Room temperature performance of mid-wavelength infrared InAsSb nBn detectors


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HIGHLIGHTS

- High temperature performance of MWIR nBn detectors was investigated.
- The quantum efficiency does not change with temperature between 77 and 325 K.
- Detector detectivity is \( D^* = 1 \times 10^9 \) (cm Hz\(^{0.5}\)/W) at \( T = 300 \) K.
- Detectors have potential for room temperature operation.

ABSTRACT

In this work we investigate the high temperature performance of mid-wavelength infrared InAsSb–AlAsSb nBn detectors with cut-off wavelengths near 4.5 \( \mu \)m. The quantum efficiency of these devices is 35\% without antireflection coatings and does not change with temperature in the 77–325 K temperature range, indicating potential for room temperature operation. The device dark current stays diffusion limited in the 150–325 K temperature range and becomes dominated by generation-recombination processes at lower temperatures. Detector detectivities of \( D^*(\lambda) = 1 \times 10^9 \) (cm Hz\(^{0.5}\)/W) at \( T = 300 \) K and \( D^*(\lambda) = 5 \times 10^9 \) (cm Hz\(^{0.5}\)/W) at \( T = 250 \) K, which is easily achievable with a one stage TE cooler.

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and GaAs substrates and covering both the mid-wavelength and long-wavelength infrared (MWIR and LWIR) spectral ranges [6–11]. However, until now the studies of these devices were hitherto limited to cryogenic temperatures.

We have recently investigated the high temperature performance of MWIR nBn InAsSb–AlAsSb detectors and demonstrate their potential for ambient temperature operation [12]. We observe that the responsivity of these detectors does not decrease for temperatures up to 325 K. Dark current at operational bias was found to stay diffusion limited in the 175–325 K temperature range and become dominated by generation–recombination (g–r) processes at lower temperature. This observed temperature dependence of dark current indicates an absence of surface leakage, even in the fully pixelated, unpassivated detectors studied here [13]. The nBn detectors with cutoff wavelength near 4.5 μm were found to stay diffusion limited in the 175–325 K temperature range for temperatures up to 325 K. Dark current at operational bias was observed that the responsivity of these detectors does not decrease even in the fully pixelated, unpassivated detectors studied here [12]. We

![Absorption quantum efficiency QEabs, at T = 77 K and 275 K, and photoluminescence (PL) signal at T = 77 K.](image)

![Minority carrier (hole) carrier lifetime vs. temperature.](image)

![Growth sequence of the nBn photodetector which consists of absorber region consists of a 2 μm thick InAs$_{0.915}$Sb$_{0.085}$ absorber followed by a 0.1 μm AlAs$_{0.1}$Sb$_{0.9}$ barrier. The device structure was grown in a Veeco Applied-Epi Gen III molecular beam epitaxy chamber: The absorbing layer was unintentionally doped, with an estimated residual n-type carrier concentration of ~10$^{15}$ cm$^{-3}$, and the barrier layer was estimated to have residual p-type carrier concentration of ~10$^{15}$ cm$^{-3}$. The doping values were obtained on separate samples specifically grown for Hall measurements. Triple axis X-ray diffraction patterns exhibited sharp peaks for the bulk InAsSb layers with FWHM less than 45 arcsec and clear Pendellosung fringes from the barrier. After growth, the absorption coefficient, the band gap and the minority carrier lifetime of the superlattice were measured using absorption spectroscopy, photoluminescence (PL) and optical modulation response [14] (OMR), respectively (Figs. 2 and 3). The absorption QE was found from the ratio of the transmissions measured in our experiment is for single pass only. The substrate absorption is high in this subbandgap photon energy region because of the free carrier absorption. The measured minority carrier lifetime is τ ≈ 300 ns in the temperature range T = 77–200 K and becomes shorter at higher temperature reaching the value of τ ≈ 100 ns at T = 325 K (Fig. 3).

Standard optical lithography (contact mode) was used to define the patterns for square mesas of area 4 × 10$^4$ μm$^2$. After pattern development, the wafer was etched in a citric acid based wet chemical etching solution to isolate individual devices. The etching depth was approximately 2 μm, resulting in etching into bottom of the absorber and full delineation of single pixel detectors.