COMPARATIVE HEAT TRANSFER METHOD

N.M. ABDULLAYEV, S.R. AZIMOVA
Institute of Physics of Ministry of Science and Education Republic of Azerbaijan, Azerbaijan, Baku, H. Javid av. 131, Az-1143,
E_mail: sevinc_azimova_82@mail.ru

The research work is devoted to the measurement of the thermal conductivity of crystals, improvement of existing methods of thermal conductivity. A comparative method for measuring heat transfer is considered. Thermal conductivity of solid substances, their theoretical justification and method of implementation are shown. The given accuracy provided in the method is expected.

Keywords: absolute method, comparative method, general measurement, heat conductor.
PACS: 536.2

1. INTRODUCTİON

Thermal conductivity is the process of transferring thermal energy from more heated parts of the body to less heated ones, carried out by randomly moving particles of the body or vibrations of the crystal lattice. This is the most important physical process: the nature of its flow determines the thermo physical properties of the material. The temperature gradient is a vector directed normal to the isothermal surface in the direction of increasing temperature and is numerically equal to the derivative of the temperature in this direction. In general:

$$T = \partial T\ (\partial n / \vec{n}_0) \quad (1)$$

where $\vec{n}_0$- is a unit vector directed along the normal to the isothermal surface.

$$\nabla T = (\nabla T)_x = (\partial T / \partial x)\ \vec{\iota} \quad (2)$$

Here $\vec{\iota}$ -is the unit vector in the direction of the x-axis. Obviously, for the chosen conditions

$$\nabla T = (\Delta T / d)\ \vec{\iota} = ((T_{hot} - T_{cold}) / \mathrm{d})\ \vec{\iota} \quad (3)$$

Thus, by forming a temperature difference between the faces of a material, we create a temperature gradient inside this material. In a particular case, the temperature gradient is a constant, i.e. the temperature changes uniformly and linearly when moving from the “hot” end (with temperature T_1) to the cold end (T_2). A state with a non-zero temperature gradient is thermodynamically non-equilibrium and, according to the second law of thermodynamics, the system will tend to move into thermodynamic equilibrium - a heat flow will occur - the process of energy transfer from the "hot" end to the "cold" end. The physical laws of this process depend on the properties of the material, as well as on the initial and boundary conditions [1]. Analogously, the dependences of total thermal conductivity in $Bi_2Te_{2.7+x}Se_{0.3}$ compounds were shown in the work [2]

The aim of the work is to develop a comparative thermal conductivity method for measuring the thermal conductivity of small crystals.

An overview of the methods available in this field was carried out. One of the disadvantages of most methods is that they are not absolute, so their implementation requires a reference sample, the thermal conductivity of which is known in advance and accurately. This significantly increases the measurement error.

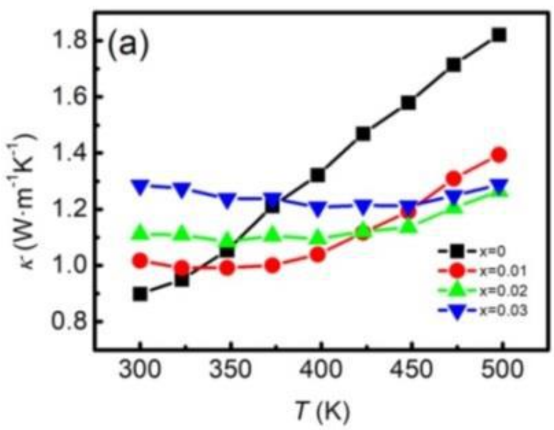

Fig. 1. Temperature dependence of thermoelectric properties of $Bi_2Te_{2.7+x}Se_{0.3}$, **a** total thermal conductivity κ [2].

Another drawback is the limitation of the range of materials under study and is due to the requirement that the thermal conductivity values of the test and reference samples are close, so the methods often do not provide the ability to measure samples with very different thermal conductions. An example is the State Standard units of thermal conductivity Standards 59-2007, which is based on the stationary method [3], where the unit of thermal conductivity is reproduced in limited ranges, W/(m·K), 0.1…5 and 5…20, while extended the relative measurement uncertainty is 0.8 - 2% [4].

