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Abstract

Full Text

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RECOMBINATION RADIATION IN InSb UNDER THE MAGNETOCONCENTRATION EFFECT

(Presented by Academician B. P. Konstantinov, November 13, 1964)

In the present communication we give preliminary results of observations of recombination radiation in *p*-InSb at room temperature, caused by the magnetoconcentration effect, as a result of which an excess concentration of nonequilibrium charge carriers arises at one of the faces of the specimen. Some recombination events near the face with the excess concentration are accompanied by radiation. The theory of magnetoconcentration effects has been set forth in a number of works ([1–6]). This effect was observed in Ge ([7]). For the observation of recombination radiation under similar conditions, InSb is a more suitable object owing to the large concentration of intrinsic charge carriers and the high mobility of the electrons.

Fig. 1. Oscillograms of the observed pulses of recombination radiation. Horizontal sweep 2.5 μsec/cm; *a* —positive pulse, *b* —negative pulse.

Starting from these considerations, we attempted to detect recombination radiation on *p*-type single crystals with an acceptor concentration of $1 \div 2 \cdot 10^{17}$ cm^{-3}.

The specimens were prepared in the form of plane-parallel plates 50–200 μ thick, with an area of 1×6 mm^2. One face of the specimen was ground with fine emery powder in order to increase the rate of surface recombination; the other was subjected to electropolishing in order to reduce the rate of surface recombination.

The measurements were carried out in a constant magnetic field in the range 1000–18 000 oersted. The electric field was produced by a 26-I rectangular-pulse generator. To obtain stronger fields a special generator was used. The radiation was recorded by a gold-doped germanium photoresistor, the signal from which was amplified by a wide-band amplifier with a bandwidth of 10 MHz. The

Fig. 2

Figure 2: Fig. 2

radiation receiver was placed on the side of the face with the low rate of surface recombination. When the specimen was placed in crossed magnetic and electric fields, radiation arose in the third, mutually perpendicular direction; it was recorded by the receiver in the form of separate pulses synchronous with the pulses of the current feeding the specimen.

Studies have shown that two types of pulses are observed, differing in their time constant. One type of pulse, with a time constant of not more than 1 μsec, may be attributed to recombination radiation arising because of the magnetoconcentration effect. The second type of pulse, with a time constant of the order of 100 μsec, is due to radiation arising because the sample is heated by the current.

In Fig. 1a an oscillogram is presented of the observed pulse under conditions when the current is sufficiently small ($j \sim 10^3$ A/cm^2) that no heating of the sample occurs. The leading edge of the pulse in Fig. 1 is determined by the time constant of the measuring circuit.

As the measurements showed, the polarity of the signal at the receiver depends on the polarity of the magnetic and electric fields applied to the sample. When the polarity of either the magnetic or the electric field separately is changed, the polarity of the signal at the receiver changes. When the polarity of both the magnetic and electric fields is changed simultaneously, the polarity of the signal is preserved. When the magnetic field is switched off, the signal disappears.

Fig. 2. Dependence of the signal magnitude on the magnetic-field intensity. a —positive signal, b —negative signal

The following interpretation of the observed phenomena may be proposed if one considers two different situations arising at the face of the sample turned toward the receiver.

1. The mutual direction of the electric and magnetic fields corresponds to an influx of excess nonequilibrium carriers to the indicated face. As a result of the resulting excess of the charge-carrier concentration over the equilibrium value, the recombination intensity exceeds the intensity of equilibrium recombination, and a positive signal arises at the receiver.
2. When the polarity of the magnetic or electric field is changed, the flux of nonequilibrium carriers is directed from the face into the interior of the sample. Near the face, during the current pulse, the concentration of charge carriers decreases, which correspondingly leads to a decrease in the recombination intensity in comparison with the intensity of equilibrium recombination. This situation corresponds to a negative pulse at the receiver (Fig. 1b).

The observed phenomena are in agreement with the theory of radiative recombination of Shockley and van Roosbroeck. In Fig. 2 the dependence of the signal on the magnetic-field intensity at a current through the sample of $\sim 10^3$ A/cm^2 is presented. It is easy to see that this dependence resembles the analogous dependence for the photomagnetic effect, with respect to which the observed effect is the inverse. The radiation power in the pulse per unit surface area of the sample at a current of 10^3 A/cm^2 is 10^{-5} W/cm^2.

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