THE THERMOMAGNETICAL EFFECTS IN n-$Pb_{0.8}Sn_{0.2}Te$

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In this paper on the data of thermomagnetic coefficients and electron component of thermoconductivity the temperature dependence of Lorentz number L is defined in n-$Pb_{0.8}Sn_{0.2}Te$. It is shown, that experimental value $L(T)$ in the interval 40-250K is less than its standard Zommerfield's value. It is established that lowered value L is caused by the inelastic electron-electron collisions.

During investigation of the thermomagnetic effects in HgSe, PbTe and HgTe, with the degenerative electron gas [1,2,5,6] the set of the pecularities which wasn't accepted in the framework of the existing theories was observed. Particularly, it was observed, that maximums of the dimensionless field of the transversal Nernst-Ettingsgausen effect (N-E) E_y and Rigi-Leduc (R-L) (-SH) shift to the big values (uH/c>1) but at the elastic character of scattering they should go through the maximum at uH/c=1. These experiments were explained after theoretical discussion of the question about inelasticity [3-5]. It was shown, that in the case of inelastic interaction of carriers of charge it wasn't allowed to carry out the unit relaxation time for all processes. But with it all the unequilibrium part of distribution function can formally express through functions, playing the role of relaxation time. Such two functions should be carried out: the one for the isothermic effects, the second for the addition for the distribution functions, connected with the gradient temperature. In the case of the interelectron interaction at the absent of the magnetic field the unequilibrium part of distribution function can be introduce in the following form:

$$\Delta f = \tau_1 \frac{\partial f_0}{\partial E} \bar{V}\Delta(\mu - e\varphi) + \tau_2 \frac{\partial f_c}{\partial E} \cdot \frac{E-\mu}{T} \bar{V}\Delta T \quad , \tag{1}$$

where $\bar{V}$ and E are velocity and energy of the electron, f_0 is Fermi's function, φ is electrostatic potential, μ is Fermi's energy. The values of relaxation times τ_1 and τ_2 are energy functions (the concentrations of the ionized impurities are equal to electron concentrations). Here τ_1 is connected with the momentum relaxation and scattering on the small angles don't influence on the τ_1. The function τ_2 is caused by relaxation of energy beam near Fermi's surface if the energy changes on the value of kT order at the collision.

The interelectron collisions don't change spontaneously the electric current, their role is the redistribution of the energy between collising carriers. At the calculation of the mobility it can be limited by the first summand in the expression (1) and in the case of the high degeneration consider $E=\mu$. The energy redistribution is insignificantly at this, the interelectron collisions don't influence on the value $\tau_1(E-\mu)$, and on the mobility, accordingly.

At the calculation of the thermoelectromotive force, thermoconductivity and thermomagnetic effects, when the second member of the expression (1) is significant, it isn't allowed to consider $E=\mu$, but it is need to consider the blured distributions of the step function. The flux of the hot and cool electrons moves to meet someone and the energy redistribution, between fluxes influences strongly on the heat effects [7] in the conditions of the observing of these facts. From this it is followed, that interelectron collisions can influence on the thermoelectric and thermomagnetic effects, the analytic expressions for which include the values τ_2 and $\partial\tau / \partial E$. That's why the complex investigation of the field, temperature and concentration dependences of the thermoelectromotive force and thermomagnetic effects can give the additional information about inelasticity of scattering.

The measurement of the coefficients was carried out: 1) the thermoelectromotive force α; 2) transversal effect N-E; 3) the magnithermoelectromotive force $\Delta\alpha$; 4) effect of M-R-L; 5) effect R-L; SH; 6) electroconductivity σ; 7)Hall R coefficient.

The results of the experiment are analised on the base of the above mentioned theory, considering the inelastic character of the scattering, in compliance which thermomagnetic coefficient have the following expression at the strong degeneration of the current carriers:

$$\Delta\chi(H) = \Delta\chi_\infty \frac{\left(\frac{UH}{c}\right)^2\left(\frac{L}{L_0}\right)^2}{1 + \left(\frac{uH}{c}\right)^2\left(\frac{L}{L_0}\right)^2} \tag{2}$$

$$-SH = \frac{\frac{uH}{c}\frac{L}{L_0}}{1 + \frac{\chi_p}{L_0\sigma T}\left[1 + \left(\frac{uH}{c}\frac{L}{L_0}\right)^2\right]\frac{L_0}{L}} \tag{3}$$

$$\Delta\alpha(H) = \Delta\alpha_\infty \frac{\left(\frac{uH}{c}\right)^2\left(\frac{L}{L_0}\right)^2}{1 + \left(\frac{uH}{c}\right)^2\left(\frac{L}{L_0}\right)^2} \tag{4}$$

