REVIEW OF RESEARCH
ISSN: 2249-894X
IMPACT FACTOR : 5.7631(UIF)
UGC APPROVED JOURNAL NO. 48514
VOLUME - 8 | ISSUE - 9 | JUNE - 2019

THEORETICAL ANALYSIS OF ELECTROMAGNETIC INTERACTION ON SUSPENDED CARBON NANOTUBES

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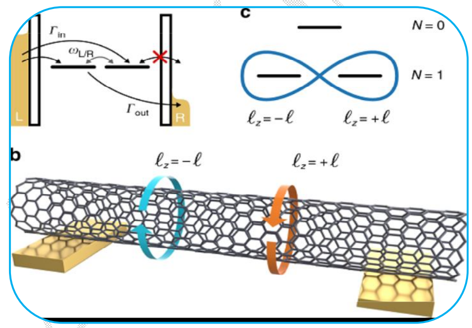

ABSTRACT:
This paper represents a first approximation to the evolution of the system and yields good results, especially when the electromechanical coupling is small, because in that case the system is quasi-linear.

KEYWORDS: *Quasi-linear, Mechanical mode & Bias voltage.*

INTRODUCTION :

The first and clearest effect of the electromagnetic interaction is the softening of the mechanical mode. [1-3]

We will derive the softening at the mean field level, that is, without thinking the fluctuations of the system given by the finite temperature or by bias voltage.

In this regime, we only consider the deterministic evolution given by force $F(x) - kx + F_0$ *[Q (t)].*

FORCE AND EQUILIBRIUM POSITIONS:

In this regime of zero temperature, the force is (we remember that μ_L = V / 2 and μ_R = V / 2):

$$F(x) = -kx + \frac{F_0}{2} + \frac{F_0}{2\pi} \sum_{\alpha = L,R} \text{aractan} \frac{\mu_\alpha - \varepsilon_0 + F_0 x}{\Gamma} \quad (1)$$

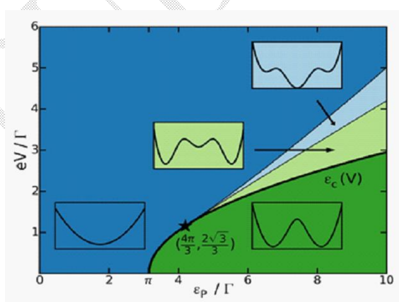

Figure 1: Full phase-diagram for the stability of the potential potential in the $eV - \varepsilon_P$ plane

An equilibrium position is defined as the solution of the equation F (x) = 0. By inspection one can verify 0 = F 0 2 /εthat x 0 = F 0/2 k is an equilibrium position if the electronic level takes the value $2A\varepsilon_P / 2$ We call this symmetric gating because the occupied and unoccupied energy levels are available to the electrons are symmetrical with respect to the zero in energy . In other words, it represents the new electron-hole symmetry point of the system.[1–6]

We devote to the study of the symmetric gating, while the effects of an asymmetric. The equilibrium position in x is $_0$ is not always a stable one Its nature is in influenced by the sign of the coefficient of the smaller term in the expansion of the potential around x [7-10] To know when this condition is satisfied, we express the forces of the dimensionless variable y $= F_0 (x - x_0) / \Gamma$, for which one can expand in y :

$$F(y) = F_0 \sum_{n=0}^{\infty} a_{2n+1y}{}^{2n+1}, \qquad (2)$$

with

$$a_n = \frac{1}{\pi n!} \arctan^{(n)}\left(\frac{V/2}{\Gamma}\right) - \frac{\Gamma}{\varepsilon p}\delta_{n,1.} \qquad (3)$$

From here, the effective potential follows immediately

$$U(x) = -\int^{x} F(x')dx' = -\Gamma \sum_{n=o}^{\infty} \frac{a_{2n+1}}{2n+1} y^{2n+2}. \qquad (4)$$

Therefore, the minimum in $y = 0$ is stable if $a_1 < 0$. This determines the region $\varepsilon_P < \varepsilon_c$ (V), where the critical value $\varepsilon_c(V)$ is defined as

$$\varepsilon_c(V) = \pi\Gamma\left(1 + \frac{V^2}{4\Gamma^2}\right). \qquad (5)$$

