of the a(p) dependence at the same temperature ($\Delta a \simeq 1.3 \times 10^{-3}$ Å).

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PHOTOCONDUCTIVITY OF GERMANIUM IN A HIGH-FREQUENCY ELECTRIC FIELD

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The use of a high-frequency electric field for the study of the photoconductivity of semiconductors has a number of advantages over other methods, since it combines the possibility of obtaining sufficiently strong fields with satisfaction of the requirement that the drift length of the non-equilibrium carriers be much smaller than the length of the sample. In this case, however, when the non-equilibrium carriers are excited by intense optical generation, non-trivial phenomena arise in the investigated germanium samples, and the present paper is devoted to their description.

We used for the investigations a pulse-modulated high-frequency voltage with carrier frequency 9.0 MHz and pulse duration 10 - 100 μsec. The output resistance of the pulse generator was 15 ohms; the voltage amplitude could range from zero to 350 V, with the envelope of the radio pulses maintained rectangular.

In the investigation of the current-voltage characteristics of p-Ge samples with antibarrier contacts it was observed that in a wide range of temperatures (20 - 300°K) at sufficiently large illumination and voltage, a reversible breakdown occurred when the current increased jumpwise by 10 - 20 times compared with its value prior to the breakdown (see Fig. 1). Such a phenomenon was observed in the investigation of p-Ge with different acceptor concentrations from 1×10^{12} to 7×10^{14} cm^{-3}. In the present study we investigated germanium with $p = 1.2 \times 10^{14}$ cm^{-3} at room temperature. The antibarrier contacts were obtained by fusing indium on the end surfaces of the samples; the samples were etched in H_2O_2 prior to the measurements.

Pre-breakdown regime. For a more detailed investigation of the aforementioned phenomenon we studied the distribution V(x) of the high-frequency potential along the samples. Figure 2 shows such distributions obtained by moving a metallic probe over the polished side face of one of the samples. Similar distributions were obtained also by other methods, namely using a moving capacitive probe and using direct measurement of the high-frequency potential on the sample with several stub probes. It is seen from Fig. 2 that the

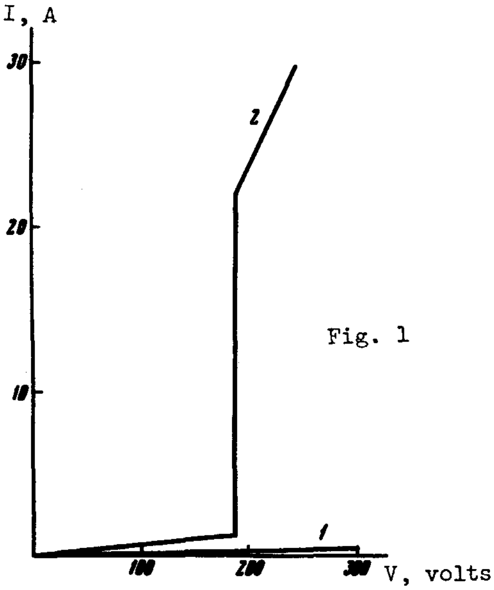

Fig. 1

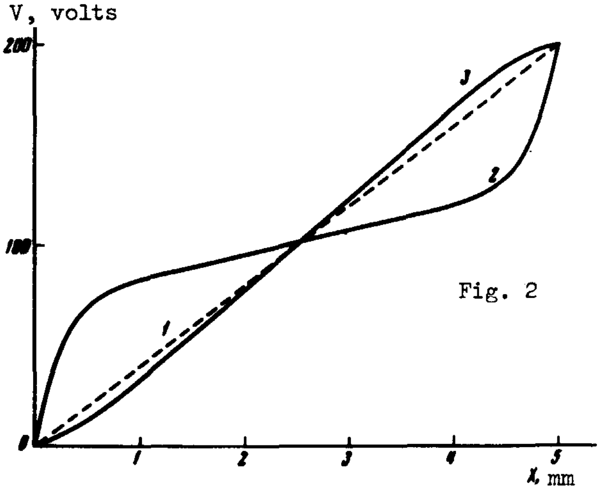

Fig. 2

Fig. 1. Current voltage characteristic of p-Ge sample with antibarrier contacts. Sample dimensions 5.0 × 0.7 × 0.6 mm; T = 300°K: 1 - unilluminated sample, 2 - illumination of sample 10^{16} quanta/sec.

