Hot Electrons, Cold Materials: Approaches for Next Generation Semiconductor Devices

As Moore's Law ends, the search for approaches enabling faster computing systems and diversification of semiconductor device applications has significantly intensified. In our group we work on both of these challenges through the lens of two questions:

1) Can hot-electrons be used efficiently in real-world devices?
2) Can materials and devices be grown at low-temperatures and non-epitaxial substrates to enable next-generation devices and architectures?

In the first part of the talk, we discuss our work efficient utilization of non-equilibrium electrons. We show that by carefully considering scattering, transport, and transfer rates, hot electron devices can be rationally designed and implemented. Through two experiments are used to illustrate that hot-electron devices can improve performance over state-of-the-art devices. The first experimental demonstration is a waveguide-integrated graphene photoemitter, where it is shown that hot electrons can reduce the power density needed for efficient emission of electrons by >5 orders of magnitude as compared to standard metal tips. The second device is a metal-insulator-semiconductor electrocatalytic device, where it is shown that hot-electrons can dramatically reduce the onset potential for a variety of electrochemical reactions, including the hydrogen evolution reaction and carbon dioxide reduction.

In the second part of the talk, we discuss our work on growing III-V semiconductors on non-epitaxial substrates using a combination of templated liquid phase growth (TLP) and metal-organic chemical vapor deposition (MOCVD). Specifically, we will discuss the fundamentals of the TLP growth technique, including some recent growth of high-mobility materials at back-end compatible temperatures of <400 ^{o}C, demonstrating unprecedented mobilities. Finally, we will discuss technologically relevant devices which can be fabricated using these materials, including emerging neuromorphic devices.

Professor Kapadia joined the faculty of the University of Southern California in the Ming Hsieh Department of Electrical and Computer Engineering in July 2014. He received his bachelors in electrical engineering from the University of Texas at Austin in 2008, and his Ph.D. in electrical engineering from the University of California, Berkeley in 2013. During his time at Berkeley, he was a National Science Foundation Graduate Research Fellow and winner of the David J. Sakrison Memorial Prize for outstanding research. He has also been awarded an Air Force Young Investigator Grant. His interests lie at the intersection of material science and electrical engineering, with a focus on developing next-generation electronic and photonic devices for computing applications beyond CMOS, such as bio-inspired devices and non-von Neumann computing. Additionally, he is the co-director of a recently created Center for Integrated Electronics and Biological Organisms (CIEBOrg) at USC, focused on fusing electronics and biological organisms at the cell and tissue level.