PHYSICAL MODEL OF THE THERMOELECTRIC CONVERTER ON SEMIMETAL CARBON NANOTUBES

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Introduction

The work presented the theoretical studying of the coefficient of thermoelectric power of the carbon nanotubes. Calculated the temperature dependence of the coefficient of thermoelectric power of semimetal carbon nanotubes. Result of our calculation is in good agreement which experiment. The simple physical model of the thermoelectric converter on semimetal carbon nanotubes is offered.

Temperature dependence of coefficient of thermoelectric power

The simple model of a graphite layer with linear dependence of density of states on energy is used:

$$N(E)= B\cdot|E|, \quad B=\text{const}. \qquad (1)$$

Consideration cylindrical shape of carbon system of nanotubes leads to occurrence of resonant levels in spectrum p- electrons at energy $|\mathbf{E_n}|$ (n-integer). It is established, that energy $|\mathbf{E_n}|$ depends on diameter of a nanotube. Broading of level $|\mathbf{E_n}|$ in the given research is approximated by Gaussian function:

$$\delta N(E) = \frac{C}{\Gamma}\exp\left(-\frac{4\ln(2)\cdot(E-E_n)^2}{\Gamma^2}\right), \qquad (2)$$

with half-width of Γ depending on a degree of perfection (or quantities of defects) of a nanotube. In the formula the normalizing constant C is determined by concentration of free p-electrons (holes). The full density of state inπ-sub-band near to Fermi's level is (in view of Eq.(2)):

$$N(E)= B\cdot|E|+\delta N(E). \qquad (3)$$

With this simple model in case of two types of a charge by means of the equation of Bolzman used the coefficient of thermoelectric power α of nanotubes calculated.

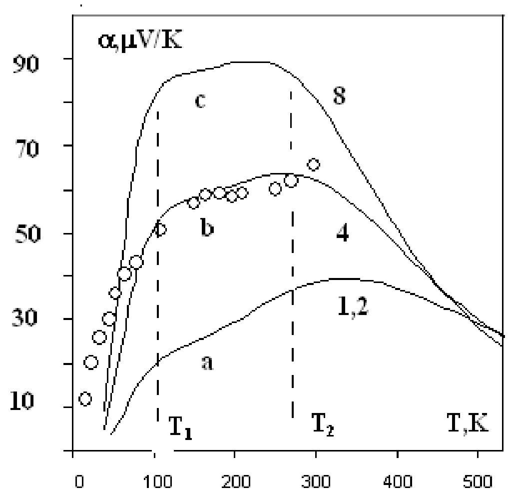

Fig.1. Temperature dependence of the coefficient of thermoelectric power α of carbon nanotubes. Figures on curves a, b, c mean concentration C of free charges in terms of: 10^{19} sm^{-3}. Vertical dashed lines demonstrated a temperature interval in which the coefficient of thermoelectric power is maximal. By circles experimental results from [6] are shown.

The calculated temperature dependences of the coefficient of thermoelectric power are presented in Fig.1. Letters a, b, c on curves mean concentration C of hole in terms of: 10^{19} sm^{-3}. Fermi level make in a valence band on depth $|\mathbf{E_F}|$=0,07 eV, and a resonant level $\mathbf{E_n}$ with a parameter Γ= 0,01 eV localized at energy $|\mathbf{E_n}|$ =0,1 eV. With this values $\mathbf{E_F}$, and $\mathbf{E_n}$ obtained the maximal coefficient α. The reason of shift of a Fermi level in valence or conductive band are discussed. Donor- and acceptor-doping changed sign of the coefficient of thermoelectric power of nanotube and temperature dependents are symmetries concerning an axis of temperatures. This important result symmetrical valence and conductive π-sub-band and is good agreement with data of experiments [3,4].

Model of the thermoelectric generator

As is known, the efficiency of thermoelectric materials *z* determined a possibility used of a material for practical application in thermoelectric generator or refrigerators:

$$z = \frac{\alpha^2 \sigma}{\chi},$$

where α - coefficient of the thermoelectric power, σ - specific electric conductivity and χ - specific heat conductivity.

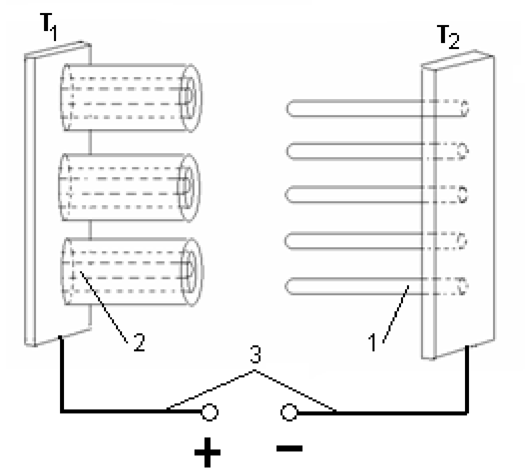

Fig. 2. The schematic diagram of a thermoelement. By figures are designated: 1 - ordered single-wall nanotubes attached by the plate with temperature of T_2. 2 - the open multi-wall nanotubes attached to a plate with temperature of T_1.

Usually value of zT (T – working temperature of the device) does not exceed 0,8. Presumably for nanotubes this value zT can be increased in 5–8 times by decreased of specific heat conductivity and possible increase of the specific electric conductivity. [5]. In particular, decrease of the specific heat conductivity χ due to making of a small vacuum interval in a thermoelement is offered (see fig. 2). It is known, that nanotubes have the anomalous big field-emission [6]. In our physical model of a thermoelement, suggested the contact of carbon nanotubes to break off . Small vacuum interval can not significantly exchanged conductivity of all system because nanotubes have the great field-emission. At the same time the vacuum gap between nanotubes will decrease of the specific heat conductivity of a thermoelement.

Conclusion

In this work the equation of Bolzman used for the coefficient of thermoelectric power α of semimetal carbon nanotubes calculated. Influence donor or acceptor on sign and value of thermoelectric power are discuss. The dependence of α from the temperature is usually bell-shaped. The calculations are in good agreement with the experiment.

The simple physical model of the thermoelectric generator or (and) refrigerator on a semimetal single-wall and multi-wall carbon nanotubes present.

References

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