structures capped with a 20nm-thick low-temperature-grown GaN (sample A) and AlGaN layer (sample B) separately. To evaluate the effect of low-temperature-grown cap layer, structure without cap layer was also demonstrated (Sample C). The growth temperature of the low-temperature-grown GaN and AlGaN layer was set at 500°C. Since Schottky barrier diodes with low-temperature-grown GaN layer had been fabricated and showed that it could block the surface pits and then reduce the leakage current, this structure is designed to understand the effect of different cap layers on the MSM photodetectors. The Ni/Au(100/100Å) contacts were deposited on the low-temperature-grown cap layer as Schottky contacts. An HP-4155 Semiconductor Parameter Analyzer was used to measure the current-voltage characteristics of these photodetectors. Spectral responsivities measurement system of the photodetectors including a 300-W xenon arc lamp light source, a monochrometer, an optical power meter, a piece of UV enhance fiber, and an HP-4155 Semiconductor Parameter Analyzer.

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3. Result and discussions

Figure 1 shows the dark I-V characteristics for the AlGaN MSM UV detectors. Under reverse bias, it the leakage current is near a constant of below $1x10^{-11}$A for devices with low-temperature-grown cap layer. The leakage current of device without cap layer is larger and increased rapidly as bias voltage increased. The difference in leakage current between devices with and without cap layer is about three orders of magnitude while operating at -5V. Comparing sample A, B and sample C, we can conclude that the low-temperature-grown cap layers result to higher potential and thicker potential barrier. Further more, it is possible that highly resistive cap layer can block most of leakage current path induced by threading dislocation surface terminations [6]. In addition, leakage current of devices with AlGaN cap layer have a lower leakage current as compared to the device with GaN layer. It suggests that Schottky barrier height of low-temperature-grown AlGaN cap layer is larger than device with GaN cap layer.

The measured photocurrent for the AlGaN MSM UV detectors with different cap layers was shown in figure 2. We can clearly observe a larger photocurrent for the device without cap layer due to the absorption of low-temperature-grown cap layer. The photocurrent to dark current contrast can be assessed by comparison of figure 1 and 2. Although device without cap layer has the highest photocurrent, its photocurrent to dark current contrast is still lower than one order of magnitude owing to higher treading dislocation-induced leakage current. On the other hand, the photocurrent to dark current contrast of device with low-temperature-grown AlGaN cap layer is three orders of magnitude higher than that of the device without cap layer. This result confirms that the low-temperature-grown cap layer can indeed block most of the leakage paths caused by threading dislocation surface terminations.

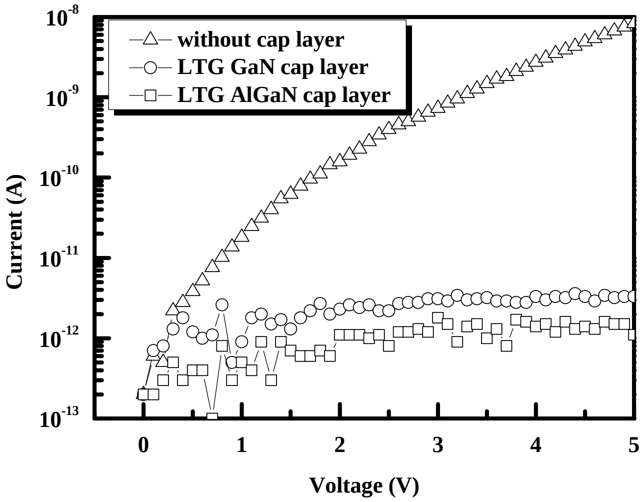

Fig. 1 Dark I-V characteristics of AlGaN MSM detectors with different cap layer.

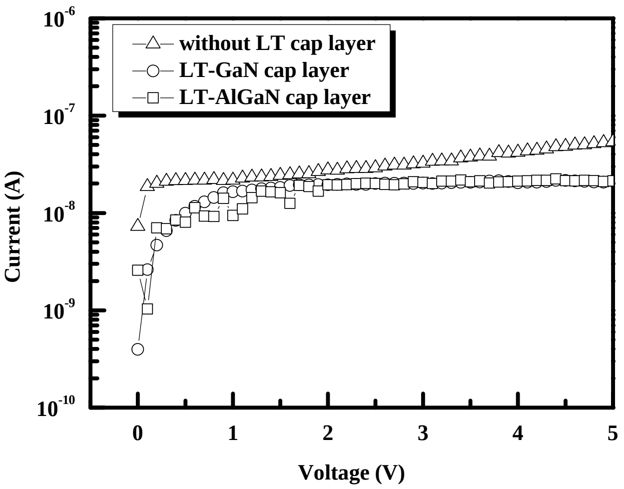

Fig. 2 Illumination I-V characteristics of AlGaN MSM detectors with different cap layer.

Figure 3 shows the responsivity as a function of wave length for AlGaN MSM detectors. It was found that a sharp cutoff that is about four orders of magnitude drop over 20nm occurs at 320nm for device without cap layer. The cutoff behaviors are inconsistent between them because the absorption of low-temperature-grown layer since its non-crystalline structure. The metastable donor/acceptor centers within low-temperature-grown [6] layers may be responsible for the flat cutoff characteristics.

4. Conclusions

In summary, the AlGaN MSM photodetectors with different low-temperature-grown cap layer were grown by MOCVD. It was found that the leakage current could be significantly decreased by introducing a low-temperature-grown cap layer that suggest that the most leakage current paths can be blocked by the high resistivity cap layer. Moreover, device with low-temperature-grown AlGaN cap layer shows higher photocurrent to dark current contrast up to three orders of magnitude.

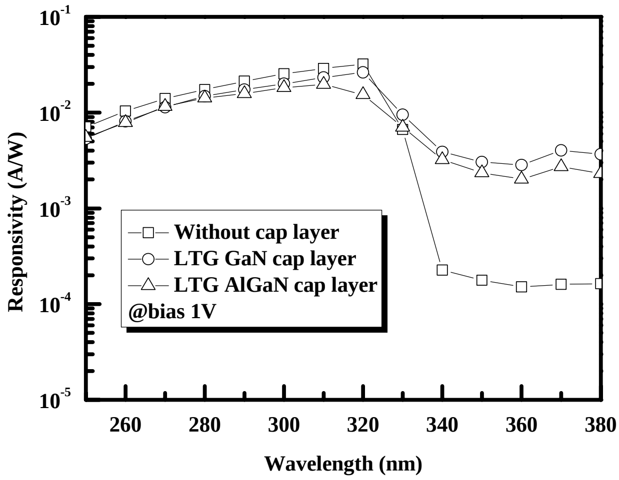

Fig. 3 Spectral responsivity of AlGaN MSM detectors with different cap layer.

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