Studies Of The Mechanical Resonances Of Carbon Nanotubes In A Field Emission Configuration

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After composite materials a second research area related to the mechanical properties of nanotubes (NTs) that is attracting increasing attention is nano-electro-mechanical systems (NEMS). The realization of viable NEMS devices based on NTs depends on the characterization, the comprehension and the control of these properties in various environments. We recently showed how mechanical resonances of the nanotubes could be excited, observed and measured in a field emission (FE) configuration [1]. The nanotubes are electrostatically excited as by Poncharal, et.al. [2]. Our work has revealed two new practical tools for NEMS control and detection:

(1) It is possible to electrically vary the resonance frequencies of NTs by up to a factor 10 by the stresses created by electrostatic forces. This direct tuning mechanism has obvious interest for nano-oscillators and has recently been implemented into an actuel NT NEMS device [3].
(2) The FE current varies when the NT is scanned in frequency through a resonance. This is a highly sensitive method for detecting a resonance, even for SWNTs, which a major concern for nanotube NEMS. This technique has recently been used in a Si cantilever NEMS [4].

The FE configuration makes it possible to study the mechanics and parameters of NTs at each modification created by the numerous treatments possible in an ultra high vacuum system, and in principle also of diverse nanowires. In this talk we will expose a preliminary experimental tour of various phenomena of the mechanics of the NTs accessible by this technique and some mathematical elements governing the specific mechanical problem. Measurements of several effects will be presented: the existence of discontinuities and effects of hysteresis in frequency response (see fig. 1(a)), common in the non-linear mechanics, variation of the frequency responses as a function the amplitude of excitation, applied static voltage, time (fig. 1(b)) and temperature.

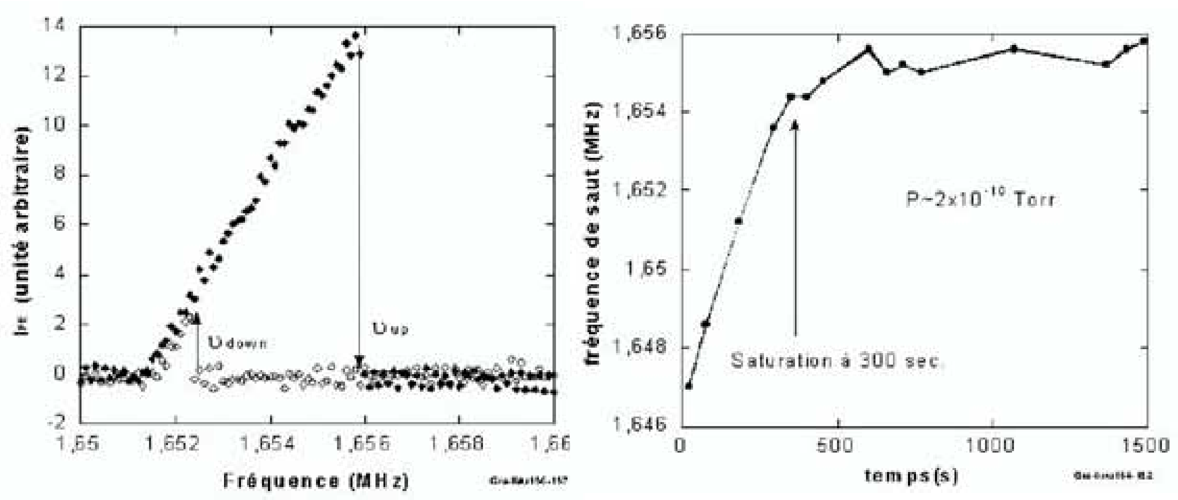

Fig. 1(a). Typical frequency response curve of a MWNT in the field emission configuration. The hysteresis and jumps are signatures of non-linear driving. 1(b) Variation of the resonance frequency in time after flash heating related either to adsorption in a system UHV or an increase in defaults and hence brittleness.

[1] S.T. Purcell, et al., Phys. Rev. Lett. **89**, 276103 (2002).
[2] P. Poncharal, et.al. Science (1999).
[3] V. Sazonova et al. Nature **431**, 284 (2004).
[4] D. V. Scheible et al. PRL **93**, 186801 (2004).