JOURNAL OF OPTOELECTRONICS AND ADVANCED MATERIALS Vol. 9, No. 6, June 2007, p. 1813 - 1815

Microthermocouples of thermoelectric microwires

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Electrophysical and thermoelectric properties of glass isolated microwires of thermoelectric materials based on bismuth telluride are reported. On the basis of the obtained microwires with conductivity of types -p and -n microthermocouples with the signal of 1÷12 mV in the temperature interval 10÷50 °C were prepared.

(Received November 14, 2006; accepted April 26, 2007)

Keywords: Microwire, Microthermocouple, Signal, Bi_2Te_3, Thermoelectrics

1. Introduction

The trend to miniaturization of electronic devices and increasing of their electric signals requires the study of the physical-chemical, electrophysical and thermoelectric processes in condensed low dimensional materials, such as microwires in glass isolation. Theoretically the problem is much simpler in one-dimensional model, in practice the obtained single crystals are much more "ideal", and effects are shown stronger than in films or bulk crystals.

The most rapid method for obtaining microwires of different metals in glass isolation is the Ulitovsky method [1].

For semiconductor materials containing volatile chemical elements and having relatively low melting temperature (<1000 °C) the Ulitovsky method for getting microwires cannot be used due to evaporation of volatile element during the technological process. Therefore the installation was modified. Peculiarity of the installation consists in the following. A furnace with resistive spiral is used as a heater, temperature stability is high, thermoelectric material is introduced into the evacuated and hermetically closed ampule for volatile elements not to evaporate in the process of microwire obtaining [2].

Electrophysical and thermoelectric properties of the obtained microwires were studied, and as a result microthermocouples with rather high electric signal were prepared.

2. Electrophysical and thermoelectric properties

Studying the dependence of value of physical parameters on growth conditions and thermal treatment of the obtained microwires it was found that the thermopower coefficient (α) and resistivity (ρ) for samples with electric conductivity of the type -p and -n at the temperature 300 K are correspondingly equal to: α_p=(150÷300) μV/K; ρ_p=(1÷7)×10^{-3} Ohm·cm; α_n=-(100÷140) μV/K; ρ_n=(1÷3)×10^{-3} Ohm · cm.

Dependences of coefficients of thermopower (α) and resistivity (ρ) are shown in Figs. 1-4. It is seen from these figures that treatment of the samples by annealing leads to increase of the coefficients α_p and ρ_p, and for the samples of type -n α_n after annealing grows in absolute value, and ρ_n decreases.

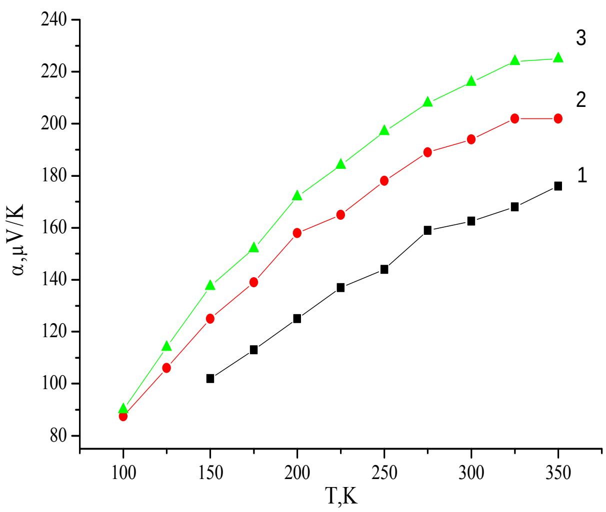

Fig. 1. Temperature dependence of thermopower (α_p) of the samples of type -p. 1 - before annealing, 2 - treated at the temperature 473 K.

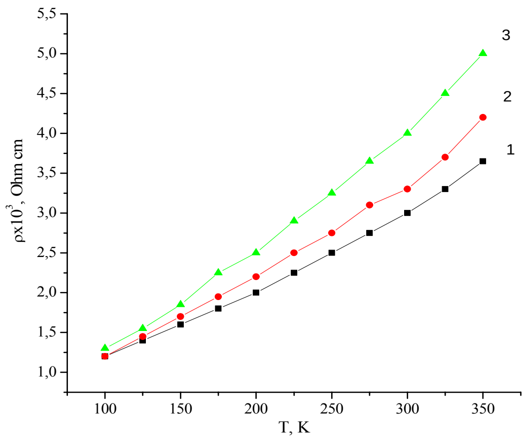

Fig .2. Temperature dependence of resistivity (ρ_p) of the samples of type -p. Notations as in Fig.1.

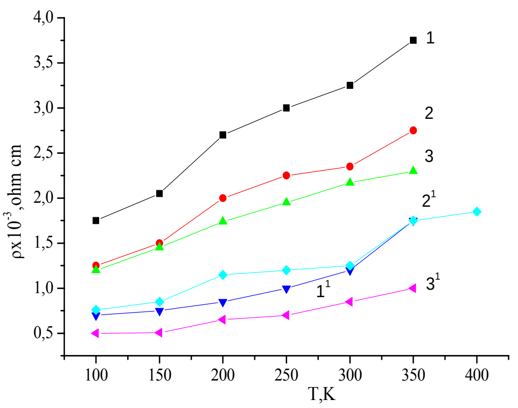

Fig.3. Temperature dependence of resistivity (ρ_n) of the samples of type -n for nontreated samples (1, 2, 3) and treated ones (1^1, 2^1, 3^1).

