High Operability 1024×1024 Long Wavelength Infrared Focal Plane Array Base on Type-II InAs/GaSb Superlattice

A. Haddadi, S. R. Darvish, G. Chen, A. M. Hoang, B-. M. Nguyen, and M. Razeghi[a]

[a]Center for Quantum Devices, Electrical Engineering and Computer Science Department, Northwestern University, Evanston, IL 60208-0893, USA
Corresponding author: razeghi@eecs.northwetern.edu

Abstract. Fabrication and characterization of a high performance 1024×1024 long wavelength infrared type-II superlattice focal plane array are described. The FPA performs imaging at a continous rate of 15.00 frames/sec. Each pixel has pitch of 18μm with a fill factor of 71.31%. It demonstrates excellent operability of 95.8% and 97.4% at 81 and 68K operation temperature. The external quantum efficiency is ~81% without any antireflective coating. Using F/2 optics and an integration time of 0.13ms, the FPA exhibits an NEDT as low as 27 and 19mK at operating temperatures of 81 and 68K respectively.

Keywords: large format focal plane array, infrared imaging, long wavelength infrared, photodetector, type-II superlattice.
PACS: 73

INTRODUCTION

Recently, the type-II InAs/GaSb superlattice (T2SL) material platform is considered as a potential alternative for HgCdTe technology in long wavelength infrared (LWIR) imaging [1, 2]. This is due to the incredible growth in the understanding of its material properties [3] and improvement of device processing [4] which leads to design and fabrication of better devices [5, 6, 7]. After demonstration of small format focal plane arrays (FPAs) in this material system [8, 9], there has been demand for demonstration of large format FPAs with higher angular resolution and a larger field of view. There are numerous challenges during the fabrication of a large format FPAs, such as material uniformity over the whole array, processing techniques, and optical measurement tools. This paper describes a high performance, high operability, large format (1024×1024 pixels) LWIR FPA fabricated with type-II superlattice technology.

FPA ARCHITECTURE AND FABRICATION

The fabrication of large format type-II superlattice FPAs has been described before [10], but some modifications were made to increase the process yield and operability of the FPA. First, metal contacts were deposited using an electron-beam evaporation

15th International Conference on Narrow Gap Systems (NGS15)
AIP Conf. Proc. 1416, 56-58 (2011); doi: 10.1063/1.3671697
© 2011 American Institute of Physics 978-0-7354-0993-4/$30.00

Downloaded 08 Apr 2012 to 141.213.168.31. Redistribution subject to AIP license or copyright; see http://proceedings.aip.org/about/rights_permissions

system prior to dielectric mask deposition. The array of 1024×1024 pixels with 18μm pitch were then etched using an inductively couple plasma (ICP) etching system. ICP etching conditions were optimized for narrow-trench etch with vertical sidewalls. The ICP etching resulted in a 71.3% fill factor, measured with scanning electron microscopy (SEM).

Windows were opened on top of the mesas using an electron cyclotron resonance (ECR) etching system. For bonding the array onto an ISC0404 readout integrated circuit (ROIC), indium bumps were deposited on top of array and ROIC using a thermal evaporation system. Hybridization of ROIC and detector array was performed with an FC 150 flip-chip bonder. Finally, a combination of mechanical polishing and chemical etching was applied to remove the 625μm-thick GaSb substrate completely.

After processing, the FPA was mounted on a 124-pin leadless ceramic chip carrier (LCCC) and was loaded into a liquid nitrogen cryostat designed by SE-IR Corporation. All testing procedures of the FPA were performed using SE-IR Corporation CamIRa infrared FPA evaluation system. The camera frame rate was set at 15.00Hz and an integration time of 0.13ms was determined as reasonable to maximize dynamic range of the camera. Applied reverse biases at 81 and 68K were set at 20mV and 35mV. Characterization was performed with mentioned settings. Figure 1 shows imaging results of FPA at 81 and 68K operation temperature using two-point uniformity correction method.

