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EXPLORING THE POTENTIAL FOR FABRICATION OF A FILM-BASED PHOTOTHERMAL CONVERTER

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Abstract: This paper presents the results of a study on the creation of a combined film photothermoelectric converter from film photo- and thermal converters. The relevance of such research is substantiated. A list of questions necessary when solving scientific problems in this direction is provided. The importance of selecting materials and types of converters for obtaining effective hybrid elements is described. The limits of temperature intervals at which a positive result of experimentation of structures can be expected are shown. The calculation method and conditions for selecting the initial data for mathematical calculations of the characteristics of the converters are outlined. The results of the study are presented and the dependence of the electrophysical properties of the thermoelements and the efficiency of the converters on the temperature of the samples are analyzed. A conclusion is drawn about the possibility of creating such current sources. The issue of creating highly efficient solar energy converters has attracted the attention of researchers worldwide on a large scale.

Keywords: Conversion, photocell, thermoelement, photothermal element, film PV/T Hybrid converters.

INTRODUCTION:

The issue of creating highly efficient solar energy converters has attracted the attention of researchers worldwide on a large scale. Many design, technological and rationalization studies have been performed in this area. One of the options for increasing the efficiency of solar converters is to combine photoelectric converters of solar energy with a thermoelectric source of electric current [1÷3].

This device justifies itself with a relatively high conversion efficiency, economic benefit and reduced heat loss. Another important advantage is the preservation of fairly good efficiency values of solar cells, even at high light intensities, by reducing their operating temperature. The latter is explained by the strong temperature dependence of the electrical parameters of semiconductor materials.

It should be noted that photothermoelectric converters (PTCs) of light and thermal energy, which are designed to operate under selective lighting conditions, have provided particularly good results [4-5]. Of course, to achieve the perfection of the latest design, it is still necessary to find ways to separate light radiation for a larger-area PTC. The results obtained by selective lighting solar cells will not match the results of large solar power plants. This is attributed the problem of separating light flux from solar radiation for large-area converters. Young researchers are currently working on this topic.

Another problem with PTC is its weight and dimensions. The presence of a thermoelectric generator of a volumetric design makes it, to some extent, rough and inconvenient to operate. Therefore, this work examines the possibility of creating film photothermal converters.

FORMULATION OF THE PROBLEM

The task of minimizing the overall dimensions of energy converters and providing a positive solution to the issue of weight and economic indicators of solar and thermoelectric sources of electrical energy certainly require a transition to film structures of such units. Until, recently film thermal converters, have been used as sensors and measuring elements in instrumentation, electronics and many other industries [6÷8]. The widespread use of film photoelectric and thermoelectric converters in practice began to develop with the transition to micro- and nanoelectronics. However, limiting ourselves to this population does not demonstrate all the possibilities of these alternative energy sources. The population's need for electricity poses the task of finding new types and designs of converters that can operate with fairly good economic and energy efficiency. Unfortunately, many factors prevent the creation of such devices, requiring scientists and engineers to find solutions to these obstacles. For example, the strong temperature dependence of the electrophysical parameters of semiconductor materials prevents solar cells from operating with concentrated light radiation, complex and expensive manufacturing technology prevents them from being widely used, and their fragility and large geometric dimensions reduce service time. For thermoelectric converters, their volumetric structures require a large amount of raw material and create difficulties for transportable movements; additionally, the low efficiency factor (efficiency) does not satisfy the needs of consumers of electrical energy. Therefore, to compensate for one device, the second device should be advantageous because it ultimately leads to a combination of converters. One of the products of such a solution is a device developed for converting light and thermal energy into electrical-photothermoelectric converters (PTCs) [3]. To date, several modifications of the PTC have been created [3÷5]. Among them, photothermal elements designed to operate under selective lighting conditions have the highest efficiency. It should be noted that for this design to be able to widely enter the consumer market, additional problems still need to be solved related to the configuration of energy converters with an optical set that serves to distribute light radiation into different spectra. In addition, it is necessary to identify the conditions for using such a converter for medium and high-power consumers. These questions remain open. Deciding on weight and dimensions is also important. The results of obtaining the scope in the area of use are highly dependent on this problem. Solving this problem leads to savings in terms of raw materials, and accessibility, reducing the problems of moving devices from one place to another and the possibility of serially producing such energy sources in large quantities [7].

