Photoluminescence and Photoluminescence Excitation Spectroscopy of Semiconducting Single Wall Carbon Nanotubes and Electric Transport in Graphene.

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I will present in two short courses and overview of two hot topics in the experimental research of carbon nanostructures: (i) Photoluminescence and Photoluminescence Excitation Spectroscopy in Carbon nanotubes; (ii) Electric Transport in Graphene.

Since the discovery of single wall carbon nanotubes (SWNT) in 1991, this nanomaterial has received an enormous attention from the nanoscience and nanotechnology community, not only due to the clear prospects for applications such as novel nanoelectronic and nano-optoelectronic devices, but also because this unique one dimensional (1D) system offered a new possibility for the investigation of novel physical phenomena in low dimensions. In 2002 it was demonstrated that photoluminescence (PL) could be observed in suspensions of isolated SWNTs and, lather on, that PL could also be observed from individual, suspended SWNTs. Since then, there has been an increasing amount of work directed towards the investigation of the optical properties of semiconducting SWNTs by PL and photoluminescence excitation spectroscopy (PLE), and the use of PL and PLE for the qualitative and quantitative identification of SWNTs species within and ensemble of carbon nantubes. In 2005 it was shown that the observed optical transitions are associated to 1D excitons and, from the point of view of optical properties, the rich physics of excitons in SWNTs has received much attention. For instance, it is now clear that excitons and exciton-phonon interactions play a major role in the mechanisms responsible for the emission and the absorption of light in SWNTs. Also, the interaction of SWNTs with their vicinity, which includes the interaction with organic and inorganic molecules, and the modifications in the excitonic system caused by changes in the dielectric constant, can be readily investigated by PL and PLE. In the first short course we will present an overview of the photoluminescence and photoluminescence excitation spectroscopy and the application of these techniques to the study of semiconducting carbon nanotubes.

One of the most important recent developments in the physics of low dimensional systems was the demonstration that high quality, few layer graphene flakes could be produced, either by micromechanical exfoliation of graphite or by surface graphitization of SiC, and that this novel two dimensional system presents high room temperature mobilities and a set of interesting electric transport phenomena such as anomalous integer quantum hall effect observed even at room temperature and non vanishing conductivity when the density of charge carriers approaches zero. For instance, in single layer graphene, the electric transport can be described by considering that the carriers behave as two dimensional massless Fermions. For monolayer graphene this is a consequence of the peculiar linear dispersion relation in the vicinity of the K and K' points of the band structure, were the minima of the conduction band and the maxima of the valence band occur. In bilayer graphene the conduction and valence band are parabolic near the K and K' and a tunable band gap can be generated by the application of an electric field between the layer. One of the major challenges to explore the physics of graphene is the reliable fabrication of multiterminal devices with well defined geometries. The fakes obtained by micromechanical exfoliation are difficult to observe by optical microscopy, have irregular and unpredictable shapes and are randomly distributed over the oxidized Silicon substrate. In order to make devices first the flakes must the found and their position indexed with respect to alignment marks and then a well defined geometry is defined usually by a combination of e-beam lithography and reactive plasma etching. After this electric contacts to the nanomaterial are fabricated, usually by e-beam lithography. Device processing, from localization in the substrate to the fabrication of electric contacts, can also be performed using direct writing photolithography with a laser beam. For this, a laser beam lithography equipment (Microtech LW405) is used. It is also easy to combine the laser witting with e-beam writing for the formation of sub-micron structures or contacts. We will make an overview on the nanofabrication techniques used for making nanoelectronic devices based on carbon nanomaterials, show some of our ongoing work in graphene and also the future prospects and developments that we expect to achieve.