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# SECTIONAL GENERATOR THERMOELEMENTS IN A MAGNETIC FIELD

*Using computer simulation, temperature distributions in the working body of sectional thermoelements in a magnetic field were determined. Temperature dependences of the efficiency of sectional gyrotropic thermoelements were found. It was established that the efficiency of generator gyrotropic sectional thermoelements depends on the number of sections. Bibl. 14, Figs. 4.*

**Key words:** thermomagnetic figure of merit, Nernst-Ettingshausen coefficient, sectional gyrotropic thermoelement, gyrotropic material, thermomagnetric figure of merit, efficiency.

## Introduction

Today, thermoelectric devices and systems are used in many industries, including medical, space, military, energy, refrigeration and instrumentation. For further development, it is important to study known and create new types of thermoelectric materials and thermoelements based on them, in particular for generating electricity in magnetic fields in the presence of a perpendicular temperature gradient [1 – 14].

Gyrotropic generator thermoelements are known to have a number of advantages over classic ones, such as the solderless connection and thereby the possibility of adjusting the required voltage, which guarantees the reliability and manufacturability of gyrotropic thermoelements and converters in general. Gyrotropic thermoelements as sensors can also increase their sensitivity and response time due to constructive solutions and can be effectively used in measuring technology.

Therefore, the study of the efficiency of gyrotropic materials and thermoelements based on them is important and relevant for their further use in general measuring and instrument-making equipment. The purpose of this work is to calculate the main parameters of sectional gyrotropic thermoelements and assess the efficiency of their use.

## Computer simulation results

To study the parameters of gyrotropic thermoelements, it is necessary to solve the following heat conduction equation with the corresponding boundary conditions:

$$\kappa\Delta T+\rho_0 j^2+2\alpha_a\left(j_y\frac{\partial T}{\partial x}-j_x\frac{\partial T}{\partial y}\right)=0\,, \tag{1}$$

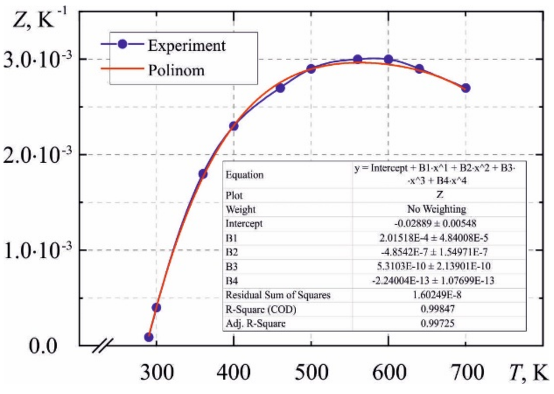
where $T$ is temperature; κ is thermal conductivity of the gyrotropic medium; $\rho_0$ is electric resistivity; $x$, $y$ are coordinates; $j, j_x, j_y$ are module and projections of the electric current density vector; $\alpha_\perp = Q_\perp B$ is the asymmetric part of the thermoEMF tensor; $Q_\perp$ is transverse Nernst-Ettingshausen coefficient; $B$ is magnetic field induction.

$$\alpha = \begin{pmatrix} \alpha_0 & \alpha_a & 0 \\ -\alpha_a & \alpha_0 & 0 \\ 0 & 0 & \alpha_\perp \end{pmatrix}, \tag{2}$$

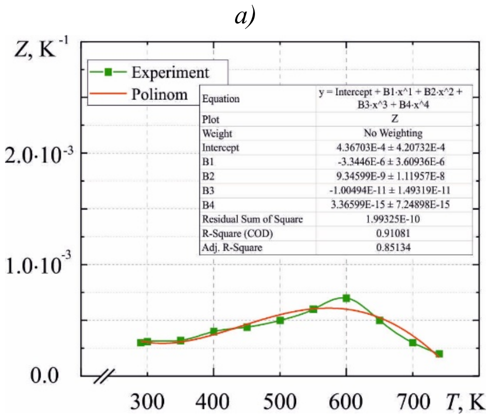
where $\alpha_0, \alpha_\perp$ are diagonal components of the thermoEMF tensor.

$$Z_Q = \frac{Q_\perp^2 B^2(r)}{\kappa\rho}. \tag{3}$$

To conduct further simulation, a number of gyrotropic materials were considered, and the most promising of them were determined. Further, using the experimental data, the temperature dependence of the thermomagnetic figure of merit was constructed for *InSb* and *InAs*, and polynomials were also obtained, which are subsequently used to construct temperature distributions and calculate the efficiency of gyrotropic thermoelements. Fig. 1 shows the temperature dependences of the thermomagnetic figure of merit of *InSb* and *InAs* materials. It is evident that the best material for the production of gyrotropic generator thermoelements is *InSb*, which is consistent with the experimental results presented in [1, 11, 12]