$$E_y^{iz} = \frac{\Delta\alpha_\infty}{\frac{k_0}{e}} \frac{\frac{uH}{c}\frac{L}{L_0}}{1+\left(\frac{uH}{c}\right)^2\left(\frac{L}{L_0}\right)^2} + \frac{L}{\frac{k_0}{e}} \frac{\frac{uH}{c}\frac{L}{L_0}}{1+\frac{\chi_p}{L_0\sigma T}\left[1+\left(\frac{uH}{c}\frac{L}{L_0}\right)^2\right]\frac{L_0}{L}} \quad (5)$$

$$E_y^{iz} = \frac{\Delta\alpha_\infty}{\frac{k_0}{e}} \frac{\frac{uH}{c}\frac{L}{L_0}}{1+\left(\frac{uH}{c}\right)^2\left(\frac{L}{L_0}\right)^2}, \quad (6)$$

where $Ey=k_0HQ_\perp/e$.

From (1-5) it is followed, that ratio L/L_0, noticing the inelasticity degree, can be defined on the dependences *Δæ*, $\Delta\alpha$, E_y and *SH* from the intensity of the magnetic field, by the формула value, according maximum is dependences $E_y(uH/c)$ and *SH(uH/c)* (as it was mentioned in the case of elastic scattering the maximums are equal to $(uH/c)=1$, but in the case of the inelastic scattering the maximums are equal to $uH/c>1$, moreover L/L_0 is defined as $(uH/c)=L/L_0$ and with the help of the defined ratios between different thermomagnetic effects, as for example:

$$\frac{L}{L_0} = \frac{\Delta\alpha}{HQ_\perp^{iz}\frac{uH}{c}} \text{ and } \frac{L}{L_0} = \frac{Q_\perp^{iz}}{R\sigma\Delta\alpha_\infty} \quad (7).$$

The character data about dependence *Δæ(H)* and two theoretical curves, calculated on the expression (1) at $L/L_0=1$ and $L/L_0=0{,}69$, obtained from the limit value $\Delta æ_{H\to\infty}$ at 100K are given on the fig.1.

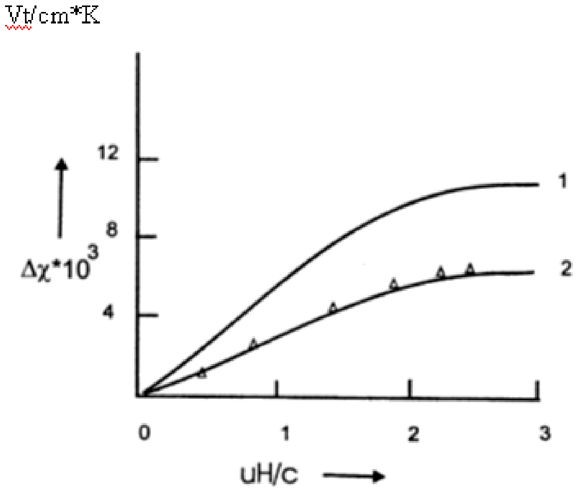

Fig.1. The dependence *Δæ* on uH/c for the sample with $u=9.6\cdot10^{18}cm^{-3}$ at 100K curve 1 - $L/L_0=1$; 2 - $L/L_0=0.69$.

The dependences $E_y(uH/c)$ and *-SH(uH/c)* at 300K in the comparison with the theoretical curves are given on the fig.2. It is seen, that the 300K the experimental data are good agree for curve, calculated at $L/L_0=1$, and maximums E_y and *SH* are equal to *uH/c*.

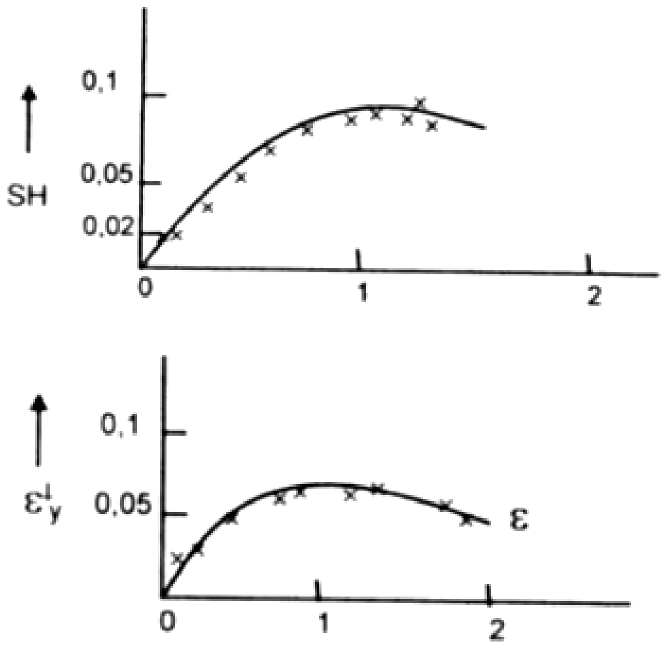

Fig.2. The dependence E_y and –SH on *uH/c* with $n=1.16\cdot10^{18}cm^{-3}$ at 300K.

