Photoconductivity and Photoelectromagnetic Effects in InSb†

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PHOTOCONDUCTIVE and photoelectromagnetic[1–3] responses have been observed at 300°K and 77°K in *p*-type samples of InSb which are intrinsic at room temperature. The data reported here were obtained in experiments on rectangular plates measuring $0.028\times0.26\times1.0$ cm^3 with an effective impurity concentration of approximately 7×10^{15} acceptors/cm^3 (as determined by Hall measurements at 77°K) and with a resistivity of 0.015 ohm-cm at 300°K and 1.1 ohm-cm at 77°K. Samples were placed in a cryostat with a rocksalt window and mounted between the pole pieces of an electromagnet. Illumination of approximately 0.05 watt/cm^2, chopped at 525 cps, was supplied by a Nernst glower with a brightness temperature of about 1600°C. The sample length, magnetic field, and illumination were mutually perpendicular. A bias voltage could be applied across the sample for photoconductivity measurements. At 300°K the sample was connected through a transformer with impedance ratio 1:1600 to a Hewlett Packard Model 450A amplifier and then to a Hewlett Packard Model 300A harmonic wave analyzer. For measurements at 77°K, the sample was connected directly to the amplifier and wave analyzer. The results are more directly interpreted in terms of i_s, the "short-circuit" current. To obtain i_s from the observed current i_o, the formula $i_s=i_oR/R_s$ is employed, where R_s is the resistance of the illuminated portion of the sample and R is the total resistance in the circuit. In cases where magnetoresistance effects (large μB) are important, the resistance must be evaluated at the appropriate value of magnetic field.

On the basis of the simple model given by Moss, the short-circuit current generated by the photoelectromagnetic (PEM) effect is given by

$$i_s=\frac{\eta QeB\mu}{1+\mu^2B^2}\,\frac{(D\tau)^{\frac{1}{2}}}{L},\tag{1}$$

where η is the quantum efficiency, Q the photon flux, e the electronic charge, B the magnetic flux density, and L the length of the illuminated portion of the sample; μ, D, τ are, respectively, the mobility, diffusion constant, and effective lifetime of the excited electrons produced by the illumination. Since the electron mobility in InSb is much higher than the hole mobility, the contribution of the excited holes to the photocurrent at low magnetic fields may be neglected. It should be noted that the factor $1/(1+\mu^2B^2)$ does not appear in Moss' expression for the short-circuit current because Moss applied the expression to data for PbS where $\mu B\ll1$.

Figures 1 and 2 show that the observed variation of i_s with B is in good agreement with Eq. (1). The curves in Fig. 1 were calculated from the equation $i_s=KB/(1+\mu^2B^2)$ using the values of K and μ best fitting the experimental data. These parameters were found by plotting B/i_s *versus* B^2 as shown in Fig. 2 for the results at 77°K. The mobilities found in this manner were 1.0 and 6.8 m^2/v-sec at 300°K and 77°K, respectively. The former value is about one-fifth of the Hall mobility reported by Tanenbaum and Maita[4] for electrons in intrinsic single crystals at 300°K, while the latter is only about 10 percent less than the Hall mobility reported by these authors for electrons in an *n*-type single crystal. The value for 300°K agrees qualitatively with the electron mobility of 1.5 m^2/v-sec derived from the magnetoresistance data of Pearson and Tanenbaum.[5]

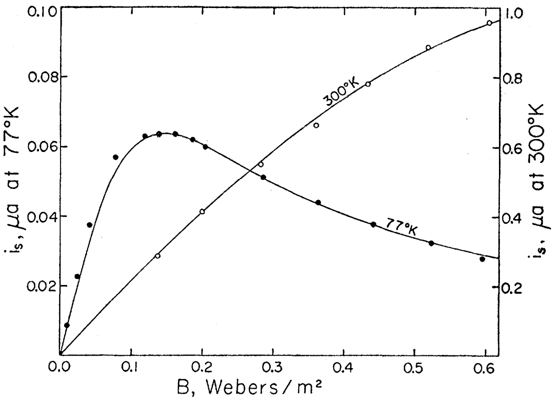

FIG. 1. PEM current *versus* magnetic flux density.

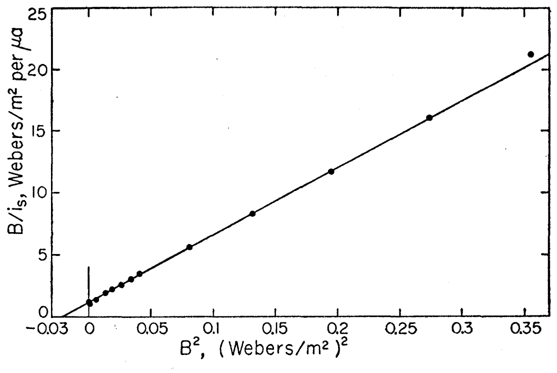

FIG. 2. Plot of B/i_s *versus* B^2.

Effective lifetimes estimated from the PEM data on the basis of Eq. (1), utilizing the derived mobilities, are about 10^{-10} and 10^{-13} sec at 300°K and 77°K, respectively. When lifetimes are derived from the photoconductive short-circuit current

$$i'=\eta Qe\mu F\tau/L\tag{2}$$

where F is the electric field, the values are 10^{-8} and 10^{-10} sec at 300°K and 77°K, respectively. The discrepancies between the photoconductive and PEM lifetimes may result at least in part from errors in the estimation of the photon flux Q. However, it seems unlikely that this is sufficient to account for all the inconsistencies since the ratio of photoconductive to PEM lifetime increases from 10^2 at 300°K to 10^3 at 77°K. Alternatively there may be real differences between the two effective lifetimes due to enhanced surface recombination in the magnetic field (Suhl effect).

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Recombination of Holes and Electrons at Lineage Boundaries in Germanium

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SMALL-angle-of-misfit grain boundaries are made up of arrays of dislocations, which, in certain lineage boundaries in germanium, have been revealed by etch pits.[1] Dislocations in or near the edge orientation act like rows of closely spaced acceptor centers with energies slightly above the middle of the gap.[2,3] An occupied acceptor is a hole trap and an empty acceptor, an electron trap. Thus excess holes and electrons should recombine at a small-angle grain boundary made up of edge dislocations, and the boundary should have a characteristic recombination velocity. This letter describes some studies of recombination at grain boundaries in germanium. The dislocations, which are parallel