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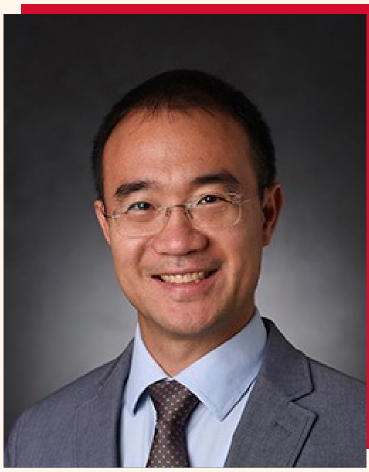
Electro-Thermal Analysis of Ultra-Wide Bandgap (UWBG) Electronics



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ABSTRACT:

To extend further the electrical performance envelope of wide bandgap (WBG) power and radio frequency (RF) electronics based on gallium nitride (GaN) and silicon carbide (SiC), device engineers are actively pursuing the development of generation-after-next ultra-wide bandgap (UWBG) devices. At the time being, aluminum gallium nitride (AlGaN), β-gallium oxide (Ga2O3), and diamond are technologically relevant UWBG materials that have bandgaps larger than that for GaN (3.4 eV). While UWBG devices are built to operate under higher power densities compared to current state-of-the-art WBG counterparts, the thermal conductivities of AlGaN and Ga2O3 are lower than those for GaN and SiC by an order of magnitude. Therefore, self-heating is a major challenge for these UWBG devices. Electro-thermal interactions that lead to self-heating in AlGaN and Ga2O3 devices need to be accurately assessed and understood to accomplish the successful transition from WBG devices to the UWBG technology. In the distinguished departmental seminar, the use of an integrated optical thermography scheme (Raman thermometry, thermoreflectance imaging, and infrared thermography) to study the steady-state and transient thermal characteristics of state-of-the-art UWBG devices will be demonstrated. Tested device technologies include AlGaN-channel high electron mobility transistors (HEMT), Ga2O3 Schottky Barrier Diodes (SBD), lateral Ga2O3 metal-oxide-semiconductor field-effect transistors (MOSFET), and hydrogen (H)-terminated diamond FETs. Results are validated through the use of coupled electro-thermal modeling. In addition, we will report our recent progress on the development of new optical temperature and stress metrology techniques suitable for UWBG electronics including "2-D transducer-assisted Raman thermography."

BIOGRAPHY:

Dr. Choi is an Assistant Professor of Mechanical Engineering at the Pennsylvania State University. He received the B.S. and M.S. degree in mechanical engineering (2005) and automotive engineering (2007), respectively, from Hanyang University, Seoul, Korea. He was with GS FuelCell Co., Ltd., Seoul, Korea in 2007. He received the Ph.D. degree in mechanical engineering from Georgia Institute of Technology in 2013. Then he worked at Sandia National Laboratories as a postdoctoral appointee (2013-2015) and received the NNSA Defense Programs Awards of Excellence (2014). His current research interest includes nanoscale thermal characterization, electro-thermal analysis of wide bandgap electronics and piezoelectric MEMS, thermal management of microelectronics, and semiconductor device reliability. At Penn State, he received the AFOSR Young Investigator Award (2016) and recently awarded the Kenneth K. and Olivia J. Kuo Early Career Professorship (2018).