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Improved Device Characteristics of InGaAsN Photodetectors Using MIMS Structure

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1. Introduction

Metal-semiconductor-metal (MSM) photodetectors have shown their advantages in several aspects such as their ease of integration, potential for high speed detection, and compatibility with planar FET process. In the application of optical fiber communications, MSM-PDs with absorption layer of InGaAs grown on InP substrates have been demonstrated extensively.[1] Compared with the readily technique, the GaAs-based PDs draws many attention owing to the low cost and high yield. Several attempts were made to improve the device characteristics ranging from high speed, low dark current, long wavelength operation and high responsivity; for example, the metamorphic growth of the InGaAs photodetectors [2], low-temperature InGaAs (LT-InGaAs) [3] and the introduction of deep-level impurities.[4]

In this report, we provide another approach to fabricate GaAs-based PDs by using the novel InGaAsN as absorption layer. Incorporating a small amount of N into the InGaAs-GaAs system leads to a reduction in both bandgap energy and lattice mismatch.[5] Thus, InGaAsN is a potentially useful material which can serve as the absorption layer of MSM-PDs fabricated on GaAs substrates for optical fiber communications.

2. Results and Discussion

The 300nm-thick $In_{0.11}Ga_{0.89}As_{0.988}N_{0.012}$ absorption layer was grown on (100) GaAs semi-insulating substrates by MOCVD. Three kinds of PDs, MSM, metal-insulator-semiconductor (MIS) and metal-insulator-metal-semiconductor (MIMS) were fabricated by standard photolithography, and the ITO-SiO2-ITO coplanar Schottky contacts were prepared by RF-sputter. The interdigitated finger electrodes were 5μm wide and with 10μm spacing in between. The total active area was 100×230μm^2.

Figure 1 shows the measured dark-current of the three types of PDs as a function of applied bias. The MSM-type presents highest dark-current of 5.5423 nA under 0.5V bias. Compared with the MSM-PDs, both MIS and MIMS-PDs have lower dark-current of 0.718nA and 0.793 nA at the same condition, respectively. The suppressed dark current can be explained by the effect of SiO_2 insertion. Besides, the dark-currents of MIS and MIMS photodetectors were approximate the same, but the photo-current of MIMS photodetector was higher than that of MIS photodetector at low applied bias, as shown in Figure 2.

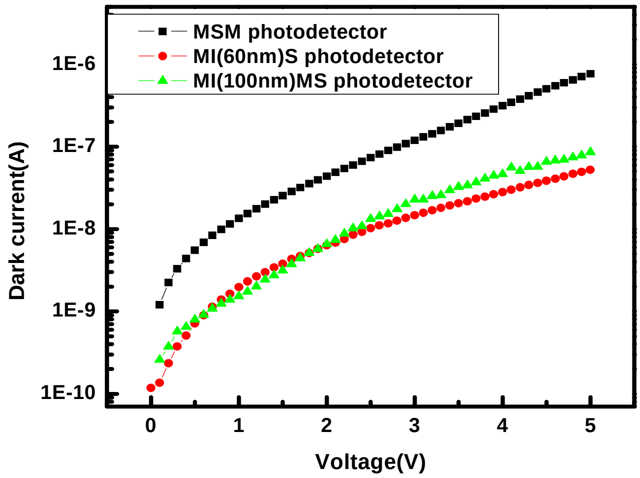

Figure1

The improved photo-current of MIMS structure could be explain by the interface roughness between the oxide films and InGaAsN absorption layer. The atomic force microscope (AFM) of SiO_2 and ITO thin films of the same thickness deposited on InGaAsN samples showed a very rough surface between SiO2 and InGaAsN. The root-mean-square roughness of SiO_2 and ITO films were 19.71nm and 0.785nm, respectively. Such a smooth surface of the ITO film would contribute to form a good contact and decrease the defects at the interface between electrode and sample. As a result, the MIMS PDs can provide higher photo-current than MIS ones.

