Each year ECS gives up to five Summer Fellowships to assist students in continuing their graduate work during the summer months in a field of interest to the Society. Congratulations to the 2010 Summer Fellowship recipients, whose reports follow.

2010 Summer Fellowship Committee

Vimal Desai, Chair
New Mexico State University

Scott Lillard
Los Alamos National Laboratory

Kalpathy Sundaram
University of Central Florida

Enrico Traversa
National Institute for Material Science

The 2010 Edward G. Weston Summer Research Fellowship — Summary Report

High Uniformity Long Wavelength Infrared Type II Superlattice Photodiodes on a 3″ Substrate

by Binh-Minh Nguyen

Type II InAs/GaSb superlattice[1] has recently gained a lot of interest and is considered as a viable alternative to the HgCdTe technology in the long wavelength infrared (LWIR) detection.[2] The material system is now entering a new development phase where the mass production and cost-effectiveness have become an important consideration. One immediate requirement is to achieve the high quality material on large size substrates, which can economize the material growth, reduce the fabrication cost, and especially allow the realization of large format imagers.

In this work, we demonstrate that high performance Type II superlattice photodiodes are achieved with excellent uniformity across a 3″ in diameter GaSb substrate, which is the largest size of commercially available GaSb wafers.

The material in this work was grown with a Gen II molecular beam epitaxy system capable of holding a 3″ wafer. We used a 3″ in diameter n-type GaSb substrate with a tellurium n-type dopant concentration of 10^{17} cm^{-3} from Wafer Technology Ltd. The growth started with a 0.1 mm thick GaSb buffer layer, then a 1.5 mm thick silicon doped n-type InAsSb ($n = 10^{18}$ cm^{-3}), followed by a 5.5 mm thick n-M-π-p superlattice device architecture[3] and terminated with 0.2 mm thick p-doped GaSb ($p = 10^{18}$ cm^{-3}) capping layer.

Uniformity investigation was performed along one radius as illustrated in Fig.1. Atomic Force Microscopy (AFM) and high resolution X-ray diffraction (HRXD) were scanned on eight locations, denoted (a) to (h), 5 mm apart from each other, while optical and electrical characterization was performed on four processed dies labeled D1 to D4. The summary of the study is presented in Fig. 1b, c, and d.

The average quantum efficiency of optical diodes in each die is shown in Fig. 2a. All diodes exhibit the same cut-off wavelength, the optical spectra line up within the tolerance of the measurement and alignment. Across the wafer, the 50% cut-off wavelength is 10.91 ± 0.04 µm, and the full cut-off wavelength is 12.01 ± 0.04 µm (Fig. 1c). At peak responsivity (~10 µm), the quantum efficiency attains 45% at 50 mV reverse bias. The resulting specific detectivity of 6 x 10^{11} cm $Hz^{1/2}/W$ at 10µm (Fig. 2b) ensures a background limited operation (BLIP) with a 300K background under a 2p field of view as the BLIP detectivity at this wavelength is 4 x 10^{10} cm $Hz^{1/2}/W$.

(continued on next page)

