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PREPARATION AND INVESTIGATION OF SOME PROPERTIES OF SEMICONDUCTIVE THERMOELECTRIC THIN FILM SENSORS BASED ON n-TYPE $Bi_2(Te, Se)_3$ AND p-TYPE $(Bi, Sb)_2Te_3$

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Abstract: *In the thermoelectric engineering, many cases it is neccessary to measure temperature of the objects without contacting with them. The temperature can be meas by using the sensors that are sensitive infrared radiation from the objects. In this pa we present the technology for preparation of thermo-couple based on n - type $Bi_2(Te,$ and p- type $(Bi, Sb)_2Te_3$ thin films...Some their properties such as: e vs T, noise fea are determined. The prepared sensors can be used to make the equipment for far measu of temprature.*

1. Introduction

In thermal technology, a popular problem is the measurement of the non-con temperature of distant object. If the object is not brightly burning, most of its radia is infrared. Infrared radiation sensors are usually made of thermoelectric semiconduc materials. The sensitivity of sensors usually is very high because it has a very l coefficient of thermoelectric as compared to other metal materials.

The object temperature is determined by measuring the total energy which is diated in the form of electric signals. Sensors operate on Seebeck effect. An advan of this type of sensor is that it can record weak radiation of $10^{-9} \div 10^{-10}$ w in a v infrared band.

In this report, we will demonstrate the semiconducting thin filter thermoele sensors which comprise 3 components. They are $Bi_2(Te, Se)_3$ of n type and of p t $(Bi, Sb)_2Te_3$ and made of highly-pure respective materials by the method of the evaporation in vacuum.

To improve thermal batteries's quality, thin film sensors are first made of si materials and then of 2 and 3 element mixtures in order to have the suitable car density and a maximum temperature difference between the hot and cold source. [1].

The noise of infrared sensors is also taken into consideration to improve sensor lity and to detect distant weak radiation.

Experimental, results and discussion

Sensors are produced by method of thermal evaporation in vacuum using German system. The sensors have several thermoelectric semi-conductor couples of n type $(Te, Se)_3$ and of p type $(Bi, Sb)_2Te_3$ in asteroid series connection (Fig.1) on plastic form.

The plastic platform is 0.1 mm k and has its surface thoroughly ted before it is put in vacuum to e the thermoelectric film. The source of the sensor concentrates de the asterism and is electrically lated. The cold source is good tact with open air by parallel contion with a copper ring.

The film's thickness is detered by optical interference. The 's thickness is about 1,5 μm.

The sensor's hot source is on focus of concave mirror (Fig.2). s makes sensor sizes very small, inner diameter $\phi = 3mm$ and r diameter $\phi = 12mm$, which udes 8 thermo-couples in series nection.

The concave mirror in the op-l system is in fact an optical sig-amplifier. This gives extra sen-ity to the sensor. The thermo-tric index of film of n-type Bi_2 $Se)_3$ and of p-type $(Bi, Sb)_2Te_3$ etermined by the method in [2] n the temperature difference be-en 2 filter ends is $\Delta T = 3 \div 4^0C$, al cords and the 2 blocks to dif-ntiate and stabilize temperature made of lead. The whole system ell insulated from environment litions.

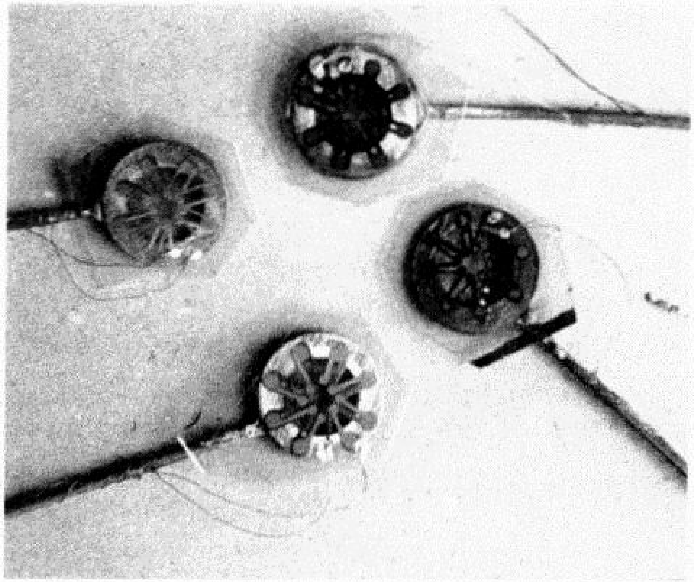

Fig.1: Photographs of IR sensor based on n-type $Bi_2(Te, Se)_3$ and p-type $(Bi, Sb)_2Te_3$

