distance), which we attribute to the presence of only one pulse in the axial period, i.e., to complete mode locking.

[1] V.I. Malyzhev, A.S. Markin, and A.A. Sychev. Zh. Tekh. Fiz. 39, 334 (1969) [Sov. Phys.-Tech. Phys. 14, (1969)].
[2] T.I. Kuznetsova and S.G. Rautian, Fiz. Tverd. Tela 5, 2105 (1963) [Sov. Phys.-Solid State 5, 1535 (1964)].
[3] C.L. Tang, H. Statz, G.A. deMars, and D.T. Wilson, Phys. Rev. 136, A1 (1964).
[4] A.M. Bonch-Bruevich, V.Yu. Petrun'kin, A.A. Asepkina, et al., Zh. Tekh. Fiz. 37, 2031 (1967) [Sov. Phys.-Tech. Phys. 12, 1495 (1968)].
[5] V.I. Malyshev, A.S. Markin, and A.A. Sychev, ZhETF Pis. Red. 9, 3 (1969) [JETP Lett. 9, 1 (1969)].
[6] V.S. Letokhov, Zh. Eksp. Teor. Fiz. 55, 1943 (1968) [Sov. Phys.-JETP 28, 1026 (1969)].

NEW SUPERCONDUCTING MODIFICATIONS OF BISMUTH

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Bridgman established in his time, by measuring the volume compressibility, that bismuth has five polymorphic transformation under pressure at room temperature. The values of the transformation pressures determined by him were $P_{I-II} = 25.3$ kbar, $P_{II-III} = 27.0$ kbar, $P_{III-IV} = 44.8$ kbar, $P_{IV-V} = 65.0$ kbar, and $R_{V-VI} = 79.8$ kbar [1].

In the transformations III-IV and IV-v, the volume change $\Delta V/V_0$ was small, approximately 0.5%. Subsequent investigations of the P-T diagram of bismuth did not confirm the presence of the last three transformations. Later on Bundy observed a large jump of resistance above the pressure of the V-VI transition [2].

Zeitlin and Brayman, using a cubic press and samples of great length, recently measured the electric resistance of bismuth under pressure at room temperature, and observed resistance jumps corresponding to five transformations, which they ascribed to the transitions I-II, II-III, III-IV, and IV-V obtained by Bridgman, and to the transition found by Bundy, which they designated V-VI [3]. The relative change of the electric resistance obtained in [3] amounts to 1 - 3% for the III-IV transition and to 1 - 2% for the IV-V transition.

The modification of Bi II and Bi III [4 - 6] and Bi VI[1] [7] are superconducting. We have investigated the properties ob bismuth in the pressure range 30 - 100 kbar, for the purpose of observing the superconductivity of the modifications Bi IV and Bi V.

The measurements were performed with a fixed-pressure setup [8]. The procedure was modernized by using a high-pressure chamber of a new type[2]. The chamber made it possible to perform the measurements on a vertically positioned sample. The pressure-transmitting media were pyrophyllite and silver chloride.

