ischaemic injury in vitrectomy. *Br J. Ophthalmol.*, 81, 789-794.

19. Zolotareva M.M., Chvialeva K.I., Vasilevich A.I. (1978). *Gipotermiia pri glaznykh zabolevaniiakh [Hypothermia with eye diseases].* Minsk [in Russian].
20. Lazarenko V.I., Chanchikov G.F., Kornilovskii I.M., Gaidabura V.G. (1976). Vliianiie umerennoi lokalnoi hipotermii na hemo- i hidrodinamicheskiie pokazateli zdorovykh glaz [Influence of moderate local hypothermia on the hemo-and hydrodynamic parameters of healthy eyes]. *Oftalmologicheskii Zhurnal - J. Ophthalmology*, 6, 419-422 [in Russian].
21. Zadorozhnyi O.S., Nazaretian R.E., Mirnenko V.V., Naumenko V.A., Pasechnikova N.V. (2018). *Eksperimentalnoie issledovaniie epibulbarnoi i intraokuliarnoi temperatury krolika v usloviiakh hipotermii [Experimental study of epibulbar and intraocular temperature of rabbit under hypothermia]. Oftalmologiia. Vostochnaia Evropa - Ophthalmology. Eastern Europe*, 1, 73-81.
22. Anatychuk L.I., Pasechnikova N.V., Naumenko V.A., Nazaretian R.E., Umanets N.N., Kobylianskyi R.R., Zadorozhnyi O.S. (2019). Dynamics of intraocular temperature in the process of vitreoretinal surgery using irrigational solutions of various temperature. *Oftalmologicheskii Zhurnal - J. Ophthalmology,* 1, 33-38 [in Russian].
23. Anatychuk L.I. (1979). *Termoelementy i termoelektricheskiie ustroistva. Spravochnik (Thermoelements and thermoelectric devices. Handbook).* Kyiv: Naukova Dumka [in Russian].

Anatychuk L.I. (2003). *Termoelektrichestvo.T.2. Termoelektricheskiie preobrazovateli energii [Thermoelectricity. Vol.2. Thermoelectric power converters].* Kyiv-Chernivtsi: Institute of Thermoelectricity [in Russian].

Submitted 10.07.2019

P.D. Mykytiuk. *cand. phys. – math. science* [1,2]
O.Yu. Mykytiuk. *cand. phys. – math. science, dochentr* [3]

P.D. Mykytiuk

[1]Institute of Thermoelectricity of the NAS and MES of Ukraine, 1, Nauky str, Chernivtsi, 58029, Ukraine;
e-mail: anatych@gmail.com;
[2]Yuriy Fedkovych Chernivtsi National University, 2, Kotsiubynsky str., Chernivtsi, 58012, Ukraine;
[3]Higher State Educational Institution of Ukraine "Bukovinian State Medical University", 2, Theatre Square, Chernivtsi, 58002, Ukraine

O.Yu. Mykytiuk.

SOME OPTIONS FOR IMPROVING PARAMETERS OF THERMOELECTRIC CONVERTERS

The sensitivity of thermal converter as a function of mutual arrangement of its structural elements was investigated. The importance of optimally matching the resistances of thermocouple and heater for each specific application of thermal converter and the advisability of optimizing its structural elements were confirmed. Bibl. 6, Fig. 2, Tabl. 1.
Key words: thermoelectric converter, thermocouple, heater, sensitivity.

Introduction

The basic parameters of metrological-purpose thermal converters up to this time have been mainly improved by increasing the thermoelectric parameters of semiconductor materials used for the manufacture of thermocouples, one of the basic structural elements of thermal converters.

However, in [1] it was shown that the use of a thermoelectric material with maximum thermoelectric figure of merit (Z) is not always a decisive factor in improving parameters of thermal converter. For example, a significant increase in the sensitivity of thermal converter can be obtained by optimizing the thermal mode of its operation in order to increase the efficiency of using the heat generated by the heater, minimizing the influence of the thermocouple on the temperature distribution in the heater [2], optimizing the structural elements, and choosing the most effective operating mode for a specific thermal converter application, etc.