One of the characteristics of the qualitative difference between semiconductors and metals is thermal conductivity. It is known that $Bi_2Te_{2.7}Se_{0.3}$ layered crystal remains one of the most popular and demanded materials in today's thermoelectric production. The problem with thermoelectrics is low

131, H.Javid ave, AZ-1143, Baku
Institute of Physics
E-mail: jophphysics@gmail.com

efficiency. Efficiency – Z varies depending on temperature (T) and for each degree (quality) is characterized by quality parameter - ZT:

$$ZT= \alpha^2\sigma\, T/\lambda \qquad (4)$$

Here, Z- efficiency, T - average temperature, α- Seebeck coefficient, σ - conductivity, λ- is the coefficient of thermal conductivity.

One of the ways to increase the ZT coefficient in thermocouples is to measure thermal conductivity [5].

For the measurements, samples of $Bi_2Te_{2.7}Se_{0.3}$ with different levels of additives were used. $Bi_2Te_{2.7}Se_{0.3}$ layered crystal has 0.1 - 0.7 mass percent nickel additive.

Fig. 2. Heat sink: 1- pictometer, 2- samples, 3- water cup, 4- penoplast holder with low thermal conductivity.

A new phase of $Ni_{1.297}Te$ grains and *Ni-Se-Te* chains were detected in the composition. No free nickel atoms were observed in its composition. The comparative thermal conductivity method was used to study the dynamics of thermal conductivity of the additive sample. Here, the method we have presented using a noncontact method from a distance has allowed the experiment to be carried out more accurately.

As can be seen from *fig. 2* , the method uses: a picometer, samples, a glass of water, a penaplast holder with low thermal conductivity.

The samples are placed in the numbered holes in the penaplas holder. The water in the glass is heated up to 40°*C*, and a plastic holder with crystals is placed on it. Two picometers are used to determine the thermal conductivity of the sample.

The advantage of this method for the determination of a small change in the thermal conductivity of additives intercalated in a small amount in the layers of the sample is undeniable.

CONCLUSİONS

With a specific implementation of the methods, the actual error will always be above the above assessment and in each particular case should be determined individually depending on the quality of performance. The method simultaneously measures the thermal conductivity of several samples with different thermal properties at once, that is, they provide an accurate thermo conductometric scanning operation, which is advantageous and significantly different.

[1] *M.V. Dorokhin, A.V. Zdoroveyshchev, Yu.M.Kuznetsov/* Measurement of the thermal conductivity by the method of stationary thermal flow, Compiled by: Workshop. – Lower Novgorod: Nizhny Novgorod State University, 2019. - 45 p.

[2] *Xi Chen, Fanggong Cai, Rong Dong, Xiaobo Lei, Runqing Sui, Lanxin Qiu, Zhili Zeng, Wei Sun, Hao Zheng, Qinyong Zhang/* Enhanced thermoelectric properties of n-type $Bi_2Te_{2.7}Se_{0.3}$ for power generation, Nature Journal of Materials Science: Materials in Electronics 2020, Springer ,https://doi.org/10.1007/s10854-020-03057-8.

[3] *N.A. Sokolov*. Method for determining studies of thermal conductivity of materials, Pat. 2276781 Russian Federation, IPC G01N 25/00, applicant and patent owner tel Federal State Unitary Enterprise “All-Russian Research Institute of Metrology them. named after D. I. Mendeleev.” - No. 2004133748; dec. 11/16/2004; publ. May 20, 2006 Bull. No. 14. - 7 p.

[4] *V.P. Khodunkov, Yu.P. Zarichnyak.* New stationary methods for measuring thermal conductivity of solid bodies, DOI: 10.17277/vestnik.2022.03.pp.455-465.

[5] *C. Gayner, K.K. Kar.* Recent advances in thermoelectric materials, Prog. Mat. Science 83, p.330, 2016.