xperimental observation of oscillations of lectronic ultrasound absorption in a semiconductor laced in an alternating field

G. D. Mansfel'd and V. S. Veretin

Institute of Radio Engineering and Electronics, USSR Academy of Sciences

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Oscillations and reversal of the sign of the coefficient of electronic absorption of ultrasound of frequency 0.5 and 0.7 GHz was observed experimentally in n-InSb crystals placed in an alternating electric field of frequency 1.8 GHz. The experiments were performed at a temperature 77 K in magnetic fields up to 6 kOe.

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Much attention has been paid recently to the study of the interaction of ultrasonic ave (USW) with electrons in semiconductors placed in an alternating electric ld.[1–5] The possible existence of "giant" oscillations of the electronic absorption efficient α as a function of the amplitude of the alternating electric field was theo-tically predicted in[1,2].

In the present paper we present the results of an experiment that confirms the istence of such oscillations. We have investigated the dependence of the electronic sorption coefficient of piezoactive shear USW propagating along the [110] direction n-InSb crystals placed in liquid nitrogen. The experiments were formed at USW quencies 500 and 700 MHz. Crystals with electron density $n \approx 1.0 \times 10^{14}$ cm^{-3} and bility $\mu_0 \approx 600000$ cm^2/V sec were cut in the form of rectangular bars measuring $\times 0.7 \times 7$ mm. An alternating voltage of frequency $\omega/2\pi = 1.8$ GHz was applied to sample in the USW propagation direction through annular indium Ohmic con-ts. The distance d between the contacts was 5 mm. The microwave voltage on the nple was measured with a stroboscopic oscilloscope. To excite and receive the USW used epitaxial CdS transducers. The experiments were performed in a magnetic d H perpendicular to the USW propagation direction. The magnetic field was suffi-nt to satisfy the condition $q_s R_c \ll 1$ (q_s is the USW wave vector and R_c is the lotron radius); according to[5], this makes the conclusion of the hydrodynamic ory[1–4] applicable. Registration of the USW, as well as the relative measurements he absorption coefficient, were carried out by an "echo" method. The experimental ıp was similar to that described in[6].

The measurement procedure consisted in the following: when the magnetic field s turned on (at $U_{\sim} = 0$), the level of the recorded "echo" signals decreased abrupt--the electronic absorption increased (α is negligibly small at $H = 0$). Turning on microwave voltage during the time of propagation of the USW through the crystal further increase of its amplitude raised the level of the echo pulses and caused n to oscillate. The electronic absorption coefficient and its field-induced changes, unit crystal length, were then calculated from the measurement results.

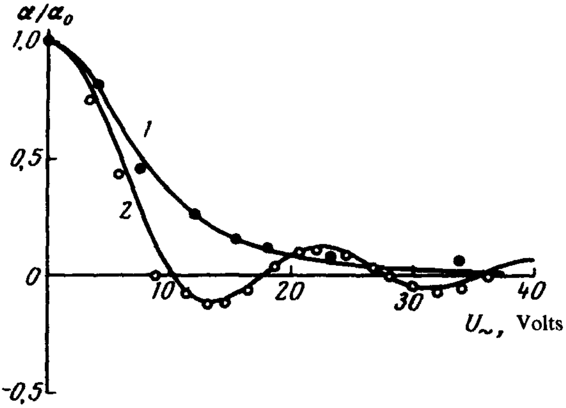

FIG. 1.

Figure 1 shows plots of the electronic absorption coefficient against the amplitude of the microwave voltage on the sample. The experimental data are shown by the points, and the solid curves are theoretical[2,3] and calculated with a computer from the formula

$$a = K^2 q_s \sum_{m=-\infty}^{\infty} I_m^2(x) \frac{(\omega_s + m\omega)\tau_M}{(1 + q_s^2 r_D^2)^2 + (\omega_s + m\omega)^2 \tau_M^2}, \ \text{cm}^{-1} \qquad (1)$$

where K^2 is the square of the coefficient of the electromechanical coupling, ω_s is the cyclic frequency of the USW, $\tau_M \approx \tau_M^0 (\mu_0 H/c)^2$, [5] where τ_M^0 is the Maxwellian relaxation time and c is the speed of light, r_D is the Debye radius, and $I_m(x)$ is an mth order Bessel function of argument $x = (V_{d\,\text{UHF}}/V_s)(\omega_s/\omega)$, where $V_{d\,\text{UHF}}$ is the drift velocity in the microwave field. In the determination of the latter we took into account the effect of the magnetoresistance $V_{d\,\text{UHF}} \approx \mu_0 (U_\sim/d)[R(0)/R(H)]$, where $R(0)$ and $R(H)$ are the sample resistances with the magnetic field turned of and on, respectively. α_0 is the value of α_e in the absence of a microwave field ($U_\sim = 0$). The curves shown on Fig. 1 correspond to two different values of the magnetic field, $H = 2$ kOe and $H = 6$ kOe. The experimental data obtained for these fields are marked by dark and light circles, respectively. As seen from Fig. 1, they agree well with the theory. At $H = 2$ kOe the absorption coefficient decreases smoothly with increasing $U_\sim$, while at $H = 6$ kOe the decrease of the absorption coefficient is accompanied by clearly pronounced oscillations. According to[1,2], the oscillations should be noticeable at $\omega\tau_M \gtrsim 1$. At $H = 6$ kOe we have $\omega\tau_M = 2, 1, \cdots$ and the oscillations are in fact observed. We note, as seen from Fig. 1, that in the presence of a microwave we have not only oscillations of the absorption coefficient but also a reversal of its sign. The possibility of the reversal of the sign of α in a microwave field was indicated in[2]. The experimental observation and investigation of the oscillations were carried out at the ultrasound frequency 700 MHz. The obtained data also agree with the theory.

We have thus obtained an experimental confirmation of the existence of "giant" oscillations of the electronic absorption coefficient and of the reversal of its sign in a semiconductor placed in alternating electric field.

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