due to Coulomb interaction of electrons of different groups in accordance with the theory of [5].

According to this theory, the transition is effected in a limited temperature range above and below which the superconductor is in the normal state. The observed effect is highly complex in nature, since it involves, in addition to the mechanism indicated, an evidently important contribution from magnetic-property anisotropy, depending on film-condensation conditions, and the increase in the transition temperature is governed partly by exchange interaction of electrons of different groups, to which attention was drawn earlier in [7].

The appearance of residual resistivity and oscillation of the TCE in the neighborhood of the transition point are evidently connected by correlation of the state-density fluctuations of the different electron groups.

The material of the paper was published in ZhETF Pis. Red. 18, 3 (1973) [JETP Lett. 18, 1 (1973)].

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N. E. Alekseevskiĭ and A. A. Slutskin. Magnetic Breakdown in Metals. The intensities of the magnetic fields used in contemporary experiments to study the low-temperature properties of metals usually conform closely to the quasiclassicism condition $\kappa = \hbar\omega_c/\epsilon_F \ll 1$ (ω_c is the characteristic cyclotron frequency and ϵ_F is the Fermi energy). As we know, this inequality has made it possible to explain many experimental results in terms of classical motion of a conduction electron on orbits in momentum space.

But it has recently become clear that a whole series of experimental facts do not fit within the framework of the classical scheme. To explain them, it is necessary to take account of the quantum nature of conduction-electron dynamics even in the zeroth approximation in the quasiclassicism parameter κ. These anomalies are due to magnetic breakdown (MB)[1]—interband tunneling transitions of conduction electrons that occur in sufficiently strong magnetic fields in narrow regions of momentum space with small interband energy gaps.

The principal dynamic characteristic of magnetic breakdown is the probability of interband tunneling $W = \exp(-H_0/H)$, where the constant $H_0 = (m_0c/e\hbar)\Delta^2/\epsilon_F$ (m_0 is the mass of the free electron, c is the velocity of light, Δ is the interband energy gap in the magnetic-breakdown region, and e is the electronic charge). In the limit $W \to 1$, $H \gg H_0$, magnetic breakdown causes only topological restructuring of the classical orbits, i.e., this limiting situation (just as in the case of weak breakdown, $W \to 0$, $H_0 \gg H$) can be treated classically. It was shown in [2] that a fundamentally different quantum limit picture appears in the intermediate field range $H \sim H_0$, $W(1-W) \sim 1$. At these values of H, kinetic phenomena in metals exhibit a kind of duality that reflects the corpuscular-wave dualism of the magnetic-breakdown dynamics of the conduction electrons. It is found [2] that two qualitatively different approaches are possible in the interpretation of experimental data on magnetic breakdown. In one of them (the stochastic approach), the electrons are regarded as classical particles that "skip" between orbits at random with a probability W in the magnetic-breakdown regions. In the other approach, the electron is regarded as a wave for which the magnetic-breakdown region is a semitransparent tunnel contact. The wave passes through this contact with an amplitude equal to $\sqrt{W}$. Since the various reflected and transmitted waves interfere coherently with one another, the kinetic coefficients of magnetic breakdown are found to be very sensitive to the phase of the electron wave function.

According to [2], which of these mutually complementary cases develops is determined by the presence of large-scale weak deformation fields created in the metal by extended defects of the dislocation type. If the concentration of these defects is high enough, quantum coherence is disturbed and a transition to the stochastic case occurs.* Inhomogeneity of the external magnetic field may also give rise to a similar stochastization. It must be stressed that the dualism described here occurs only under magnetic-breakdown conditions.

The above aspects are particularly conspicuous in the behavior of the magnetic susceptibility tensor $\rho_{ik}(H)$. We studied the susceptibilities of Nb and Be experimentally. The measurements were made in a solenoid, either superconductive or water-cooled, that created a field of 150 kOe. Use of magnetic concentrators made it possible to perform measurements in fields up to 180 kOe with sufficiently high field homogeneity.

1. Magnetic breakdown in Nb [3]. Highly perfect specimens of Nb with $\rho(300°K)/\rho(4.2°K)_{H=0} = 10^5$ and a dislocation density $\approx 10^4\ cm^{-2}$ were used for the measurements. Figure 1 shows the characteristic $\rho_{xx}(H)$ curve. It shows that $\rho_{xx}(H)$ reaches saturation. For metallic Nb with an open surface in the third zone and $n_1 \neq n_2$, this definitely indicates the intervention of magnetic breakdown. Analysis of the data showed good agreement between the experiment and the "coherent" theory. And this should be expected in view of the perfection of the Nb specimens. Comparison of theory with the experiment showed that the breakdown field $H_0 = 280 \pm 20$ kOe and that the interband gap $\Delta \approx 0.09$ eV (0.0068 rydberg). The value obtained for Δ agrees with theoretical conceptions [4] as to the electronic spectrum of Nb.

