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ON THE MOBILITY OF CURRENT CARRIERS IN TIN TELLURIDE

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Tin telluride proved to be a rather difficult material with respect to interpreting of the experimental results of its investigations. The valence band structure and density of states are opened to discussion [1-3]. The model of the halite-type lattice is complicated by the presence of a great concentration of metal vacancies. In the conditions of great current carriers concentrations and unparabolic band structure the determination of the effective scattering cross section is rather difficult [4] and has not been carried out so far. The great dielectric constant makes questionable any intention to use the well-known interpretations proposed by semiconductor physics [5].

Having in mind the upper considerations we undertook mobility investigations on a large number of samples (here we represent 16 of them), prepared by different methods and annealed in different manner, in single or polycrystal form, with the purpose to create an empiric formula for the concentration and temperature dependences of mobility. The samples are grouped according to the preparation and annealing methods as follows: group I-ingot No 8: single crystal samples grown by the horizontal Bridgman method, annealed at 600°C for 300 hours (6 samples); group II-ingot No 29, grown by gaseous phase crystallization wit graphite powder added to tbe melt, annealed in the same powder at 750°C for 3 months (4 samples); group III-ingot No 30, grown by the same method from tin solution of the telluride, taken from the middle of an ingot which had been prepared by tbe vertical Bridgman method (3 samples) group IV-ingot No 32, grown by gaseous phase crystallization with aluminium added during the synthesis (2 samples) and one sample from each of the following ingots: No 34, grown by vertical Bridgmann method and annealed in mercury vapours

at 550°C for 880 hours, No 35 and No 37, synthesized by the iodide method and annealed in gas flow [6], and No 44, prepared by the same method, without annealing. The Hall coefficient and conductivity were measured in the interval 80 to 460 K. The temperature dependence of mobility for several samples from various groups are shown in Fig. 1.

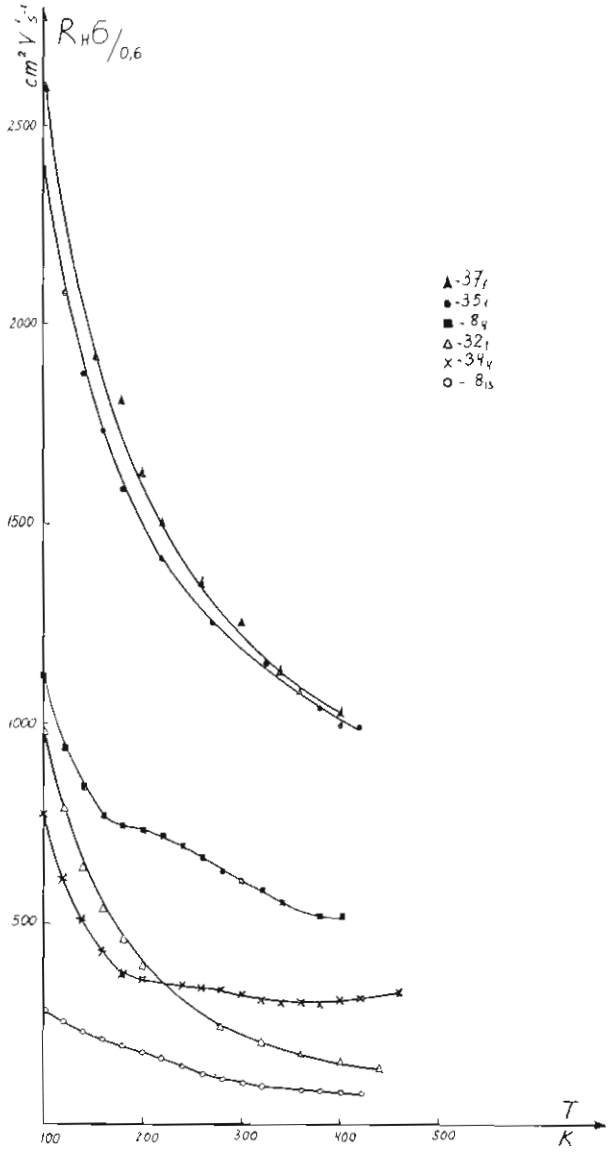

Fig. 1. Temperature dependence of mobility.