The development of PTCs based on film solar cells and thermoelectric converters may perhaps be one of the works that could respond positively to the task set. An analysis of domestic and foreign literature shows the lack of sufficiently illuminated work in this regard. To date, there has been one work [9], in which a thermoelectric converter was used as a low-power electricity generator and a cooling device for a film photocell. This combination of converters was created based on the Peltier effect [10,11]. In comparison, the most interesting solution is to create a combined film PTC that operates on the basis of the Seebeck effect [12,13].

THIS IS EXPLAINED AS FOLLOWS

Despite the lack of a forecast for the efficiency of the planned design of a film photothermal converter, the development of this source has made it possible to obtain a certain gain in economic efficiency. The device becomes compact, lightweight and transportable. It is widely used in hard-to-reach areas of the planet. It is an autonomous source of direct current. In any case, under equal operating conditions, the efficiency of the device is greater than the efficiency of photoelectric conversion. By varying the parallel and serial connections of the photo and thermocouples of the converters, the operating current and voltage of the device can be adjusted. In summary, the beginning of research in the direction of creating a film photothermal converter, in our opinion, is promising to some extent.

Based on the above reasoning, the objectives of this research are to analyze and select the designs, types and materials of film photoelectric and thermoelectric converters of light and thermal energy; develop technology for manufacturing film PTCs; identify their operating conditions; conduct experimental studies; measure and determine the operational characteristics of the device under laboratory and field conditions; determine the configuration of the converter; solve the issue of cooling the cold junctions of the thermoelectric part of the unit; and perform a theoretical calculation of parameters using modeling with modern software.

Note that creating the planned design and studying it within a wide range of light intensities and operating temperature differences may require the creation of additional experimental installations. The work plan includes provisions for the possibility of working in created installations with various types of measurements, for example, with concentrated radiation.

Analysis and Selection of Film Type Film Solar Cells for PTCs

Considering that the choice of a film photoelectric converter is made with the aim of creating a photo thermoelectric converter that is convenient to use and has good weight and size characteristics, we carry out a comparative analysis of technologies, materials, cost and efficiency of thin-film solar cells. These materials have the best qualities in terms of flexibility. There are several types of inorganic film converters of light energy into electrical energy: films made on the basis of amorphous silicon (a-Si), cadmium telluride films (CdTe) and film solar cells made of copper-indium and gallium selenide (CuInGaSe2) Of course, depending on the electrophysical parameters and manufacturing technology, the efficiency ranges from 10% to 22%. For example, the efficiency of photoconverters manufactured by First Solar from amorphous silicon is approximately 10÷11%. The Japanese company Solar Frontier produces solar cells based on copper, indium and gallium selenide materials with efficiency. 12÷13%. In contrast to these samples, commercially produced solar cells made of cadmium telluride (Mia Soli modules) are efficiency. 15.7%. in 2016, solar cells with the highest conversion coefficients based on CuInGaSe2 (EMPA) produced products with efficiency. 18.7%. the laboratory samples of the listed elements exhibited values an order of magnitude greater, that is, greater efficiency. Individual thin-film solar cells; and laboratory samples of elements made of amorphous silicon - 12.2% (United Solar), CdTe - 17.3%; (First Solar), and CIGS - 20.5%; (ZSW) were used.

Note that today there are solar film batteries with significantly higher efficiency indicators. Table №1 shows the energy and weight-dimensional characteristics of the flexible solar panels of the KIBOR panel.

Table No. 1 [14]. Thin-film flexible solar panels KIBOR.

