ΦΥΣΙΚΗ. — **Quick technique to measure the absolute thermopower of short semiconductor samples,** *by P. S. Ioannides**. Ἀνεκοινώθη ὑπὸ τοῦ Ἀκαδημαϊκοῦ κ. Καίσαρος Ἀλεξοπούλου.

A B S T R A C T

An apparatus for measuring the absolute thermopower of semiconductor specimens as a function of temperature is described. It is designed for fast investigation of very short samples. The method has been applied to pyrite and galena single crystals in the temperature range 10 - 110° C.

1. INTRODUCTION

The thermopower is the most sensitive electronic transport property of solids and constitutes a powerful tool in the investigation of the electronic properties of them, such as scattering mechanism, carrier concentration, carrier sign etc. In the usual experimental arrangements [**1-3**] for measuring the thermoelectric power or Seebeck coefficient, the specimen is in the form of wire or rod of several centimeters in length. Even in the case of specimens in form of parallelepipeda, the length should be long enough in order that the necessary temperature gradient of a few degrees is possible to be established along the specimen. However, in some natural single crystals or brittle materials it is not so easy to have a homogeneous specimen longer than a few millimeters. On the other hand in the numerous reported techniques [**4 - 18**] for measuring the thermoelectric power or Seebeck coefficient there is a certain complexity in the apparatus involved and in the needed instrumentation. What is often desired is an easy and quick information on the thermoelectric properties of a large number of specimens (e. g. when we want to choose, among a large number of specimens, only a few, the most appropriate ones, for our particular main experiment, or when we want to check the specimen thermoelectric properties change after a certain treatment in a large number of specimens).

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* Π. Σ. ΙΩΑΝΝΙΔΟΥ, **Τεχνικὴ ταχείας μετρήσεως τῆς ἀπολύτου θερμοηλεκτρικῆς ἰσχύος βραχέων δοκιμίων ἡμιαγωγῶν.**

The purpose of this paper is to present a simple as well as inexpensive apparatus for easy measurements of the absolute thermopower of small specimens of semiconductors in the form of parallelepipeda 4-5 mm of length in the temperature range 10-110^{0}C. In literature [13] there is an apparatus for measuring Seebeck coefficient on high resistivity materials based almost on the same idea but it is not so compact and stable as the present one. Moreover on designing the apparatus for specimens of low resistivity, the thermal conductivity of the electrodes have to be taken much into account.

2. EXPERIMENTAL TECHNIQUE

The thermopower of a circuit of two materials a and b can, in principle, be measured in two ways: One way is to keep one of the junctions at a fixed temperature and to measure the Seebeck emf E_{ab} as the temperature T of the second junction is raised; the thermopower S_{ab} of the material a with respect to b is obtained as the slope $\partial E_{ab}/\partial T$ of the curve E_{ab} versus T. In practice, when measuring short specimens, the following method is preferable: The temperature of both junctions is varied, keeping a small temperature difference ΔT (say 5^{0}C) between them, and the small Seebeck emf ΔE_{ab} (fig. 1) is measured. The thermopower may then be obtained for the mean temperature of the specimen as $\Delta E_{ab}/\Delta T$, and the absolute thermopower of the specimen a may be calculated if the absolute thermopower of the material b is known:

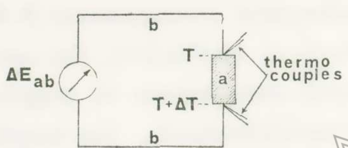

Fig. 1. The thermopower of the material (a) with respect to (b) is $S_{ab} = \Delta E_{ab}/\Delta T$.

$$S_a = S_b - S_{ab} = S_b - \Delta E_{ab}/\Delta T.$$

Figure 2 shows the basic apparatus used for measuring the thermopower of a specimen (sp) with respect to copper for which the absolute thermopower against temperature is known [19]:

$$S_{Cu} = 1.54 + 5.45 \times 10^{-3}\,T \;\mu V/\text{degree},$$

where T is in ^{0}C.

The holder of the specimen is made up by two copper discs 6 mm thick and 24 mm in diameter. These two discs press the specimen (say $4 \times 2 \times 3$ mm^3) between them with the aid of two small springs which allow the thermal expansion of the specimen (fig. 2). The side-surfaces of the discs are covered by teflon cylinders so that there is no horizontal heat flow inside the copper discs. This allows the temperature of the specimen ends to be measured by thermocouples that are fixed into small holes drilled into the inner surfaces of the copper discs close to

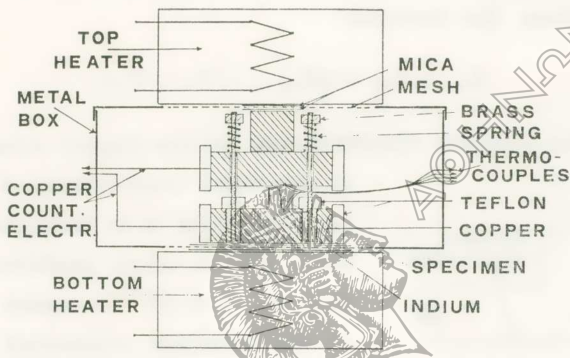

Fig. 2. Details of the apparatus.

their centers. The good contacts between the specimen and the copper discs are established with thin sheets of indium that do not influence rhe results since the temperature of both sides of them are practically the same. The holder is enclosed in a metal box ($35 \times 15 \times 3$ cm^3) to protect measurements from both air droughts and electrostatic noises (guarding).