In the case of a highly degenerate gas and assuming two band Kane model, the most common expression for mobility

$$\mu = q \left\langle \frac{\tau}{m} \right\rangle \tag{1}$$

turns into:

$$\mu = q \frac{T_{\varepsilon_F}}{m_p} ; \qquad m_p = m_p^0 \left(1 + 2 \frac{E_F}{E_g}\right) \tag{2}$$

In the case of lead chalcogenides the assumption of optical phonons scattering predominates. Here the relaxation time is expressed by

$$\tau^{-1} = 2kTq^2 (E_\infty^{-1} - E_o^{-1})/\hbar v \qquad [7] \tag{3}$$

where q is the electron charge, E_o and E_∞ are the static and dynamic dielectric constants, V is the current carriers velocity [7]. This expression is obtained for a parabolic band.

The mobility of all our samples may be described by

$$\mu = \frac{A}{p_o} l^{5\cdot 2\alpha} T^{-\alpha} ; \qquad \alpha = \sqrt{\frac{p_o}{\alpha_1}} ; \qquad p_o = \frac{0{,}6}{q R_{H const}} \tag{4}$$

Tbe coefficient A may be described having in mind (2) and (3):

$$A = \frac{q}{m_{p_\tau}} \frac{\hbar T^{-0\cdot 015}}{q^2 m_{p_\tau}^{1/2}} \left(\frac{\varepsilon_v}{E_\infty^{-1} - E_o^{-1}}\right)\gamma ; \qquad E_v = 8{,}8543.10^{-12}\ F/m$$

(an explicit slight temperature dependence is added). Then (4) may be expressed by

$$\mu = \frac{q}{m_o^{3/2}} \frac{\hbar T^{-0\cdot 015}}{q^2 \left(\frac{m_{p_\tau}}{m_o}\right)^{3/2}} \left(\frac{E_v}{E_\infty^{-1} - E_o^{-1}}\right) \frac{\gamma}{p_o} l^{5,2\sqrt{\frac{p_o}{\alpha_1}}} T^{-\sqrt{\frac{p_o}{\alpha_1}}} \tag{5}$$

$$E_o = 1200 \ ; \quad E_\infty = 45$$

The coefficient γ does not depend on temperature. If we calculate it from mobility measurements in an interval of constant Hall coeffi-

cient, from (5) we can calculate the mobility at any temperature in the investigated interval. In Table 1 we give the greater part of the investigated samples; P_0 and α are experimentally determined, α_1 and γ are calculated, $R_H\sigma/0,6$ is obtained from measurements; μ_{100} is calculated from (5). The calculation of m_p is connected with the following peculiarity. According to the model, proposed in [8], the valence band fills with electrons from the impurities with temperature increasing. As a result the Fermi level is situated deeply in the valence band; significantly higher is the last occupied by electrons level E_{F_1}. This model and a Kane band give

$$E_{F_1} = \frac{1}{4} E_g(\sqrt{1 + A_\tau} - 1) \quad ; \qquad A_\tau = \frac{(3\pi^2)^{2/3}\hbar^2 P_\tau^{2/3}}{m^0_{p\tau} E_{g\tau}} ;$$

where $m^0_{p_\tau}$ is the mass at the top of the valence band, calculated in the manner shown in [9].

In Table 2 we give examples of calculated from (5) mobilities at 380 K for several samples, as well as experimentally determined $R_H\sigma / 0,6$ for comparison. The included samples change α. Only for sample No 37_1 α does not vary for the whole interval.

TABLE 1

N	$P_0.10^{-23}m^{-3}$	α	$\alpha_1.10^{-23}m^{-3}$	$\gamma.10^{-3}$	$R_H\sigma/0,6 \times 10^4 m^2V^{-1}s^{-1}$	μ_{calc}	m_p/m_0
8_1	1,25	0,87	1,6514	2,5572	1022	1077	0,215
8_3	1,44	1,08	1,2345	2,6961	1014	1017	0,221
8_4	1,25	1,0	1,250	2,6634	1150	1150	0,215
8_{12}	2,2	0,84	3,1179	3,4958	657	657	0,241
8_{13}	4,57	0,58	13,5850	4,6377	281	281	0,284
29_1	3,75	1,32	2,1522	2,1617	289	264	0,272
29_2	5,375	0,90	6,6136	4,7407	280	280	0,295
29_4	5,357	0,92	6,3291	3,648	218	218	0,295
30_7	3,75	1,0	3,75	3,460	350	350	0,272
30_8	5,37	0,89	6,7794	4,6769	274	273	0,296
32_1	1,87	1,24	1,2165	2,6672	787	787	0,233
32_2	1,70	1,12	1,3552	1,8195	568	568	0,228
34_4	2,13	1,33	1,2041	3,8002	1000	1000	0,239
35_1	0,517	0,6	1,4361	2,3059	2397	2396	0,184
37_1	0,493	0,65	1,1668	2,2979	2584	2601	0,183
44_1	2,19	0,66	5,0275	1,550	263	263	0,241
					100K		

