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Understanding electronic and mechanical properties of graphene down to atomic scale

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Nanoscale materials are sensitively influenced by atomic scale defects and adsorbates. Such sensitivities can be used to impart various functionalities to develop new device technologies, but they can also introduce a large uncontrollable variability to measurements and mask the intrinsic properties. Using a unique approach to control experiments down to atomic scale, my laboratory performs quantitative measurements on nanoscale materials. In this talk, I will discuss two example scientific problems to demonstrate the capability of our experimental approach. The first problem is on the origin of the variability of field effect mobility of graphene on silicon oxide. This highly debated problem has a large impact on the utility of graphene in electronics. There are two main "suspects" (charged impurities and atomic scale defects) with different carrier scattering strengths. In the absence of any knowledge of the number of scatterers as a function of mobility, arguments on this topic have been rendered non-scientific. Over the last three years, we have developed a new quantitative method to count the number of scatterers in graphene with known carrier mobility and are able to determine that charged impurities are the culprit for the observed variability. The second problem is on the temperature-dependent friction of gold nanoparticles on graphene. This problem is important for nanoscale electromechanical systems (NEMS). By controlling the atomic scale environment between the nanoparticles and graphene, we have determined the friction as a function of temperature. Our result represents the first quantitative measurement of the frictional forces on nanoparticles and paves way for understanding temperature-dependent friction at nanoscale.