Fig. 2. Distribution of high-frequency voltage over the length of a p-Ge sample with antibarrier contacts. The sample dimensions are the same as in Fig. 1. The sample voltage is 200 V, T = 300°K: 1 - unilluminated sample (P-1), 2 - pre-breakdown regime, illumination of sample 2×10^{16} quanta/sec (P-2), 3 - pre-breakdown regime, illumination of sample 4×10^{16} quanta/sec (P-3).

distribution for an unilluminated sample is linear (henceforth P-1). Illumination of the sample led to the occurrence near the contacts of regions of increased high-frequency field compared with the central part of the sample (distribution P-2). Immediately before the breakdown the field amplitude could reach $(1 - 2) \times 10^3$ V/cm in the near-contact regions and $(2 - 3) \times 10^1$ V/cm in the central region of the sample. The distribution P-2 normalized to the total high-frequency voltage on the sample becomes stabilized already at relatively low illumination L and voltage V. Thus, when the samples were investigated with two stub probes located in the central part of the sample, the ratio $\sigma_c/\sigma_p = f(L)$ at V = const (σ_c - conductivity of the sample in the current contact - probe region, σ_p - in the probe - probe section) first decreased rapidly with increasing L, but then the decrease slowed down; immediately before the breakdown σ_c/σ_p does not depend on L.

The distribution P-2 can be treated as an essential depletion of the carriers from the near-contact regions of the sample (over a length ∿0.7 - 1.0 mm) compared with the central part. Comparison of the $\sigma_p(L)_{cf}$ plots at a constant field E = 0.1 V/cm for samples with two probes with $\sigma_1(L)_{hf}$ at different high-frequency voltages V has shown that they coincide at low V; at appreciable V, especially at low temperatures, $\sigma_p(L)_{hf}$ lies below $\sigma_p(L)_{cf}$. The latter is connected with the heating of the carriers. Thus, the carrier concentration in the central part of the sample remains unchanged when the high-frequency field is turned on.

The distribution P-2 of the high-frequency voltage in illuminated samples is accompanied by a special distribution of the constant field, manifest in the form of dc pulses synchronous with the radio pulses when the measurements are made between one of the current contacts and a stub probe located in the middle of the sample. The amplitude of the dc voltage in the steady-state was ∿0.1 of the amplitude of the high-frequency voltage. The probe potential was positive relative to the two current contacts.

The kinetics of the establishment of the current through the illuminated sample is unique: at the start of the pulse, the current always exceeds the steady-state value (see Fig. 3). The time of establishment of the current, which is equal to the time of establishment of the constant field and also of the high-frequency field from the initial P-1 distribution to P-2, usually decreased with increasing illumination and with increasing voltage on the sample; it amounted to 3 - 5 μsec before the breakdown.

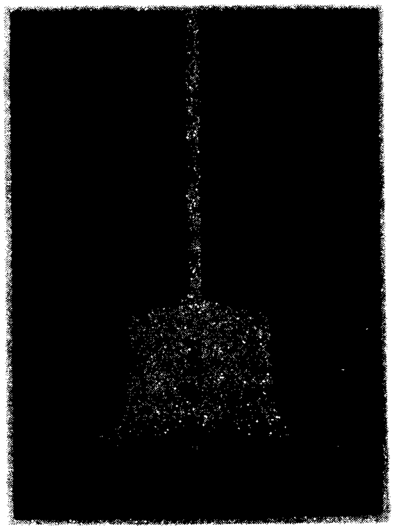

Fig. 3. Current pulse through a p-Ge sample with antibarrier contacts. T = 300°K. Pulse duration 30 μsec.

