Electro-Thermal Co-Design of High-Power Semiconductor Devices

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Phonon conduction governs heat removal and cooling in a wide range of modern semiconductor devices. Electrons in the active device junction emit phonons, which subsequently carry heat away from the heated electronic region. In many transistors, defects and interfaces near the active junction impede phonon conduction and thus significantly reduce the thermal conductivity of the near-junction materials (by up to orders of magnitude compared to their bulk values), leading to substantial junction temperature rises that degrade device performance and reliability [1]. The problem is arguably most severe in high-power wide bandgap (e.g., GaN) and ultrawide bandgap (e.g., Ga_2O_3) transistors, where local power densities can approach several MW/cm^2 [2,3].

This talk will summarize our efforts to implement electro-thermal co-design for WBG GaN and UWBG Ga_2O_3 electronics. We will discuss (i) the use of laser-based pump-probe thermoreflectance techniques, such as frequency-domain thermoreflectance, to measure the thermophysical properties of device material stacks [4], (ii) an electro-thermal device modeling scheme capable of predicting the temperature-dependent electrical output characteristics as well as the device self-heating behavior [5], and (iii) the use of the electro-thermal model to design novel thermally-aware device structures [6,7].

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