The purpose of this work is to study possible options for improving parameters of thermal converters based on the optimization of thermal converter structural elements and their operating mode.

Dependence of thermal converter sensitivity on the geometric dimensions of its housing

When designing thermal converter, it is necessary to keep in mind that thermal mode of thermal converter is determined not only by the geometric dimensions of thermocouple and heater, but also by the distance between them and thermal converter housing.

To optimize thermal converter by the geometric dimensions, a series of experimental studies was carried out to determine the sensitivity of thermal converter to the distance between the housing cover and the plane in which thermocouple and heater are located. The studies were carried out in the media with different heat transfer conditions - in vacuum, xenon and air.

The results of the experiments are presented in Fig.1.

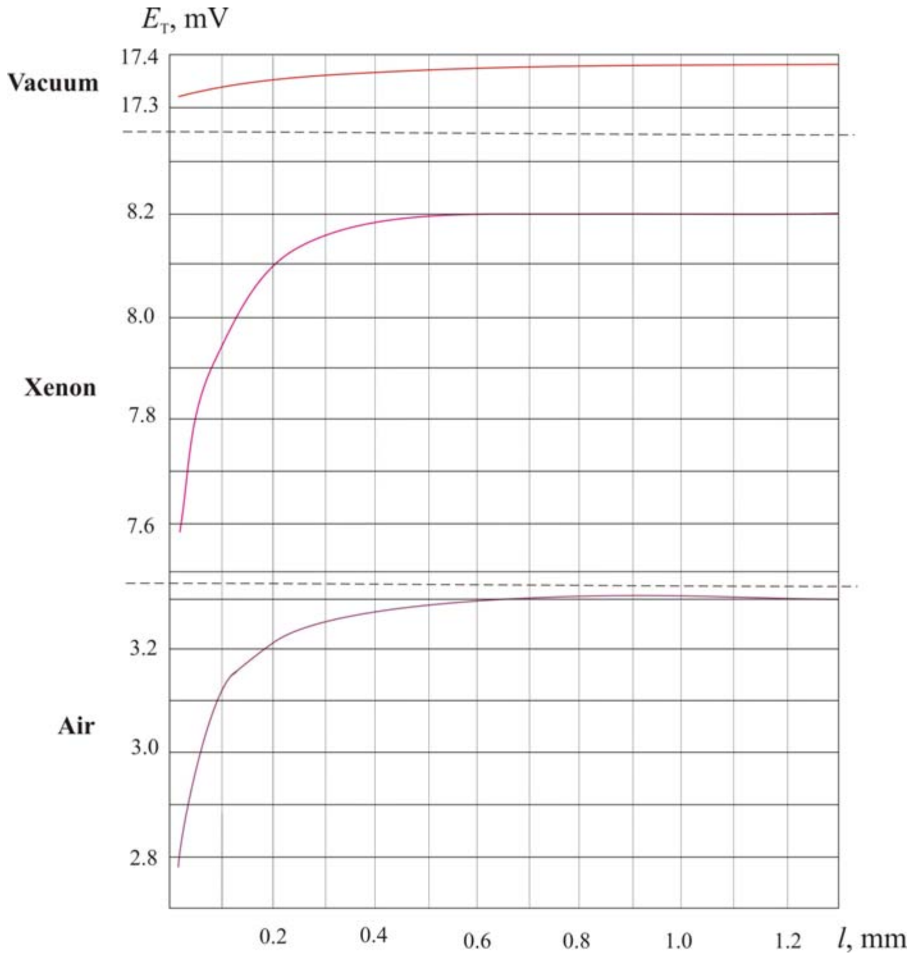

Fig.1. Dependence of output signal E_T of thermal converter on the height l of the housing cover above the thermocouple.

It can be seen from Fig. 1 that from a distance $l = 0.5 \div 0.6$ mm, further increase of L practically does not change the conditions of heat exchange between the structural elements of thermal converter and its housing.

The data obtained in xenon and vacuum confirm the theoretical calculations that the intensity of heat transfer in vacuum is much lower than the intensity of heat exchange in a gas environment.

