GaAs/AlGaAs Broad-band and Multi-band Large Format Long-wavelength Quantum Well Infrared Photodetector (QWIP) Focal Plane Arrays

S. D. Gunapala, S. V. Bandara, J. K. Liu, S. B. Rafol, J. M. Mumolo, and F. M. Reininger

Jet Propulsion Laboratory, California Institute of Technology
4800 Oak Grove Drive, Pasadena, CA 91109, USA
Voice: (818) 354-1880, Fax: (818) 393-4540, Email: sarath.d.gunapala@jpl.nasa.gov

Broadband quantum well infrared photodetector (QWIP) device structure is designed by repeating a unit of several quantum wells with slightly different parameters such as well width and barrier height. The positions of ground and excited states of the quantum well are determined by the quantum well width (L_w) and the barrier height. Since each single set of parameters for a bound-to-quasibound (B-QB) quantum well corresponds to a spectral band pass of about 1.5 μm, three different sets of values are sufficient to cover a 10-16 μm spectral region. The device structure reported here involved 33 repeated layers of GaAs three-quantum-well units separated by $L_B \sim 575$ Å thick $Al_xGa_{1-x}As$ barriers. The well thickness of the quantum wells of three-quantum-well units are designed to respond at peak wavelengths around 13, 14, and 15μm respectively. These wells are separated by $L_u \sim 75$ Å thick $Al_xGa_{1-x}As$ barriers. The sample was grown on a semi-insulating 3-inch GaAs substrate by molecular beam epitaxy. Responsivity spectrum at $V_B = -2.5$ V bias voltage shows broadening of the spectral response up to $\Delta\lambda \sim 5.5$ μm, i.e. the full width at half maximum from 10.5 - 16μm. This broadening $\Delta\lambda/\lambda_p \sim 42$ % is about a 400 % increase compared to a typical (B-QB) QWIP. The 640x512 QWIP focal plane arrays (FPAs) were fabricated by dry etching. The pitch of the FPA is 25 μm and the actual pixel size is 23x23 μm^2. The measured noise equivalent temperature difference (NEΔT) histogram of the FPA at an operating temperature of T = 35 K, bias $V_B = -2.5$ V at 300 K background with f/2 optics and the mean value is 55 mK. The quantum efficiency of the FPA is 9.5%.

The long-wavelength infrared (LWIR) and very long-wavelength infrared (VLWIR) dualband QWIP device structure consists of a 30 periods stack, of VLWIR QWIP structure and a second 18 periods stack of LWIR QWIP structure separated by a heavily doped 0.5 μm thick intermediate GaAs contact layer. The first stack (VLWIR) consists of 30 periods of a 500 Å $Al_xGa_{1-x}As$ barrier and a 60 Å GaAs well. Since the dark current of this device structure is dominated by the longer wavelength portion of the device structure, the VLWIR QWIP structure has been designed to have a B-QB intersubband absorption peak at 14.5 μm. The second stack (LWIR) consists of 18 periods of a 500 Å $Al_xGa_{1-x}As$ barrier and a narrow 40 Å GaAs well. This LWIR QWIP structure has been designed to have a bound-to-continuum intersubband absorption peak at 8.5 μm, since photo current and dark current of the LWIR device structure is relatively small compared to the VLWIR portion of the device structure. This dualband QWIP structure is then sandwiched between 0.5 μm GaAs top and bottom contact layers doped with $n = 5 \times 10^{17}$ cm^{-3}, and has been grown on a semi-insulating GaAs substrate by MBE. GaAs wells of the LWIR and VLWIR stacks were doped with $n = 6\times10^{17}$ and 2.5×10^{17} cm^{-3} respectively. All contact layers were doped to $n = 5\times10^{17}$ cm^{-3}. These dualband FPAs were tested at a background temperature of 300 K, with f/2 cold stop, and at 30 Hz frame rate. Simultaneously measured responsivity spectrum of vertically integrated LWIR and VLWIR dualband QWIP detector shows two separate peaks at 9.1 and 14.4 μm. The experimentally measured NEΔT of LWIR and VLWIR detectors at 40 K are 36 and 44 mK respectively.