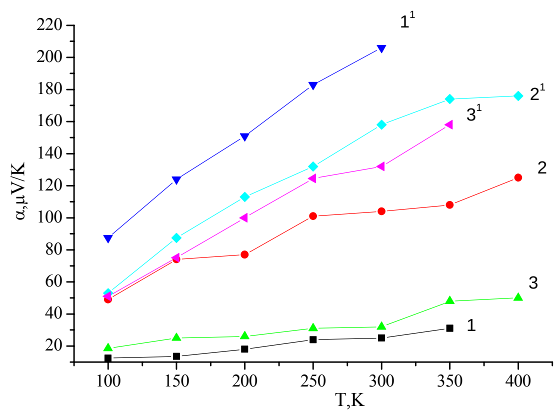

Fig.4. Temperature dependence of thermopower (α_n) of the samples of type -n. Notations as in Fig.3.

3. Preparation of microthermocouples

For temperature measurement by contact of different solid, liquid, gaseous or biological objects thermocouples of different metals such as chromel-copel, chromel-alumel, copper-constantan, platinum-platinorhodium are successfully used, their signal is or the order (2.54÷6.5) μV/K.

In order to increase accuracy of temperature measurement it is necessary to use transducer with electric signal high enough. For this purpose the microwires obtained of thermoelectric materials based on bismuth telluride were used.

Hot and cold contact of the microthermocouple were made by electrochemical method. For this purpose two ends of microwires, one of type -p and the other of type -n are united together and introduced into a cuvette with chemical solution, which consists of 16 g $NiSO_4 \cdot 7H_2O$+4,5 g Na_2SO_4+27 g $MgSO_4$+ 0,7 g NaCl+2,3 g H_3BO_3 per 100 ml H_2O. The obtained solution is connected to the other pole of the power supply. Solution H_3BO_3 is prepared preliminarily separately. It is dissolved by boiling, and after cooling it is added to the basic solution until Ph=5.5 is obtained [3].

For example, for formation of nickel contact with the diameter 30÷40 μm at room temperature it is necessary to maintain the electric current density of 5 A/dm2 during 30 minutes.

Due to small diameter of the microwires and glass coating (10÷30) μm the obtained thermocouple is flexible enough.

Fig. 5 shows the temperature dependence of the obtained thermocouple signal. As it is seen in the temperature range 230÷270 K the temperature dependence of the signal is linear. Depending on thermal treatment of initial microwires it is possible to control their sensibility too (Fig.6).

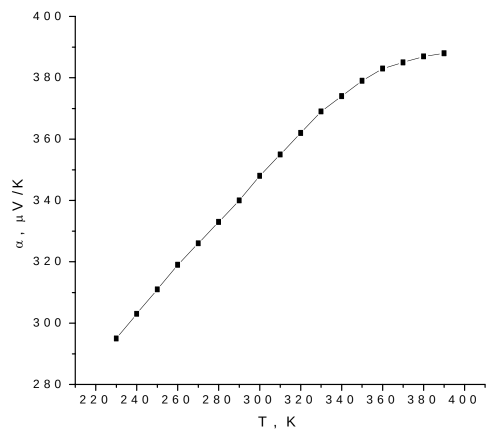

Fig. 5. Dependence of the thermocouple thermopower on temperature.

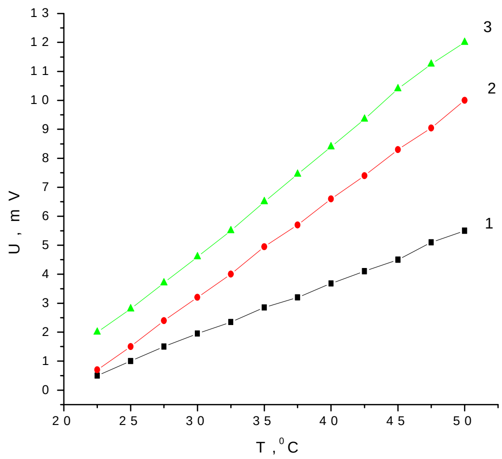

Fig. 6. Dependence of the thermocouple signal on temperature.

4. Conclusion

It is found that optimal electrical-thermoelectrical characteristics of microwires based on Bi_2Te_3 are the following: α_p=(180÷200) μV/K; ρ_p=(4÷6)×10^{-3} Ohm · cm; α_n=-(130÷140) μV/K; ρ_n=(1÷3)×10^{-3} Ohm · cm.

It is found that the microthermocouple of microwires is sufficiently flexible and may be used for temperature measurement even in aggressive environment.

Signal of the microthermocouple prepared on the basis of Bi_2Te_3 alloy is higher by an order of magnitude than in the thermocouple of metals.

References

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