Panel power (W)	Size (mm)	Efficiency %	I mp (A)	Vmp (V)	Isc (A)	Voc (V)	Weight, (kg)
18 W	277*434*3 mm	20.5 %	0,92 A	19,3 V	1,04 A	23,6 V	0,29
25 W	277*555*3 mm	21.5 %	1,43 A	17,5 V	1,55 A	21,5 V	0,57
30 W	375*535*3 mm	19.6 %	1,72 A	17,4 V	1,93 A	21,3 V	0,75
40 W	415*535*3 mm	22.2 %	2,34 A	19,4 V	2,06 A	23,5 V	0,90
50 W	535*555*3 mm	21.5 %	2,85 A	17,5 V	3,06 A	21,5 V	1,0
60 W	535*734*3 mm	19.6 %	3,44 A	17,4 V	3,71 A	21,11 V	1,46
75 W	535*820*3 mm	21.1 %	3,81 A	19,3 V	4,11 A	23,93 V	1,65
80 W	540*922*3 mm	18.8 %	5,20 A	15,3 V	5,62 A	18,79 V	1,85
85 W	550*1050*3 mm	18.6 %	5,06 A	16,8 V	5,61 A	20.19 V	2,10
90 W	540*1050*3 mm	19.0 %	5,27 A	17,0 V	5,71 A	20,69 V	2,00
95 W	540*1050*3 mm	20.2 %	5,47 A	17,3 V	5,90 A	20,89 V	2,00
100 W	540*1050*3 mm	21.3 %	5.71 A	17,6 V	6,07 A	21,69 V	2,00
110 W	540*1175*3 mm	20.5 %	5,64 A	19,54 V	6,03 A	23,49 V	2,25
120 W	540*1305*3 mm	20.5 %	5,44 A	22,09 V	5,86 A	26,49 V	2,45
130 W	540*1435*3 mm	19.5 %	5,43 A	24,09 V	5,96 A	29,00 V	2,60
135 W	540*1435*3 mm	20.8 %	5,61 A	24,19 V	6,04 A	29,29 V	2,60
140 W	796*1082*3 mm	19.5 %	7,08 A	19,79 V	7,78 A	24,98 V	2,68
150 W	796*1082*3 mm	21.3 %	7,51 A	20,01 V	8,11 A	24,49 V	2,68
180 W-1	796*1305*3 mm	20.0 %	5,49 A	32,91 V	5,86 A	39,79 V	3,0
180 W-2	796*1305*3 mm	20.0 %	10,72A	16,79 V	11,58A	20,29 V	3,0

As shown in Table №1, on average, solar panels can be efficiently constructed. ☐ 20%. In [3], it was clearly formulated that to create a photothermal converter capable of compensating for a decrease in the efficiency of the photoelectric converter with increasing temperature and having the highest conversion coefficient values, it is important to select a sample with the best efficiency values. and temperature coefficient, we will focus on solar converters with an indicator of this parameter of at least 20%. This is a good indicator, even compared to the crystalline solar panels currently used. Thus, a study of the modern market has shown that samples from cadmium telluride and indium-copper-gallium sulfide are recommended for creating a combined photothermal converter. By 2020, despite the continued production of rigid variants, cadmium telluride solar cells had become the most common modification of the flexible battery market. This connection benefits from its low cost and high efficiency, even under nonideal lighting conditions. The efficiency of serial products made from these materials reaches 20-22% [15]. An important parameter is that the temperature coefficient for such samples is 2-3 times lower than that for monocrystalline and polycrystalline silicon.

Among the flexible panels under consideration, today we consider indium-copper-gallium sulfide $CuInGaSe_2$ to be the most effective. However, they have a high manufacturing cost. Currently, they are practically not used on earth. Due to the high cost, only spacecraft are equipped with this type of photovoltaic energy. The efficiency of the best samples of these elements reaches 35-40% or higher [16]. The produced samples are extremely reliable and minimally degradable even under extreme conditions at extremely low and high temperatures.

However, there is a third generation of thin films based on polymers, organics and quantum dots. However, for now, we are neglecting them due to the relatively low efficiency values: 14-17%. Despite this, in the future it may be necessary to pay serious attention to the following advantages: general availability and cheap production, maximum functionality, environmental safety and the ability to make films almost transparent [17]. Perovskite elements are a continuation of third-generation elements. However, these elements are not suitable for our purposes. The latter is explained by the short service life, which lasts only 1.5-2 years.

