Editorial

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Brief on Nanowire in Field Emission

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Editorial Note

Nano Electro Mechanical Systems (NEMS) based on mechanical resonances of nanostructures, such as nanotubes or nanowires, are drawing interest from both technical and scientific communities. Their extremely small dimensions make them highly sensitive to external electrostatic perturbations and, due to their outstanding mechanical properties such as strong Young's modulus or high quality factor Q their mechanical response can exceed the quality of electrical signals from purely electronic devices. As well, NEMS oscillators have been proposed for use in ultrasensible mass detection or radio frequency for wireless communication.

Among the great variety of these nanocomponents, NEMS based on singly clamped cantilevers in Field Emission (FE) configuration have recently proven original capabilities. In this FE configuration, a nanotube or nanowire is connected to the cathode and a DC voltage V is applied between the cathode and an anode positioned in the vicinity of the nanostructure. For a voltage Uref, the electric field at the nanowire apex, enhanced by its tip effect, becomes sufficient to extract electrons by tunnelling effect. This quantum process results in a field emission DC current depending on the applied voltage V.

One of the originalities when using cantilevered nanostructures as field emitters is that their extreme mechanical sensitivity reveals dependence of the FE current on the position of the emitter. The new NEMS applications in this configuration take advantage of this original coupling between the emitted current and the position of the emitter apex in its environment. One can also mention that this configuration is well adapted for mechanical studies on nanotubes and nanowires, as the resulting patterns of the emitted electrons give a direct projection of the apex motion on a phosphor screen. This allows investigations of linear and nonlinear behaviour of nanocantilevers.

A particularly interesting application recently shown by some researcher, using highly resistive nanowires, has been the observation of self-oscillations resulting from the electromechanical interactions between the electrical and mechanical properties of the cantilever. They showed that above a critical DC voltage, the nanostructure starts to oscillate resulting in an AC field emission current. The realization of an AC current generator at the nanoscale simply commanded by a DC voltage has interesting potentialities in autonomous nanosystems such as smart dust applications. From a theoretical point of view, this system exemplifies an original coupling that appears at the nanoscale between mechanical behaviour, electrostatic environment and FE properties.

This paper gives a low-dimensional model to simulate the nonlinear behaviour of a cantilevered nanowire in field emission. The numerical method was presented with a bi-articulated nanowire but can easily be adapted to another kinematics for obtaining quantitative results rather than qualitative ones. We here highlighted the ins and outs of this electromechanical system resulting from an original coupling between the nanostructure nonlinear motion, its electrostatic environment and electrical contributions coming from the FE current emergence. For a given applied voltage, the linear stability of the static equilibrium results from the interplay of the FE current dependence on the nanowire absolute position and its dependence on the emitter's voltage. This interplay, illustrated by the Fowler-Nordheim formula, is very sensitive to external parameters and the same is also true for the emergence of oscillations. We showed that a minimum initial angular tilting, a high Q factor and a sufficiently high electrical resistance are required to trigger instability.

For a threshold of applied voltage, the direct integration of the nonlinear electromechanical governing equations simulates the limit cycles of the system pointing out the possibility of DC/AC conversion in this electromechanical device. The dimension of the electromechanical system and its strong linearities are sufficient to display complex behaviour of the limit cycles when increasing the control parameter v. Future work would focus more on this original Hopf bifurcation to improve the physical understanding of the self-oscillations.