Breakdown. It was already noted that the breakdown of the carrier-poor near-contact regions in the p-Ge samples with antibarrier contacts usually occurred under conditions when the light intensity and the voltage on the sample reached definite critical values L_{cr} and V_{cr}, respectively. The region of values $L > L_{cr}$ and $V > V_{cr}$, in which the breakdown must occur, is determined qualitatively by a relation of the type LV = const. The V(x) distribution in breakdown, obtained as before with the aid of a metallic probe, was significantly altered (see P-3 in Fig. 2). Now the depletion of carriers in the near-contact regions compared with the central region of the sample gave way to enrichment. At room temperature, the sharp jump of the current at breakdown could lead to a significant heating of the sample (up to about 50°C) and to thermal generation of carriers. As a result, the current pulse had a fast component and then a slowly-growing component connected with the heating. The current amplitude could reach in some cases 20 - 30 A at a sample cross section 0.7 - 1.0 mm^2. At low temperatures there was no slow current component at breakdown.

We have described above only certain features of the conductivity of p-Ge samples with antibarrier contacts. It should be noted only that the occurrence of a distribution of the type P-2 has an appreciable effect in the measurement of the photoconductivity relaxation time, when the sample was illuminated, in synchronism with the radio pulse, by a short flash of light (∿0.5 μsec). The relaxation time τ, determined in this case from measurement of the envelope of the high-frequency pulse, decreased with increasing constant illumination, to several μsec at 300°K, and, just as the time of establishment of the current at constant illumination of the sample, characterizes the relaxation of the P-2 distribution. During the time of breakdown τ increased jumpwise, reaching the value of the photocurrent relaxation time measured in a small constant field (∿100 μsec).

All these phenomena indicate that they are connected with the bipolar part of the conductivity regardless of its occurrence. This is confirmed also by the fact that the characteristic shape of the current pulse, the distribution of type P-2, and the breakdown were observed by us when the unilluminated sample was heated to ∿100°C at a constant amplitude of the high-frequency voltage. A distribution of the type P-2 was observed by us also in illuminated samples of n-Ge with antibarrier contacts. In p-Ge samples with barrier contacts we observed a distribution of the type P-3, which is evidence of enrichment of the near-contact regions with carriers, and a current pulse that increases with time.

The nature of these described phenomena is apparently connected with complex manifestations of exclusions under conditions of a strong high-frequency field and are presently under study.

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EXPERIMENTAL INVESTIGATION OF THE NONLINEAR STAGES OF DEVELOPMENT OF ION-ACOUSTIC INSTABILITY IN A PLASMA-BEAM DISCHARGE

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As is well known, low-frequency (LF) instabilities play a decisive role in processes of anomalous diffusion, heating, and acceleration of ions due to collective interactions in a plasma.

The linear stage of development of LF instabilities was investigated in sufficient detail theoretically and experimentally [1 - 3]. The investigation of the nonlinear stage has barely begun. The main characteristics of the nonlinear turbulent stage of development of the instability, as is well known, are the spectral density of the energy of the excited electric fields, the space-time correlation functions, the presence of phase jumps, and the dispersion relation. All these are being experimentally investigated at the present time with the aid of methods described in [4 - 7].

The experiments were performed with a setup described in detail in [4]. The main parameters were: electron-beam current 5 A, energy 10 - 12 keV, current pulse duration 100 μsec, density of plasma produced by the beam 5×10^{12} - 2×10^{13} cm^{-3}, intensity of longitudinal magnetic field up to 2 kOe, working gas - hydrogen.

We have investigated the LF oscillations excited upon interaction of an electron beam with a highly-ionized plasma. The shape of these oscillations was investigated with the aid of probes placed along the interaction region (inside the plasma chamber) and registering the E_z component of the electric field in the frequency range up to 8 MHz. The signals from the probes were photographed with a 5-beam cathode ray oscilloscope and the results were processed with a computer. Two excitation regimes of the LF oscillations can be distinguished: the first regime (pressure 2.4×10^{-4} Torr), the start of the current pulse, Fig. 1a, is characterized by excitation of LF oscillations that have a relaxation character and go over in time (after 30 - 40 μsec) into oscillations pertaining to the second regime. The latter includes also oscillations generated during the entire duration of the current pulse at a gas pressure in the system above 6×10^{-4} Torr, in view of the fact that the first regime terminates for these oscillations after several microseconds. We present in this paper results of an investigation of oscillations pertaining to the first regime.

The spectrum of the excited oscillations $S_{xx}(\omega)$, characterizing the first regime, consists of a fundamental frequency $\omega/2\pi \sim 560$ kHz and clearly