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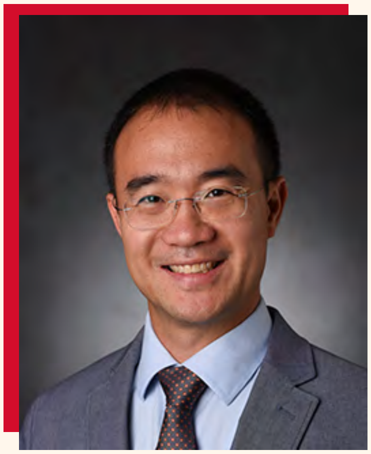
Micro/Nanoscale Electro-thermal Analysis of Ultra-wide Bandgap Electronic Devices



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ABSTRACT:

To extend further the electrical performance envelope of power and radio frequency (RF) electronics, device engineers are actively pursuing the development of generation-after-next ultra-wide bandgap (UWBG) devices. The UWBG materials aluminum gallium nitride (AlxGa1-xN, where x is the Al compsition), β-type gallium oxide (β-Ga2O3), and diamond (which possess a bandgap larger than 3.4 eV), give promise to accomplish such dramatic leap in electrical performance. While UWBG devices are built to operate under higher power densities compared to current state-of-the-art gallium nitride (GaN) and silicon carbide (SiC) counterparts, the thermal conductivities of AlxGa1-xN and β-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 AlxGa1-xN and Ga2O3 devices need to be accurately evaluated and understood to accomplish the successful transition from WBG devices to the UWBG technology. In this distinguished departmental seminar, a process for device-level electro-thermal co-design of UWBG electronics will be demonstrated. First, laser-based pump-probe techniques such as frequency-domain thermoreflectance and steady-state thermoreflectance are used to measure the thermophysical properties of the UWBG materials. An integrated optical thermography scheme (Raman thermometry, thermoreflectance imaging, and IR thermography) is then used to understand the self-heating behavior of the UWBG devices. These experiments are used to build a fully-coupled electro-thermal device model, which is eventually used to design passive and active thermal management solutions.

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 a research staff at GS FuelCell Co., Ltd., Seoul, Korea in 2007. In 2013, he received the Ph.D. degree in mechanical engineering from Georgia Institute of Technology. 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 awarded the Kenneth K. and Olivia J. Kuo Early Career Professorship (2018).