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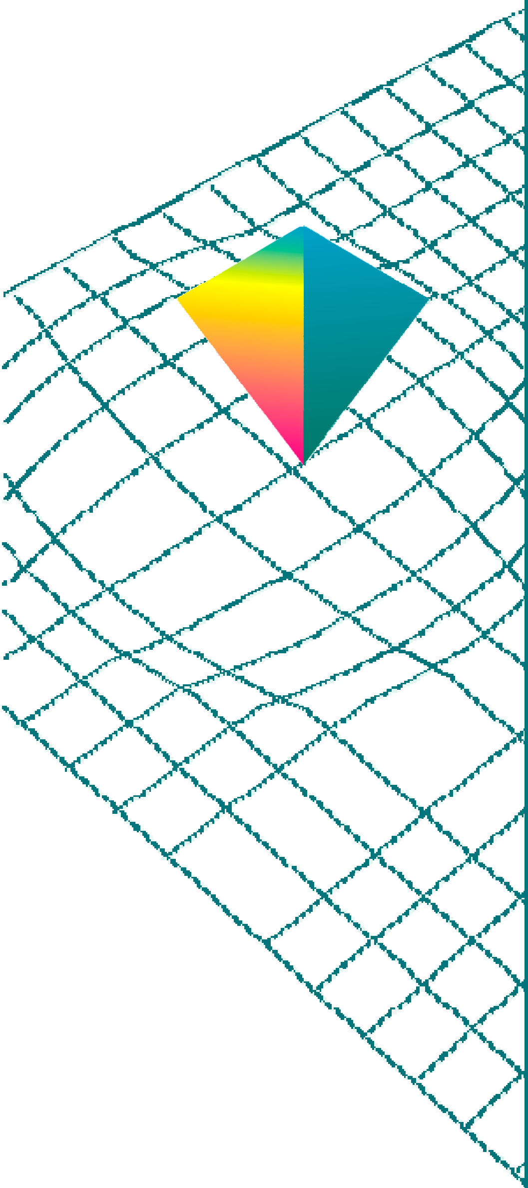


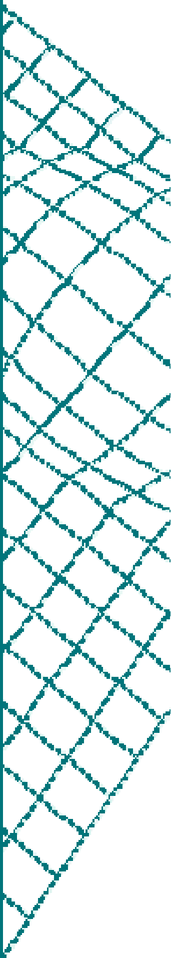
50. Internationales Wissenschaftliches Kolloquium

September, 19-23, 2005

Maschinenbau von Makro bis Nano / Mechanical Engineering from Macro to Nano

Proceedings

Fakultät für Maschinenbau /
Faculty of Mechanical Engineering



Startseite / Index:
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Impressum

Herausgeber: Der Rektor der Technischen Universität Ilmenau
Univ.-Prof. Dr. rer. nat. habil. Peter Scharff

Redaktion: Referat Marketing und Studentische Angelegenheiten
Andrea Schneider

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Redaktionsschluss: 31. August 2005
(CD-Rom-Ausgabe)

Technische Realisierung: Institut für Medientechnik an der TU Ilmenau
(CD-Rom-Ausgabe) Dipl.-Ing. Christian Weigel
Dipl.-Ing. Helge Drumm
Dipl.-Ing. Marco Albrecht

Technische Realisierung: Universitätsbibliothek Ilmenau
(Online-Ausgabe) ilmedia
Postfach 10 05 65
98684 Ilmenau

Verlag: isle
Verlag ISLE, Betriebsstätte des ISLE e.V.
Werner-von-Siemens-Str. 16
98693 Ilmenau

ISBN (Druckausgabe): 3-932633-98-9 (978-3-932633-98-0)
ISBN (CD-Rom-Ausgabe): 3-932633-99-7 (978-3-932633-99-7)

Startseite / Index:
http://www.db-thueringen.de/servlets/DocumentServlet?id=15745

50. Internationales Wissenschaftliches Kolloquium
Technische Universität Ilmenau
19.-23. September 2005

L.S. Lunin / V.F. Kataev / V.I. Ratushniy

Measurement of the influence of the magnetic field on the thermo electromotive force in micro and nano semiconductor 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.

