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"TURNING" OF CURRENT-VOLTAGE CHARACTERISTIC OF GERMANIUM IN A STRONG MAGNETIC FIELD

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The influence of the boundary conditions on the current-voltage characteristic of a semiconductor in the presence of a strong magnetic field H perpendicular to the electric field E was considered theoretically by Bass [1] for different mechanisms of the energy and momentum dissipation by the electron. Usually one considers in the theory the extreme cases

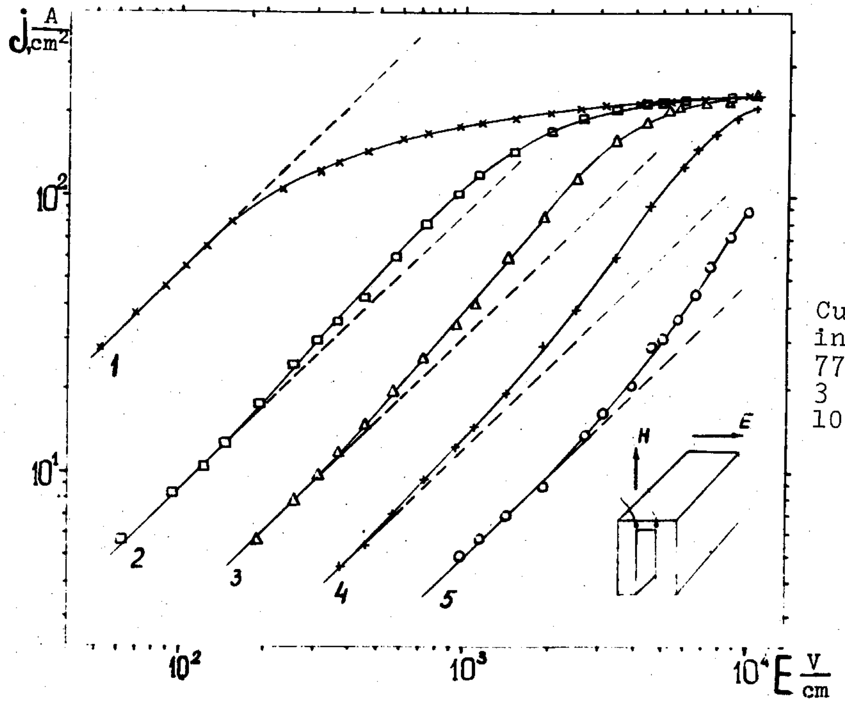
$$E_H = 0, \quad j_H \neq 0 \tag{1}$$

and

$$E_H \neq 0, \quad j_H = 0, \tag{2}$$

where E_H and j_H are the Hall field and the Hall current, respectively. Both cases, especially the first, are difficult to realize experimentally in pure form. Indeed, the case (1) can be realized only on a sample in the form of a Corbino disc, which in our case, however, is not suitable for the investigations, first because in an anisotropic and multivalley semiconductor the field has different directions relative to different valleys, and second because the electric field is inhomogeneous. Yet a case close to (1) can be realized with a sample having a small ratio of length b to the width c [2]. The Hall field is then weak, since a strong Hall current will flow through the current-conducting electrodes. We have prepared samples of p-Ge 2 mm long and 25 mm wide (see the figure). Massive electrodes, with areas about 10 - 15 larger than the area of the narrow working part, made it possible to eliminate injection. We measured the current-voltage characteristics of such p-Ge samples ($p \simeq 1.4 \times 10^{14}$ cm^{-3}) in static magnetic fields 0, 10, 25, 50, and 100 kOe at T = 77°K, when electron-phonon scattering takes place. The electric field pulse duration was 2 μsec.

The measurement results are shown in the figure. We see that the behavior of the current-voltage characteristics is radically altered, viz., whereas at H = 0 the conductivity decreases with increasing temperature, in a strong magnetic field H perpendicular to E, to the contrary, the conductivity increases with increasing E. A "turning" of the current voltage characteristics takes place. Such a change in the form of the current-voltage characteristics in a strong perpendicular magnetic field, when the boundary conditions (1) are satisfied, was indicated in [1], in particular, also for the case experimentally realized by us of electron scattering by the deformation potential of the acoustic phonons. Physically this change of the behavior of the current-voltage characteristics is perfectly understandable. In an electric field crossed with a strong magnetic field ($\vec{E} \perp \vec{H}$) the electron drifts in the direction of $\vec{E} \times \vec{H}$. The larger the number of electron-phonon collisions, the larger experimentally-measured current in the F direction.



