EFFECT OF PRESSURE UP TO 10 kbar ON THE FERMI SURFACE OF TIN

N. B. Brandt, S. V. Kuvshinnikov, and Ya. G. Ponomarev
Moscow State University
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The influence of hydrostatic pressure on the Fermi surface of white tin was investigated. Pressure dependences were obtained for several characteristic cross sections of the equal-energy surfaces in the third and fourth Brillouin zones.

The main difficulty hindering the investigation of the effect of the pressure P on sufficiently large sections of the Fermi surface of metals by oscillatory methods are the stringent

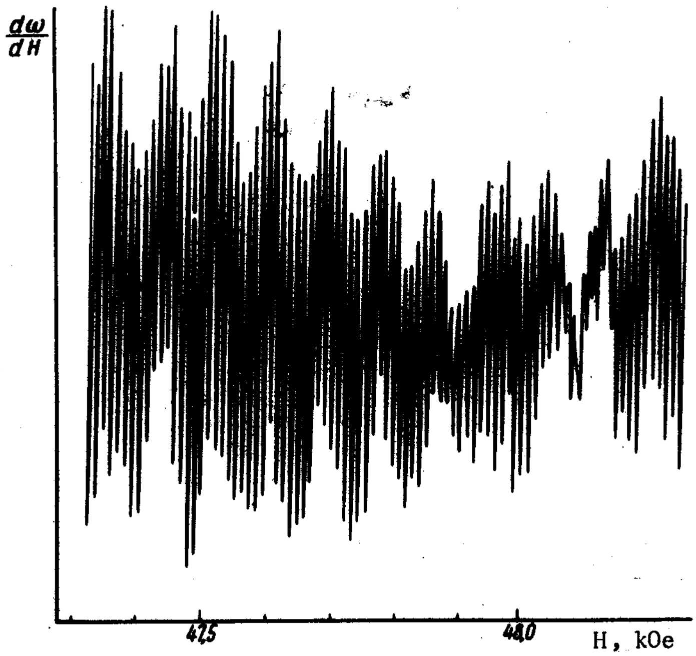
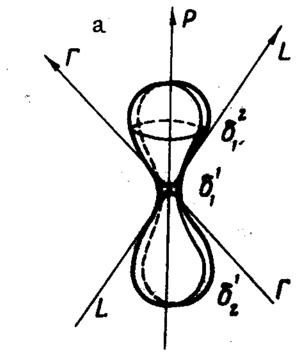
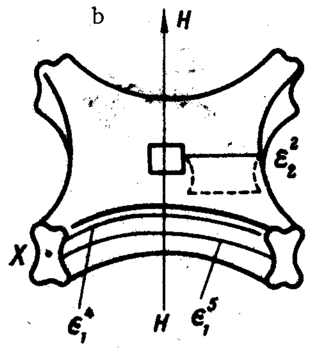


Fig. 1. High-frequency oscillations attributed to the cross sections in the fourth zone at a pressure 10.3 kbar, T = 1.6°K.





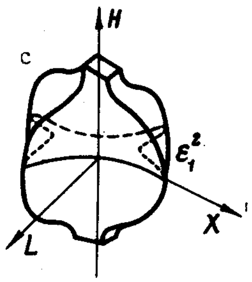


Fig. 2. Equal-energy surfaces and orbits corresponding to the oscillations observed in the present paper. The designations of the orbits and of the cross sections were taken from [4]: a — dumbbell in third hole zone, b — open hole surface in fourth zone, 4 — electron surface in fourth zone, having a geometry of intersecting convex lenses.

requirements imposed on the degree of uniformity of the hydrostatic compression. Known methods of producing high pressures at low temperatures [1] do not ensure the required degree of hydrostatic uniformity, so that investigations of metals are usually limited to low pressures (up to 100 bar) produced by helium gas.

A modification which we have introduced in Itskevich's procedure has enabled us to increase the degree of hydrostatic compression to such an extent, that we were able to investigate, at pressures up to 10 kbar and at a temperature 1.6°K, the oscillatory effects from large sections of the Fermi surface of tin, for which, in so far as we know, there are no data on the effect of pressure on the Fermi surface.

The pressure was produced in the bomb described in [2], with a working-channel diameter 4.5 mm. The pressure-transmitting medium was a mixture of 70% n-pentane and 30% dehydrated transformer oil. The initial pressure was produced at room temperature. The hydrostatic pressure was increased at low temperatures by induction heating of the sample with an alternating magnetic field while the bomb was being cooled, in such a way that the sample remained surrounded by a liquid envelope down to a temperature 50 — 70°K. The heating was then stopped, the liquid envelope contracted to the sample and its volume decreased, while the sample froze gradually in the solid pentane-oil medium [3].

