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The 640×512 LWIR type-II superlattice detectors operating at 110 K

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Abstract

The type-II InAs/GaSb superlattices (T2SLs)-based 640×512 long wavelength infrared (LWIR) Focal Plane Array (FPA) detector with15 μm pitch and 50% cut-off wavelength of 10.5μm demonstrates a peak quantum efficiency of 38.6% and peak detectivity of 1.65×10^{11}cmHz$^{1/2}$W^{-1} at 8.1μm, high pixel operability of 99.5% and low responsivity non-uniformity of 2.69% at 80 K. The FPA exhibits clear infrared imaging at 110K and diffusion-limited dark current densities below Tennant's 'Rule07' at temperature above 100K, which is attributed to the efficient suppression of diffusion dark current and surface leak current by introducing M-structure barrier and double hetero-structure passivation layers.

Keywords: Superlattice; LWIR detectors; M-structure barrier; Double hetero-structure passivation

1. Introduction

Type-II InAs/GaSb and InAs/InAsSb superlattice (T2SL) materials [1] are considered as excellent candidates for long-wavelength infrared (LWIR) [2-6] and very-long-wavelength infrared (VLWIR)[7,8] detection and imaging. Since the wave functions of electrons and holes are separately localized in the InAs and GaSb layers, respectively, in InAs/GaSb-based T2SLs, therefore arbitrarily narrow band-gap [9,10] and large effective mass [11] can be obtained by adjusting the thickness of InAs and GaSb layers to realize LWIR and VLWIR photodetectors with low tunneling dark current [4]. The tunneling dark current is further minimized by introducing barriers, such as M-structure superlattice, where an AlSb barrier is inserted in the middle of GaSb layer of each InAs/GaSb period [4,5]. The auger recombination or Shockley-Read-Hall recombination can also be suppressed by tailoring the valence band of T2SLs [12,13]. Multi-wafer Production of 2-5"GaSb-based photodetector materials grown by Molecular Beam Epitaxy (MBE) show high uniformity and well controlled periodic thickness and interfaces [14]. Meanwhile, the technology of GaSb-based device fabrication is being developed gradually. Especially the optimization of surface passivation processing efficiently reduces the surface leakage current [15-17]. The LWIR Focal Plane Arrays (FPAs) of InAs/GaSb-based T2SLs demonstrate low dark current, good uniformity and high detectivity, even at high operating temperature, and imply the outstanding superiority over that of HgCdTe (MCT) FPAs, which have low uniformity in materials and low operating temperature. There are two major challenges for developing high performance T2SL detectors working in long wavelength infrared range. The first challenge is growth of high quality T2SL materials with perfect interfaces, well controlled minority carrier concentration and introduction of barriers. The second one is surface passivation of small pixels in large format detector arrays to eliminate the surface leak current, particularly as the cutoff wavelength beyond 10 μμ. High operating temperature (HOT) [18] is an extremely important merit for infrared photodetectors and highly expected for reducing the size, weight and power consumption for cryogenic cooling systems