Current-voltage characteristics in different magnetic fields at 77°K: 1 = 0 kOe, 2 - 10 kOe, 3 - 25 kOe, 4 - 50 kOe, 5 - 100 kOe.

If we turn now to the figure, then we notice the following peculiarities in the current-voltage characteristics:

First, in a weak electric field, when the current density is $j \sim E$, the conductivity increases with increasing H not like $\sigma \sim 1/H^2$, as it should in a strong magnetic field when the condition (1) is realized, but somewhat slower. Thus, when the magnetic field is increased from 50 to 100 kOe, the conductivity in the region of Ohm's law decreases not by a factor of 4, but approximately by a factor of 2.5. The reason is that the condition (1) is not completely satisfied, and there exists a weak Hall field that reaches a maximum value at the center of the sample.

Second, it is also seen from the figure that the current-voltage characteristics (compare those for 25, 50, and 100 kOe) shift approximately linearly in the direction of stronger electric fields with increasing H. This fact is a clear-cut illustration of the cooling of the electrons by a strong magnetic field. On the other hand, the linear shift follows from formula [3] for the effective temperature T_e in electron-phonon scattering and in the case of boundary conditions of the type (1)

$$T_e = T\left[1 + \frac{1}{3}\left(\frac{cE}{sH}\right)^2\right] , \tag{3}$$

where s is the speed of sound. Indeed, in order to reach such an effective temperature in a magnetic field $H_2 > H_1$ we need an electric field $E_2 = (H_2/H_1)E_1$.

Third, in the case of very strong heating, when $\omega_c\tau < 1$ (ω_c is the cyclotron frequency and τ the relaxation time) and the magnetic field does not affect the current-voltage characteristics, the latter overlap. Naturally, the larger the magnetic field, the larger the electric field needed for this purpose. Thus, at H = 100 kOe, even at $E \gtrsim 10^4$ V/cm, the condition $\omega_c\tau < 1$ is not satisfied (see curve 5 of the figure).

In the presence of boundary conditions close to (2) on samples with b/c >> 1, a strong magnetic field likewise exerts an influence on the current-voltage characteristic, but this influence is not so strong [4, 5]. In this case the behavior of the current-voltage characteristics is connected with the Hall current only near the edges of the sample, at a distance on the order of c, and since b/c >> 1, the influence of the magnetic field on the current-voltage characteristics is not so large as described in the present paper.

Thus, for the case of electron-phonon scattering, we have demonstrated experimentally that when $\vec{E} \perp \vec{H}$ and when boundary conditions close to $E_H = 0$ and $j_H \neq 0$ are realized, a "turning" of the current-voltage characteristic takes place.

The authors are grateful to F.G. Bass for indicating the possibility of observing this phenomenon.

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PRODUCTION OF TENSOR AND SCALAR MESONS IN ee COLLISIONS

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1. The use of accelerators with colliding electron beams makes it possible to investigate thoroughly vector resonances (ρ, ω, ϕ) [1]. Production of resonances with other spins (0, 2, ...) occurs in the next higher orders in accordance with the schemes of Figs. 1a [2], 1b [3], or 2.

To extract information on the resonance-production cross section in accord with Fig. 1a is difficult because of the large radiation background connected with the production of the vector resonances ρ, ω, and ϕ. The study of resonances in processes of Fig. 1b depends strongly on the model employed. We shall consider the production of resonances in the process of Fig. 2, and for concreteness we shall consider e^-e^- beams. The colliding electron beams serve as sources of opposing (virtual) photon beams producing the resonance. To study the properties of the resonances, we must measure the energies E_i and the scattering angles θ_i of the final electrons. This makes it possible to study

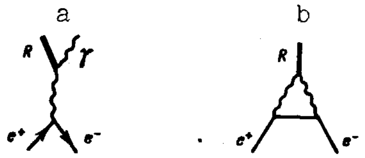

Fig. 1

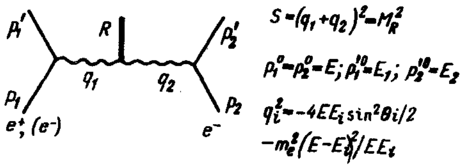

Fig. 2