PROCEEDINGS OF THE INTERNATIONAL CONFERENCE
NANOMATERIALS: APPLICATIONS AND PROPERTIES
Vol. **3** No 2, 02NEA04(2pp) (2014)

Energy Conversion of an Environmental Thermal (T~300K) Energy into Electrical Energy by Nanoscale Field Emission Systems

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(Received 25 May 2014; published online 29 August 2014)

Physical and numerical modeling of the field emission energy conversion (FEEC) nanoscale systems is carried out. It is shown, that FEEC systems with a cathodes based on an array of carbon nanotubes or quantum dots (at a temperature of the cathode T ~ 300 K) are able to realize effective conversion of an environmental thermal energy into electrical energy.

Keywords: Energy conversion, Field emission, Nanostructures, Nanotubes, Quantum dots

PACS numbers: 84.60. – h, 79.70. + q, 85.45.Db

1. INTRODUCTION

Achievements of last decades in area of micro-and nanotechnology promoted revival of scientific interest to a problem of direct transformation of thermal to electric energy. As a result of development of nanotechnology methods researchers had new possibilities for use in the workings out of the fundamental physical phenomena which remained earlier not claimed. In particular, reproduced formations of quasi 1D and 2D nanostructures have allowed to essentially raise efficiency of thermoelectric materials and devices [1, 2] and also to start working out of "solid-state" thermionic energy converters [3].

In the present work was studied the possibility to create effective devices capable of converting environmental thermal energy (at T ~ 300 k) into electrical energy.

2. PHYSICAL AND NUMERICAL MODELING OF THE FEEC NANOSCALE SYSTEMS

As is known, electron emission from a condensed matter surface can be achieved, in particularly, via two mechanisms: tunneling and thermionics.

At present, the thermionic phenomenon is widely used for direct conversion of heat energy into electrical energy [4]. Converting thermal energy to electrical power using thermionic emission mechanism is achieved by generation of an electron current from the emitter to collector and production of a voltage potential between electrodes due to the potential energy difference between the electrodes [4].

In [5-7] was first proposed and justified the concept of building effective systems for direct conversion of heat energy into electrical energy through the tunnel and thermal field electron emission mechanisms. In these works [5-7] opportunities for improving technical characteristics of the vacuum thermal–to-electrical energy convertors on a bases of the thermal field emission phenomenon [8-10] by means of the following factors: (i) by structuring emission surface of the convertor electron source and (ii) by physical "separation" of the two interrelated processes – electron emission and electron transport processes was offered, investigated and developed.

To implement a process of "separation" (ii) is proposed to introduce into traditional thermionic two electrodes electron-optical system additional extracting electrode, creating on the cathode surface an electrostatic field large enough to compensate space charge field and initiate thermal field emission process. Additional extracting electrode allows create necessary conditions for thermal field high intensity e-flux emission. For the subsequent transport of the e-flux from the structured cathode surface to collector surface with a potential that approximately equal to contact potential difference (between the cathode and the convertor collector) it was suggested to use a magnetic isolation method. Magnetic isolation helps prevent direct deposition (collisions) of an emitted electrons with the extracting electrode [5-7].

Physical and numerical modeling of an electron emission and transport processes for two different FEEC converter prototypes were carried out. Simulation results are shown in Figs. 1, 2. Следует отметить здесь, что для приведенных на рисунках 1и 2 конфигураций электродов FEEC систем метод магнитной изоляции не использовался.

It should be noted here that for the figures 1 and 2 electrode configurations of FEEC systems, (see Figs. 1 and 2) magnetic isolation method is not used.

Thus, as a result of the carried out physical and numerical modeling it was shown that FEEC systems with a cathodes based on an array of carbon nanotubes or quantum dots (at a temperature of the cathode T ~ 300K) are physically able to realize effective conversion of an environmental thermal energy into electrical energy.

In other words, the proposed energy conversion principle allows create a highly efficient devices for direct conversion of an environmental thermal (T ~ 300K) energy into electrical energy.

AKNOWLEDGEMENTS

This work is supported by the Russian academy of sciences.

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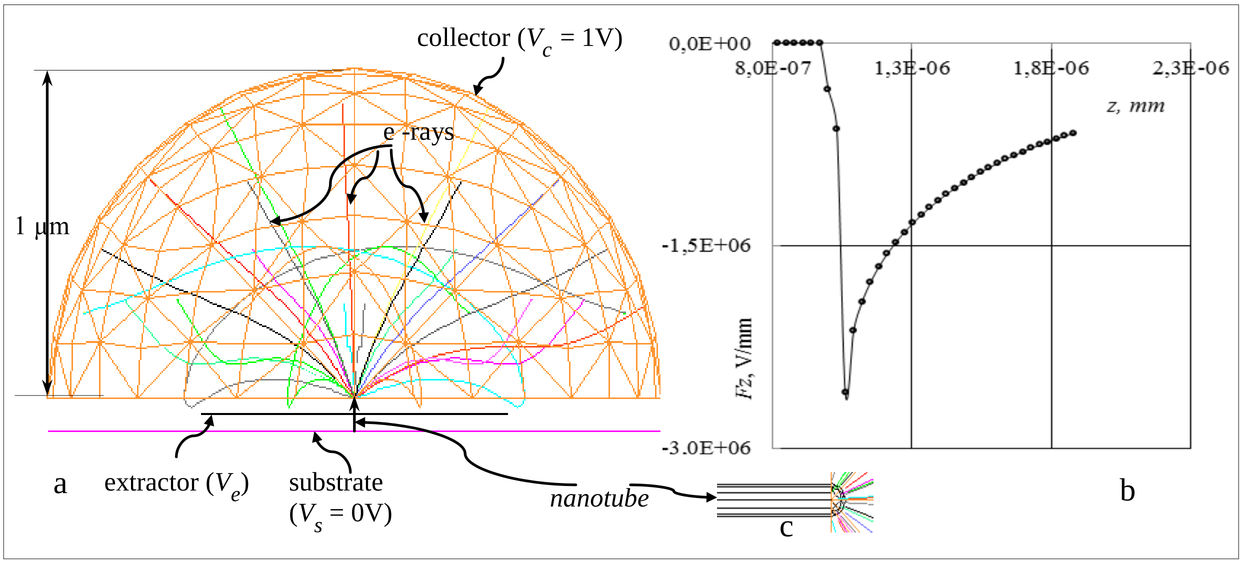

