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Toward realization of small-size dual-band long-wavelength infrared photodetectors based on InAs/GaSb/AlSb type-II superlattices

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Highlights.

- Demonstration of 12×12µm² dual-band LWIR type-II superlattice-based photodetectors
- Surface leakage reduction using high quality dry etching technique and SiO_2 passivation
- Small dark current density variation was observed for a large range of pixel areas

Abstract.

In this study, we demonstrate 12×12 µm² high-performance, dual-band, long-wavelength infrared (LWIR) photodetectors based on InAs/GaSb/AlSb type-II superlattices. The structure consists of two back-to-back heterojunction photodiodes with 2 µm-thick *p*-doped absorption regions. High quality dry etching combined with SiO_2 passivation results in a surface resistivity value of 7.9×10^5 Ω·cm for the longer (red) channel and little degradation of the electrical performance. The device reaches dark current density values of 4.5×10^{-4} A/cm² for the longer (red) and 1.3×10^{-4} A/cm² for the shorter (blue) LWIR channels at quantum efficiency saturation. It has 50 % cut-off wavelengths of 8.3 and 11.2 µm for the blue and red channel, respectively, at 77 K in back-side illumination configuration and exhibits quantum efficiencies of 37 % and 29 %, respectively. This results in specific detectivity values of 2.5×10^{11} cm·Hz$^{1/2}$/W and 1.3×10^{11} cm·Hz$^{1/2}$/W at 77 K.

Keywords: *Infrared imaging, Photodiodes, Solid state detectors, Photodetectors, Type-II superlattices*

1. Introduction

InAs/Ga(In)Sb type-II superlattices (T2SLs) are starting to challenge the current state-of-the-art infrared detection technology, Mercury-Cadmium Telluride (MCT). MCT photodetectors have several issues: they are toxic, relatively costly, and can be inhomogeneous over large wafers. Long-wavelength infrared MCT photodetectors are often limited by Auger recombination, which T2SLs have been theorized to be able to suppress (Ref. [1]), which could potentially lead to better performance. Thanks to the flexibility of superlattice structures, the valence and conduction band energy levels can be controlled separately by varying the thicknesses of the InAs and GaSb layers. The bandgap of InAs/GaSb/AslSb T2SLs can be varied between 1.5 µm to semi-metals (Refs. [2, 3]). AlSb layers can also be introduced to further enhance the design flexibility (Refs. [4, 5]).

However, T2SL-based infrared photodiodes still suffer from higher dark current density than MCT, mainly due to the generation-recombination (G-R) and surface leakage currents. To reduce the G-R current, heterojunction photodiodes have been used in T2SLs to shift the depletion region from the narrow-bandgap absorption region to the larger bandgap region (Refs. [6-8]). Solving the surface leakage issues is more challenging, especially in smaller pixel-sized devices. Surface states lead to band bending that can induce an inversion of the majority carrier type close to the surface, thereby creating a surface leakage channel. (Ref. [9]). Heterojunctions may help to reduce the surface leakage because the larger bandgap is more immune to surface inversion. However, suppressing surface leakage is highly dependent on the surface treatment. Techniques have been studied to improve surface quality and it has been demonstrated that the Inductive Coupled Plasma (ICP) dry etching technique, without citric acid-based wet etching afterwards, can reduce the surface leakage current significantly for single color LWIR T2SLs photodetectors (Ref. [10]). However, this has not been demonstrated for dual-band photodetectors.

There has been a recent desire for higher and higher resolution focal plane arrays (FPAs) that demand smaller pixels. Reducing the pixel size has multiple advantages: it results in a more compact FPA requiring less semiconductor material and thus allows for a lower cost as well as higher yield. It allows for better spatial resolution. Even if the pixels are smaller than the diffraction limit