The question of which substrate (glass, plastic or metal) should be used in a thin-film light-to-electric converter will be decided upon later. The use of these devices depends on the switching materials; and the soldering and connection technology of the photoelectric converter to the TEG. Analysis and accounting of the toxicity of starting materials can also be considered not yet part of our task. This is explained by the creation of a hybrid PTC converter based on ready-made components; that is, we obtain the PV and TEC in finished form.

Selecting a Film Thermal Converter

Compared to that of solar cells, the transition from bulk thermoelectric generators to thin film generators is an important factor. This procedure justifies itself primarily by solving the problem associated with the weight and size characteristics. The significant impact of the transition is also reflected in the savings in raw materials from which thermoelements are made.

The development of technology for producing thermopiles by microminiaturization has achieved noticeable progress in recent years. Their dimensions today are at the millimeter level. The length of the branches of thermoelements was reduced by more than ten times, that is, to 0.15-0.2 mm [18]. Currently, experts in this field know that thermoelements, unlike bulk thermoelements, are manufactured by thin-film deposition in various ways on an electrical and thermal insulating substrate. This can be achieved by vacuum deposition, solution deposition, metal-organic chemical vapor deposition (MOCVD), and molecular beam epitaxy (MBE). In general, a module is manufactured by applying thin films and creating patch plates in the form of a pattern.

The choice of a film thermal converter should take into account not only its advantages, but also its disadvantages compared to volumetric thermal converters. In [18], by comparing the characteristics of two types thermal converters (bulk and thin-film), it was concluded that thin-film TECs have an advantage in terms of the generated thermoelectromotive force (thermo-EMF).

$$Y = 2NS \tag{1}$$

$$E = \alpha \frac{2N}{S} S\Delta T = \alpha Y * S\Delta T, \tag{2}$$

$$\frac{E_b}{E_{T.f}} = \frac{\alpha_b}{\alpha_{T.f}} * \frac{Y_b}{Y_{T.f}} \approx 1{,}5 * (0{,}05 \dots 0{,}1) \approx 0{,}08 \dots .0{,}15 \tag{3}$$

where Y is the packing density of the TE, and 2 N thermoelements; ET.f and Eb are, the thermopowers of thin-film and bulk TECs, respectively; and S is the surface area of the TE.

This large value of the thermoelectromotive force (EMF) makes further use of the converted energy easier. It is also shown that with a correct comparison of the generated thermo-EMF relative to the heat flux, the efficiency of volumetric TEGs is noticeably greater both in terms of generated power and conversion efficiency. In addition, volumetric TEGs have advantages in terms of efficiency. noticeably compared to thin-film generators. The disadvantages of the latter include the low efficiency of the semiconductor thermoelectric material and high resistance. The first drawback fundamentally limits converter manufacturing technologies. The second disadvantage is the cost of miniaturization and high-density packaging of thermoelements. For the application of electricity generation with a thin film converter, it may be promising to search, among other new thermoelectric materials, for more efficient hybrid structures, in particular those with photovoltaic devices.

The design of the combined-film photothermal generator we propose is shown in Figure 1. However, the creation of such a hybrid design is also not without the importance of solving several issues related to switching, flexibility, and the complexity of the collection technology and determining the scope of their application. Therefore, Figure - 1a shows a general top view of a film photothermal converter. The area of the photoconverter must be equal to the area of the free area on the side of the TEC hot switching plates. The light energy arriving at the surface of photovoltaic converters (PVCs) is not converted into electrical energy. Most of the light, turning into heat, should arrive at the hot junctions of the TEC. Therefore, a serial connection thermoelement (TE) is placed around the perimeter of the solar cell.

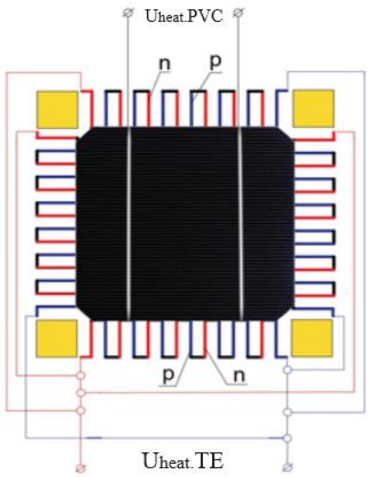

Fig.1. Top and side views of a film photothermal converter.

