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New Approach to the Thermal-to-Electrical Energy Conversion Problem on a Basis of the Thermal Field Emission Phenomenon

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New approach to the thermal-to-electrical energy conversion problem on a basis of thermal field emission phenomenon is offered and developed. Physical and numerical modeling of an electron emission and transport processes for different electron-optical energy conversion systems with nanostructured surface electron sources (cathodes) is carried out. It is shown that offered approach permits to realize energy conversion processes with high efficiency.

Keywords: Energy conversion, Thermal field electron emission, Nanostructures.

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

1. INTRODUCTION

State-of-the-art of the thermionic energy conversion method researches was studied. Noted that a fundamental physical cause limit the effectiveness and stability of the thermionic energy converters (TEC) is the effect of the emitted electrons space charge (SC) field on the electron emission and electron transfer processes [1]. Based on an analysis of the current state of the TEC method researches concluded that on the basis of traditional approaches the "development potential" of this method has been exhausted. In this work opportunities for improving technical characteristics of the vacuum thermal-to-electrical energy convertors on a bases of the thermal field emission phenomenon [2-5] 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.

2. PHYSICAL AND NUMERICAL MODELING OF AN ELECTRON EMISSION AND TRANSPORT PROCESSES IN ENERGY CONVERSION SYSTEMS WITH STRUCTURED EMISSION SURFACES OF AN ELECTRON SOURCES (CATHODES)

To implement a process of "separation" (ii) is proposed to introduce into traditional TEC two electrodes electron-optical system (EOS) additional extracting electrode, creating on the cathode surface an electrostatic field large enough to compensate SC 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 (Fig. 1). Magnetic isolation helps prevent direct deposition (collisions) of an emitted electrons with the extracting electrode. Physical and numerical modeling of an electron emission and transport processes for different converter prototypes were carried out. One of the simulation results is shown in Figs. 2, 3.

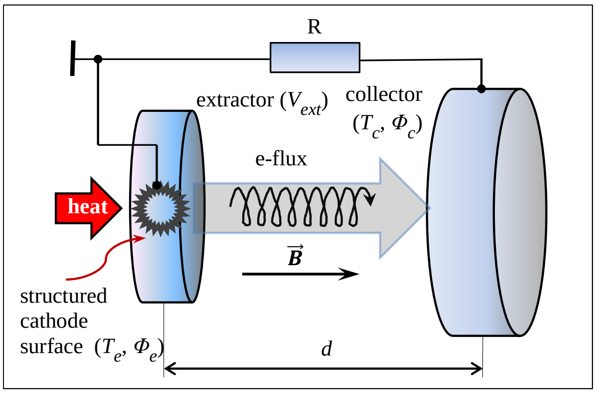

Fig. 1 – Phenomenological cheme of an emission and electron transport processes in an energy converter with a structured surface of the thermal field emission electron source; here is indicated by: T_e, T_c, Φ_e, Φ_c are the temperature and work function of the emitter and collector, respectively; B is the magnetic field induction

Thus, as a result of the carried out physical and numerical modeling [6, 7] it was shown that the proposed approach allows create a highly efficient devices for conversion of thermal energy to electrical energy.

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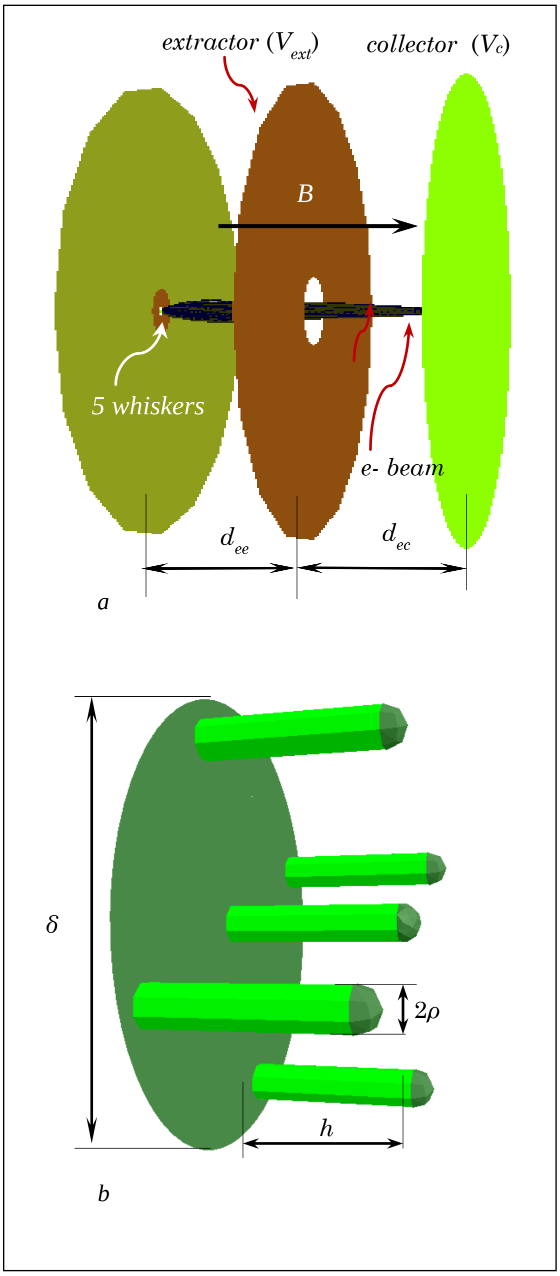

