## Exfoliated black phosphorus: the new graphene?

Richard Martel
Département de chimie Université de Montréal, C. P. 6128, Succursale Centre-Ville, Montréal, Québec H3C 3J7, Canada

Elemental nanomaterials, such carbon nanotubes (CNTs), graphene and more recently exfoliated black phosphorus (bP), are studied in my group for their low-dimensional semiconducting properties. Graphene is a semi-metal, whereas bP and CNTs are semiconductors having tunable band gaps in the near infrared, which depend on sample thickness for bP (Eg≈0.3-1.9 eV) and diameter for CNTs (Eg≈0.6-1.1 eV). Not present in bulk materials, the confinement effects also induce unexpected chemical, electrical, and optical properties, which are of interest for applications.

An overview of the general characteristics of quantum confinement will be presented first to highlight the impact on the optical and electrical properties of bP, graphene and NTs. This talk will more specifically present recent studies on exfoliated black phosphorus prepared in a glovebox as mono-, bi- and multilayered bP. Similar to the case of graphene, thin bP layers exhibit strong and unexpected optical resonances in Raman, the so-called D-modes, which can be understood in the context of coherent scattering involving defects and phonons. Because the process relaxes the optical selection rule forbidding access to $q \neq \Gamma$ phonons, the mechanism can produce strong and unexpected spectral features in different conditions, giving for instance anti-resonances in the mid-IR part of the spectrum and second-order Raman modes. Our work show that the defect-mediated resonances are ubiquitous in exfoliated bP, CNTs, and graphene and of interest for potential applications, such as THz wave modulators, nanoprobes and photodetectors. They are also useful to nanoscience because they help analyze interface properties, reactivity, and solve processing hurdles for making electronic nanodevices.