MICROTHERMOCOUPLE BASED ON THERMOELECTRIC MICROWIRES

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Introduction

Tendency to miniaturization of electronic devices and increasing of their electric signals requires study of physical-chemical, electrophysical, and thermoelectric processes in condensed low dimensional materials. In the theoretical aspect, solution of the problem is much simpler for one-dimensional models; in practice, obtained single crystals are much more "ideal", and effects are shown stronger than in films or bulk crystals.

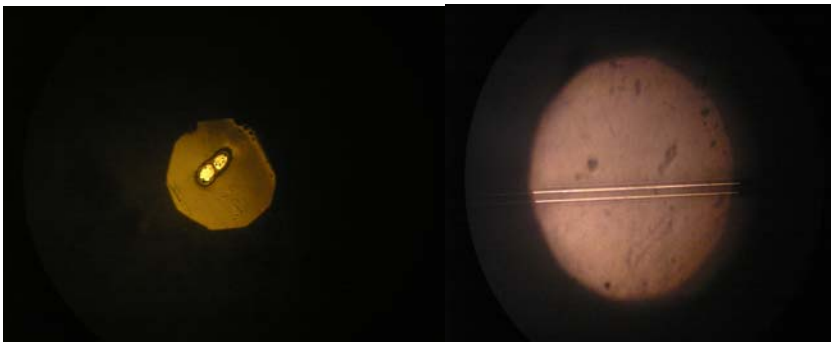
The most rapid method for obtaining of microwires of different metals in glass isolation is the Ulitovsky method [1], where microwires are obtained in open ampules or in rarefied inert gas.

For semiconductor materials containing volatile chemical elements this method cannot be applied due to evaporation of volatile elements resulting in a change of initial composition of alloys. Therefore, the installation for obtaining of microwires of these materials was modified. Peculiarities of the installation consist in the following. A furnace with highly stabilized resistive heating is used as a heater, the thermoelectric material is introduced into the evacuated, hermetically closed ampule [2].

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

Electrophysical and thermoelectric properties

Transverse and longitudinal cross-sections of the obtained bifilar microwire based on the material Bi_2Te_3 of p- and n- types are shown in Fig. 1.



a) b)
Fig. 1. a) transverse cross-section; b) longitudinal cross-section

In the result of studying the dependence of the parameter value 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 equal to α_p=150-300 μV/K; $\rho_p=(1\div7)\bullet10^{-3}$ Ohm•cm; $\alpha_n=-(100\div140)$ μV/K; $\rho_n=(1\div3)\bullet10^{-3}$ Ohm•cm, correspondingly.

Dependences of coefficients of thermopower (α) and resistivity (ρ) are shown in Figs. 2-5. It is seen from these figures that annealing of the samples leads to an increase of the coefficients α_p and ρ_p; for the samples of type -n, α_n grows in absolute value and ρ_n decreases.

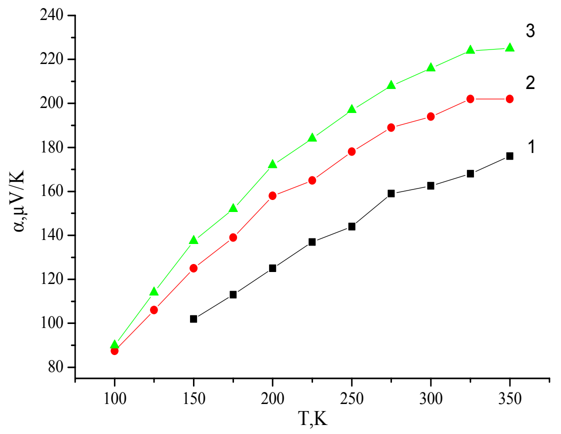


Fig. 2. Temperature dependence of thermopower (α_p) of the samples of type -p. 1 - before annealing, 2 - treated at the temperature 473 K, 3 -treated at the temperature 520 K. Annealing time is 24 h.

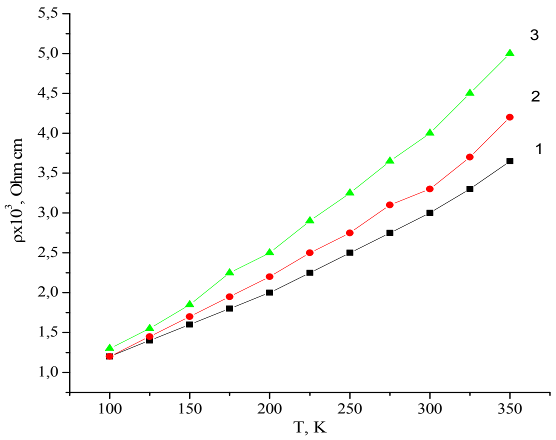


Fig. 3. Temperature dependence of resistivity (ρ_p) of the samples of type -p. Designations as in Fig. 2.

