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LINEAR EFFECT OF MAGNETORESISTANCE OF MANY-VALLEY SEMICONDUCTORS IN HEATING ELECTRIC FIELDS

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The usually considered magnetoresistance of homogeneous crystals in weak electric fields depends only on the even powers of the magnetic field, this being a simple consequence of Onsager's general relations [1]. It is assumed in these relations that a linear connection exists between the electric field intensity and the current produced by the field. In heating electric fields, however, this connection is violated, and one can expect the magnetoresistance to depend on the sign of the magnetic field. In this paper we consider, in particular, magnetoresistance that is linear in the magnetic field, occuring in n-type silicon.

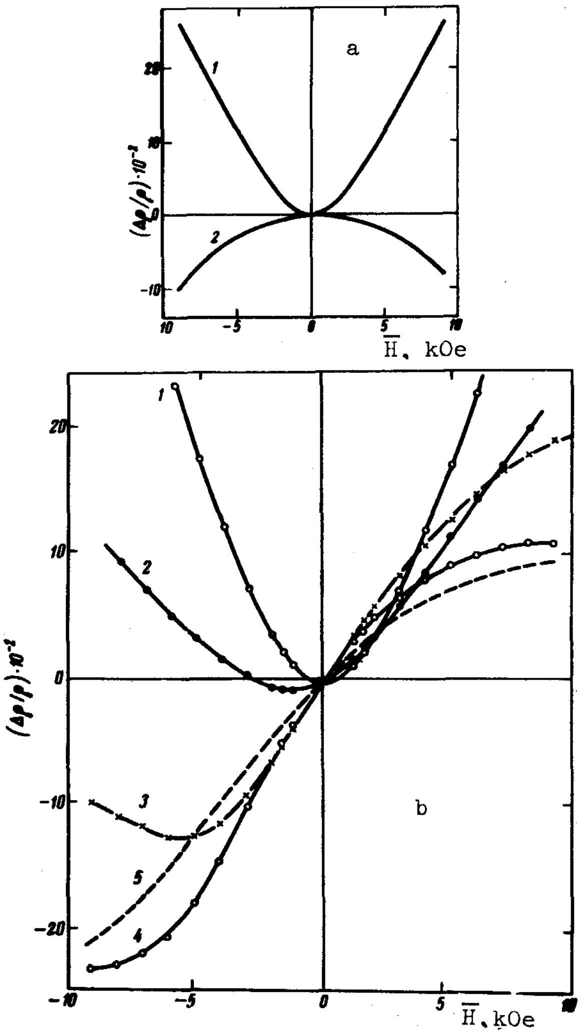

Fig. 1. Dependence of $\Delta\rho/\rho$ on H for different electric fields: a) 1 - log E = 0; 2 - log E = 3.01; b) 1 - log E = 0, 2 - log E = 2.21; 3 - log E = 2.41, 4 - log E = 2.66, 5 - log E = 3.01

The measurements were performed at 77°K on n-Si doped with phosphorus and having a resistivity $\rho_{300} = 7$ ohm-cm. The electric current was in the (110) plane, inclined 24° to the direction of the <100> axis in this plane; the magnetic field was perpendicular to the current.

The measurement results are shown in Figs. 1 and 2. Figures 1a and 1b pertain to cases when the magnetic field is parallel and perpendicular to the (110) plane, respectively. In the former case the negative magnetoresistance already described in [2] was observed, and reversal of the direction of the magnetic field did not change the magnetoresistance at any electric-field intensity. In the second case, the onset of electron heating was accompanied by a dependence of the magnetoresistance on the sign of the magnetic field. An analysis of this dependence shows that the term linear in H predominates as $\vec{H} \to 0$. In accordance with the general considerations advanced above, there is no linear effect in weak electric fields, but only the quadratic effect; the linear effect appears with the onset

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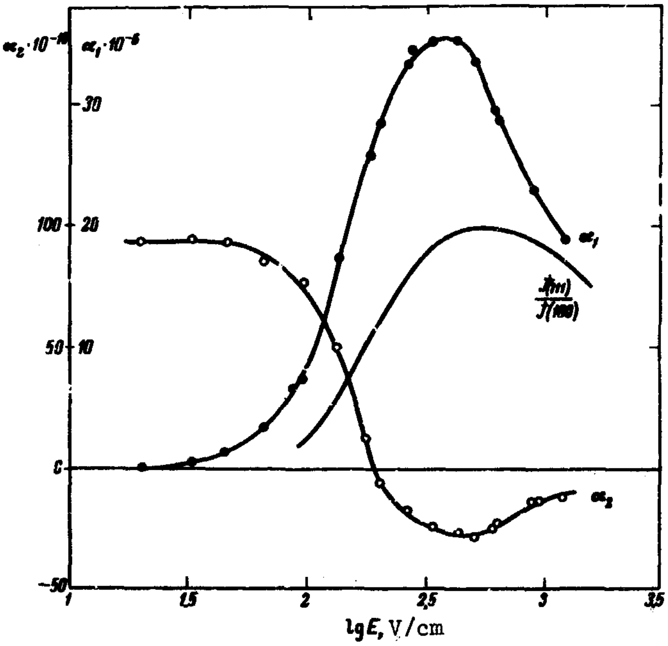

Fig. 2. Dependence of linear (α_1) and quadratic (α_2) magnetoresistance on the electric field.

of the heating of the electrons and goes through a maximum at a definite electric-field intensity.

The appearance of linear magnetoresistance in a bounded many-valley semiconductor can be described in the following manner: the directions of the currents of electrons from different valleys do not coincide with the direction of the total current of all the electrons, which is governed by the contacts to the crystal. When a magnetic field is applied, the resultant Hall field changes both the direction of these currents and the average energy and concentration of the electrons in the valleys. In the general case these changes depend on both even and odd powers of $\vec{H}$. However, the presence of terms linear in $\vec{H}$ in the average energy and concentration of the electrons in the valleys is still not sufficient for the appearance of linear magnetoresistance, since the terms connected with different valleys can cancel each other. It is easily seen from symmetry considerations that such a compensation occurs, for example, in the case described above, when the direction of the current and of the magnetic field in the n-Si lies in the (110) plane. It takes place also in germanium and silicon, when the electric current is directed along one of the symmetry axes of the crystal (except for the 100 axis in n-Si, where there are no terms even in $\vec{H}$ also for individual valleys). In general, linear magnetoresistance should be observed if the Hall field has a component along the direction of the anisotropy field that exists independently of $\vec{H}$ in a strong electric field. It follows from the latter that the course of the linear magnetoresistance should correlate with the course of the conductivity anisotropy in a heating electric field. Such a correlation indeed takes place, as is seen from Fig. 2, which shows the dependence of the conductivity anisotropy, characterized here by the ratio $j_{<111>}/j_{<100>}$ on the electric field at H = 0.

In conclusion, the authors thank P.M. Tomchuk, V.I. Stafeev, and K. Repsis for a discussion.

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[2] M. Asche, V.M. Bondar, and O.G. Sarbey, Phys. Stat. Sol. 31, K143 (1969).

ACOUSTIC NUCLEAR EFFECT-SOLIDE IN LITHIUM FLORIDE

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The possibility of realizing an acoustic "effect-solide" or "dynamic