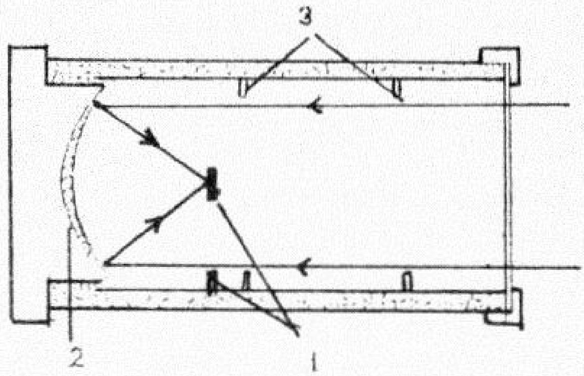

Fig.2: Structure of sensor unit. (1) sensor; (2) concave mirror; (3) diaphrams.

From experimental curves in Fig.3 and 4, the α index at 20^0C is inferred as α $-92\mu V/^0C$, and $\alpha_p = +171\mu V/^0C$.

The experiments show that linear recurrence is more accurate than log funct recurrence so it doesn't correspond to normal semiconductor rules. This maybe ca by a slight change in carriers density as a result of temperature variation or perhap temperature change is too small for the dependence a =f(logn) to appear clearly.

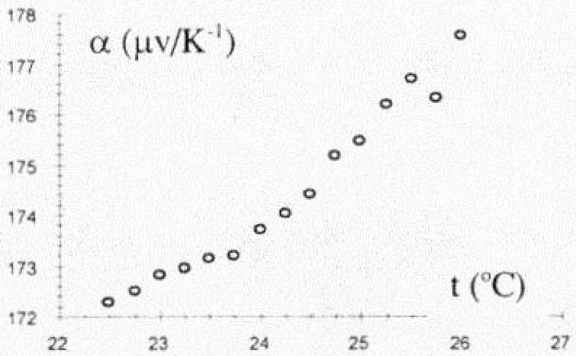

Fig.3: Dependent of α-index of p type$(Bi,Sb)_2Te_3$ film on temperature

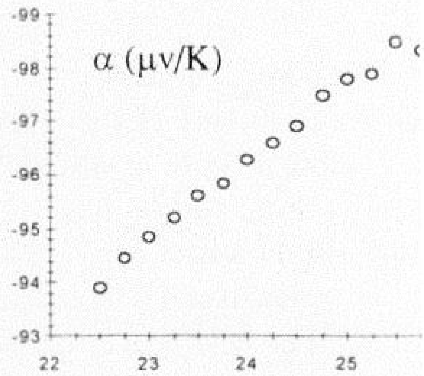

Fig.4: Dependent of α-inde of n type $Bi_2(Te,Se)_3$ film on temp

However, the a index measured by extrapolating from room temperature is quite similar to the announced results for the 3 dimensional devices in [3].

With sensors as Fig.1, the e.m.f is determines according to the temperature of a conical coal piece at a constant distance from the sensor (by non-contact method) as shown in Fig.5 on a X-Y recorder. So with reasonable accuracy, this can be considered as unfiltering wide band infrared sensors.

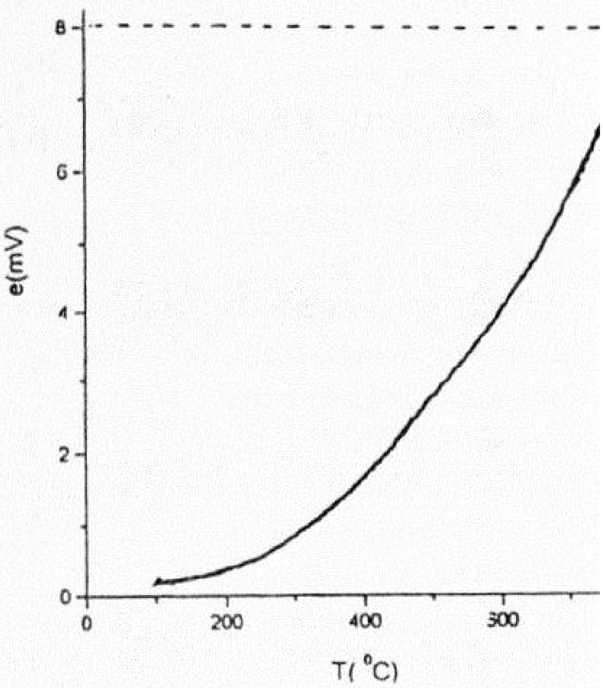

Fig.5: Dependent of e.m.f on perature (of the conical coal piece)

In order to identify the cord-sensor contact, the votage-amperage quality is measured on DLTS8000. The finding is shown on Fig 6 as a straight line, which indicates that the cord-sensor contact is omic.

