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Measurement of magnetic field influence on thermal electromotive force in micro and nano semi-conductor films without creation of temperature gradient

Process of charging thermoelectric capacitor which represents system of metal - semiconductor - isolator - metal, from a constant source of a voltage applied through resistor *R*, occurrence of the thermal electromotive force in such system and influence on this process of a magnetic field is considered. Change of the thermal electromotive force and coefficient Peltier in a cross magnetic field is measured.

For measurement of thermal electromotive force and its change it is necessary to create a temperature gradient that is not always convenient, especially if researched samples represent a thin film or a plate. Creating difference of temperatures even in 1 degree in such case is extremely difficult as the gradient of temperatures turns out very big because of subtlety of a sample. Therefore real difference of temperatures appears to be shares of degree which makes measurements of temperature difference difficult and strongly influences measurement accuracy. So thermal electromotive force measurement without creating temperature gradient represents an actual task.

Let's examine a charge of the thermoelectric condenser which is system of metal - semiconductor-isolator-metal powered from a constant source of a voltage applied through resistor *R*.

The equation describing this process is:

$$RC\frac{du}{dt}+u_{C_1}+u_{C_2}+u_{C_3}=U_k+U_0, \quad (1)$$

Where $C=\frac{C_1C_2C_3}{C_1C_2+C_1C_3+C_2C_3}$, C_2, C_3 - capacity between metal and the semiconductor, formed because of the electric field penetrating into the semiconductor, C_1 - capacity of interelectrode space where isolator is, $u_{C1}=\varphi_1'-\varphi_0'$, $u_{C2}=\varphi_0'-\varphi_0$, $u_{C3}=\varphi_1-\varphi_1'$ change of potential on C_i. If there is used an enough low-ohm conductor (with conductivity more 0,1 ohm^{-1} x cm^{-1}) than electric field penetration depth into the semiconductor does not exceed the 100-th shares of micron, and thickness of a dielectric film gets out within the limits of several micron, so $C_1 << C_2$ and $C_1 << C_3$. In a same way $u_{C_1}>>u_{C_2}, u_{C_1}>>u_{C_3}$.

Then, designating $u_{C_1}\approx u$ and $C=\frac{C_1C_2C_3}{C_1C_2+C_1C_3+C_2C_3}$, we can compile an equation for a condenser voltage:

$$RC\frac{du}{dt}+u=U_k+U_0 \quad (2)$$

The solution for the equation (2) is:

$$u(t)=Ae^{-\frac{t}{RC}}+U_k+U_0. \quad (3)$$

At the initial moment of time the condenser is not charged, therefore $u_{0C_1}=0$ $u_{0C_3}+u_{0C_2}=U_k$, and, $u(0)=U_k$ as $u=u_{C_1}+u_{C_2}+u_{C_3}$. Then $A+U_k+U_0=U_k$, $A=-U_0$ and

$$u(t)=U_0(1-e^{-\frac{t}{RC}})+U_k. \quad (4)$$

Current flowing through the condenser is $i=\frac{U_0}{R}e^{-\frac{t}{RC}}$, and energy of the charged condenser is

$$W_C=\int_0^\infty udi=\int_0^\infty U_0(1-e^{-\frac{t}{RC}})\frac{U_0}{R}e^{-\frac{t}{RC}}dt+\int_0^\infty\frac{U_kU_0}{R}e^{-\frac{t}{RC}}dt=\frac{CU_0^2}{2}+CU_kU_0=\frac{U_0^2+2U_0U_k}{2}C \quad (5)$$

Where: $\frac{CU_0^2}{2}$ is the energy received by the condenser from a voltage source, CU_0U_k - the energy absorbed from an environment because of the charge current direction is chosen in a way that metal-semiconductor contact electrons pass from metal into the semiconductor. At a direction of a current when electrons pass from metal in the semiconductor, they should overcome the potential barrier equal to a energy difference between Fermy level and a bottom of a conductivity zone. Only the "fast electrons" are able for this. Therefore only "cold" electrons remain in contact and it is cooled. When the current goes in an opposite direction, electrons pass from the semiconductor in metal. As electron energy in the semiconductor becomes more than in metal electrons give a part of the energy to a crystal lattice when transiting , and transition is heated up. This phenomenon is known as effect Peltier, and Peltier factor Π is equal to a contact potential difference [5] ($\Pi=U_k$).

The energy allocated on the resistor is

$$W_R=\int_0^\infty i^2Rdt=\frac{CU_0^2}{2}. \quad (6)$$

In [1-5] it is shown, that external fields (magnetic, electromagnetic emission, a field of mechanical deformations) can change thermal electromotive force. Therefore $U_kA = U_k + \Delta U_k$ *(3),* where A - key parameter of an external field (for a magnetic field it is an induction of a magnetic field B, for electromagnetic emission - intensity of emission on frequency of maximal absorption I, for deformations it is S, where S is relative deformation).

For example, the magnetic field changes a ratio of fast and slow electrons in a current because fast electrons dissipate on thermal fluctuations of a crystal lattice less, than slow electrons, i.e. fast electrons quantity depending on size of a magnetic field in a current is increased, that increases Peltier factor $\Pi = \alpha T= U_k$, and thermal electric force $\alpha = \alpha_0 [1+c_\alpha(\eta_H B)^2]$ (where α_0 is thermal electromotive force) consequently. In absence of a magnetic field, c_α - the factor depending on character of electron dispersion (at dispersion on thermal photons *with* $c_\alpha \approx 0{,}154$), η_H - Hall mobility of electrons in the semiconductor. Because time of electron dispersion on thermal photons has the order of size 10^{-11}c [4] than at each change of a magnetic field new equilibrium distribution of electrons will be established also at this time. It means, that change α and U_k will occur to delay 10^{-11}c, and this delay can be neglected, if a time constant of condenser charge is $RC >> 10^{-11}$c.

If while charging thermoelectric condenser it is placed in an external field, then

$$W_C = \frac{U_0^2 + 2U_{kA}U_0}{2}C \quad . (7)$$

When carrying out the charged condenser from external field *(A=0)* its energy will not change, as external fields of non-electric origin can not change a condenser charge when it's opened, and the capacity is not supposed to change under external fields influence. For example, the magnetic field can not make work on charging the condenser because the magnetic field varied in time (as it's deenergizing) derivates a vortical electric field which, in turn, derivates vortical currents only in electrodes of the condenser, not changing its charge.

Hence, energy of the condenser in absence of external field (B=0) is

$$W_{CA=0} = W_{CA\neq 0}\text{, I.e.:}$$

$$C\frac{U^2 + 2U_kU}{2} = C\frac{U_0^2 + 2U_0U_{kA}}{2} \quad , (8)$$

Where *U* is a voltage on metal electrodes of the thermoelectric condenser:

$$U = -U_k + \sqrt{U_k + U_0^2 + 2U_0U_{kA}} \quad .. (9)$$

Obviously that if $U_0=0$, $U=0$, and if $U_0 > > U_{kA}$, $U_kU \approx U_0 + \Delta U$, $\Delta U=U_{kA}-U_k$.

Thus measuring a voltage on the condenser in an external field and in its absence it is possible to determine the amount of ΔU, i.e. change of Peltier factor under action of an external field. When temperature is known, it is possible to determine specific thermal electromotive force.

We have developed and made installation for measurement of change from a magnetic field. It was established, that at room temperature in crystals of indium antimonide thermal electromotive force and Peltier factor in a cross magnetic field with an induction of 0,2 T changes unless on 5 %.

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