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Superlattice and Quantum Dot Unipolar Barrier Infrared Detectors

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We report device performance and provide theoretical analysis of a modified long-wavelength complementary barrier infrared detector structure that incorporates a double tunnel junction contact designed for simpler material growth while retaining the robustness for processing. We also provide analysis of a mid-wavelength quantum dot barrier infrared detector and explain its spectral shape and turn-on characteristics.

Key words: Infrared detector, type II superlattice, quantum dot, unipolar barrier, mid-wavelength infrared, long-wavelength infrared

INTRODUCTION

The antimonide material system consisting of the nearly lattice-matched semiconductors InAs, GaSb, and AlSb (and their alloys with InSb, GaAs, and AlAs) has recently emerged as a highly effective platform for development of sophisticated heterostructure-based mid-wavelength infrared (MWIR) and long-wavelength infrared (LWIR) detectors, as exemplified by high-performance double heterostructure (DH),[1] nBn,[2–4] XBn,[5–8] and type II superlattice infrared detectors.[9–18] A key enabling design element is the unipolar barrier,[17] which is used to implement the barrier infrared detector (BIRD) design for increasing the collection efficiency of photogenerated carriers, and reducing dark current generation without impeding photocurrent flow. Effective use of unipolar barriers in heterostructure III–V MWIR and LWIR detectors has resulted in substantial reduction in generation–recombination dark currents and enhanced detector performance. One example is the InAs/GaSb type II superlattice-based complementary barrier infrared detector (CBIRD),[17] which has already demonstrated good performance in LWIR detection. In this paper, we discuss the performance of a CBIRD with a modified design for simpler material growth while retaining the robustness for device and focal-plane array processing. We also provide theoretical analysis of the CBIRD device operation. Another example of the effective use of unipolar barriers is the MWIR nBn detector.[2] The standard nBn detector is based on the InAsSb absorber lattice-matched to the GaSb substrate. The quantum dot barrier infrared detector (QD-BIRD)[19] incorporates self-assembled InSb quantum dots into the active detection area of the standard nBn structure, and extends the detector response to longer wavelengths. In this work, we describe new analysis of the QD-BIRD that offers possible explanations for its bimodal spectral shape and turn-on characteristics.

COMPLEMENTARY BARRIER INFRARED DETECTOR (CBIRD)

As illustrated in Fig. 1, the active region of the CBIRD[17] design consists of a *p*-type InAs/GaSb LWIR absorber superlattice (SL) sandwiched between an *n*-type InAs/AlSb hole-barrier (hB) SL (which also serves as the top contact) and a *p*-type InAs/GaSb electron-barrier (eB) SL. The hB and eB SL are designed with the goal of having approximately zero conduction and valence subband offsets, respectively, relative to the absorber SL; i.e., they act as a pair of complementary unipolar barriers

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