The equivalent circuit of the sensor, therefor can be described as shown in Fig

+ Equivalent circuit and noise sensor:

In which R_{c1}, R_{c2} are the contact resittivity between the cord and the sensor; $T, \lambda)$ is the branch resitivity of p-type and n-type of thermoelectric films in continual nection.

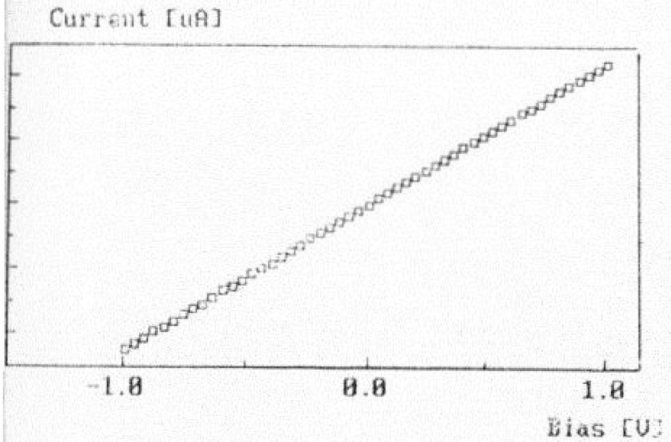

Fig 6: The voltage-amperage quality of infrared sensor.

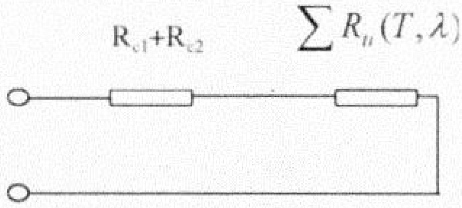

Fig. 7: The equivalent circuit of the sensor

In ordinary sensor, total noise has many types of of components whose source is the ical coal piece.either known or unknown.

Based on our diagram on infrared radiation sensors, total noise may include coments such as:

$$\bar{i}^2_{\text{total}} = \bar{i}^2_{\text{thermal}} + \bar{i}^2_{\text{short}} + \bar{i}^2_{\text{Flicker}} + \cdots$$

+ Noise Spectrum of sensor:

The spectrum of total noise neasured on FSEA30 Spectrum lyser at the Institute of Mate- Science when sensors are not lable and when infrared radia- sensors are available.

Results showed that within the uency band from 0 Hz ÷ 250 z there are a lot of noise ele- ts in different frequencies that ribute to the total noise. Com- ng to the Spectrum of thermal e from radiators and studying in trum analyzer, we can see that are of similar forms. Conse- ntly, typical noise is mainly ther- (Fig.8).

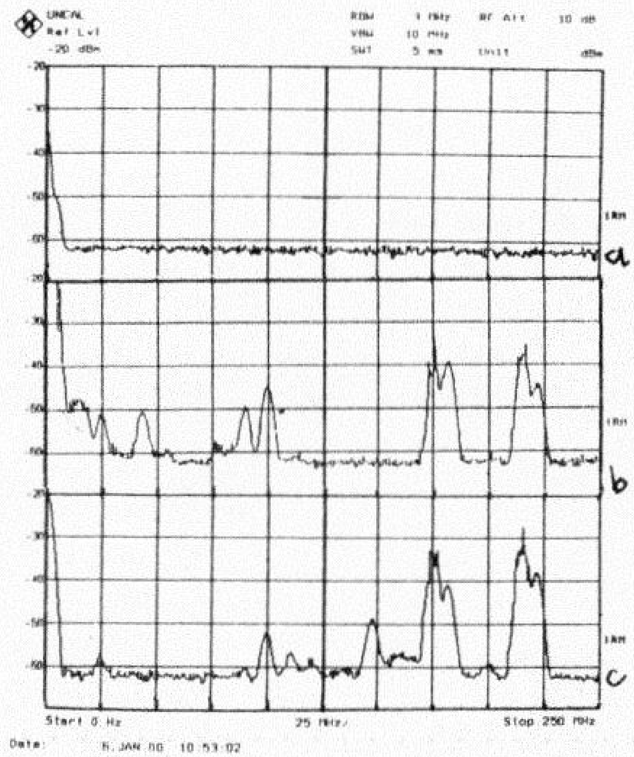

Fig.8: Noise spectrum density:
a- Floor noise; b- White noise; c- Noise of sensor

Fig 9 describees 1/f noise of ors measured by Lock-In-Amplifier 30 DSP. As can be seen in this figure 1/f noise apparently strengthens within the low frequency band. This noise is mε concerned with surface conditions of sensors, wich is the meeting point between thei electric branches and conductor-wire thermal electric web contacts. the noise spect does not depend on frequency but is more likely attricbuted to thermal and short r on higher frequency band.

