Multidimensional characterization of Graphene at ultralow temperatures

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It is a challenge to study 2D materials, such as Graphene, MoS2, WeSe2, etc. at temperatures down to 10oK when one considers the wide variety of physical phenomena that have to be applied to get a full picture of the functionality of these materials. A variety of properties of these 2D materials are important to understand at low temperature including their chemistry (Raman), structure, nanoscale photoconductivity, electrical and thermal properties, and near-field optical. The ability to simultaneously measure these properties is especially important so that correlations and interactions between these properties at these low temperatures can be understood. All of these phenomena are common not only to 2D materials but also to carbon nanotubes and related nanomaterials.

This presentation will describe the development of cryogenic multiple SPM probe instrumentation to probe this variety of properties of graphene and other 2D materials. The system that will be described has a completely free optical axis from above and below that is not obscured by electrical or other probes. This design permits on-line AFM-Raman and Tip Enhanced NanoRaman Scattering (TERS). With such a system we have investigated graphene and HfO2 using multiprobe electrical, Kelvin probe, NSOM and on-line Raman. The results have yielded new insights into the chemical changes that are correlated to the electrical conductivity.