To measure thermo electromotive force (thermo e.m.f.) it is necessary to create temperature gradient what is not always convenient in case the samples under investigation are thin films or plates.

To create a temperature overfall even in one degree is unusually complicated, as the temperature gradient is very big, as the sample is thin.

The real temperature overfall is parts of a degree and makes it complicated to measure the temperature overfall and it affects the precision of the measurement. So, it's quite an essential problem to measure thermo electromotive force without creating a temperature gradient.

Let's consider the charge of the thermoelectric condenser which represents the system "metal – semiconductor – isolator-metal" from a constant source of voltage through resistor R.

The equation of the process can be:

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

where $C=\dfrac{C_1C_2C_3}{C_1C_2+C_1C_3+C_2C_3}$, C_2, C_3 – is a capacity between the metal and the semiconductor, formed by means of penetration of the electric field into the semiconductor, C_1 – a space capacity between the electrodes, the place of a non-conductor, $u_{C1}=\varphi_1'-\varphi_0'$, $u_{C2}=\varphi_0'-\varphi_0$, $u_{C3}=\varphi_1-\varphi_1'$ the potential change into C_i. When using a sufficiently low ohm conductor (at more than 0,1 om^{-1} cm^{-1} conductivity) the depth of penetration of the electric field into the conductor doesn't exceed hundredth parts of the micron, the depth of the dielectric film is within several microns, so $C_1 << C_2$ and $C_1 << C_3$. Accordingly $u_{C_1} >> u_{C_2}, u_{C_1} >> u_{C_3}$.

Then designating U$_{c1}$ ≈ U and $\boldsymbol{C} = \dfrac{\boldsymbol{C}_1\boldsymbol{C}_2\boldsymbol{C}_3}{\boldsymbol{C}_1\boldsymbol{C}_2 + \boldsymbol{C}_1\boldsymbol{C}_3 + \boldsymbol{C}_2\boldsymbol{C}_3}$ **≈*C,*** it is possible to write down for voltage condenser:

$$\boldsymbol{RC}\frac{\boldsymbol{du}}{\boldsymbol{dt}} + \boldsymbol{u} = \boldsymbol{U}_k + \boldsymbol{U}_0 \qquad (2)$$

The equation decision (2) is as follows:

$$\boldsymbol{u}(\boldsymbol{t}) = \boldsymbol{A}\boldsymbol{e}^{-\frac{t}{RC}} + \boldsymbol{U}_k + \boldsymbol{U}_0 \qquad (3)$$

In the initial period the condenser is not charged, so $\boldsymbol{u}_{0C_1} = 0$, $\boldsymbol{u}_{0C_3} + \boldsymbol{u}_{0C_2} = \boldsymbol{U}_k$, that is why $\boldsymbol{u}(0) = \boldsymbol{U}_k$, so far as $\boldsymbol{u} = \boldsymbol{u}_{C_1} + \boldsymbol{u}_{C_2} + \boldsymbol{u}_{C_3}$.

Then $\boldsymbol{A} + \boldsymbol{U}_k + \boldsymbol{U}_0 = \boldsymbol{U}_k$, $A=-U_0$ and

$$\boldsymbol{u}(\boldsymbol{t}) = \boldsymbol{U}_0(1 - \boldsymbol{e}^{-\frac{t}{RC}}) + \boldsymbol{U}_k \qquad (4)$$

The current through the condenser is $\boldsymbol{i} = \dfrac{\boldsymbol{U}_0}{\boldsymbol{R}}\boldsymbol{e}^{-\frac{t}{RC}}$, and the power of the charged condenser is

$$\boldsymbol{W}_C = \int_0^\infty \boldsymbol{udi} = \int_0^\infty \boldsymbol{U}_0(1 - \boldsymbol{e}^{-\frac{t}{RC}})\frac{\boldsymbol{U}_0}{\boldsymbol{R}}\boldsymbol{e}^{-\frac{t}{RC}}\boldsymbol{dt} + \int_0^\infty \frac{\boldsymbol{U}_k\boldsymbol{U}_0}{\boldsymbol{R}}\boldsymbol{e}^{-\frac{t}{RC}}\boldsymbol{dt} = \frac{\boldsymbol{CU}_0^2}{2} + \boldsymbol{CU}_k\boldsymbol{U}_0 = \frac{\boldsymbol{U}_0^2 + 2\boldsymbol{U}_0\boldsymbol{U}_k}{2}\boldsymbol{C}, \qquad (5)$$