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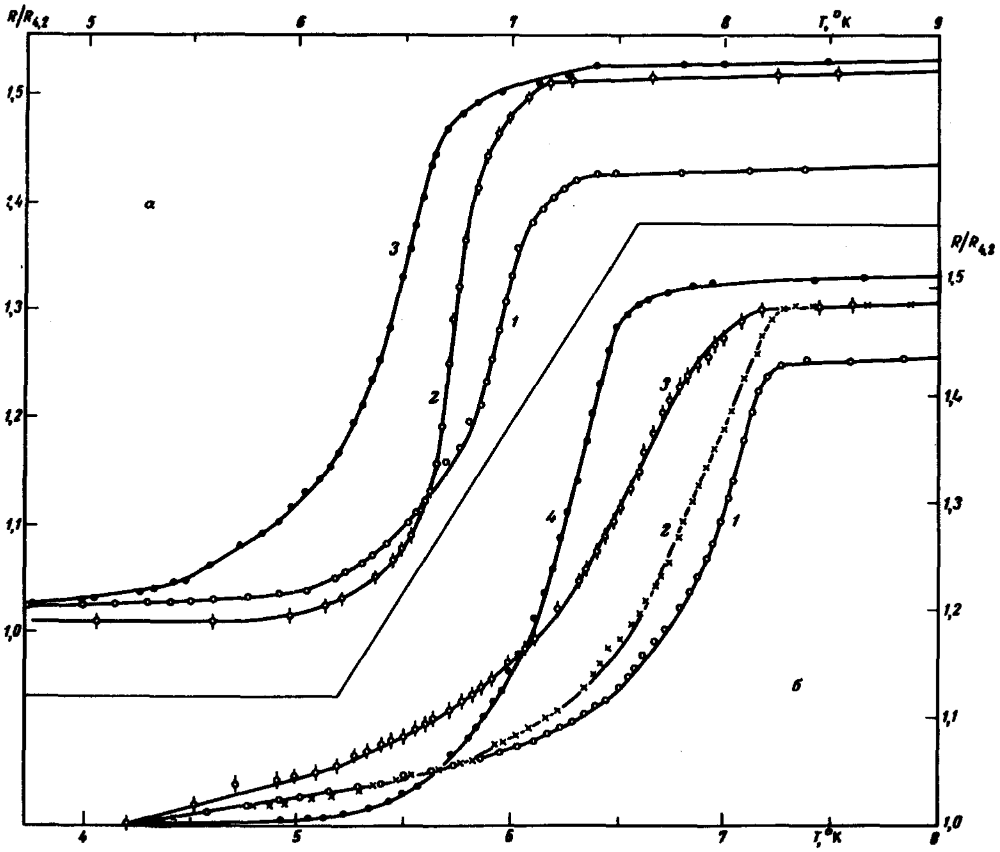
[1] In accord with [3], we designate as Bi VI the modification designated by Bundy as Bi VIII.

[2] We are grateful to L.F. Vereshchagin, L.G. Khvostantsev, and A.P. Novikov for furnishing the chamber that they developed.

Fig. 1. Change of electric resistance of bismuth samples on going over to the superconducting state in the pressure region 30 - 60 kbar. a) Bi III: 1 - 28.5 kbar, 2 - 33.5, 3 - 39.5; b) Bi IV: 1 - 43.5 kbar, 2 - 47.5, 3 - 53.5, 4 - 58.5.