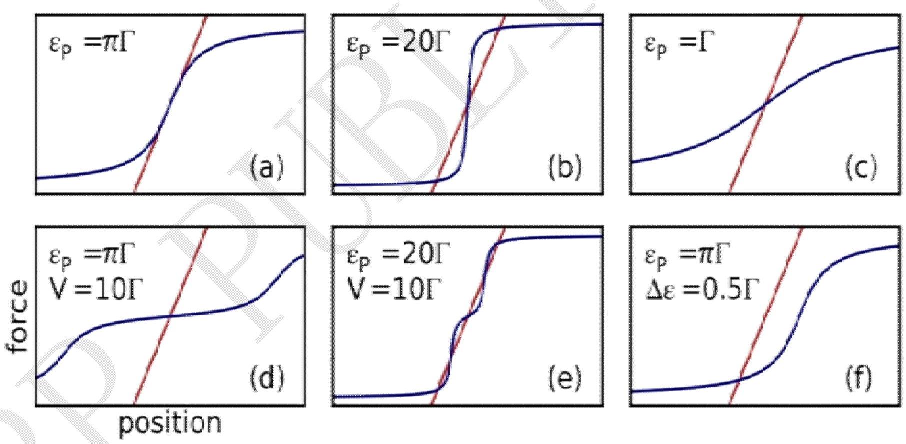

Figure 2: Graphical solution of Eq. (1) with elastic force in red and electronic force in blue.

The graphical solution of the equation F (y) = 0 con firms that is always a solution at $y = 0$, provided the gating is symmetric (see Figure 2) . However, it also shows that situations with three or five solutions may occur

Since the function is regular, the stationary points correspond to the alternating maxima and minima of the potential. Also, the system is bounded and symmetric, so the most external solution This proves that the region of the phase diagram $\varepsilon_P > \varepsilon_c(v)$ the potential is two symmetric minima (see Figure 1) . Also, it proves that three solutions imply a maximum in y = 0, while one or five solutions a minimum.

The situation is more complex when the origin is stable ($a_1 < 0$), because the total number of solutions is defined by the next coefficients in the tailor series. When $a_3 < 0$, only one solution is allowed, while we are still having one or five solutions. By direct calculation one finds that $a_3 < 0$ for $V < 2$

MECHANICAL RESONANCE FREQUENCY:

Starting from the expression of the force, we can define a mean field frequency ω_m that describes the frequency of oscillation around the constant equilibrium position. It is defined as

$$\omega_m^2 = -\frac{1}{m}\frac{dF}{dx}\bigg|_{x_{\min}}, \qquad (6)$$

By analogy with the definition of the resonance frequency of a harmonic oscillator. It takes the value

$$\begin{cases} \omega_m^2 = \omega_0^2\left(1 - \dfrac{\varepsilon_\Gamma}{\varepsilon_c}\right) & \text{for } \varepsilon p \le \varepsilon_c, \\ \omega_m^2 \approx 2\omega_0^2\left(\dfrac{\varepsilon_p}{\varepsilon_c} - 1\right) & \text{for } \varepsilon p \gtrsim \varepsilon_c, \end{cases} \qquad (7)$$

where we recover the;

Eq. (6) explains the softening of the oscillator that has been measured in several experiments. Interestingly, at $\varepsilon_P = \varepsilon_c$, this mean field resonance frequency ω_m goes to zero. The corrections due to fluctuations will be the dominant term.

POTENTIAL OF THE SYSTEM:

At zero temperature, vanishing bias voltage, and symmetric gating, the full analytical expression of potential energy reads

$$U(y) = \frac{\Gamma}{2\pi}\left[\frac{\pi\Gamma}{\varepsilon_p}y^2 - 2y\arctan y + \log\left(1 + y^2\right)\right], \qquad (8)$$

again if = $F_0 (x - Q_0) / .\Gamma$

Expanding it around y = 0, as we have done in Eq. (4), we have at the fourth order

$$U(y) \approx \frac{\Gamma}{2\pi}\frac{\pi\Gamma}{\varepsilon_p}\left[\left(1 - \frac{\varepsilon p}{\pi\Gamma}\right)y^2 + \frac{1}{6}\frac{\varepsilon p}{\pi\Gamma}y^4\right] \qquad (9)$$

One can verify that, along with the critical line $\varepsilon_P = \varepsilon_c(V)$, the second-order term of potential disappeishes and $U(x)$ can be approximated by a fourth-order potential.

CONCLUSION

In this paper, different aspects for electromagnetic interaction has been discussed such as potential of the system, mechanical resonance frequency.

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