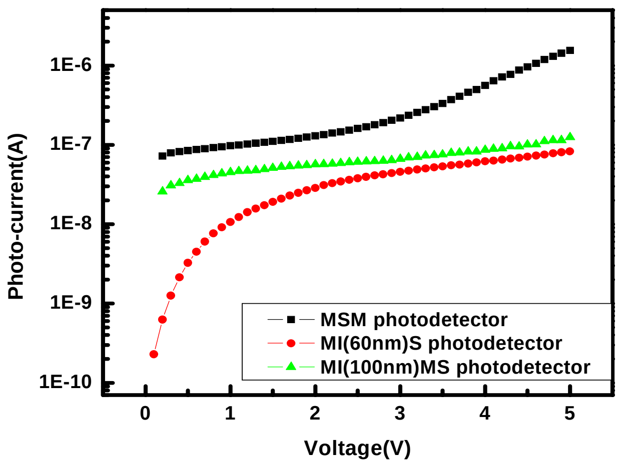

Figure 2

In addition, the photo-currents of MSM PDs were higher than the other two types of PD under the bias range of 0-5V. This phenomenon can be attributed to photo-generated carriers were somewhat blocked by the insulator layer of SiO_2. In spite of the lower photo-current, the MIMS PDs have better photo-current to dark-current ratio. Figure 3 illustrated the calculated ratio of the three types PDs. Under 0.5v bias, the ratio of MIMS PDs was 45.29; meanwhile, the ratio of MSM and MIS was 17.7 and 4.54 respectively. The higher photo-current to dark-current ratio could be attributed to the combined-effect of suppressed dark-current by SiO_2 and increased photo-current by utilizing MIMS structure.

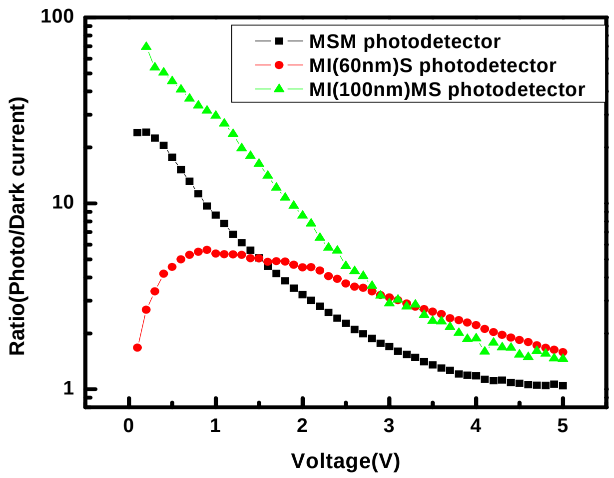

Figure 3

Figure 4 shows measured responsivity spectra as we applied a 0.2V bias on the MSM and MIMS PDs. Compared with the MSM photodetector, it was found that curve of measured responsivity was more precipitous from 4.21×10^{-3} A/W at 1200nm to 6.51×10^{-4} A/W at 1300nm.

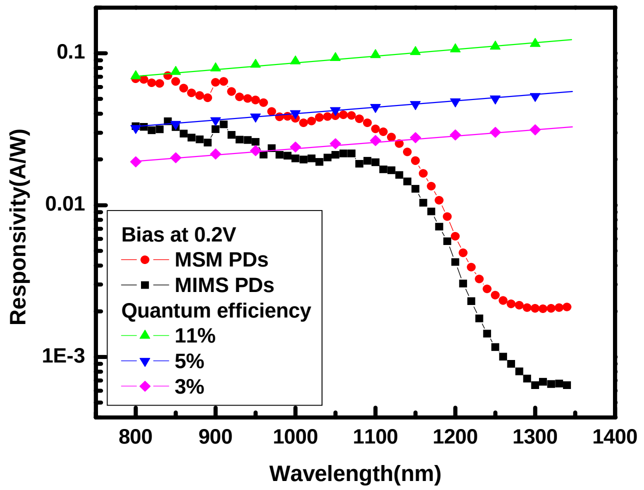

Figure 4

3. Conclusions

We have fabricated the InGaAN PDs with MSM, MIS, and MIMS structures. Among the three structures, the MIMS have highest photo-current to dark-current ratio of 45.29 under 0.5v bias. The improved photo-current was also observed in the MIMS PDs as compared with MIS ones.

Acknowledgements

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