Nanoresonator based on relative vibrations of the walls of carbon nanotubes

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A new type of ultra high frequency nanoresonator based on the relative vibrations of the walls of carbon nanotubes is proposed. The resonator could be used for the detection of absolute mass of nano-objects with atomic resolution. The scheme of mass nanosensor is suggested. The resonance can be determined through registering a change in the gate-nanotube capacity, which depends on the amplitude of vibrations of the wall with the attached nano-object. The change in the capacity causes the change in the current through the nanotube that can be measured.

Density functional theory is used to compute the interaction energy of the walls of carbon nanotubes as a function of their relative position (see [1] for details of calculation technique). The computed interaction energy curves are fitted analytically and further exploited in the calculations of the frequencies of small relative axial and rotational vibrations of the walls for the set of double-walled carbon nanotubes (DWNT) with chiral commensurate walls. These frequencies are found to be in the range 70−700 GHz and do not depend on the length of the walls for nanoresonator with the vibrating wall which is shorter than fixed one. The shear strength for relative motion of walls is also calculated. Experimental measurements of calculated quantities using terahertz vibrational spectroscopy and atomic force microscopy techniques are suggested.

To estimate the sensitivity of mass detection by the proposed mass nanosensor and the quality factor of the resonance, microcanonical molecular dynamics simulations of the model resonator based on the (9,0)@(18,0) DWNT with the movable outer wall have been performed. The estimated average values of the resonator Q-factor are Q=160 at 77K and Q=540 at 4.2K, with the mass sensitivity of 4.5 and 1.3 carbon atoms at 77K and at 4.2K, respectively.

Recent advances in techniques for building of nanotube-based nanoelectomechanical systems are discussed.

[1] E. Bichoutskaia, M.I. Heggie, A.M. Popov, Yu.E. Lozovik, *Phys. Rev. B* **73**, 0454359 (2006).