$Al_XGa_{1-X}N$-based engineered intersubband devices

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BIOGRAPHY

Can Bayram: is currently working as a Research Scientist at IBM Thomas J. Watson Research Center, Yorktown Heights, NY, USA.

He received the Ph.D. degree in Electrical Engineering and Computer Science with a focus on Solid State and Photonics at Northwestern University, IL, USA (Faculty Advisor: Prof. Manijeh Razeghi), and B.S. degree in Electrical Engineering from Bilkent University, Ankara, Turkey (Senior Project Advisor: Prof. Abdullah Atalar).

During his PhD, he worked as a part of Center for Quantum Devices and developed high reliability AlGaInN-based optical and electronic devices. As a part of his PhD work, he has also pioneered in energy-efficient environmental semiconductor devices. He has particularly gap- and material-engineered wide band gap semiconductors (AlGaInN and ZnO) in pursuit of higher performance from ultraviolet towards terahertz wavelength optoelectronic devices. During his undergraduate work, he has studied and designed microelectromechanical systems for ultrasonic applications including medical imaging and high-intensity focused ultrasound treatments.

His current research interests at IBM focus on III-V materials and devices. He is mainly involved in the development of high efficiency III-V solar cells, III-N light emitting diodes, and novel growth and fabrication technologies.

He is an expert in metalorganic chemical vapor deposition and material characterization of III-V materials, and fabrication/packaging/measurement of optoelectronic devices. By using metalorganic chemical vapor deposition, he has realized thousands of growths, and using conventional semiconductor fabrication techniques and tools, he has fabricated self-grown devices ranging from ultraviolet detectors, visible light emitting diodes, and intersubband devices to solar cells.

He is the recipient of most distinguished world-wide awards including *Engineer of the Year* (awarded by Boeing Company), *Sustainability Innovator* (awarded by Dow Chemical Company), and *PhD Fellowships* (awarded by International Business Machines (IBM) cooperation and Link Foundation). He is also the awardee of the top recognitions from IEEE Photonics and IEEE Electron Devices societies, SPIE, and ICDD.

He has (co-)authored 27 high-impact journal papers and made 56 total scientific contributions. He is a proposal reviewer for government agencies (DOE), and a reviewer of high impact journals including Applied Physics Letters and Optics Express. He is a member of the IEEE, SPIE, OSA, MRS, APS, AAAS, ECS, IOP, ICDD, ACS, and TASSA.

TECHNICAL ABSTRACT

III-Nitrides ($Al_XGa_YIn_{(1-X-Y)}N$) are a unique group of semiconductors offering a direct bandgap over its entire composition range. The nitride based optoelectronic devices promise high reliability and efficiency as well as clean, robust, and a compact alternative to existing technologies such as those in use in our daily-life (lighting), military defense, or even space exploration. Historically, two key spectral regimes, ultraviolet and visible, have drawn most of the attention for a wide range of commercial applications in sanitation and solid state lighting. Recently, a better control over deposition, e.g., by metal-organic chemical vapor deposition (MOCVD) coupled with better understanding of the material system have enabled the engineering of III-nitride superlattices for applications in infrared to terahertz intersubband devices. MOCVD has been the backbone of the III-nitrides growth and an industry standard for epitaxial growth of compound semiconductors on a crystalline substrate. There has been a sustained improvement in wafer throughput by MOCVD making it cost-effective in mass-production. In this talk, design, growth, and measurement of MOCVD-grown $Al_XGa_YIn_{(1-X-Y)}N$ intersubband devices will be discussed.

We have investigated and engineered AlGaN-based intersubband devices for a wide range of infrared applications. We demonstrate ISB absorption from near- to mid-infrared. Moreover, we demonstrate for the first time, a reliable and reproducible negative differential resistance in GaN-based resonant tunneling diode. Eliminating the piezoelectric fields, improving the material quality, and employing a new nonpolar design enabled this room-temperature and low temperature operational demonstration. Control over intersubband transitions combined with reproducible negative differential resistance at room temperature marks an important milestone in exploring the $Al_XGa_{(1-X)}N$-based engineered intersubband devices as our results open the pathway for fundamental quantum transport studies and more complex device architectures such as quantum cascade lasers. The following key highlights will be discussed: (1) composition dependent variables for each layer (e.g. conduction band offset, effective masses...) and their interaction with one another (e.g. lattice- and thermal mismatch); (2) inherit characteristics of the material system (e.g. piezoelectricity) that can complicate the design; and (3) MOCVD implementation of a well-thought design which requires controlling the composition, thickness, and doping of each layer and a deep understanding of interface stability, interdiffusion, and thinning effects in superlattices.

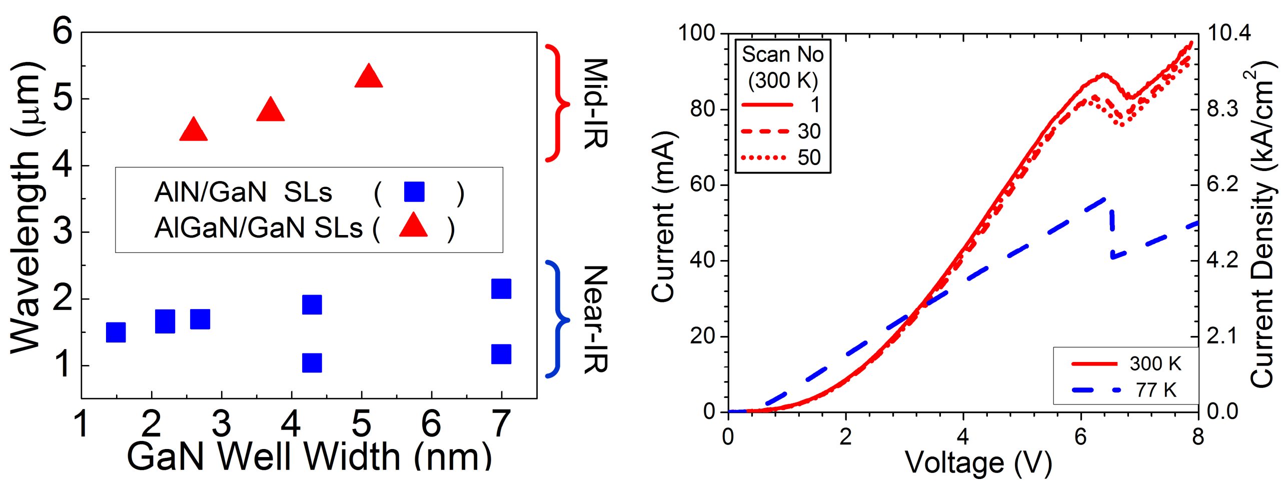

Figure 1: **(LEFT)** Demonstration of intersubband transitions from near- to mid-infrared (1.0 to 6.0 µm) by $Al_XGa_{(1-X)}N$ superlattice engineering. **(RIGHT)** Reliable and reproducible negative differential resistance phenomena observed in $Al_XGa_{(1-X)}N$ resonant tunneling diodes at room temperature (300 K) and low temperature (77 K).

Keywords: AlGaN, superlattice, intersubband devices, resonant tunneling diodes, metalorganic chemical vapor depositon.

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