Infrared Optical Spectroscopy with Atomic Monolayers

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The discovery of two dimensional crystals—monolayers with atomic thickness—continues to drive exciting developments in physics, chemistry and nanotechnologies. At the core is the construction and detection of novel material structures based on existing or new monolayers. My study is to develop infrared optical spectroscopy for detecting intrinsic properties of the monolayers and their interaction with other nanostructures, such as molecules and photon crystals. Two examples will be shown in this talk. First, I will talk our recent work aiming for nanoscale optoelectronic devices based on monolayer and bilayer $MoTe_2$, the monolayer semiconductor with an infrared bandgap compatible with silicon. We have developed the first atomically thin light emitting diode devices that is coupled with silicon waveguide. Second, I will show you how we can use monolayer graphene to understand microscopic physical and electrochemical processes at electrolyte/electrodes interfaces. Such processes are critical to electrocatalysis, batteries and bioelectrical phenomena, but are very challenging to probe using traditional means. By developing a new infrared vibrational spectroscopy, we are able to unveil the adsorption of methylene group at the interface and a reversible field-induced electrochemical deposition. Our technique can be extended to the resonance vibration frequencies of multiple functional groups that is promising for deeper understanding of chemical electrocatalysis and bioelectrical signal detection.

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