The design is designed for separate loads. However, if the geometric dimensions and number of TECs are selected, methods of connecting them in parallel or in series, you can include them in the total load. For this purpose, a TEC must be manufactured on a film with a rectangular shape and a free area in the middle equal to the photoactive surface of the photoconverter. Since the industry does not yet have such a TEC design, it will be necessary to resolve this issue. In the literature [19], there are film thermoelements with a round configuration (Fig. 2). Since the industry produces round-shaped solar cells, we think it is possible to select such a system for combining two generators. The sample was made of silver selenide.

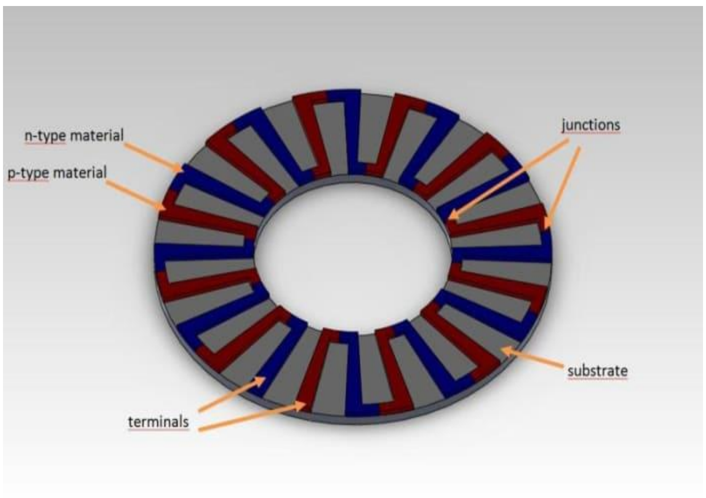

Fig.2. The arrangement of the film fuel cells is circular

CALCULATION METHOD FOR THE FILM PHOTHERMAL CONVERTER

In principle, we can assume that in this case it is also possible to use the method of calculating the PVC of a volumetric structure [20]. Heat is supplied to the hot junctions of the TEC through the electrically insulating layer from the photoelectric converter. Here we should note another problem associated with the selection of an electrically insulating, but well-thermal-conducting layer material between the hot junction of the TEC and the PVC. We will leave this task for the experimental part of the work. In this case, the proximity of the coefficients of thermal expansion of the layer materials, hot switching plates and rear contact of the solar cell should be considered. Solving this issue also requires determining the flexibility of the material. At low light intensities, this difference may not be significant. However, the use of this design with concentrated radiation becomes important. Using [20] will not require any corrections to the formulas. The reflective layer allows thermal energy to be transferred from the solar cell to the hot junctions of the TEC without loss.

Because the photovoltaic and thermoelectric parts are connected to different loads, the following formulas can be used to calculate the efficiency of converters

$$\eta_{PVC} = \frac{P_{pvc}^{max}}{P_{inc}} \qquad (4)$$

$$\eta_{TEC} = \frac{T_h - T_c}{T_h} * \frac{M-1}{M+\frac{T_c}{T_h}} \qquad (5)$$

In the above formulas P_PV^max and P_inc- are the powers released at the PV load and incident on the front surface of the solar cell, respectively; Th and Tc- are the temperatures of the hot and cold junctions of the thermoelement branches, respectively.

$$M = \sqrt{1 + Z_{av}T_{av}}.$$

After these values, are determined the efficiency of the hybrid unit

$$\eta_{PTC} = \eta_{PVC} + \eta_{TEC}(1 - \eta_{PVC}) \qquad (6)$$

Using formula (2.34), proposed by A.F. Ioffe, the values of Peltier and Joule heat cane be considered. It is well known that formula (2.34) includes the parameter Z, which is called the thermoelectric figure of merit, and the higher this indicator is, the greater the efficiency value. transformations. To carry out computational studies, substances with the best thermoelectric properties were taken. These temperatures corresponded to room temperature and their temperature dependence was taken into account. Conditions were set for the temperatures of the photoelectric converter and the hot junctions of the TEC to be identical. In the calculations, temperature values were specified to be significantly lower than room temperature, that is, down to -80°C toward cold temperatures.