2. Magnetic breakdown in Be was observed in [5] from the break on the $\rho(H)$ curve. It was later shown in [6] that magnetic breakdown in Be between the small "cigar" orbit and the large "corona" orbit is accompanied by giant oscillations of $\rho(H)$ (Fig. 2) that are periodic in $1/H$ with period $e\hbar/cS$, where S is the area of the small orbit. The relative amplitude A of the oscillations was ~ 1, indicating that they are of "coherent" origin and fundamentally different from all hitherto known oscilla-

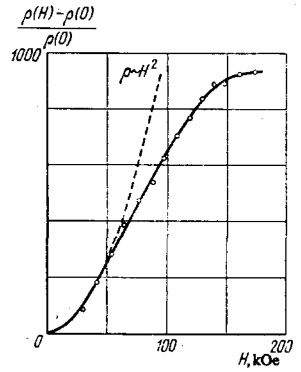

FIG. 1.

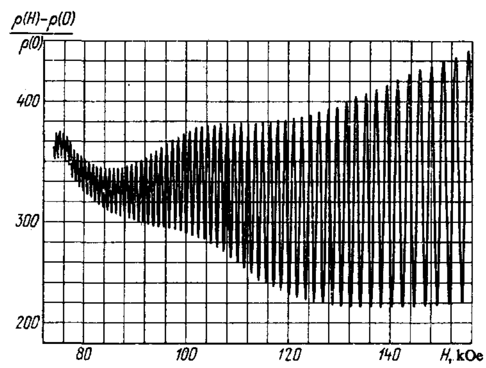

FIG. 2.

tory effects. This large value of A was explained in[2,6] in terms of the formation on coherent magnetic breakdown in Be of a narrow layer of current states whose contribution to the transverse conductivity is decisive. Electrons in these states move like waves in a periodic waveguide whose transmitting capacity is determined by the phase increment of the quasiclassical wave function in a circuit around the small orbit. The variation of this phase periodically modulates the entire transverse current, thus giving rise to the giant oscillations of $\rho(H)$. A calculation based on this idea yielded fully satisfactory agreement with experiment[7].

The coherence of magnetic breakdown in Be was especially conspicuous in the recent study[8] of the phase difference in the oscillating dependences of ρ_{xx} and ρ_{xy}. An S-shaped specimen was used for simultaneous measurement of these components. The voltage picked off the specimen was applied to an automatic x-y recorder. The phase difference θ was determined from the shape of the ellipses obtained on a 2—3 kOe change of H. It is highly significant that the dependence of θ on the angle α between **H** and the [0001] axis was found to be very strong: $\theta(0^\circ) = 0$, $\theta(3^\circ) \sim \pi/2$. Such behavior of $\theta(\alpha)$ can be explained only within the framework of the "coherent" theory, according to which even small deviations of **H** from the [0001] axis result in sharp phase aperiodicity of the wave function in p-space along the y axis (periodicity is preserved along the x axis, which is perpendicular to **H** and to the [0001] axis) and, as a consequence, in dephasing of the oscillations of ρ_{xx} and ρ_{yy} by an amount $\theta \sim b\alpha^2/\kappa$ (κ is the quasiclassicism parameter; the constant $b \sim 1$). This formula is in good agreement with experiment.

The amplitude A decreased sharply in an inhomogeneous field, assuming the value typical for the oscillations that arise under stochastic conditions. Simultaneously, it was found that $\theta(\alpha) \equiv 0$. Thus, the form of the functions $\theta(\alpha)$ is a good indicator of the coherence or stochasticism of the magnetic breakdown.

The above implies that macroscopic magnetic breakdown is manifested as a giant quantum anomaly in normal metals that is highly sensitive to the phase of the electron wave functions. This permits the use of magnetic breakdown in the design of quantum interferometers for operation in large magnetic fields. A device that can be used to determine the magnitude and gradient of the magnetic field has been built around the giant oscillations of $\rho(H)$ in Be, as well as a magnetometer capable of measuring the susceptibilities. These instruments are accurate to better than 10^{-5} and this figure can be improved on substantially.

Needless to say, Nb and Be do not exhaust the list of metals in which magnetic breakdown occurs, which now includes more than 10: Al, Zn, Mg, and others. A further increase in the magnetic fields would doubtless lengthen this list considerably and lead to the observation of fundamentally new effects of considerable conceptual and practical interest.

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2)The characteristics of the disturbing field then drop out of the final expressions, so that their roles are those of what might be called "latent" parameters.

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