BCICTS 2024 Short Course

Studio 2&3

Date: Sunday, October 27, 2024
Time: 8:00 AM – 3:00 PM
Topic: How to Grow and Model High Reliability III-V Semiconductor Devices

Speakers:
- Dr. Edwin L. Piner (Texas State University)
- Dr. Markus Müller (TU Dresden, Rohde & Schwarz)
- Dr. Lan Wei (University of Waterloo)

8:00 – 8:45 AM **Breakfast (Primer/Short Course Only)**

8:45 – 8:50 AM **Welcome**
Doug Weiser (Texas Instruments)

8:50 – 10:20 AM
III-V Epitaxial & Thin Film Deposition, Processes and Opportunities
Instructor: Dr. Edwin L. Piner, Texas State University

Abstract: Epitaxial and thin film formation processes on single-crystal semiconductor substrates directly enable the various elaborate III-V heterojunction device designs and, therefore, dictate the resulting electronic or optoelectronic device performance. The III-V heterojunction comprises not only the concept of varying dopant species across the junction, but more importantly, also varying the semiconductor crystals and thereby differentiates III-V device design options and concomitant performance benefits over silicon-based devices. The earliest commercially viable example is the AlGaAs/GaAs junction which exploits the energy bandgap difference to engineer charge carrier confinement. GaAs has a narrower bandgap than AlGaAs, and the AlGaAs bandgap may be 'tuned' by precisely controlling the Al-composition. Several decades of research have led to the development of III-V heterojunction compounds across the entire semiconductor spectrum; B-, Al-, Ga- and In- from column-III, with N-, P-, As-, and Sb- from column-V of the periodic table. This presentation will delve into the topics of III-V epitaxy and thin film deposition techniques, key process considerations, heterojunction challenges and limitations, and offer perspectives on future opportunities.

Edwin L. Piner received his Ph.D. in Material Science and Engineering from North Carolina State University in 1998. He held multiple research & development related positions in industry beginning with ATMI Corp., Epitronics division in Phoenix, AZ, then with Nitronex Corp. in Durham, NC. In 2010 he joined Texas State University's Physics department, coinciding with the launch of the Materials Science, Engineering & Commercialization Ph.D. program where he attained tenure and promotion to Professor in 2013. In addition to his Texas State faculty appointment, Dr. Piner is Chair of the Physics Department. Dr. Piner has numerous publications in the areas of wide- and ultra-wide bandgap materials and devices, is inventor on 33 US patents, and is a member of MRS, ECS and senior member of IEEE.

10:20 – 10:35 AM **Coffee Break**

10:35 – 12:05 PM
Device and Compact Modeling of InP HBTs
Instructor: Dr. Markus Müller, TU Dresden, Rohde & Schwarz

Abstract: High-speed Heterojunction Bipolar Transistors (HBTs) based on III-V semiconductors are highly favorable for mm-wave and sub-mm-wave applications due to their high transconductance, transit frequency (fT), and maximum oscillation frequency (fmax). The most advanced technologies achieve ultra-high fT > 500 GHz and fmax > 1 THz, but compact and TCAD modeling for these technologies lag behind those for SiGe, necessitating further research. This lecture begins with a review of the most advanced high-speed InP HBTs and their experimental characterization. It will then compare competing III-V HBT technologies based on the InP/GaAsSb and InP/InGaAs material systems. Following this, a review of available compact models and critical effects will be provided, highlighting phenomena such as self-heating, non-quasi-static (NQS) effects, and negative differential mobility (NDM) effects. A high-level overview of the parameter extraction process will be given. Subsequently, the necessary physics and material parameters for TCAD simulation of III-V HBTs will be detailed, along with exemplary results. The session will conclude by highlighting open questions in the field.

Markus Müller earned his Master's in Electrical Engineering in 2019, followed by a Ph.D. in 2024, both from TU Dresden. In 2024, he joined Rohde & Schwarz as a device engineer in the MMIC group. His work focuses on III-V semiconductor compact and TCAD modeling, with several publications in high-impact journals. Additionally, Markus co-founded SemiMod GmbH, where he contributed to the extraction of scalable HICUM/L2 libraries for some of the world's most advanced SiGe HBT technologies.

12:05 – 1:15 PM Lunch

1:15 – 2:45 PM
Compact Modeling of GaN HEMTs
Instructor: Dr. Lan Wei, University of Waterloo

Abstract: With the maturing and commercial rollout of Gallium-nitride (GaN) technology, compact modeling has become an essential part of the GaN design and manufacturing ecosystem. In this short course, we start with a brief introduction of the GaN HEMT technology and the needs of compact modeling, and then discuss the general requirements for compact model and challenges for GaN modeling. A few different approaches of compact modeling will also be compared, followed by a brief introduction of the physics-based MVSG GaN HEMT compact model.

Lan Wei received her B.S. in Microelectronics from Peking University, China (2001), M.S and Ph. D. in Electrical Engineering from Stanford University, USA (2007 and 2010, respectively). She worked as a Postdoc Associate in MIT from 2010-2012 and as a Member of Technical Staff with Altera Corporation from 2012-2014. She joined University of Waterloo, Canada, in 2014, where she is currently an Associate Professor. Prof. Wei has intensive experience in device physics-based compact modeling including silicon and GaN technologies, device-circuit interactive design and optimization, integrated nanoelectronic systems with low-dimensional materials, cryogenic CMOS device modeling and circuit design for quantum computing. She was listed as one of the key contributors to the Process Integration, Devices, and Structures Chapter (PIDS) of International Technology Roadmap for Semiconductors (ITRS) 2009 Edition. She is the co-developer of the MIT Virtual Source GaN HEMT (MVSG) Compact Model, which is an Industry Standard approved and supported by the Compact Model Coalition for GaN HEMT compact model. She has authored/co-authored more than 100 peered reviewed publications and served on the technical program committees including IEDM, ICCAD, DATE, ISQED, and BCICTS etc.

2:45 – 3:00 PM Adjourn and feedback