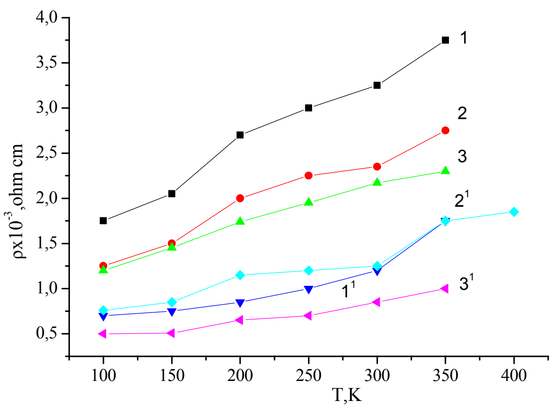


Fig. 4. Temperature dependence of resistivity (ρ_n) of the samples of type -n for nontreated samples (1, 2, 3) and treated ones (1^1, 2^1, 3^1).

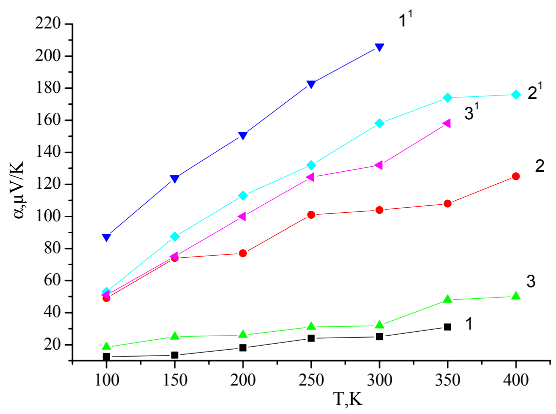


Fig. 5. Temperature dependence of thermopower (α_n) of the samples of type -n. Designations as in Fig. 4.

Preparation of microthermocouples

The studied bifilar microwires were used for preparation of microthermocouples for contact temperature measurement of various solid, liquid, gaseous, or biological objects. It is known that for these measurements, thermocouples of different metals are used, such as chromel-copel, chromel-alumel, copper-constantan, platinum-platinorhodium, their electric signal is of the order of (2,54-6,5) μV/K.

In order to increase accuracy of temperature measurement it is necessary to use transducers with sufficiently high electric signal. For this purpose, the microwires obtained of thermoelectric materials based on bismuth telluride (Bi_2Te_3) were used.

Hot and cold contact of the microthermocouple were made by electrochemical method [3]. Due to small diameters of the conductors and glass coatings, the thermocouple obtained of the bifilar microwire is flexible enough.

Fig. 6 shows the temperature dependence of the obtained thermocouple signal.

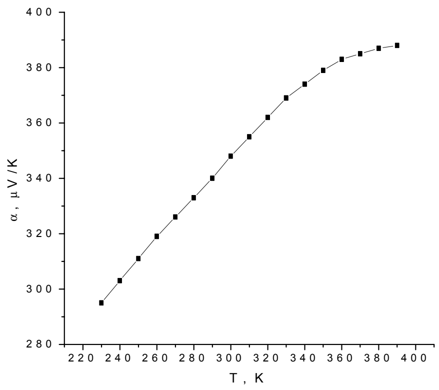


Fig. 6. Dependence of the thermocouple thermopower on temperature

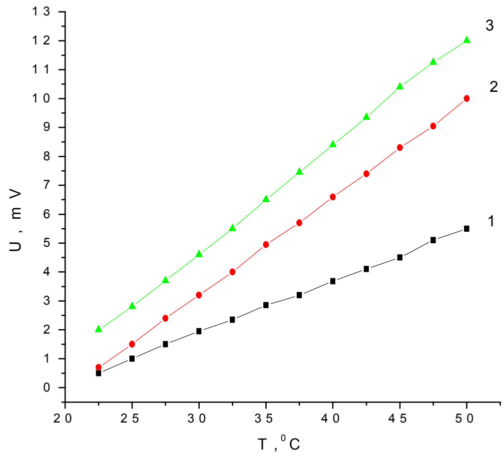


Fig.7. Dependence of the thermocouple electric signal on temperature

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 bifilar microwires it is possible to control their sensibility too (Fig. 7). As a result, value of the thermoelectric signal of the thermocouple is about 2-12 mV in the temperature range 23-50^{o}C.

Conclusions

1. Bifilar microwires of thermoelectric material based on Bi_2Te_3 with one electrode being of type -p and the other of type -n have been obtained.
2. The electric and thermoelectric properties have been studied.
3. Microthermocouples with thermoelectric signal value of 2-12 mV in the temperature range of 25-50^{o}C have been prepared.
4. The autors acknowledge support by 069/p project.

References

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