where $\dfrac{\boldsymbol{CU}_0^2}{2}$- is the power of condenser got out of voltage source, CU_0U_k – the power absorbed out of the environment, as the purposefully chosen voltage current removes electrons out of metal into the semiconductor in the contact 'metal-semiconductor'. With current direction when the electrons remove out of metal into the semiconductor they have to overcome a potential barrier, equivalent to the difference between Fermi level and the bottom of the conductivity zone. It is possible only with 'fast' electrons. That's why there's an abundance of 'cold' electrons in the contact and it cools. When the current direction is opposite, the electrons remove out of the semiconductor into metal. As the electron power in the semiconductor is higher than in the metal, they return a part of the power to the crystal grate and the transition heats. This phenomenon is called Peltier effect and Peltier *П* coefficient. It is equal to the contact difference of the potential [3] (***П=U****$_k$*).

The power in the resistor is

$$W_R = \int_0^\infty i^2 R dt = \frac{CU_0^2}{2} \qquad (6)$$

In [1-3] is shown that outward fields (magnetic, electromagnetic radiation, mechanical deformation field) can change thermo electromotive force. So, $U_{kA}= U_k+\Delta U_k(A)$, where A is a basic parameter of the outward field (for magnetic field it is the induction of the magnetic field B, for electromagnetic field it is the intensity of the radiation at the frequency of maximum absorption I, for deformations-S, where S is a relative deformation).

For example, the magnetic field changes the correlation of ‘fast’ and ‘slow’ electrons in the current, as the ‘fast’ electrons are dispersed less in the heat oscillations of the crystal grate than ‘slow’ electrons, i.d. depending on the magnitude of the ‘fast’ electrons the quantity of the fast electrons in the current grows and increases Peltier coefficient $\Pi=\alpha T=U_k$, and hence, the thermo electromotive force increases as well $\alpha=\alpha_0[1+c_\alpha(\eta_H B)^2]$, where α_0 is a thermo e. m. f. when the magnetic field is absent, c_α is a coefficient depending on the character of the electron disperse (at he disperse in the heat phonons $c_\alpha \approx 0,154$), η_H – is a hollow movement of the electrons in the semiconductor. As the disperse time of the electrons in the heat phonons is 10^{-11}s [2], then in every change of the magnetic field a new balance distribution is made within this time. It means that the change of α и U_k will be done at 10^{-11}s late, but this may be ignored if the time constant at the condenser charge is $RC >> 10^{-11}$s.

If thermoelectric condenser is placed into the outward field, then

$$W_C = \frac{U_0^2 + 2U_{kA}U_0}{2}C \tag{7}$$

If the charged condenser is in the outward field (A=0) its power won’t change, as the non-electric outward fields can’t change condenser charge when it is broken, and the capacity is not supposed to change under the influence of outward fields.

For example, a magnetic field can’t charge the condenser because the changing in time magnetic field (when it is switched off) raises a vortical electric field which in_it’s turn, raises □ertical currents only the condenser electrodes without changing their charge.

Hence, in the absence of the outward_field (B=0) the power of the condenser

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

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

where U – is the voltage in metal electrodes of the thermoelectric condenser:

$$U = -U_k + \sqrt{U_k + U_0^2 + 2U_0U_{kA}} \tag{9}$$

It is obvious that with $U_0=0$, $U=0$, and with $U_0>>U_{kA}, U_k$ $U\approx U_0+\Delta U$, $\Delta U=U_{kA}-U_k$.

Thus, when measuring the condenser voltage in the outward field and in its absence it is possible to define ΔU, i.e. the change of Peltier coefficient under the influence of the outward field.

When the temperature is know, specific thermal electromotive force can be measured.

We have worked out and made the installation to measure thermo electromotive force in the magnetic field.

It was obtained that at room temperature in InSb crystals the thermo electromotive force and Peltier coefficient in a cross magnetic field at 0,2T induction has a change not more than 5%.

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