Parameter M is equal to the optimal ratio of the load resistance of TEG. Based on the fact that T_av is found from the absolute values of the temperature of the hot and cold junctions of the thermoelement branches, it is possible to calculate the average integral thermoelectric figure of merit of the material for the selected temperature range and both branches of the thermoelectric element

$$T_{av} = \frac{T_h - T_c}{2} \qquad (7)$$

$$Z = \frac{1}{2}\left(Z_{av}^{n} + Z_{av}^{p}\right). \qquad (8)$$

In (8), the parameters Z_{av}^{n} and Z_{av}^{p} were calculated from the relations

$$Z_{av}^{n} = \frac{1}{T_h - T_c}\int_{T_c}^{T_h} \frac{\alpha_n^2(T)dT}{\chi_n(T)\rho_n(T)}, \text{ and } Z_{av}^{p} = \frac{1}{T_h - T_c}\int_{T_c}^{T_h} \frac{\alpha_p^2(T)dT}{\chi_p(T)\rho_p(T)}.$$

where $\alpha_n(T), \alpha_p(T), \chi_n(T), \chi_p(T), \rho_n(T), \rho_p$ are, the values of the coefficient of thermal field, the thermal conductivity and the resistivity of the p-n branches, respectively.

Note that the thermoelectric efficiency of p- and n-branch materials can be calculated graphically. Graphical calculation of the Z parameter is carried out by integrating the known temperature dependencies $Z_n = Z_n(T)$ *and* $Z_p = Z_p(T)$. However, taking into account that numerous calculations give almost identical results, that is, Z_{av}^{n} and Z_{av}^{p} are close, the expression

$$Z = \frac{Z_{av}^{n} + Z_{av}^{p}}{2}. \qquad (9)$$

The main purpose of this theoretical study was to consider the temperature dependence of the thermoelement efficiency, taking into account the temperature dependence of the electrophysical parameters of the thermoelectric semiconductor material α, ρ, and χ. Therefore, the parameters of the real substance were chosen among materials in the low-temperature region. This was based on the assumption that the operating temperature range of the film photothermal converter is from -80°C to 120°C. A temperature of 120°C on the surface of the photoconverter, and, consequently, on the hot junctions of the thermoelement, can be obtained with concentrated radiation of approximately twenty times the amount of sunlight [3]. Thus, it was possible to use increased light intensity incident on the front surface of the solar cell.

The thermal resistance, internal resistance and optimal current at the thermopile load were calculated using the following formulas:

$$E_{TEC} = n(\alpha'_n - \alpha'_p)(T_h - T_c) \quad (10)$$

$$r_{int} = n(\rho'_n + \rho'_p)\frac{l}{s} \quad (11)$$

$$I_{l.opt} = \frac{E}{m+1}, \quad (12)$$

where $m = \frac{R}{r_{int}} = \sqrt{1 + Z_{av}T_{av.}}$

Here, $\alpha' = \frac{1}{T_h - T_c}\int_{T_h}^{T_c} \alpha(T)dT$; $\rho' = \frac{1}{T_h - T_c}\int_{T_h}^{T_c} \alpha(T)dT$;

n is the number of thermoelements in the TEG.

The heat flow from the back of the photoelectric converter to the hot junctions of the TEC is:

$$Q = Q_\chi + Q_п \quad (13)$$

where Q_χ and $Q_п$ are the heat flows leaving the hot junctions due to the thermal conductivity of the branches and the Peltier effect, respectively.

Note that due to the insignificant values of heat flows arising from the Thomson and Peltier effects, they can be neglected. Due to the weak temperature dependence of the thermal conductivity of the material, these heat flows are linearly distributed along the branches of the fuel cell. This justifies the method of averaging adopted when calculating the internal resistance of the TEC and the heat flow due to the thermal conductivity of the branches Q_χ by integration over temperature, together with integration over the length of the branches. If taken into account, they can be determined using the Ioffe formula [21].