Fig. 1 – Numerical model of the field emission energy converter with a "nanotube" as an electron source
a – energy converter electrode (2D) configuration, b - self-consistent electric field distribution on the nanotube axis, c – nanotube (cathode) model; (nanotube top radius ρ = 1 nm, h/ρ = 100; extractor has a shape of a disk (D_1 = 0.5 μm) with a hole (D_2 = 50 nm); T_e = 300K, Φ_e = 3 eV, V_e = 3.6 V; field emission current 0.53 nA; current density 8.4E+03A/cm²; average cathode brightness is equal to 2.6 E+03 A/(ster·cm²)).

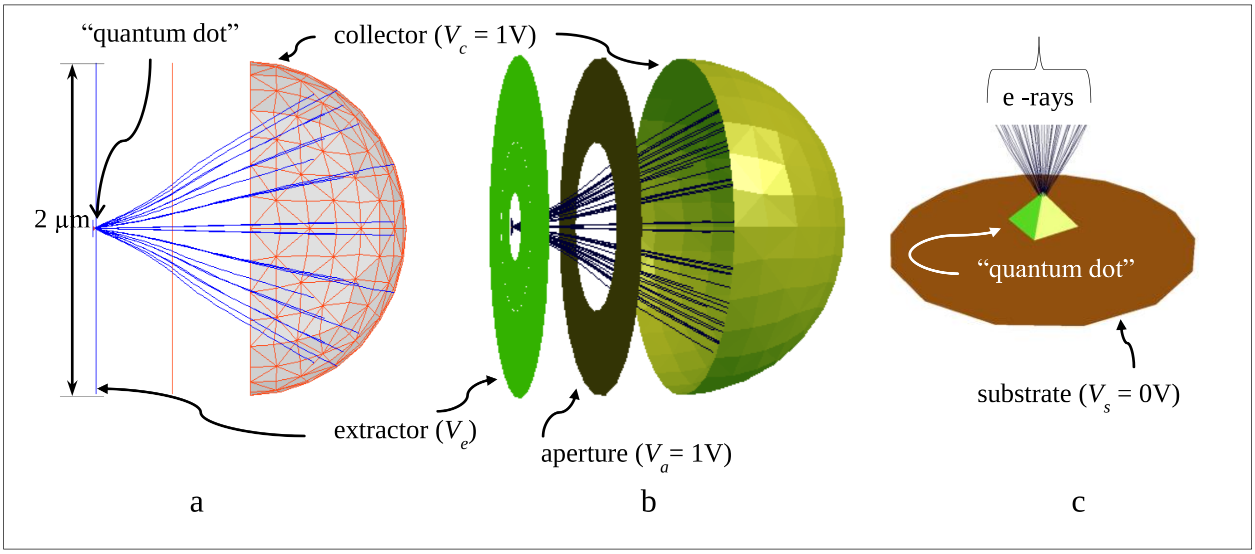

Fig. 2 – Numerical model of the field emission energy converter with a "quantum dot" as an electron source
a, b – energy converter electrode (2D and 3D) configurations, respectively; c – "quantum dot" (cathode) model; (quantum dot top radius ρ = 1nm, T_e = 300K, Φ_e = 3eV, V_e = 25V; field emission current 57 nA; current density 9.05E+05A/cm²; average cathode brightness is equal to 2.8 E+05 A/(ster·cm²)).

REFERENCES

1. L. D. Hicks, M. S. Dresselhaus, *Phys. Rev.* B **47**, 727 (1993).
2. G. D. Mahan, L. M. Woods, *Phys. Rev. Lett..* **18**, 4016 (1998).
3. A. Shakouri, E. Y.Lee, D. L. Smith, V. Narayanamurti, J. E. Bowers, *Microscale Thermophys. Eng.* **2**, 37 (1998).
4. G.N. Hatsopoulos, E.P. Gyftopoulos, *Thermionic Energy Conversion*(Cambridge, MA, MIT Press, vol. I, 1973; vol. II, 1979).
5. V.E. Ptitsin., *Nauchnoie priborostroenie* **23** No. 4, 25 (2013).
6. V.E. Ptitsin, *NAP'2012 Proceedings* **1** No 4, 04NEA03 (2012).
7. V.E. Ptitsin, *NAP'2014 Proceedings* **3** No 2, 02NEA03 (2014).
8. A. Modinos, *Field, Thermionic and Secondary Electron Spectroscopy* (NY: Plenum Press, 1984).
9. V.E. Ptitsin, *Adv.s in Imag. and Elect. Phys.* **112**, 165 (2000).
10. K.L. Jensen, *J. of App. Phys.* **102**, 024911-1-11 (2007).
11. *Charge Particle Optics programs*: http: www.electronoptics.com
12. V.E. Ptitsin, V.F. Tregubov, *Ultramicroscopy* **95**, 131 (2003).