Abstract

UV Photodetectors, Focal Plane Arrays, and Avalanche Photodiodes

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The study of III-Nitride based optoelectronics devices is a maturing field, but there are still many underdeveloped areas in which to make a contribution of new and original research. This work specifically targets the goals of realizing high-efficiency back-illuminated solar-blind photodetectors, solar-blind focal plane arrays, and visible- and solar-blind Avalanche photodiodes. Achieving these goals has required systematic development of the material growth and characterization, device modeling and design, device fabrication and processing, and the device testing and qualification. This work describes the research conducted and presents relevant devices results.

The AlGaN material system has a tunable direct bandgap that is ideally suited to detection of ultraviolet light, however this material system suffers from several key issues, making realization of high-efficiency photodetectors difficult: large dislocation densities, low n-type and p-type doping efficiency, and lattice and thermal expansion mismatches leading to cracking of the material. All of these problems are exacerbated by the increased aluminum compositions necessary in back-illuminated and solar-blind devices. Overcoming these obstacles has required extensive development and optimization of the material growth techniques necessary: this includes everything from the growth of the buffer and template, to the growth of the active region.

The broad area devices realized in this work demonstrate a quantum efficiency that is among the highest ever reported for a back-illuminated solar-blind photodetector (responsivity of 157 mA/W at 280nm, external quantum efficiency of 68%). Taking advantage of the back illuminated nature of these detectors, we have successfully developed the technology to hybridize and test a solar-blind focal plane array camera. The initial focal plane array shows good uniformity and reasonable operability, and several images from this first camera are presented. However, in order to improve the performance of these devices to the point where they can effectively compete with photo-multiplier tube technology, it is necessary to develop devices with internal gain. To this end GaN and AlGaN based avalanche photodiodes have been studied, and we report the first realization of a solar-blind back-illuminated avalanche photodiode. The next logical step is to continue this work and realize Geiger mode avalanche photodiodes capable of single photon detection.