C, B, N and P in Nanotubes: Low Doping vs. Heteronanotubes

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The electronic properties of single-walled carbon nanotubes are outstanding and promising from many different points of view. However, one of the most interesting facts is related to their full dependence on the arrangement of the Carbon atoms. The geometry of this molecular nanostructure is what determines the electronic behavior of the nanotube as a whole. These properties can also be tailored upon various methods. In this presentation we will deal with the case of heteroatom substitution (doping) and formation of heteronanotubes that contain C, B, N and/or P in their structure.

To exemplify this, we will focus on substitutional doping of B in single-walled carbon nanotubes. Here, it is expected that B atoms substitute C atoms without additional atomic rearrangement, leading to the formation of an acceptor state in the SWCNT electronic structure even at very low B concentrations. These nanotubes have recently gained major attention. Interestingly, superconductivity was reported in thin films containing this material. B substitution in the SWCNT lattice is not necessarily uniform, and the formation of B nano-domains has been considered for a long time. For this reason, quantifying the amount and bonding environments of B in the SWCNT lattice has been challenging, particularly when the doping concentration is below 1at%. In B doped samples similar to those used in this study, EELS studies carried out in a TEM failed to detect the substituted B in the C network. For this reason, B induced changes in the intensity of the RBM and shifts in G' band have been used as indirect proof of substituted B in the SWCNT lattice. It will be shown the direct detection of B in the SWCNT lattice from the core level signal recorded with high resolution x-ray photoelectron spectroscopy (XPS). I will show how the corresponding line shape analysis is utilized to identify the different B bonding environments and to correlate the changes in the electronic properties of B doped SWCNTs with Raman spectroscopic studies, elucidating the site selective bonding environments with unprecedented detail even when the B concentration is below 1at%.