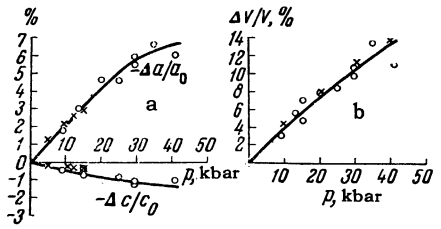

FIG. 1. a) Dependence of the linear compressibility of tellurium on pressure. Circles denote x-ray diffraction data, crosses give Bridgman's data[7]; b) dependence of the volume compressibility of tellurium on pressure. Circles denote x-ray diffraction data, crosses give Bridgman's data.[7]

clear that the data for $\Delta a/a_0$, $\Delta c/c_0$ and $\Delta V/V_0$ (Fig. 1a and 1b) agree to within the experimental error with the Bridgman data.[7,1] The dependence of c/a on pressure, given in Fig. 2, is not continuous: it shows clearly the presence of a phase transition in tellurium at k = 15 kbar, although in calculating c/a for p > 15 kbar the change of symmetry was not allowed for and consequently c was not doubled. The discontinuities of the curves for $\Delta a/a_0$, $\Delta c/c_0$, and $\Delta V/V_0$ plotted as a function of p were masked by the scatter of the experimental points.

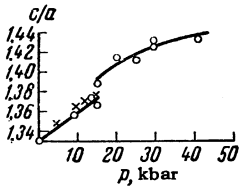

FIG. 2. Dependence of c/a on pressure. Circles denote x-ray diffraction data (for the A7 phase at p = 15 kbar c/2a was used), and crosses denote the values of c/a calculated from Bridgman's data.[7]

This explains the anomaly of the pressure dependence of the melting point of the new phase,[3] characteristic of bismuth and antimony, which belong to the A7 structures.

X-ray diffraction patterns of tellurium at p > 45 kbar indicate a fundamental change of its structure at the second phase transition. Table II gives the interplanar spacings for the new high-pressure phase. We were unable to establish its structure. We merely found that in the pressure range 45—90 kbar the x-ray diffraction patterns of tellurium did not change, and therefore there is some doubt about the existence of the phase transition at 69 kbar detected by Bridgman.[1]

Table II

d_{meas}, Å	I	d_{meas}, Å	I
2.92	strong	1.45	medium
2.43	medium	2.395	weak
2.36	medium	1.33	weak
1.82	strong	1.23	very weak
1.78	medium		

[1)] Pressures corresponding to the phase transitions in bismuth were based on the generalization of the experimental data in Wentorf's book.[6]

[1] P. W. Bridgman, Proc. Amer. Acad. Arts Sci. **74**, 425 (1942).

[2] P. W. Bridgman, Proc. Amer. Acad. Arts Sci. **81**, 169 (1952).

[3] N. A. Tikhomirova and S. M. Stishov, JETP **43**, 2321 (1962), Soviet Phys. JETP **16**, 1639 (1963).

[4] J. C. Jamieson and A. W. Lawson, J. Appl. Phys. **33**, 776 (1962).

[5] S. S. Kabalkina and Z. V. Troitskaya, DAN SSSR **151**, 1068 (1963), Soviet Phys. Doklady **8**, 800 (1964).

[6] R. H. Wentorf, Modern Very High Pressure Techniques, London, 1962.

[7] P. W. Bridgman, Proc. Amer. Acad. Arts Sci. **60**, 366 (1925).

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ANISOTROPY OF THE ENERGY GAP IN SUPERCONDUCTING TIN

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THE anisotropy of the energy gap in superconducting tin, detected by Bezuglyĭ, Galkin, and Korolyuk[1,2] and by Morse et al.[3] in the study of the absorption of ultrasound, amounted to about 30%. The analysis of these experiments carried out by Privorotskiĭ and Pokrovskiĭ[4,5] showed that the minimum energy gap in tin had not yet been observed and that it did not lie on a principal crystallographic axis.