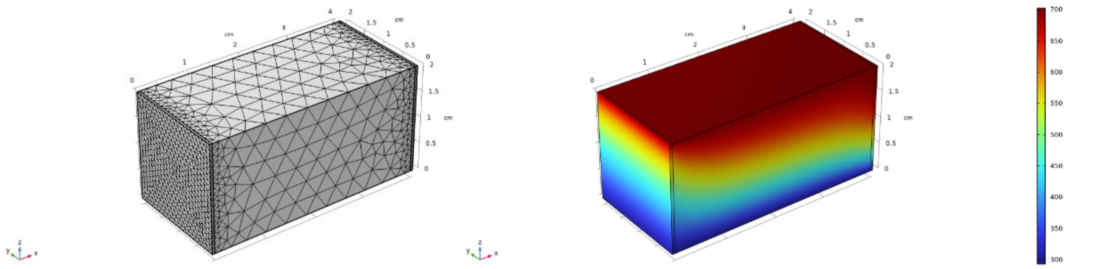

*a)*




*b)*

*Fig. 1. Temperature dependence of thermomagnetic figure of merit for InSb (a) and InAs (b) materials*

Hereinafter, the Comsol Multiphysics 6.2 application program package was used to build computer models of sectional gyrotropic thermoelements. Calculation of temperature distributions in gyrotropic thermoelements was carried out using the finite element method. Using computer simulation, temperature distributions were determined for the *InSb* material in the temperature range of 300–700 K and a magnetic field with induction $B = 1.4$ T (Fig. 2).



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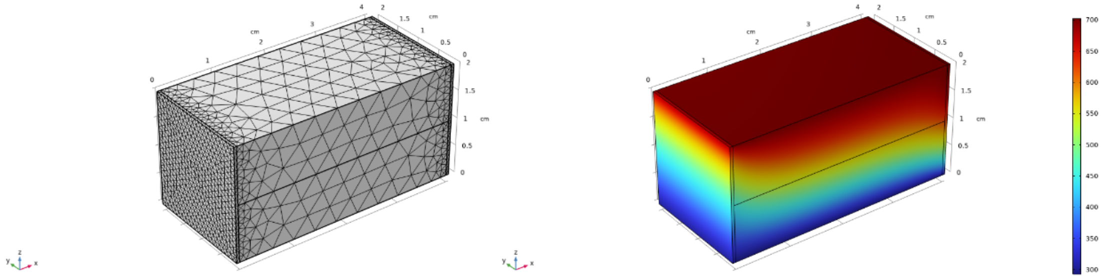

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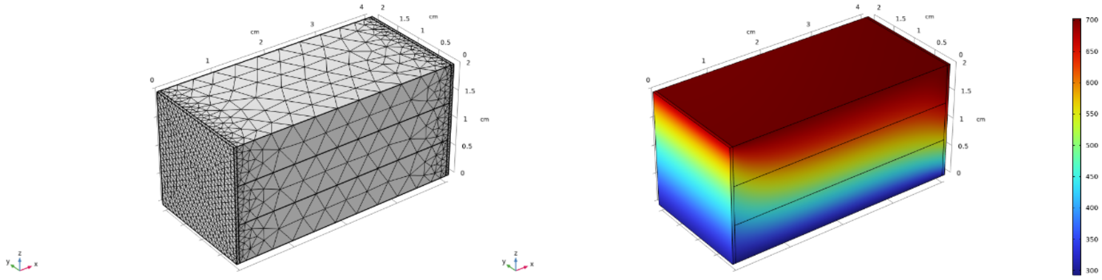

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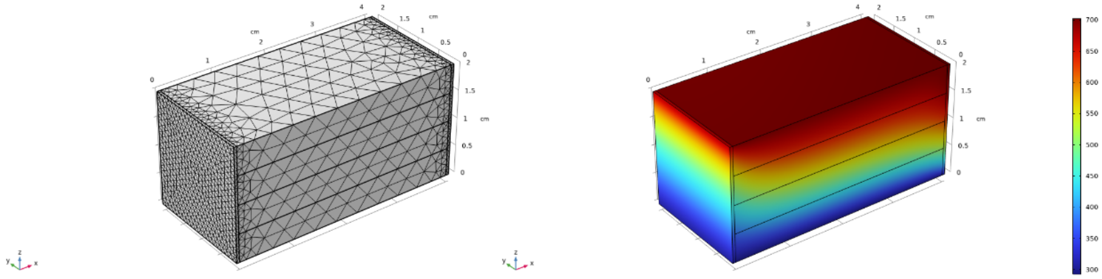

*d)*

*Fig.2. Three-dimensional models of the finite element method mesh (left) and temperature distribution (right) in single- and multi-section rectangular gyrotropic thermoelements with regard to thermoelectric contacts (where a – 1 section, b – 2 sections, c – 3 sections, d – 4 sections)*

It is worth noting that contact electrical resistances are taken into account on the edges, which usually reduce the expected positive effect from the use of sectional legs.

