Optoelectronic properties comparison of 10 and 20 multi quantum wells $Ga_{0.952}In_{0.048}N_{0.016}As_{0.984}$/GaAs p-i-n photodetector for 1.0 µm wavelength

ABSTRACT

This study proves the addition of quantum wells to the intrinsic regions of p-i-n GaInNAs/GaAs has improved the performance of optoelectronic devices. The optoelectronic properties that contribute to the device's dark current and photocurrent need to be well understood to develop photo-response at longer wavelengths. This study reports an optoelectronic properties comparison of different quantum well number for $Ga_{0.952}In_{0.048}N_{0.016}As_{0.984}$/GaAs-based dilute nitride multi-quantum wells (MQWs) p-i-n photodetector devices. From photoluminescence (PL) analysis, 20 MQWs shows a higher PL peak than 10 MQWs. The maximum quantum efficiency (QE) is found to be 80.3% for 20 MQWs and 46% for 10 MQWs, where 20 MQWs being the highest QE value ever reported for GaInNAs-based MQWs photodetector. Current versus voltage (I–V) measurement shows that 20 MQWs produces lower dark current than 10 MQWs. Besides, 20 QWs sample produces a higher current density (-12.43 µAcm^{-2}) than 10 MQWs (-7.52 µAcm^{-2}) under illumination. Impedance spectroscopy analysis shows that a lower dark current of 20 MQWs is due to a high intrinsic resistivity and low dielectric loss peak compared to 10 MQWs. SimWindows simulation shows good correlation with responsivity analysis and impedance analysis where at -5 V, 20 MQWs produces higher responsivity (0.65AW^{-1}) due to wider depletion region (deduce from conduction band profile) and lower intrinsic capacitance and dielectric loss (deduces from impedance analysis) than 10 MQWs (0.37AW^{-1}). At room temperature, the detectivity (D*) of the 20 MQWs photodetector (7.12×10^{10} cmHz$^{0.5}$W^{-1}) is higher than 10 MQWS photodetector (4.89×10^{10} cmHz$^{0.5}$W^{-1}). Finally, the 20 MQWs's (4.02×10^{-11} WHz$^{-0.5}$) has produces lower noise-equivalent power (NEP) than 10 MQWs (5.85×10^{-11} WHz$^{-0.5}$). This study has succesfully presenting an understanding of optoelectronic properties and simultaneously producing a sensitive photodetector with high quality, low-noise which is comparable with $\sim 10^{10}$ cmHz$^{0.5}$W^{-1} of commercial III-V alloy based near-infrared GaAs-based photodetectors.