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EFFECT OF UNIAXIAL COMPRESSION ON THE QUANTUM OSCILLATIONS OF THE MAGNETIC SUSCEPTIBILITY OF BISMUTH

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The effect of uniaxial compression along the trigonal axis, using pressures up to 340 kg/cm^2, on the frequency and amplitude of the quantum oscillations of the magnetic susceptibility of bismuth was investigated for temperatures between 1.6 and 4.2°K. The results obtained are discussed on the basis of the semi-phenomenological theory of Kosevich.

DURING a study of the effect of hydraulic pressure on the magnetic susceptibility oscillations in bismuth, it was found that the deformation of the Fermi surface due to pressure was strongly anisotropic;[1,2] such an anisotropy was not found in zinc.[3,4]* From the standpoint of Kosevich's theory[5] a deformation of this type, associated with a change in the dispersion relationship, shows that the basic cause of the deformation is not a change in the Fermi energy E_0 (without a significant change in the dispersion law, as occurs in zinc), but is a change in the crystal lattice angles and an associated change in the dispersion law. In this connection one can expect the effect of uniaxial compression on the oscillation frequency, E_0/β, of the magnetic susceptibility of bismuth to be anomalously large compared with that to be expected if only E_0 changed; here β is the effective Bohr magneton — see the Landau formulae quoted by Shoenberg.

The apparatus for producing the uniaxial compression is shown in Fig. 1. The housing 1, the piston 2, which transmits pressure to the specimen 3, the threaded bushing 4 and the specimen enclosure 6 were made from very pure aluminum bronze; the spring 5 was made from 4% beryllium bronze. The calibration of the spring was performed in a special apparatus and the result was recalculated in terms of the pitch of the compression bushing thread 4. The elastic constant of the spring was 15 kg/mm. The whole apparatus, with the help of the adjusting device 9, was fixed on the glass rod of a torsion balance suspension system.

The measurements were performed on three single-crystal specimens made from "Hilger" bismuth after it had been recrystallized 30 times; the specimens were strictly cylindrical, 3 mm in diameter and 10 mm long. The trigonal axis of the specimens coincided with the longitudinal axis to within 0.5°. To avoid possible bending of the specimen during compression a sliding support was used; this consisted of a layer of graphitic lubricant 50 μ thick completely filling the space between the specimen 3 and the enclosure 6.[7] The small error in the orientation of the trigonal axis of the specimen relative to the axis of the suspen-

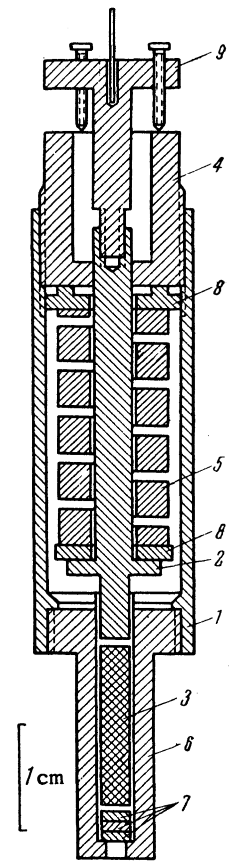

FIG. 1. Apparatus for studying the magnetic anisotropy of single crystals under uniaxial compression. 1 – housing, 2 – piston transmitting pressure to the specimen, 3 – specimen, 4 – threaded bushing, 5 – spring, 6 – specimen enclosure, 7, 8 – washers, 9 – adjusting device.

*The effect of uniaxial deformation on the magnetic susceptibility oscillations in zinc has also been studied.[4]

sion was corrected by means of the adjusting apparatus 9. When the orientation is correct there is no couple for any direction in a magnetic field of 12,000 oersteds at room temperature. The complicated variation of the couple[2,8] observed in the basal plane at helium temperatures is, apparently, a consequence of the phase shifts and different amplitudes of the oscillations associated with each of the three ellipsoids of the Fermi surface; this destroys the mutual compensation of the magnetic moments which takes place at high temperatures.

The magnetic susceptibility anisotropy was measured on specimens at zero stress, at stresses of 35, 70, 200, and 340 kg/cm², and after removing the stress, for temperatures between 1.6 and 4.2° K. If the load did not exceed 250 kg/cm² the amplitude of the oscillations was almost completely restored on removing the stress. For large loads there was noticeable hysteresis. For every value of the load the values of E_0/β (proportional to the area S_m of the extremal section of the Fermi surface by a plane perpendicular to the magnetic field[9]) were determined for angles Ψ between the vector **H** and the twofold axis of the specimen of 0, +2, −2 (or +3, −3), +28, +30, +32, +15, +45°. The dependence of $E_0/\beta \sim S_m$ on Ψ which was obtained is shown in Fig. 2. As is seen from the

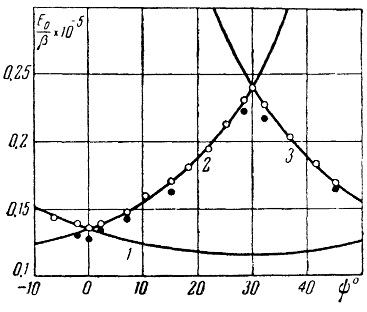

FIG. 2. Variation of oscillation frequency with the angle Ψ between the magnetic field direction and the diad axis. 1, 2, 3 – theoretical curves derived from Landau's formulae. Experimental data: ○ – unstressed, ● – with a stress of 340 kg/cm².

figure, the values E_0/β for uncompressed specimens agree very well with the theoretical curves (continuous lines) derived from Landau's formulae using the tensor-effective masses determined by Shoenberg.[6] On applying uniaxial compression the frequency of oscillation falls. Since the relative frequency change should be the same for all values of Ψ, the changes of E_0/β obtained for the same stress but for different angles Ψ were averaged; this was done to decrease the effect of errors in the relative determination of the twofold axis orientation in experiments with different loads. The variation of $\Delta(E_0/\beta)/(E_0/\beta)$ with stress is shown in Fig. 3.

The change of E_0/β on compressing bismuth along the trigonal axis is anomalously large. For a stress of 350 kg/cm² the reduction of E_0/β cor-

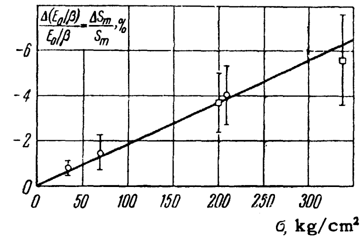

FIG. 3. Variation of relative oscillation frequency change with applied stress: ○ – specimen Bi-1, □ – specimen Bi-2.

responds to that which occurs for the same orientation at a hydrostatic pressure of about 1000 atmos.[2]

Thus, for bismuth, which has no groups of electrons with greatly differing concentrations and in which the Fermi surface deformation corresponding to a change in the bounding energy E_0 cannot, therefore, be a determining effect, the main cause of the Fermi surface deformation is the change of the crystal lattice angles. It is very possible that a similar deformation mechanism will be observed also in metals similar to bismuth.

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