FIGURE 1. Pictures of a student taken with the 1024×1024 FPA at operating temperature of 81K (left) and 68K (right)

RESULTS AND CONCLUSION

A high performance, high operability LWIR 1024×1024 FPA based on Type II superlattice was demonstrated. Optical characterization showed the 50% cutoff wavelength in responsivity is ~11μm. The optical response of the array was perfectly linear with incoming irradiance, resulting in a median quantum efficiency of 81% at

Downloaded 08 Apr 2012 to 141.213.168.31. Redistribution subject to AIP license or copyright; see http://proceedings.aip.org/about/rights_permissions

7.9μm without any antireflective coating. The FPA exhibited excellent operability and non-uniformity in term of optical response. At 81K the FPA was 95.8% operable with 7.28% non uniformity and the values are 97.4% and 5.71% respectively at 68K.

The median noise equivalent differential temperature (NEDT) was measured as low as 27mK at 81K and 19mK at 68K using F/2 optics and an integration time of 0.13ms. The FPA demonstrated a dark current density of 1.09×10^{-3}A.cm^{-2} and an RA product of 36Ω.cm^{2} at 81K, and a dark current density of 2.78×10^{-4}A.cm^{-2} and an RA product of 309Ω.cm^{2} at 68K operating temperature.

The demonstration of excellent QE operability and uniformity proves that the type-II material system is a promising candidate for the next generation of LWIR infrared imaging systems.

REFERENCES

1. M. Razeghi, US Patent 6864552, "Focal plane arrays in type II-superlattices," (2005).
2. W. E. Tennant, ""Rule 07" Revisited: Still a Good Heuristic Predictor of p/n HgCdTe Photodiode Performance?," *J. of Electron. Mater*., vol. 39, no. 7, pp. 1030-1035 (2010).
3. B. -M. Nguyen, D. Hoffman, Y. Wei, P.-Y. Delaunay, A. Hood, and M. Razeghi, "Very high quantum efficiency in type-II InAs/GaSb superlattice photodiode with cutoff of 12μm," *Appl. Phys. Lett.*, vol. 90, no. 23 (June 2007).
4. E. K.-w. Huang, D. Hoffman, B.-M. Nguyen, P.-Y. Delaunay, and M. Razeghi, "Surface leakage reduction in narrow band gap type-II antimonide-based superlattice photodiodes," *Appl. Phys. Lett.*, vol. 94, no. 5 (February 2009).
5. B. -M. Nguyen, D. Hoffman, P.-Y. Delaunay, E. K.-W. Huang, M. Razeghi, and J. Pellegrino, "Band edge tunability of *M*-structure for heterojunction design in Sb based type II superlattice photodiodes," *Appl. Phys. Lett.*, vol. 93, n. 16 (October 2008).
6. B.-M. Nguyen, D. Hoffman, E. K.-w. Huang, P.-Y. Delaunay, and M. Razeghi, "Background limited long wavelength infrared type-II InAs/GaSb superlattice photodiodes operating at 110 K," *Appl. Phys. Lett.*, vol. 93, no. 12 (September 2008).
7. D. Z. Y. Ting, C. J. Hill, A. Soibel, S. A. Keo, J. M. Mumolo, J. Nguyen, and S. D. Gunapala," A high-performance long wavelength superlattice complementary barrier infrared detector," *Appl. Phys. Lett.*, vol. 95, no. 2 (July 2009).
8. P. Y. Delaunay, B.-M. Nguyen, D. Hoffman, E. K. W. Huang, and M. Razeghi, "Background Limited Performance of Long Wavelength Infrared Focal Plane Arrays Fabricated From M-Structure InAs–GaSb Superlattices," *IEEE J. Quantum Electron*., vol. 45, no. 2, pp. 157-162 (January 2009).
9. M. Razeghi, E. K.-w. Huang, B.-M. Nguyen, S. A. Pour, and P. Y. Delaunay, "Type-II antimonide-based superlattices for the third generation infrared focal plane arrays," *Proc. SPIE*, vol. 7660 (2010).
10. P. Manurkar, S. R. Darvish, B. -M. Nguyen, M. Razeghi, and John Hubbs, "High performance long wavelength infrared mega-pixel focal plane array based on type-II superlattices," *Appl. Phys. Lett.,* vol. 97, no. 19 (November 2010).

Downloaded 08 Apr 2012 to 141.213.168.31. Redistribution subject to AIP license or copyright; see http://proceedings.aip.org/about/rights_permissions