Fig. 2 – "Flat" model of the vacuum thermal field emission convertor: *a* – EOS electrode configuration and *b* – 5 quasi-one-dimensional whiskers as the thermal field emission cathodes ($\Phi_e = 3$ eV, $V_{ext} = 100$ V, $V_c = 1$ V, $B = 0.15$ T, $\rho = 100$ nm, $h = 1$ μm, $\delta = 2.4$ μm, $d_{ee} = d_{ec} = 0.5$ mm; (simulation results: 1. $T_{e1} = 2000$ K, beam current $I_1 = 2.15E-04$ mA, beam power density $\chi \approx 4.74$ W/cm^2 and 2. $T_{e2} = 2200$ K, $I_2 = 1.35E-03$ mA, ($\chi \approx 29.8$ W/cм^2)

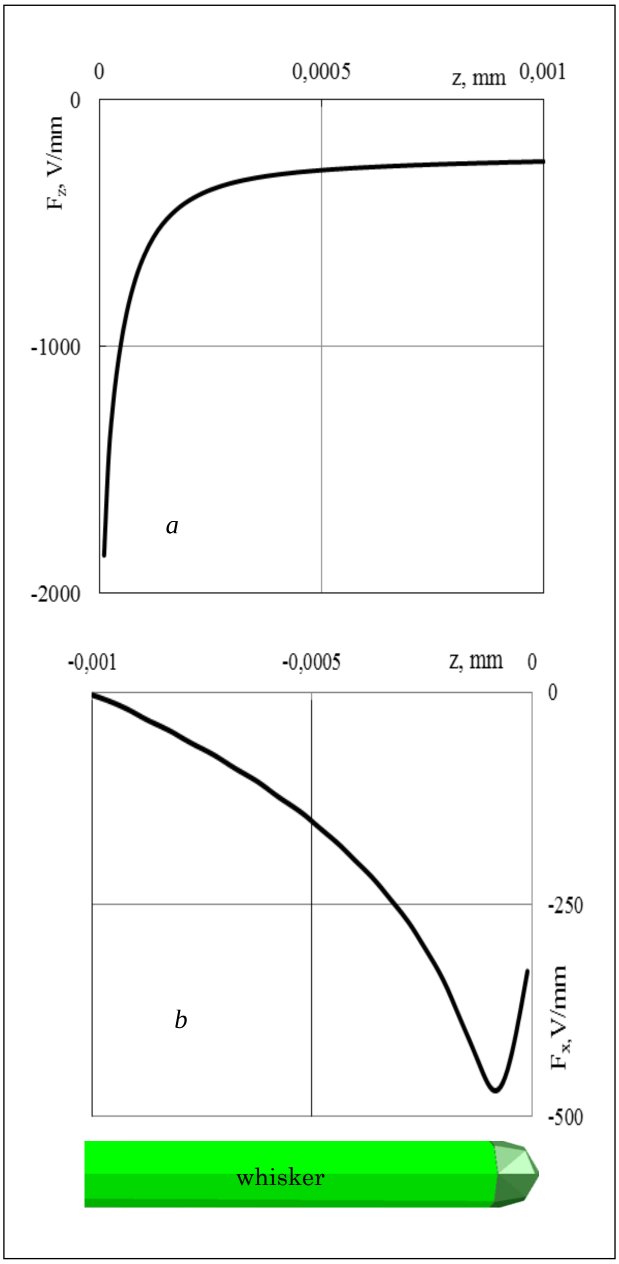

Fig. 3 – Distribution curves self-consistent field strength along the axis (Fz (*z*)) of the electron-optical system (a) and on the whisker lateral surface (Fx (*z*)) (b); (under the z axis shows the whisker model)

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