Thus, the useful power released at the load of the thermoelectric converter

$$P^{us}_{TEC} = I^2R = I^2 r_{int} M. \quad (14)$$

The efficiency of the thermoelectric part of the photothermal converter is calculated according to

$$\eta_{TEC} = \frac{P^{us}_{TEC}}{Q_п + Q_\chi}. \quad (15)$$

RESULTS AND DISCUSSION

Based on the calculation results, the temperature dependence of the useful power of the photoelectric converter, thermal converter and photothermal converter was obtained. Figures 3-5 show the results of studying the electrophysical parameters of the branches of a film thermopile.

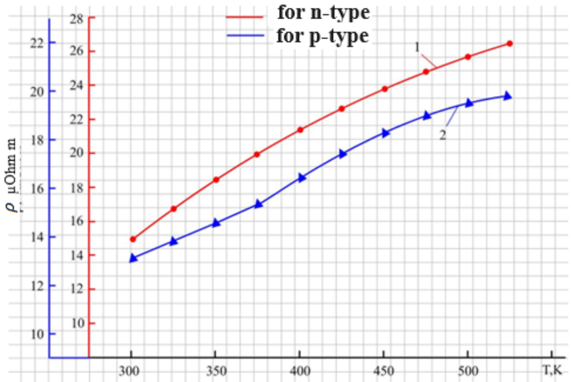

Fig. 3. Temperature dependence of the resistivity of the TE branches.

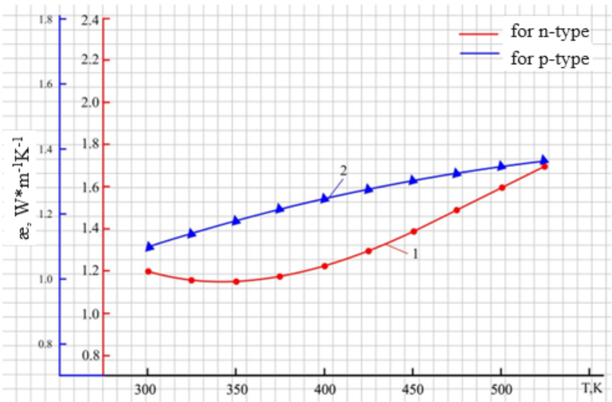

Fig. 4. Temperature dependence thermal conductivity of the TE branches.

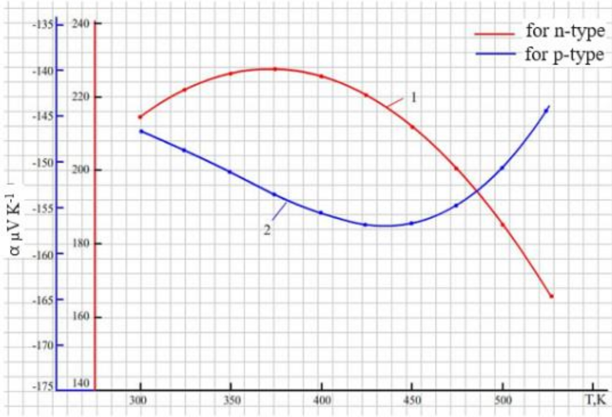

Fig. 5. Temperature dependence of the thermoelectromotive force coefficient of fuel cell branches.

As show in Figure 3, the resistivity of the electronic conductivity branch increases monotonically with increasing temperature. For the positive branch, this parameter first increases slowly up to a value of 375 K, after which the growth accelerates. From this we can conclude that the electrical conductivity of the n-type conductor decreases faster than that of the p-type conductor. There is a noticeable difference in the temperature dependences of the thermal conductivity of the TE branches (Fig. 4). In this case, the thermal conductivity of the electronic conductivity branch up to 375 K remains practically unchanged. In addition, the thermal conductivity is significantly less than that of the p-type alloy. This phenomenon to some extent compensates for the decrease in electrical conductivity, which contributes to an increase in the value of TE efficiency. In addition, thermal emf. The n-branch first increases with increasing temperature, and then decreases (Fig. 5). In contrast to that of the n-branch, the coefficient of thermoelectromotive force of the positive branch first decreases, and after reaching a temperature of aapproximately 450 K, it grows strongly.