The above studies were carried out for a type 4604 thermal converter with a rated current of 25mA and a thermocouple signal $E_T \geq 10$ mV. Such 4604 thermal converter is structurally manufactured in a housing of height of 5.5 mm and diameter of 4.9 mm. It should be noted that for thermal converters of other ratings mounted in a similar housing, the research data can be somewhat different. However, the purpose of the experimental studies was to establish the very fact of the influence of the thermal converter housing on the location of thermocouple and heater in it.

Matching of thermal converter thermocouple resistance with load resistance

The question of choosing the optimal operating mode for thermal converter has long been fully considered in [3]. However, thermal converter developers do not always take into account the importance of matching thermocouple resistance with load resistance. Therefore, it makes sense to dwell on this issue once again.

The expression for the electric power P_{out}, which the thermocouple develops at load r, can be written as:

$$P_{out}=(E-I_{T}\cdot R_{T})\cdot I_{T}=E_{n}\cdot I_{T} \quad (1)$$

where R_T, I_T are the resistance and rated current of the thermocouple, and E_n is the load voltage r.

Let us transform E_q. (1), expressing it through the resistance ratio of thermocouple R_T and load r.

$$P_{вих} = \frac{E_T^2}{R_T}\frac{1}{(m+2+\frac{1}{m})} \quad (2)$$

where $m = \frac{r}{R_t}$where $m=r/R_T$

Fig. 2 shows a plot of the maximum thermocouple power w versus m, where for convenience the values of E_T and R_T are taken to be 1.

As can be seen from Fig. 2, the maximum load power is observed at $m = 1$.

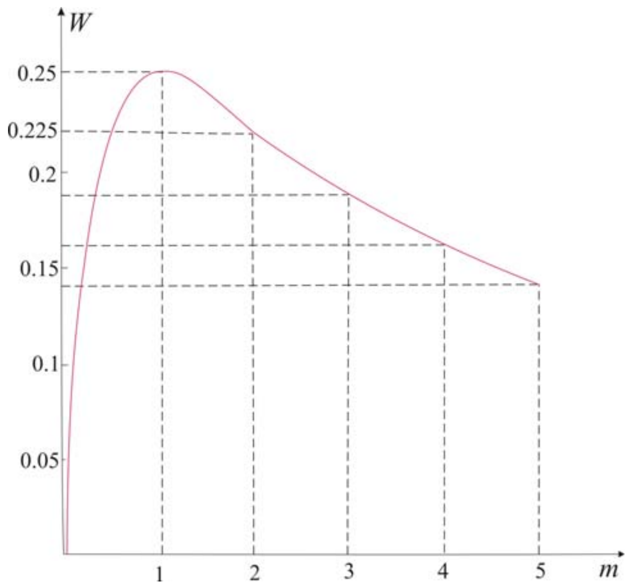

Fig. 2. The plot of w versus m

Optimization of heater and thermocouple

A significant increase in the volt-watt sensitivity of thermal converter can be achieved by improving the efficiency of using the heat generated by the heater. In [4], the option of using a heater with a variable resistance along the length was studied, with the aim of maximizing the concentration of heat at the point of contact between the heater and the thermocouple junction. According to estimates made in [4], this approach allows increasing the temperature at the point of contact between the thermocouple junction and the heater by almost a factor of two. Based on these research results, several thermal converter designs with heaters of variable cross section were created. Such thermal converters were studied in the air, in xenon, and in vacuum on a VUP-4A unit at a pressure of 10^4 mm Hg. The experimental results are shown in Table 1. For comparison, Table 1 presents the parameters of the product adopted as an analogue, namely thermal converter 2101.

