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Transmission Electron Microscopy : a tool for the direct determination of carbon nanotube structure

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Abstract – We introduce what are the different strategies of structural characterization of carbon nanotubes by TEM, including merits and flaws, and their application to statistical analysis different samples. First example is the measurement of the helicity distribution of carbon nanotube synthetized by Fe or Co CCVD. Second is the sorting efficiency of carbon nanotube with gradient density ultracentrifugation experiments, for both SWNTs and DWNTs. Those results can be correlated with spectroscopic analysis of carbon nanotubes such as Raman spectroscopy or optical absorption.

Since the discovery of carbon nanotubes by S. Iijima by Transmission Electron Microscopy (TEM), this technique has been shown to be an essential tool for investigating and determining the structure of these nano-objects. Different modes – electron diffraction, high resolution imaging, and electron energy loss spectroscopy – can provide in a direct way quantitative information on structural properties such as diameter, number of layers, helicity, chemical composition, which are mostly difficult to extract from macroscopic spectroscopic measurements which are indirect methods of structural investigation.

This talk will focus on the determination of the atomic structure given either by (n,m) indices or equivalently by the diameter and helicity of a given tube. It will be shown how these parameters can be extracted quantitatively from high resolution imaging and from electron diffraction of individual tubes and how these techniques can be used to perform a statistical analysis of a given sample and evaluate the population of tubes.

TEM analyses are achieved to evaluate and quantify whether the helicity distribution of Fe or Co CCVD synthetized carbon nanotubes [1], or the structural sorting of both single- (SWNT) and double (DWNT)-walled nanotubes. We show that thanks to a statistical analysis of high resolution images, one can determine the tube diameter distribution and its standard deviation [2]. In particular, we have applied the gradient centrifugation technique to a sample containing SWNT and DWNT of different diameters and have evaluated the efficiency of the technique for separating both kinds of tubes as well as the diameter sorting of each kind [3].

Finally, we will discuss how to cross check TEM data with spectroscopic measurements such as Raman, optic absorption and photoluminescence in order to validate these latter.

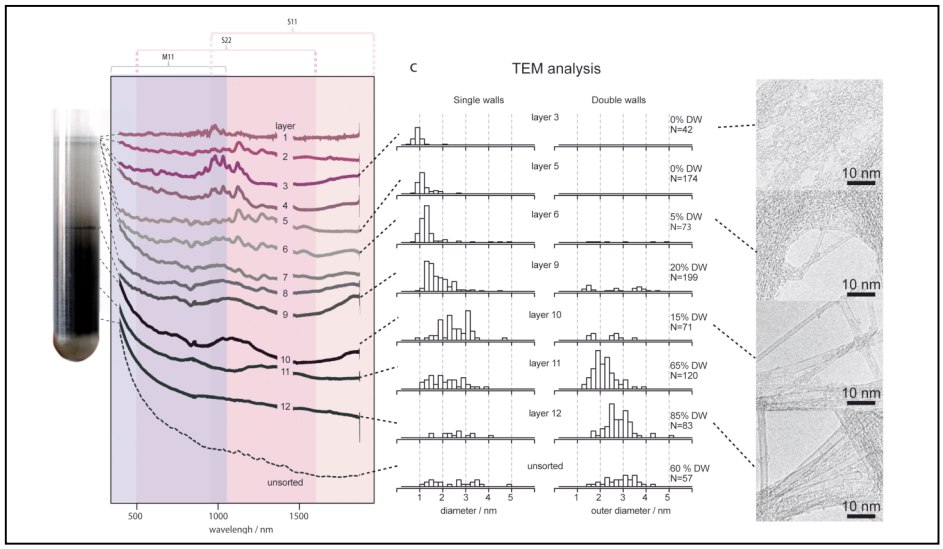

Figure 1: diameter distribution measured by TEM analysis, compared with the optical absorption spectra of a mix of SWNT and DWNT sorted by DGU

References

[1] M.-F. Fiawoo et al, Surface Science (2009)
[2] R. Fleurier et al, Adv.Func.Mater. (2009)

[3] R. Fleurier et al, submitted (2009)