A comparison of the research results with the results of previous works [22÷25] showed that our results maintain an intermediate limit between the data given in these studies.

Figure 6 shows the efficiency dependence. Photo, thermal and photothermal converters from temperature, as a result of processing the received data. Based on the results of a computational and theoretical study, it was established that the efficiency of a film photocell decreases with increasing temperature in the same way as that of plate solar converters. The pattern of decrease in sample productivity is similar to that of the second type, that is, the plate type. The efficiency of the thermal converter increases monotonically. The value of the payload on the external circuit of the TEC is relatively low in volume. This can possibly be explained by the geometric dimensions of the film thermoelements. However, reducing the temperature of the cold junction of the thermoelement traditionally leads to an increase in the efficiency of the converter, which confirms the presence of the Seebeck effect. Overall, the efficiency of the hybrid film photothermal converter allows us to conclude that it is logical to create a film PTC. [26÷27].

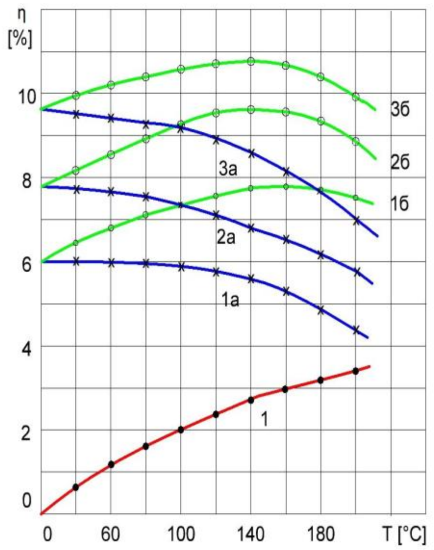

Fig.6. Dependence of the efficiency of thermo (1), photo (1a, 2a, 3a) and photothermal batteries (1b, 2b, 3b) batteries on temperature at TC=0oC (a).

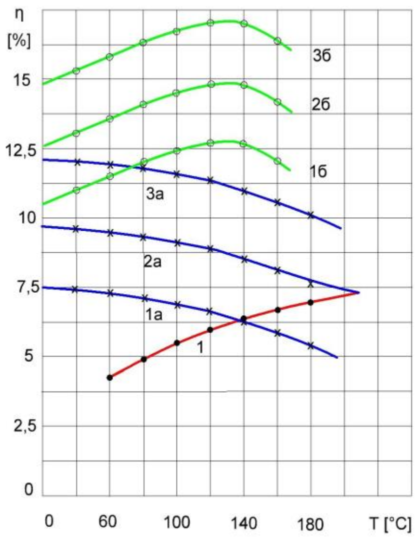

Fig.6. Dependence of the efficiency of thermo (1), photo (1a, 2a, 3a) and photothermal batteries (1b, 2b, 3b) batteries on temperature at TC=-80oC (b).

For their manufacturing technology, we can say the following. Unlike in the installation of volumetric PTCs, the manufacture of film combined elements does not require the selection of special chemicals because of the compatibility of the soldered parts of the ceramic plate, photoconverter or thermal converter, as was shown in [3]. In this case, they can be constructed by spraying or gluing. Only here is it also important to correctly select the sequence of spraying with the appropriate substance. [28,29].

CONCLUSION

The conducted research shows that ways of finding economic and design solutions for weight, size and technical and economic indicators, a method of creating film combined converters based on film photoelectric and thermoelectric current sources, is encouraging for obtaining positive results from experimental studies of such structures. The creation of a proposed current source contributes to the transition to hybrid generators with fairly good efficiency values. and, perhaps, obtain tangible productivity when using secondary resources of heat sources. Weight, size and transportability characteristics are undoubtedly improving. Savings are achieved in the consumption of raw materials. When solving the issue related to finding flexible, well-heat-conducting and electrically insulating materials, their use becomes more convenient.

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