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Abstract

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ON THE ANISOTROPY OF THE EVEN (TRANSVERSE) PHOTOMAGNETIC EFFECT IN GERMANIUM SINGLE CRYSTALS

In ([1,2]) it was shown that, alongside the usual photomagnetic effect in semiconductors, there exists another photomagnetic effect, which was called transverse.

Let us recall that this effect consists in the following: when a specimen in the form of a flat plate, placed in a magnetic field whose direction makes a certain angle with the plane of the specimen, is illuminated, an electric field (and the corresponding potential difference) arises in the specimen, directed perpendicular to the electric field of the usual photomagnetic effect.

The usual photomagnetic potential difference, as is known, is an odd function of the magnetic field, i.e., it changes its sign when the direction of the field is changed. The potential difference of the "transverse" photomagnetic effect does not change sign when the direction of the field is changed. Therefore, in what follows it is preferable to call this effect the even photomagnetic effect, in distinction to the usual odd photomagnetic effect.

In studying this even photomagnetic effect in polycrystalline cuprous oxide it was shown ([1]) that the magnitude of the potential difference V_q caused by this effect is

$$V_q = AH^2 \sin 2\alpha, \tag{1}$$

where H is the magnetic-field strength, α is the angle between the direction of the field H and the plane of the specimen, and A is a coefficient depending on the light intensity, the properties of the specimen, the state of its surface, etc.

The explanation of this effect reduced to the fact that it is a kind of Hall effect caused by the odd photomagnetic current, which immediately leads to expression (1).

In germanium single crystals the even photomagnetic effect differs in many respects from that observed in polycrystalline cuprous oxide.

Thus, in ([2]) it was shown that in germanium single crystals the coefficient A depends in a complicated way on the magnetic-field strength and the temperature.

Fig. 1 and Fig. 2

Figure 1: Fig. 1 and Fig. 2

Fig. 3

Figure 2: Fig. 3

As for the dependence of the even photomagnetic effect on the angle α, it seemed that it was correctly determined by equation (1). The theory of this phenomenon, first set forth in ([3]) and later in ([4]), also leads to this simple dependence.

However, experiments carried out by us recently have shown that for single crystals this angular dependence is not justified. The angular dependence of the transverse photomagnetic effect, obtained experimentally for germanium single crystals, is presented in Fig. 1. The function $\sin 2\alpha$ is also shown there by a dashed line. Such a sharply asymmetric angular dependence can—

can be explained only by assuming a substantial anisotropy of the effect. In this connection we undertook a study of the anisotropy of the even photomagnetic effect.

Fig. 1. Dependence of the even photomagnetic potential difference on the angle between the plane of an n-germanium sample and the magnetic field

Fig. 2

For this purpose it is convenient to carry out the investigations not on rectangular samples, as was done in previous experiments, but on samples in the form of circular disks (Fig. 2). The teeth cut along the periphery of the disk served as electrodes. With the aid of conductors soldered to the teeth, any two electrodes situated along a diameter of the disk were connected to the measuring circuit. The sample prepared in this way was fixed on a special stage, which made it possible to rotate it both about the normal passing through the center of the sample O, and about the axis AA.

Fig. 3. Anisotropy of the even photomagnetic effect in n-germanium. $\alpha = 45°$; $H = 2400$ oersted, the axis [111] is perpendicular to the plane of the sample (V_q —in arbitrary units)

The sample was placed in the magnetic field H, whose direction is indicated in the figure, and was illuminated in a direction perpendicular to the field. The potential difference was measured between two electrodes situated along the straight line BB. The plane formed by the line BB and the direction of the magnetic field is perpendicular to the plane of the sample (in the case when the plane of the sample is parallel to the field, BB is also parallel to the field).

By rotating the sample about the axis O, any two diametrically situated electrodes can be brought into coincidence with the line BB. The angular distances

Fig. 4. Anisotropy of the even photomagnetic effect in n-germanium. The plane of the specimen is parallel to the magnetic field ($\alpha = 0$), $H = 10000$ oersted; the [111] axis is perpendicular to the plane of the specimen (V_q—in arbitrary units).

Figure 3: Fig. 4. Anisotropy of the even photomagnetic effect in n-germanium. The plane of the specimen is parallel to the magnetic field ($\alpha = 0$), $H = 10000$ oersted; the [111] axis is perpendicular to the plane of the specimen (V_q—in arbitrary units).

between

electrodes are the same and are determined by the number of teeth on the specimen. Depending on the dimensions of the specimen, the number of teeth varied from 16 to 32. By rotating the specimen about the axis AA, one can vary the angle α between the plane of the specimen and the direction of the field (or, equivalently, between the line BB and the direction of the field).

It is obvious that, in the case of an isotropic substance, the potential difference measured between any two electrodes located along BB, at a given angle α, should not depend on the angle φ—the angle of rotation of the specimen about the axis O.

Experiment showed a substantial dependence of the potential difference on the angle φ. Figure 3 shows the dependence of the even photomagnetic effect on φ for a specimen of n-germanium cut so that the [111] axis is perpendicular to the plane of the specimen. Particularly interesting is the fact that, in the case where the plane of the specimen is parallel to the magnetic field, the even photomagnetic potential difference proved to be nonzero and also sharply anisotropic, as is evident from Fig. 4.

Fig. 4. Anisotropy of the even photomagnetic effect in n-germanium. The plane of the specimen is parallel to the magnetic field ($\alpha = 0$), $H = 10000$ oersted; the [111] axis is perpendicular to the plane of the specimen (V_q—in arbitrary units).

Similar anisotropy curves were obtained in the case where the normal to the specimen coincided with the [110] axis. In this case the curves correspond to an axis of symmetry of the second order.

The anisotropy of the even photomagnetic effect is not limited to what has been stated above. It turned out that the orientation of the crystal axes with respect to the magnetic field determines the dependence of the even photomagnetic potential difference on the magnetic-field strength.

The totality of the experimental data shows that the elementary theory of the even photomagnetic effect, which leads to expression (1) and does not take into account the anisotropy of the effect, is in sharp contradiction with experiment.

Thus, for example, it follows from this theory that, for a given angle between the direction of the field and the plane of the specimen, the ratio of the potential differences

of the even and odd effects proportional to the field. Meanwhile, the odd photomagnetic effect does not change its sign under any conditions, whereas the even effect changes its sign at certain values of the field or for certain orientations of the axes. It also follows from this same theory that at $\alpha = 0$ the even effect vanishes, which likewise does not agree with the experimental data presented above.

From what has been said it apparently follows that there is no simple correlation between the even and odd photomagnetic effects, and that the theory of the even effect must be constructed with allowance for the observed, sharply expressed anisotropy.

A more detailed description of the experiments and of the results obtained will be published elsewhere.

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Note: Figure translations are in progress. See original paper for figures.