Towards 2D and 1D Heterostructures for Optoelectronics

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The field of two-dimensional materials has been gradually enriched by new structures such as hexagonal Boron Nitride (hBN) dichalcogenides (e.g MoS_2), Black Phosphorus… These nearly zero thickness crystals exhibit fundamental properties that, when strongly interacting in layered heterostructures, can offer new paradigms for photonics, electronics or magnetism.

In the first part of this talk, we focus on Black phosphorus and present some spectroscopic insights of exfoliated layers of this material (1) that highlight the potential of P(black) based Van der Waals heterostructures. First we discuss the quantum oxidation mechanism responsible for the high reactivity of P(black) on air based on combined Raman and TEM-EELS (Electron Energy Loss Spectroscopy) measurements and how this mechanism can be used for preparing suitable samples. Then we show that Electron Energy Loss Spectroscopy (EELS) in the 1eV-50eV range, coupled with *ab initio* calculations, provides a unique approach to the anisotropic dielectric response of P(Black) at the nanoscale. Indeed, thanks to its angular resolution, our EELS set-up implemented in a TEM –STEM machine is capable to probe excitonic effects, optical transitions and plasmons dispersions as a function of the q momentum, for selected crystallographic orientations in the Brillouin zone of different symmetries. Finally we apply this spectroscopy on other 2D materials involved in heterostructures such as hBN and MoS_2.

The quantum confinement phenomena and interlayer effects that are now scrutinized in 2D materials and their heterostructure also fully make sense for 1D hybrids based on SWCNT or BNNT. As an illustration of this consistency, we will show in the second part of the talk, that the control of the 1D aggregation of active molecules inside nanotube, observed by Raman and EELS hyperspectral imaging (2), enables the observation of original and specific optical properties (3). These confinement effects represent a great interest in various applicative fields such as multispectral bio-detection, multiplexing and super-dyes.

[1] Favron et al. Photooxidation and quantum confinement effects in exfoliated black phosphorus. Nature Materials 14, (2015)
[2] Gaufrès et al Isothermal encapsulation of sexithiophene in SWCNT (submitted)
[3] Gaufrès et al. Giant Raman scattering from J-aggregated dyes inside carbon nanotubes for multispectral imaging Nature Photonics, 8, (2014)