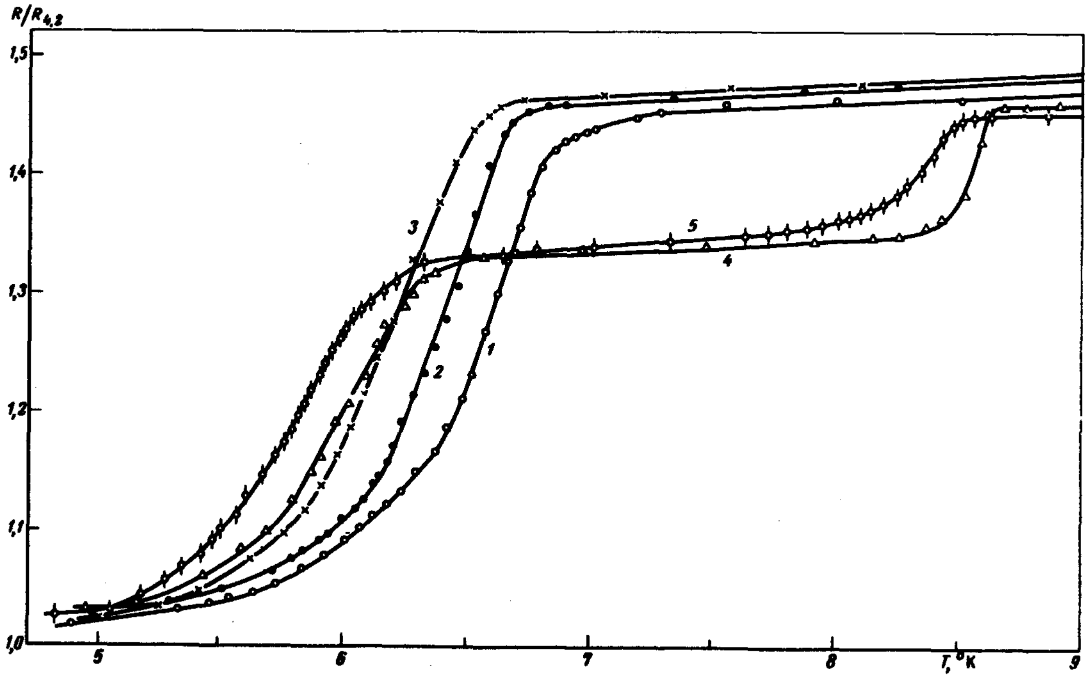


Fig. 2. Change of electric resistance of bismuth samples on going into the superconducting state in the pressure region 60 - 100 kbar. Bi V - 1 - 68.5 kbar, 2 - 77.0 kbar, 3 - 83.0 kbar; Bi V and Bi VI - 4 - 91.0 kbar, 5 - 97.5 kbar.

We used the Kennedy-La Mori pressure scale [9].

The samples were Bi wires drawn through a die from initial material 99.999% pure. The transition into the superconducting state was revealed by the sharp decrease of the electric resistance. Temperatures in the region from 4.2°K upward were obtained by heating the cold booster [8] over the level of liquid helium, and were determined with a copper - gold-iron alloy thermocouple. We used rapid cooling of the cold booster in order to obtain the metastable high-pressure phases III and VI.

Figures 1 and 2 show the obtained temperature dependences of the relative electric resistance $R/R_{4.2}$ at different pressures. Transitions into the superconducting state are observed in the entire investigated pressure region. However, the function $T_c(P)$ is not continuous, but breaks up into several parts. We assume that these parts correspond to the superconductivity of the nodifications III - VI. Figure 3 shows the transition temperature T_c as a function of the pressure for all the investigated modifications. We see that two modifications, Bi V and Bi VI, exist in the pressure region 90 - 100 kbar.

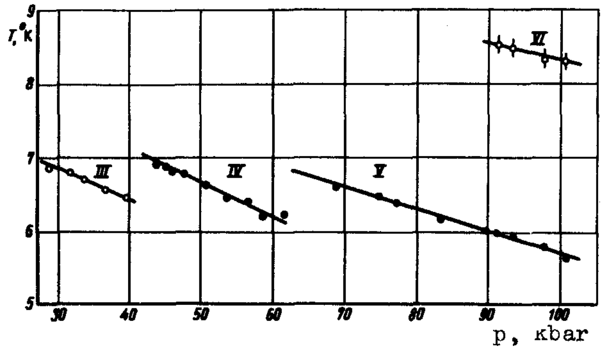


Fig. 3. Dependence of the temperature of the superconducting transition of various modifications of bismuth on the pressure. The Roman numbers denote the corresponding modifications.

The modification Bi III has T_c = 7.00°K at P = 27 kbar and $dT_c/dP = -(4 \pm 0.5) \times 10^{-5}$ deg/bar. The value of T_c for Bi III is in satisfactory agreement with the data of [4 - 6]. The modification Bi IV has T_c = 7.0°K at p = 43 kbar and $dT_c/dP = -(4.6 \pm 0.5) \times 10^{-5}$ deg/bar. The modification Bi V has T_c = 6.7°K at P = 68 kbar and $dT_c/dP = -(3 \pm 0.5) \times 10^{-5}$ deg/bar. For Bi VI, T_c = 8.55°K at P = 90 kbar and $dT_c/dP = -(2.3 \pm 0.5) \times 10^{-5}$ deg/bar; this is in satisfactory agreement with the data of [6, 7].

It should be noted that Eichler and Wittig [6] present an electric-resistance curve for a bismuth sample compressed to the pressure of the transition into the modification VI, containing two transitions into the superconducting state, the first at T_c = 8.55°K, which the authors ascribe to Bi VI, and the second at T_c = 6.2°K, which they ascribe to Bi III. The last value fits well on the $T_c(P)$ curve obtained by us for Bi V at the corresponding pressure.

The superconductivity observed by us in modifications Bi IV and Bi V, together with the previously obtained data on the superconductivity of the new modification of barium [10], allows us to conclude that the transition to the superconducting state is a good test for determining the polymorphic transformations in metals in the presence of small volume and resistive effects.