Further, Fig. 3 shows the dependences of the efficiency of single- and multi-section thermoelements on the hot side temperature of *InSb* and *InAs* material.

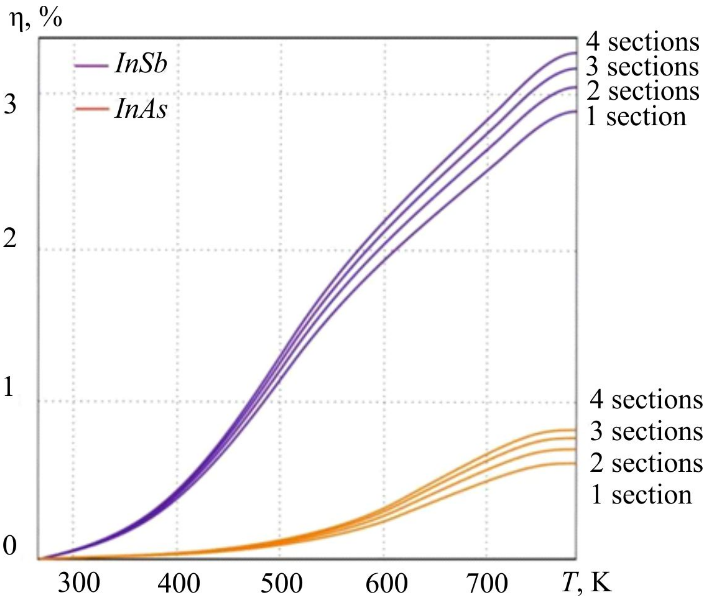


*Fig. 3. Dependence of the efficiency on the temperature of sectional gyrotropic generator elements*

From Fig. 3 it is evident that for the *InSb* material the efficiency of the sectional thermoelement is approximately 3.35 %, for the temperature range of 280 – 780 K and magnetic field induction of 1.4 *T*, which is almost 1.2 times greater than for a conventional rectangular thermoelement. Fig. 4 shows the dependence of the maximum efficiency on the number of sections *N* for *InSb* and *InAs*).

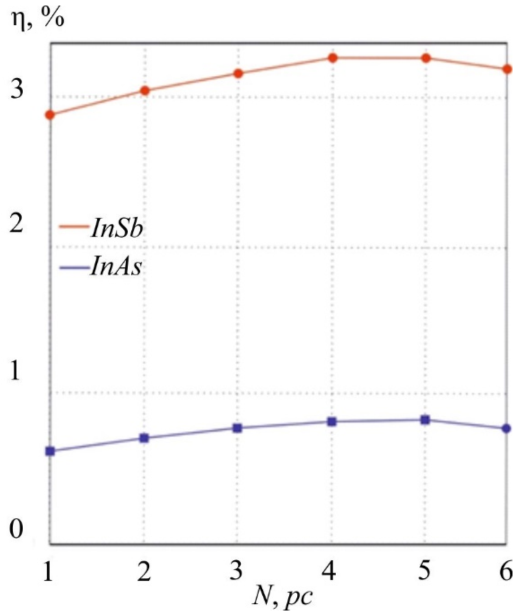


*Fig. 4. Dependence of the maximum efficiency η on the number of sections N (upper row of curves – InSb, lower row of curves – InAs)*

From Fig. 4 it can be seen that with an increase in the number of sections, the efficiency of the thermoelement decreases due to the influence of contact phenomena, which become more significant in this case.

## Conclusions

1. Computer simulation methods were used to study temperature distributions in rectangular generator thermoelements, single- and multi-section, made of *InSb* and *InAs* thermoelectric materials.
2. The temperature dependences of the efficiency of sectional gyrotropic generator thermoelements were compared for different numbers of sections. It was found that for a 4-section thermoelement, the efficiency is approximately 3.35 %, for a temperature range of 280 – 780 K and a magnetic field induction of 1.4 *T*, which is almost 1.2 times more than for a conventional rectangular thermoelement for *InSb* material.

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## СЕКЦІЙНІ ГЕНЕРАТОРНІ ТЕРМОЕЛЕМЕНТИ В МАГНІТНОМУ ПОЛІ

*За допомогою комп'ютерного моделювання визначено розподіли температур у робочому тілі секційних термоелементів у магнітному полі. Визначено температурні залежності ККД секційних гіротропних термоелементів. Встановлено, що ККД генераторних секційних гіротропних термоелементів залежить від кількості секцій. Бібл. 14, рис. 4.*
**Ключові слова:** термомагнітна добротність, коефіцієнт Нернста-Еттінгсгаузена, секційний гіротропний термоелемент, гіротропний матеріал, термомагнітна добротність, ККД.

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