Table

Parameters of thermal converter

Type or design of thermal converter	Average parameters of thermal converter							
	R_n, Ohm not more	R_T, Ohm not more	E_T in the air not less	S_w in the air V/W	E_T in xenon, mV	S_w in xenon, mV	E_T in vacuum, mV	S_w, in vacuum, mV
Thermal converter 2401 (АЮЖ 3.360.009 ТУ)	12	7	-	-	8	8	-	-
Thermal converter with a profile heater	16	10	3.0	7.5	5.2	13	7.2	18
Thermal converter with a prefabricated heater	16	10	2.8	7	4.4	11	6.4	16
Thermal converter with increased thermocouple resistance	16	20 40	3.2 3.6	8 9	6.0 7.2	15 12	8.8 12	22 90

Table shows that a significant increase in the volt-watt sensitivity of thermal converter can be achieved by evacuating its working volume. However, in this case, the problem is the availability of a vacuum-tight case for thermal converter. Nevertheless, creating such a case will not solve the problem. A number of studies will have to be carried out under vacuum conditions, which may require the development of new technology for the production of such material and methods for its investigation.

From the standpoint of practical applications, an interesting variant is the design of thermal converter with increased thermocouple resistance. As can be seen from Table 1, the sensitivity of such thermal converter at R_T = 40 Ohm reaches 30 V/W significantly exceeding the sensitivity of thermal converters, in which the thermocouple has R_T = 10 Ohm.

The problem with the widespread use of high-resistance thermal converters is the technological complexity of manufacturing microminiature thermocouples with a cross-section of legs at the level of 15 × 15 microns. Currently, the technology for manufacturing such products is mainly based on the use of manual labor.

Conclusion

1. The dependence of thermal converter sensitivity on the mutual arrangement of the heater thermocouple and housing for the thermal converter 46014 is established.
2. When matching the load and thermocouple resistances, high metrological parameters of thermal converter are achieved when their resistance ratio m is within $0.6 \le m \le 2$.

References

1. Mykytiuk P.D., Mykytiuk O.Yu. (2019). In reference to the choice of thermocouple material for metrological-purpose thermal converters. *J.Thermoelectricity*.

2. Mykytiuk P.D., Mykytiuk O.Yu. (2018). Impact of thermocouple on temperature distribution in the heater of measuring thermal converter. *J.Thermoelectricity*, 1, 64–59.
3. Anatychuk L.I. (1979). *Termoelementy i termoelektricheskiie ustroistva [Thermoelements and thermoelectric devices].* Kyiv: Naukova dumka [in Russian].
4. Mykytiuk P.D., Mykytiuk O.Yu. (2018). Temperature distribution in a heater with a resistance variable along its length in thermoelectric converter. *J.Thermoelectricity*, 2, 79–74.

Submitted 18.07.19

Микитюк П.Д. *канд. фіз.-мат. наук*[1,2]
Микитюк О.Ю. *канд. фіз.- мат. наук, доцент*[3]

[1]Інститут термоелектрики НАН і МОН України,
вул. Науки, 1, Чернівці, 58029, Україна,
e-mail: anatych@gmail.com;
[2]Чернівецький національний університет
імені Юрія Федьковича, вул. Коцюбинського 2,
Чернівці, 58012, Україна,
[3]Вищий державний навчальний заклад України
«Буковинський державний медичний університет»,
Театральна площа, 2, Чернівці, 58012, Україна

ПРО ДЕЯКІ ВАРІАНТИ ПОКРАЩЕННЯ ПАРАМЕТРІВ ТЕРМОЕЛЕКТРИЧНИХ ПЕРЕТВОРЮВАЧІВ

Досліджено залежність чутливості термоперетворювача від взаємного розташування його конструктивних елементів. Підтверджено важливість оптимального узгодження опору термопари з опором нагрівника для кожного конкретного застосування термоперетворювача та доцільність оптимізації елементів його конструкції. Бібл. 4, рис. 2, табл. 1
Ключові слова: термоелектричний перетворювач, термопара, нагрівник, чутливість.

Микитюк П.Д. *канд. физ.-мат. наук*[1,2]
Микитюк О.Ю. *канд. физ.- мат. наук, доцент*[3]

[1]Институт термоэлектричества НАН и МОН Украины,
ул. Науки, 1, Черновцы, 58029, Украина, *e-mail: anatych@gmail.com*;
[2]Черновицкий национальный университет
имени Юрия Федьковича, ул. Коцюбинского 2,
Черновцы, 58012, Украина
[3]Высшее государственное учебное заведение Украины
«Буковинский государственный медицинский университет»,
Театральная площадь, 2, Черновцы, 58002, Украина