The relative deviation of the calculated values from the experimentally found ones slightly exceeds the measurement error.

For some samples a region with higher mobilities is observed for temperatures higher than 350-400 K. The calculated from (5) mobility of sample No 37_1 exibits such a region at temperatures higher than 400 K.

We hope that further investigations on samples analogical to those from ingots No 35 and 37 will make it possible for us to say something more about the coefficients γ and α_1. It may be possible that the term $T^{-0,015}$ will have another appearance at higher temperatures.

TABLE 2

N	m_p/m_0	α	$R_H\sigma/0,6 \times 10^4 m^2V^{-1}s^{-1}$	μ_{calc}	rel. dev. %
8_4	0,189	0,62	529	477	— 9,8
8_{13}	0,280	1,0	85	95	+11,7
32_1	0,203	0,36	301	347	+15,3
34_4	0,212	1,35	231	190	—15,1
35_1	0,169	1,0	1050	891	—14,4
37_1	0,168	0,65	1026	1182	+15,0

REFERENCES:

1. G. Giucci and G. Nardelli. Physics of Semiconductors. Stuttgart (1974), p. 1292.
2. H. Neumann and A. Kosakov. Phys. stat. sol. (b) 85, K 11 (1978).
3. J. Melvin and D. Hendy. J. Phys. C **12**, 3003 (1979).
4. Yu. Ravich, B. Efimova and I. Smirnov. Semiconducting Lead Chalcogenides, Moscow, 1968, p. 109.
5. H. Heinrich. Defects and Impurities in IV-VI Componnds. Intern. Summer School on Narrow Gap Semiconductors Physics and Applications. Nimes, France. Sept. 1979 (to be published).
6. M. Moldovanova, E. P. Trifonova, R. Assenov and L. Karagiozov. Phys. stat sol. (a) **58**, k 47 (1980).
7. Yu. Ravich, B. Efimova and V. Tamarchenko. Phys. stat. sol. (b) **43**, 11 (1971)
8. R. Assenov. On the Behavior of Some Impurities in SnTe (in press-Bulgaria).
9. M. Moldovanova and R. Assenov. Phys. stat. sol. (a) **48**, k 193 (1978).

ΠΕΡΙΛΗΨΗ

ΕΠΙ ΤΗΣ ΕΥΚΙΝΗΣΙΑΣ ΦΟΡΕΩΝ ΣΤΟ SnTe

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Τὸ SnTe ἔχει ἀποδειχθεῖ ἕνα ἀρκετὰ δύσκολο ὑλικὸ στὴν ἑρμηνεία τῶν πειραματικῶν ἀποτελεσμάτων του. Ἡ δομὴ τῆς ταινίας σθένους καὶ ἡ πυκνότητα τῶν καταστάσεων παραμένουν ἀκόμη θέματα ἀνοικτὰ σὲ συζήτηση. Ἔχοντας ὑπόψη τὴ συμπεριφορὰ αὐτὴ τοῦ ὑλικοῦ πραγματοποιήσαμε μετρήσεις εὐκινησίας σὲ ἕνα μεγάλο ἀριθμὸ δειγμάτων κατασκευασμένα μὲ διαφορετικοὺς τρόπους καὶ μὲ πολλὲς διαφορετικὲς θερμοκρασίες ἐπεξεργασίας. Ἔτσι δίνονται ἐμπειρικὲς ἐκφράσεις γιὰ τὴν ἐξάρτηση τῆς εὐκινησίας ἀπὸ τὴ συγκέντρωση καὶ τὴ θερμοκρασία.