The small temperature gradient along the specimen in a temperature range 10 - 110^{0}C, is obtained by proper combination of electric currents through two heaters at the bottom and the top of the holder. For minimizing the metal box heating without interrupting the guarding we open two holes (8×8 cm^2) on both bottom and top sides of the metal box and close them with thin wire mesh. The electric insulation between mesh and copper disc on the one hand and electric heater on the other, is assured by thin sheets of mica. The distance between the upper mesh and the upper copper disc is bridged by inserting a short copper rod (fig. 2).

For measurements at room temperature and below, the bottom heater is replaced by a cooler, that is a copper rod immersed in an ice bath. The higher the surface of the bath, the nearer to 0^0 C is the temperature of the bottom copper disc.

The two copper leads for measuring the $\Delta E_{sp,Cu}$ and the wires of the two thermocouples for measuring the temperatures T_B and T_T of the specimen ends, pass through the walls of the metal box by means of electrically insulated binding posts (fig. 2). Measuring the three quantities $\Delta E_{sp,Cu}$, T_B and T_T we can calculate S_{sp} at the temperature: $(T_B + T_T)/2$ from the formula:

$$S_{sp} = S_{Cu} - \Delta E_{sp,Cu} / |T_B - T_T|,$$

where S_{Cu} is the absolute thermopower of the copper counter electrodes at the mean temperature of the specimen. In this point it is indicated that a Seebeck emf is taken positive if it is such that as $T + \Delta T$ increases the potential of the terminal connected to the end at the temperature $T + \Delta T$ also increases, or in other words, if it is such that electric current flows via the sample from the «hot» end to the «cold» one (fig. 3).

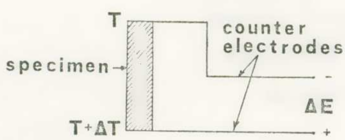

Fig. 3. Sign convention of the Seebeck emf.

3. RESULTS

The apparatus was tested on two natural semiconductors: pyrite and galena single crystals of high conductivity and the results are shown in figure 4. The Seebeck emfs were measured by a Dana digital voltmeter of accuracy 0.1 μV and the temperatures at the ends of the specimen were measured by chromel-alumel thermocouples connected to a Doric digital thermometer of accuracy 0.1^0C. The method is found sufficiently sensitive for small changes of the thermopower, of the order of 5 μV/degree. The criterion of the good functioning of the apparatus is that the thermopower $S_{sp,Cu}$ remains the same in both value and sign for either direction of the temperature gradient ΔT. There are on the way measurements of controlled conductivity on natural single crystals. By measuring the thermopower of a crystal against temperature the

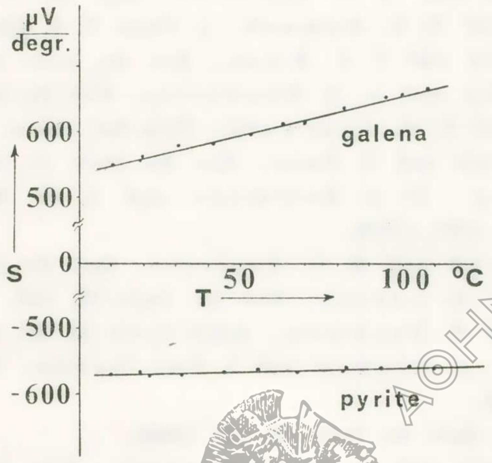

Fig. 4. The absolute thermopower of pyrite and galena single crystals against temperature.

apparatus is used as a tool to check any conductivity changes of the crystal.

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ΠΕΡΙΛΗΨΙΣ

Διὰ τῆς παρούσης ἐργασίας περιγράφεται συσκευὴ μετρήσεως τῆς ἀπολύτου θερμοηλεκτρικῆς ἰσχύος ἡμιαγωγῶν συναρτήσει τῆς θερμοκρασίας, διὰ τὴν ταχεῖαν διερεύνησιν πολὺ βραχέων δοκιμίων, καὶ γίνεται ἐφαρμογὴ τῆς μεθόδου εἰς δοκίμια μονοκρυστάλλων σιδηροπυρίτου καὶ γαληνίτου εἰς τὴν περιοχὴν θερμοκρασιῶν 10 - 110°C.

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