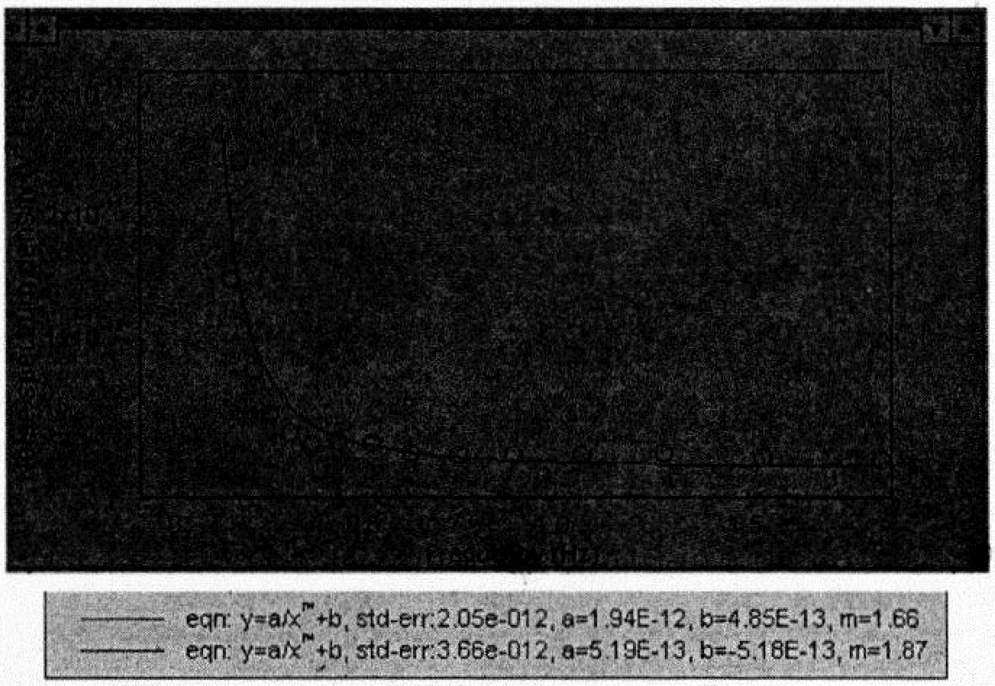

Fig.9: 1/f noise of sensors

3. Conclusion

The operation of multi component thermoelectric sensors corresponds well to Stefan-Boltzmann function within an acceptable error range. The sensors are sensi stable enough and their noise has been preliminary assessed, which brings chances tc them to determine distant thermal threshold.

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REFERENCES

[1] B.M.Golzman. *Semiconducting thermoelectric based on Bi_2Te_3*, *"Science"*, Mos 1972 (Russian).

[2] L.V.Vu, T.D.Canh, N.An, D.T.Don, P.N.Hai. IFRa - Red Radiative sensor u the Bi - Te thermoelectric thin film. *VNU, Journal of Science, Nat.Sce.*, **5** 19 12 ÷ 16.

[3] D.D.Thong, V.Linh, P.V.Uyen. Procedings of the science conference of HPC Noi 1990, p 84 ÷ 89.

[4] N.T.Binh and D.K.An. Some noise features and noise equivalent circuit of photodiode using in measurement and optical instrumenrs. *Communications in Physics*, Vol.9, **1** (1999) pp 51÷ 60.

[5] A.Van Der Ziel. *Fluctuation Phenonmena in Semiconductors*. London, 1959.

[6] S.M. Sze. *Physics of Semiconductor Devies*. New York, 1981.

P CHÍ KHOA HỌC ĐHQGHN, KHTN, t.XVI, n^{0}4 - 2000

NGHIÊN CỨU CHẾ TẠO VÀ KHẢO SÁT MỘT SỐ TÍNH CHẤT CỦA SENSOR NHIỆT ĐIỆN TRÊN CƠ SỞ $Bi_2(Te, Se)_3$ LOẠI n VÀ $(Bi, Sb)_2Te_3$ LOẠI p

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Trong kỹ thuật nhiệt điện, nhiều trường hợp cần đo nhiệt độ của vật mà không tiếp xúc được với vật. Người ta có thể dùng các sensor nhận các bức xạ hồng ngoại it ra từ vật, từ đó biết được nhiệt độ của vật. Trong bài báo này, chúng tôi trình bày ig nghệ chế tạo Sensor $Bi_2(Te, Se)_3$ loại n và $(Bi, Sb)_2Te_3$ loại p bằng phương pháp bay nhiệt trong chân không. Một số tính chất của các sensor đó đã được khảo sát r: sự phụ thuộc của suất điện động e vào nhiệt độ T, đặc trưng nhiễu...

Các kết quả bước đầu cho thấy triển vọng ứng dụng sensor này vào thiết bị đo ệt độ từ xa là khách quan.