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PRESSURE DEPENDENCE OF THE ELECTRICAL PROPERTIES OF PbTe AND PbS

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We have measured the variation of the thermoelectric power α and the electrical conductivity σ with uniform (omnidirectional) pressure up to 9000 kg/cm^2 applied at room temperature to single-crystal n- and p-type samples of PbTe and PbS. Oil was used as the pressure-transmitting medium. The apparatus was the same as that used in earlier work [1].

The thermoelectric power α, the electrical conductivity σ, and the carrier density n are listed in the adjoining table. This table also gives the percentage change in α and σ at a pressure P = 1000 kg/cm^2 ($d\alpha/\alpha dP$ and $d\sigma/\sigma dP$). One of the experimental curves is shown in the figure; the other curves were similar.

From the variation of the thermoelectric power and the electrical conductivity we can calculate the variation of the effective mass m* and the mobility u. The method of calculation of m* and u was the same as that used earlier in analyzing the results of similar measurements carried out on samples of PbSe [1].

The variation of m* was calculated from the variation of the thermoelectric power

$$\alpha = \frac{k}{q}\left[\frac{r+2}{r+1}\frac{F_{r+1}(\mu^*)}{F_r(\mu^*)} - \mu^*\right];$$

$$\frac{1}{\alpha}\frac{d\alpha}{dP} = \frac{k}{\alpha q}\left[\frac{r+2}{r+1}\frac{d}{d\mu^*}\left(\frac{F_{r+1}}{F_r}\right) - 1\right]\frac{d\mu^*}{dP} \quad (1)$$

$$n = \frac{4\pi(2m^*kT)^{3/2}}{h^3}F_{1/2}(\mu^*);$$

$$\frac{d\ln m^*}{dP} = -\frac{1}{3}\frac{F_{-1/2}(\mu^*)}{F_{1/2}(\mu^*)}\frac{d\mu^*}{dP},$$

where F_r are Fermi integrals, μ^* is the chemical potential level in units of kT, r is the power exponent in the dependence of the mean free path (l) of an electron on its energy [$l(\varepsilon) \sim \varepsilon^r$]. The table lists the values of d ln m*/dP calculated using Eqs. (1) and (2) for r = 0 [2, 3].*

The linear variation of the electrical conductivity with pressure is related to the variation of the mobility. This was confirmed by measurements of the Hall coefficient R_H, at pressures up to 9000 kg/cm^2, on the purest n- and p-type samples.

To determine that part in the mobility variation which is related to the variation of the chemical potential μ^*, the equivalent variation of the mobility was calculated for a nondegenerate sample (denoted by the subscript "nd"):

$$\sigma = nqu_{nd}\frac{\Gamma\left(\frac{3}{2}\right)}{\Gamma(r+1)}\frac{F_r(\mu^*)}{F_{1/2}(\mu^*)};$$

$$\frac{d\ln\sigma}{dP} = \frac{d\ln u_{nd}}{dP} + \frac{d}{d\mu^*}\left(\frac{F_r}{F_{1/2}}\right)\frac{d\mu^*}{dP}, \quad (3)$$

where Γ is the gamma function.

The calculated values of $d(\ln u_{nd})/dt$ are also given in the table.

Calculations carried out for r = 1/2 and r = 1 (not listed in the table) give practically the same values of d(ln m)/dp.

Results of Measurements and Calculations for PbTe and PbS Samples

Compound	Sample No.	Type	Carrier density, cm^{-3}	α, μV/deg, at 300°K	σ, Ω^{-1}-cm^{-1}	$d\alpha/\alpha dP$, in % per tone	$d\sigma/\sigma dP$, in % per tone	dm^*/m^*dP, in % per tone	$du_{nd}/u_{nd}dP$, in % per tone	s
PbTe	3/1	n	9.4×10^{17}	280	230	− 1.1	6.9	− 2.49	7.0	− 2.8
	26/2	n	4.1×10^{19}	57	4500	− 1.92	5.4	− 1.95	6.25	− 3.2
	14/5	p	2.3×10^{18}	263	280	− 1.2	7.0	− 2.47	7.1	− 2.88
	12/1	p	6.9×10^{18}	191	820	− 1.4	6.7	− 2.24	7.0	− 3.12
	20/1	p	2.0×10^{19}	117	1640	− 1.64	6.2	− 2.12	6.65	− 3.14
	19/1	p	5.0×10^{19}	64	2950	− 1.8	5.8	− 1.82	6.4	− 3.5
PbS	14	n	4.9×10^{18}	236	360	− 0.93	3.7	− 1.8	3.8	− 2.1
	27	n	2.2×10^{19}	94	1860	− 1.35	3.2	− 1.7	3.78	− 2.22
	25	n	7.4×10^{19}	51	3660	− 1.6	3.0	− 1.4	3.7	− 2.64
	43	p	2.1×10^{18}	290	170	− 1.06	6.4	− 2.26	6.56	− 2.9
	42	p	1.1×10^{19}	191	800	− 1.3	4.7	− 2.05	5.0	− 2.44