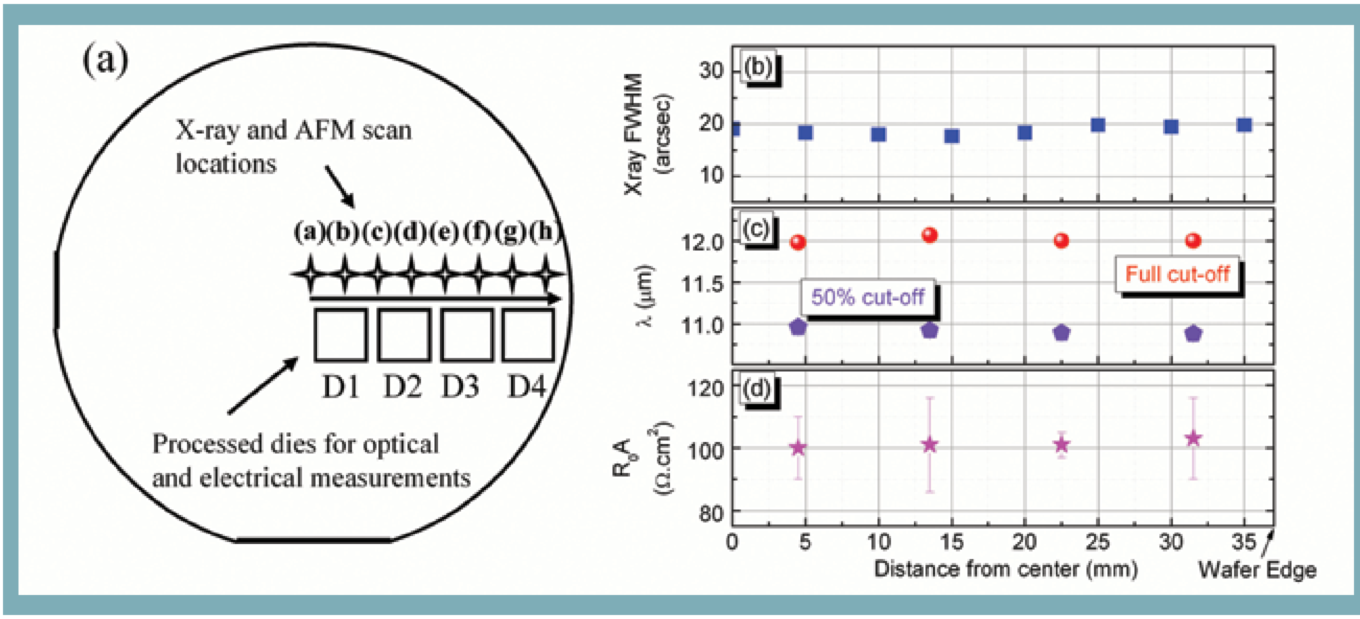

Fig. 1. *Three inch wafer layout (a) and test locations for uniformity characterization; (b) X-ray FWHM of the π-region peak; (c) average R_0A of tested diodes in each die; and (d) full and 50% cut-off wavelength of optical diodes in each die. In (c) and (d), the data points are put in the center of the dies, but represent the whole die area of 6 mm x 6 mm.*

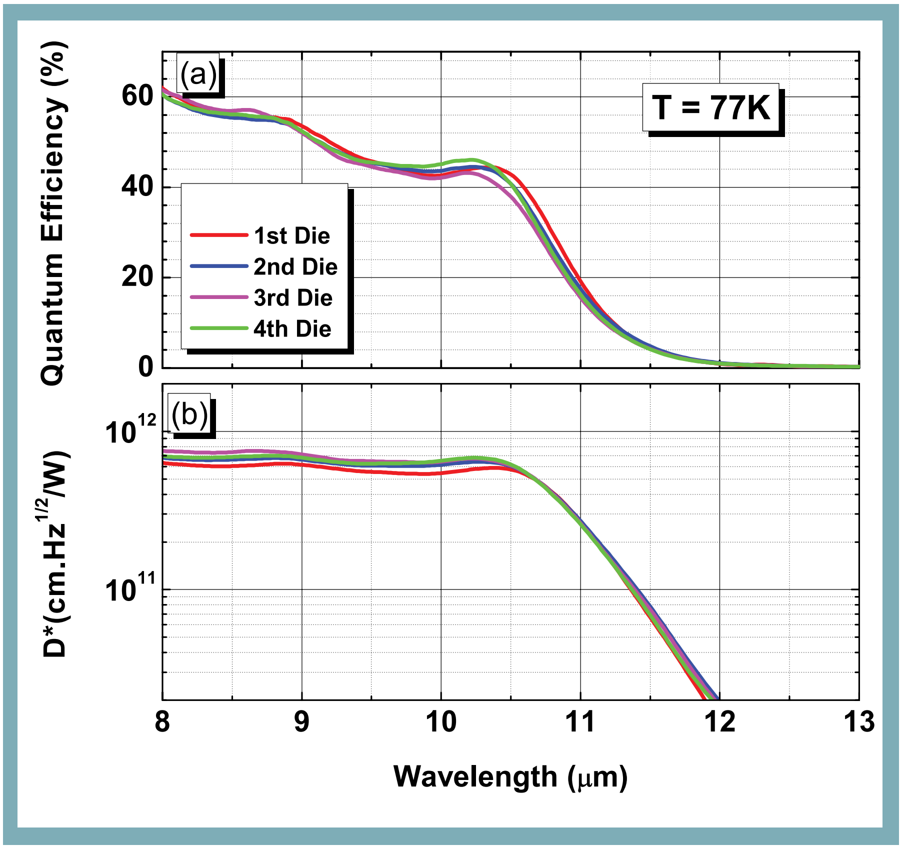

Fig. 1. *Quantum efficiency (a) and detectivity (b) at 50 mV reverse bias of four dies across the wafer.*

The demonstration of high performance LWIR Type II superlattice photodiodes with excellent structural, optical, and electrical uniformity across a 3″ wafer proves that Type II superlattice is a promising materials system, viable for the cost reduction and size expansion of infrared imagers in the third generation.

Acknowledgments

The author gratefully acknowledges ECS for the 2010 Edward G. Weston Summer Fellowship, and Prof. Manijeh Razeghi for her guidance and support.

About the Author

Binh-Minh Nguyen is working toward his PhD in electrical engineering at the Center for Quantum Devices, EECS Department, Northwestern University, under the supervision of Prof. Manijeh Razeghi. Nguyen may be reached at minh-nguyen@u.northwestern.edu.

References

1. G. A. Sai-Halasz, R. Tsu, and L. Esaki, *Appl. Phys. Lett.*, **30**, 651 (1977).
2. M. Z. Tidrow, *Infrared Physics & Technology*, **52**, 322 (2009).
3. B.-M. Nguyen, D. Hoffman, E. K.-W. Huang, P.-Y. Delaunay, and M. Razeghi, *Appl. Phys. Lett.*, **93**, 123502 (2008).