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N-structure based on InAs/AlSb/GaSb superlattice photodetectors

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ABSTRACT

We have studied the theoretical and experimental properties of InAs/AlSb/GaSb based type-II superlattice (T2SL) pin photodetector called N-structure. Electronic properties of the superlattice such as HH–LH splitting energies was investigated using first principles calculations taking into account InSb and AlAs as possible interface transition alloys between AlSb/InAs layers and individual layer thicknesses of GaSb and InAs. T2SL N-structure was optimized to operate as a MWIR detector based on these theoretical approaches tailoring the band gap and HH–LH splitting energies with InSb transition layers between InAs/AlSb interfaces. Experimental results show that AlSb layers in the structure act as carrier blocking barriers reducing the dark current. Dark current density and R_0A product at 125 K were obtained as 1.8×10^{-6} A cm^{-2} and 800 Ω cm^2 at zero bias, respectively. The specific detectivity was measured as 3×10^{12} Jones with cut-off wavelengths of 4.3 μm at 79 K reaching to 2×10^9 Jones and 4.5 μm at 255 K.

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1. Introduction

6.1 Å family of semiconductors (InAs/GaSb/AlSb) is highly desirable for realization of high performance T2LS photodetectors operating at high temperatures (HOT) to be used in infrared applications since it offers flexible combination of constituent alloys. Band alignment of the T2SL system leads to the spatial localization of electrons in InAs and holes in GaSb layers. On the other hand, large gap material AlSb may be used as a carrier barrier whose conduction band offset is higher than that of GaSb and valence band offset is slightly higher than that of InAs. By varying the thickness of constituent materials, the band gap of superlattice can be tailored over a wide spectral range between 2 and 30 μm which covers short-to-very long infrared wavelengths in the atmospheric window [1,2]. There have been numbers of high performance photodetector architectures reported in the literature. These include p-i-n structures [3–5] and heterojunctions such as nBn [6,7], pBp [8], CBIRD [9], M-structure [10] and review of barrier detectors [11].

Proper combination of constituent alloys in the T2SL system and band gap engineering may enable the design of high performance detectors with unipolar electron barriers and the requirement of third generation imaging systems operating at higher temperatures. For this purpose we designed new T2SL photodetector with unipolar electron barrier called N-structure. N-structure is a InAs/AlSb/GaSb based T2SL p-i-n photodetector [12] where two mono layers (MLs) of thin AlSb layers are placed in between InAs and GaSb layers in contrast with M structure [13] having AlSb barriers placed in the GaSb layers of the InAs/GaSb T2SL system. Layer sequences in growth direction and the schematic band diagram of N-structure are shown in Fig. 1(a) and (b) respectively. AlSb layer in the structure acting as a barrier plays important role. First, AlSb barrier pushes carriers towards GaSb/InAs interface to increase electron and hole wavefunction overlap, enhancing type-II optical transition under reverse bias (Fig. 2). Second, acting as an electron blocking barrier, AlSb blocks the thermally generated carriers to reduce the diffusion current. Third, G-R current may also be suppressed down to cryogenic temperatures since AlSb is a large band gap material with a large electron effective mass. Therefore, optical and electrical performances are improved by N-structure design. In this report, we present the theoretical and experimental results for the new design N-structure photodetector. Electronic properties of N-structure such as HH–LH splitting energies are investigated by taking into account the constituent layer thicknesses and possible interface transition layers such as InSb and AlAs between InAs/AlSb interfaces. Experimental results on electrical and optical performance of the N-structure photodetector

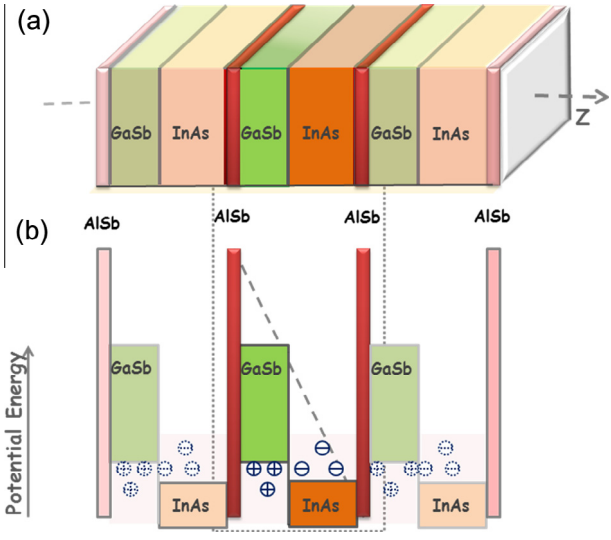

Fig. 1. (a) Layer sequence in growth direction, (b) conduction and valence band profiles for N-structure.