We investigated the quantum oscillations of the imaginary part of the surface impedance of tin at frequencies 10 — 15 MHz in a magnetic field up to 50 kOe. Single-crystal samples were grown from tin with a resistance ratio $\rho(300°K)/\rho(4.2°K) = 5\times10^4$ and were oriented with a goniometer accurate to 1°. The absolute error in the determination of the period of the oscillations was ∿ 1%. The relative error in the determination of the change of the period upon compression was 0.1%. The characteristic dependence of the derivative of the imaginary part ω of the surface impedance on the magnetic field is shown in Fig. 1.

The analysis of the results was based on the model proposed by Graven and Stark for the Fermi surface of tin [4]. According to this model, the oscillations observed in weak fields were attributed to the third hole zone, and the high-frequency oscillations appearing in strong fields were attributed to part of the equal-energy surface in the fourth zone (Fig. 2).

The oscillations from the other parts of the Fermi surface had low amplitudes, and their analysis called for a lower temperature. Figure 3 shows typical plots of the areas of the sections of the Fermi surface against the applied pressure. It is interesting that these plots become linear if the abscissa is chosen to be not the pressure but the change of the volume sample.

The results are summarized in the table, which shows the observed frequencies of the oscillations in terms of the reciprocal fields, the corresponding areas A of the extremal sections of the Fermi surfaces, and their rates of change under hydrostatic compression, as determined from the initial sections of the plots of A against the pressure.

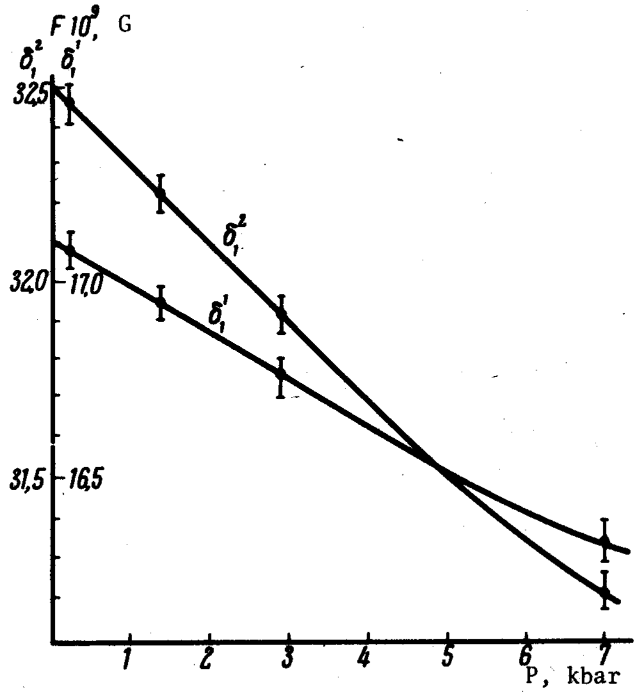


Fig. 3. Pressure dependence of the areas of two extremal sections of the equal energy surface of the third zone.

Magnetic field direction	Sect. per model of [4]	Freq., 10^7 G	Extremal sect. area A, at.un.	$\frac{\Delta A}{A} \Big/ -\frac{2}{3}\frac{\Delta v}{v}$	Surface type
[001]	δ_1^1	0,171	$4.59 \cdot 10^{-3}$	$-5,0 \pm 0,5$	holes
[001]	δ_1^2	0,325	$8.68 \cdot 10^{-3}$	$-6,5 \pm 0,5$	holes
[001]	ϵ_1^2	3.400	$9,11 \cdot 10^{-2}$	$2,2 \pm 0,5$	electrons
[001]	ϵ_1^4	10.300	$2.76 \cdot 10^{-1}$	-0.5	holes
[001]	ϵ_1^5	11.200	$3,00 \cdot 10^{-1}$	$-0,5$	holes
[100]	δ_2^1	1,570	$4.22 \cdot 10^{-2}$	$-6,2 \pm 0,5$	holes
[100]	ϵ_2^2	3.280	$8.80 \cdot 10^{-2}$	$-1,8 \pm 0,5$	holes

$$\frac{\Delta A}{A} = \frac{A(p) - A(0)}{A(0)}, \quad v \text{ — volume of sample}$$

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[2] N. B. Brandt and Ya. G. Ponomarev, Zh. Eksp. Teor. Fiz. 55, 1215 (1968) [Sov. Phys.-JETP 28, 653 (1969)].
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[4] I. E. Graven and R. W. Stark, Phys. Rev. 168, 849 (1968).