The piezoresistance effect in carbon nanotubes and graphene ribbons

O.S. Lyapkosova, N.G. Lebedev

Volgograd State University, University Avenue, 100, Volgograd, 400062 Russia
lyapkosovaolga@mail.ru

The piezoresistance effect is in the change of the electroconductivity of the semiconductors caused by the anisotropic deformation of a crystal [1]. The piezoresistance effect in single walled carbon nanotubes [2] of two geometry modifications "arm-chair" and "zigzag" has been investigated. The electronic structure of nanotubes has been simulated within the framework of π-electronic approach and Hubbard's model [3] taking into account only for the energy of electrons in carbon atoms and the energy of the transition between the neighbor lattice units. The band structure of carbon nanotubes is described by the dispersion relation for the graphite sheet [2]:

$$\varepsilon(k_x, k_y) = \pm\gamma_o \left\{1 + 4\cos\left(\frac{\sqrt{3}k_x R}{2}\right)\cos\left(\frac{k_y R}{2}\right) + 4\cos^2\left(\frac{k_y R}{2}\right)\right\}^{1/2}, \quad (1)$$

where γ_0 is the transfer integral, k_x and k_y are the wave vector components, one of which is continuous along the tube axis and another is quantized along the tube circumference according to "arm-chair" or "zig-zag" geometry type, R is the interatomic distance, which has beendefined to be equal 1.44 A.

The bulk and linear deformations have been simulated by small changes of the bond length R. The band structure change caused by small deformation can be expressed within the framework of the linear approximation as following:

$$\varepsilon(k_x, k_y) \approx \varepsilon_0(k_x, k_y) + R\frac{\partial\varepsilon}{\partial R}\delta, \quad (2)$$

where $\varepsilon_0(k_x, k_y)$ is band structure of the ideal carbon nanotube expressed by the formula (1), δ - relative change of carbon-carbon bond length.

The band structure changes, which influence on conducting properties of carbon nanotube and graphene and cause the piezoresistance effect, have been analyzed. The effect can be used for the identification of single walled carbon nanotubes and the development of electro-mechanical energy transformers.

The work is supported by Education Ministry of Russian Federation (project NK-16(3)).

References

[1] G.L. Bir, G.E. Pikus, Symmetry and deformation effects in semiconductors, Moskow, “Nauka”, 1972, 584 p. [in Russian]

[2] P.J.F. Harris, Carbon nanotubes and relative structures. New materials of twenty-first century, (Cambridge University Press, 1999; 336).

[3] Yu.A. Izyumov, N.I. Chaschin, and D.S. Alekseev, Theory of Strongly Correlated Systems: Method of Generating Potential (Moscow, NITs “Regulyarnaya i Khaoticheskaya Dinamika,” 2006) [in Russian].