The largest energy gap cannot be detected at all by experiments on the absorption of ultrasound because these give information only about the minimum value of the gap for a Fermi surface strip

satisfying the condition $v_F \cos\theta = c$, where θ is the angle between the directions of motion v_F of electrons on the Fermi surface and the wave vector k, and c is the velocity of sound.[6]

Some results are given below of a study of the absorption of longitudinal ultrasound in the frequency range 100—250 Mc in single crystals of pure tin (impurity content $\sim 10^{-4}$%) at temperatures of 1—4°K. The samples were oriented so that the ultrasound was propagated at right angles to the planes (101), (301), and (111).[1)]

Figure 1 gives the curves for the temperature dependence of the ratio of the ultrasonic absorption coefficients (α_S/α_n) for these samples and the theoretical curve[8] for an isotropic gap equal to 3.53 kT_k. After extrapolating these curves to T = 0 to eliminate the non-electronic absorption,[3] we can, using the formula of Bardeen, Cooper, and Schrieffer[8]

$$\alpha_s/\alpha_n = 2\,[\exp(\Delta/kT) + 1]^{-1}$$

determine $2\Delta_0$, which is the minimum energy gap at T = 0°K for the corresponding strip on the Fermi surface.

Figure 2 gives the dependences of $\ln(2\alpha_n/\alpha_S - 1)$ on T_k/T, the slopes of which at low temperatures give the following values of $2\Delta_0/kT_k$: $\sim 3.9 \pm 0.2$ for k⊥(101), $\sim 4.1 \pm 0.2$ for k⊥(301), and $\sim 4.8 \pm 0.3$ for k⊥(111).

The observed deviation from the exponential law at the lowest temperatures is possibly connected with the relationships for an anisotropic superconductor predicted by Pokrovskiĭ.[6] A similar observation was made by Bohm and Horwitz in a study of vanadium,[9] but unfortunately they give

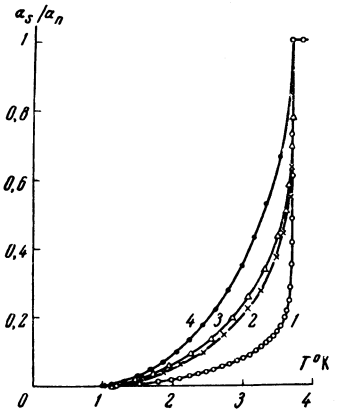

FIG. 1. Temperature dependence of the ratio of the coefficients of longitudinal sound absorption in the superconducting and normal states of tin. Curve 1) sound wave vector ⊥ (111), sound frequency f = 252 Mc; curve 2) k⊥(301), f = 175 Mc; curve 3) k⊥(101), f = 175 Mc; curve 4) isotropic model data.[8]

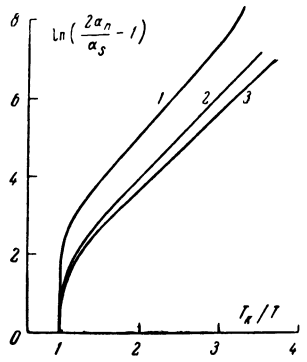

FIG. 2. Dependence of $\ln(2\alpha_n/\alpha_S - 1)$ on T_k/T for longitudinal ultrasound in tin. Curve 1) k⊥(111); curve 2) k⊥(301); curve 3) k⊥(101).

no information about its nature. It is obviously of interest to obtain more precise information on this problem.

The results reported here give grounds for assuming that the anisotropy of the energy gap in superconducting tin is not less than 50%. Fuller data will be published elsewhere.

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1)In general, complex vibrations appear in the crystal, but the temperature dependence of the electronic absorption of high-frequency sound at low temperatures, which governs the magnitude of the minimum energy gap, is independent of the polarization of sound vibrations.[7]

[1] Bezuglyĭ, Galkin, and Korolyuk, JETP **36**, 1818 (1959), Soviet Phys. JETP **9**, 1296 (1959).

[2] P. A. Bezuglyĭ and A. A. Galkin, JETP **39**, 1163 (1960), Soviet Phys. JETP **12**, 810 (1961).

[3] Morse, Olsen, and Gavenda, Phys. Rev. Lett. **3**, 15 (1959).

[4] I. A. Privorotskiĭ, Dissertation for Candidate's Degree, Leningrad, 1963.

[5] V. L. Pokrovskiĭ, Dissertation for Doctor's Degree, Novosibirsk, 1962.

[6] V. L. Pokrovskiĭ, JETP **40**, 898 (1961), Soviet Phys. JETP **13**, 628 (1961).

[7] T. Tsuneto, Phys. Rev. **121**, 402 (1961).

[8] Bardeen, Cooper, and Schrieffer, Phys. Rev. **108**, 1175 (1957).

[9] H. V. Bohm and N. H. Horwitz, VIII Intern. Conf. on Low Temp. Phys., London, 1962.

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