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AlGaN solar-blind APD with low breakdown voltage

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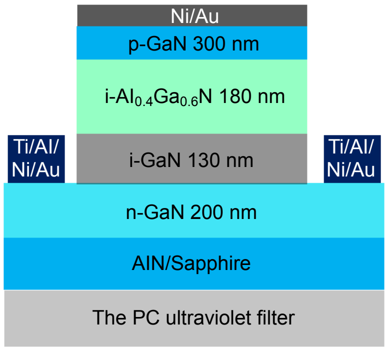

Schematic of the designed solar-blind APD.

Abstract: Solid-state avalanche photodiodes (APDs) based on AlGaN with Al composition exceeding 40% are being heavily studied because they have intrinsic solar-blindness, which could be a viable alternative to Si-based photodiodes or photomultiplier tube (PMT) used in ultraviolet (UV) military, civilian and scientific areas. However, the development of the solar-blind AlGaN APDs with high gain has been still suffered from some problems, such as low p-type doping efficiency and high dislocation densities for high-Al content AlGaN layer. In addition, the breakdown voltages of the conventional AlGaN APDs are generally more than 90 V, which results in a large leakage current. Large dark current can increase the device noise, as well as confine the APDS avalanche gain. In this work, a back-illuminated p-i-i-n type AlGaN heterostructure APDs is proposed that exploits high-Al-content AlGaN as multiplication layer, low-Al-content AlGaN as absorption layer and GaN as p-type layer. The calculated results show that the designed APD can significantly reduce the breakdown voltage by almost 30%, and about sevenfold increase of maximum gain compared to the conventional AlGaN APD. This is because the direction of polarization-induced electric fields in high-Al content multiplication layer is the same as those of the build-in electric field and applied reverse-bias field, and thus the total field in multiplication layer increases, which leads to the enhancement of carrier ionization rate together with the gain of APD. Meanwhile, the extra polarization field in the multiplication region can lower effectively the applied voltage value at the point of avalanche breakdown. Moreover, the voltage drop in p-GaN and n-GaN layers reduces due to the direction of polarization field opposited to those of the build-in electric field and applied voltage field in these two layers, which further reduces the breakdown voltage. The reduction of avalanche breakdown voltage is an advantage for decreasing the dark current. So the calculated noise in designed APD is also less than that in conventional APD at the breakdown voltage point due to its low dark current. Finally, for the purpose of realizing the solar-blind characteristic of designed APD, the one-dimensional (1D) dual-periodic photonic crystal (PC) with anti-reflection coating filter stacked by Si_3N_4/SiO_2 is designed. The filter has a high reflectance over 99% with the wavelength of incident light varying from 285 nm to 398 nm, and less than 20% reflectivity when λ<272 nm. So, the solar-blind characteristic and cutoff wavelength of 282 nm for designed APD is obtained, which attributes to the high reflectivity of PC filter with λ in the range of 285 nm to 398 nm.

Keyword: AlGaN; avalanche photodiodes; solar-blind

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