In conclusion, the authors consider it their pleasant duty to thank Academician L.F. Vereshchagin for support and valuable advice, and N.V. Baryshev for help with the experiments.

[1] P.W. Bridgman, Proc. Am. Acad. Arts, Sci. 81, 165 (1952).
[2] F.P. Bundy, Phys. Rev. 110, 314 (1958).
[3] A. Zeitlin and J. Brayman, ASME Publication 62-WA-265.
[4] N.B. Brandt and N.I. Ginzburg, Usp. Fiz. Nauk 85, 485 (1965) and 98, 95 (1969) [Sov. Phys.-Usp 8, 202 (1965) and 12, 344 (1969)].
[5] E.M.Compy, Phys. Lett. 18, 228 (1965).
[6] A Eichler, J. Wittig. Z. Angew. Phys. 25, 319 (1968).
[7] J. Wittig, Zs. Phys. 195, 228 (1966).
[8] L.F. Vereshchagin, M.A. Il'ina, and E.S. Itskevich, PTE No. 1, 219 (1969).
[9] G.C. Kennedy and P.N.L. La Mori, Progr. in Very High Press. Phys., 1961, p. 304.
[10] M.A. Il'ina and E.S. Itskevich, ZhETF Pis. Red. 11, 26 (1970) [JETP Lett. 11, 15 (1970)].

WAVE PROCESSES IN He II NEAR THE SURFACE OF A HEATER

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Mobile "sources" of radiation of (first) sound, which are not produced in He I, were observed near a heated surface in He II by Schlieren photography of the optical inhomogeneities excited in the liquid helium following a pulsed release of Joule heat from a thin flat heater; the propagation of these sources along the heater is also accompanied by excitation of second sound.

The investigated flat layer of liquid helium, 57 mm thick, was poured into the chamber between two plane-parallel glass discs. Figure 1 shows part of this layer in the form of a parallelepiped measuring 51 × 57 × 100 mm, bounded by the discs (not shown in the figure), and also by vertical (2, 3) and horizontal (4, 5) walls (laminated bakelite). The flat heater 1, parallel to the wall 3 and located 50 mm away from it, was made up of vertical sections of constantan ribbon 0.02 mm thick and 0.47 mm wide, spaced about 1 mm apart (the mass of the constantan was about 9 mg/cm^2). The surface area of the metal exposed to the liquid equalled the area of the section occupied by the heater, and the heat flux was calculated per unit of this area. On the left wall was placed heater 2, made of horizontal sections of ribbon. The temperature of the liquid was regulated and measured by determining the saturated vapor over it (T_{58} scale). The chamber with the liquid helium was installed in the beam of parallel light rays of the shadow instrument in such a way that the projection of the heater 1 represented a thin line (the dark vertical line in the centers of the photographs in Figs. 2 and 3). A single rectangular pulse of duration t_* and front rise time ≤ 0.05 μsec was passed through the heater ribbon. The pulse amplitude was measured with a digital voltmeter. The power N (in the pulse) is dissipated on both sides of the heater 1. After a time t_+, reckoned from the leading front of the pulse, a light flash (∿1 μsec) is started and registers the instantaneous picture of the perturbations. The construction of the cryostat and the experimental procedure are described in [1]. The photographs in Figs. 2 and 3, obtained by the knife-edge and slit method (vertical slit 0.05 mm wide) give the horizontal projections of the density gradient of the liquid. The smallest distinguishable values are equal to $d\rho/dx \geq 1.5 \times 10^{-6}$ g/cm^4 and $d\rho/\rho dx \geq 10^{-5}$ cm^{-1}. Such a

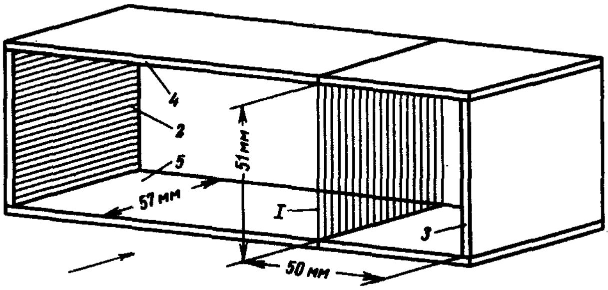

Fig. 1