The values L/L_0, obtained by the different methods for формула n-$Pb_{0.8}Sn_{0.2}Te$ are given in the table 1. Thus, on the data $\Delta æ_{el.}$ and thermomagnetic coefficients the temperature dependence of Lorentz number L is defined in n-$Pb_{0.8}Sn_{0.2}Te$. It is shown, that experimental value *L(T)* in the interval 40-250K is less than its standard Zommerfield value. It is established that lowered value L is caused by the inelastic electron-electron collisions.

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Table 1.

The value of share of inelasticity of electron scattering (*L/L_0*) in *n*-$Pb_{0.8}Sn_{0.2}$obtained by different calculated methods.

№ samp	T, K	n·10^{-18}, cm^{-3}	U, cm^{2}·$V^{-1}s^{-1}$	L/L_o				
				$\Delta æ_\infty$	$\Delta æ$ (*uH/c*)	$\Delta\alpha$ (*uH/c*)	SH (*uH/c*)	
1	15	2,5	3.000	1,01	1	1	1	1
	21			0,81	0,8	0,79	-	-
	30,4			0,61	0,55	0,6	-	-
	104			0,59	0,6	0,52	0,60	0,60
	118			0,57	-	-	-	-
	205			0,55	0,6	0,62	0,6	-
	16			0,99	1	1	1	-
	23,6			0,72	0,8	0,76	-	-
2	90	1,16	4.000	0,58	0,5	0,53	0,54	-
	102			0,58	0,5	0,52	0,55	-
	122			0,55	-	-	-	-
	204			0,53	0,5	0,52	0,55	-
	16			0,96	1	1	1	1
	27,6			0,79	0,8	0,85	-	-
3	41,3	9,6	3.200	0,74	0,75	0,74	-	-
	84			0,68	0,69	0,65	0,67	0,65
	205			0,67	0,66	0,65	0,66	-
	300						1	1

[1] *S.A. Aliyev, L.L. Korenblit, S.S., Shalit*. FTP, 1966, 8, 3, p.705. (in Russian).

[2] *V.M. Mudzhdaba, V.K. Ogorodnikov, S.A. Aliyev, S.S. Shalit*. FTP, 1969, II, №2, p.545. (in Russian).

[3] *L.L. Korenblit, B.E. Sherstobitov*. FTP, 1968, t.2, v.5, 688. (in Russian).

[4] *V.I. Tamarchenko, Yu.I. Ravich, L.Yu. Morgovskiy, L.H. Dubovskaya.* FTP, 1969, II, v.12,3206. (in Russian).

[5] *Y.I. Ravich, V.A. Ephimova, V.J. Tomarchenko.* Phys.State Solid, 1971, 43, №11, p.453.

[6] *T. Knitel and H.J. Goldsmit*. Phys. C. Solid. State Phys, 1979, v. 12.

[7] *Yu.I. Ravich, B.A. Yephimova, I.A. Smirnov*. Metodi issledovaniya poluprovodnikov v primenenii k khalkogenodam svinca PbTe, PbSe, PbS. Nauka, 1968. (in Russian).

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n-$Pb_{0.8}Sn_{0.2}Te$ TERMOMAQNİT HADİSƏLƏRİ

İşdə *n*-$Pb_{0.8}Sn_{0.2}Te$ kristalının termomaqnit əmsallarının və istilikkeçirmə əmsalının elektron komponentinin qiymətinə görə *L* Lorens ədədinin temperaturdan asılılığı müəyyən edilmişdir. Göstərilmişdir ki, temperatur 40÷250 K intervalında *L(T)*–nin təcrübi qiymətləri onun standart zommerfeld qiymətindən kiçikdir. Müəyyən edilmişdir ki, *L*-in belə kiçik qiymətlər alması qeyri-elastiki elektron-elektron toqquşmaları ilə bağlıdır.

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ТЕРМОМАГНИТНЫЕ ЯВЛЕНИЯ В *n*-$Pb_{0.8}Sn_{0.2}Te$

В работе по данным термомагнит коэффициентов и електронной составляющей теплопроводности определена температурная зависимость числа Лоренса *L* в кристалле *n*-$Pb_{0.8}Sn_{0.2}Te$. Показано, что экспериментальное значение *L(T)* в интервале 40÷250K меньше его стандартного зоммерфельдского значения. Установлено, что заниженное значение *L* обусловлено неупругими электрон-электронными столкновениями.

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