Thus, the experiments demonstrate the feasibility of using the proposed excitation system to heat a plasma in a closed magnetic trap. The system has significant design advantages over those used in [1 - 3]. The measurements of nT show that high-frequency power absorption is resonant in a region close to the ion-ion hybrid frequency.

In conclusion, the authors consider it their pleasant duty to thank Professor K.N. Stepanov and Professor V.T. Tolok for interest in the work and for useful discussions.

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MAGNETOSENSITIVE INJECTION-FIELD EFFECT IN SEMICONDUCTORS

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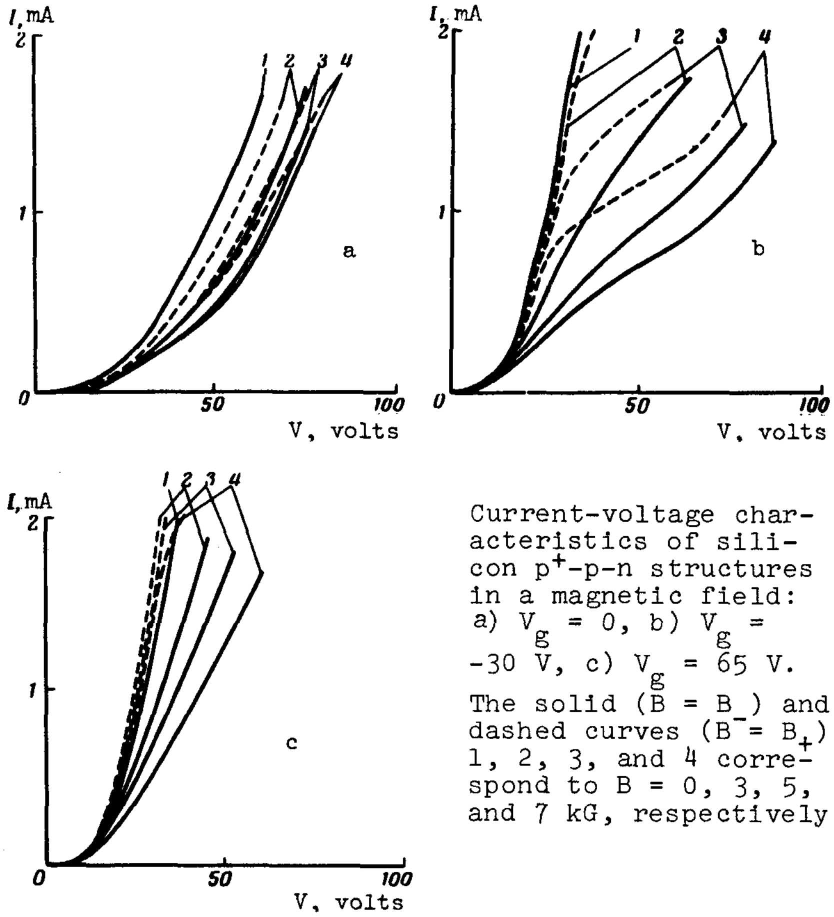
It is known that the magnetodiode effect [1, 2], wherein the nonequilibrium conductivity produced in a semiconductor by carrier injection in a magnetic field B, is due to the dependence of the ratio of the effective distance d_{eff} between the injection contacts to the effective length L_{eff} of the fusion displacement on B. L_{eff} can vary as a result of a change of carrier mobility in the magnetic field or a change of their effective lifetime τ_{eff}, which is determined by the volume and surface recombination. In the latter case the magnetodiode effect depends on the state of the semiconductor surface, particularly on the rate of surface recombination S [3 - 5].

Since S is a function of the surface potential ψ_s, the surface-recombination rate can be controlled with the aid of an external electric field E_s perpendicular to the semiconductor surface, which leads to a change of ψ_s. Therefore in semiconductor samples of thickness $\ell \lesssim L_{eff}$ the value of τ_{eff} and consequently L_{eff} should be determined also by the value of E_s. In this case one can expect variation of E_s to change the ratio d_{eff}/L_{eff} (even if $B \neq 0$), and accordingly the injection conductivity of the semiconductor. It is known that for differently processed semiconductor surfaces the $S(\psi_s)$ dependence can be either "monotonic" or "nonmonotonic" (in the simplest case, "bell-shaped") [6]. The magnitude of the effect under consideration will vary accordingly. It is also necessary to take into account the dependence of S on the injection level.



Current-voltage characteristics of silicon p^+-p-n structures in a magnetic field: a) $V_g = 0$, b) $V_g = -30$ V, c) $V_g = 65$ V. The solid ($B = B_-$) and dashed curves ($B = B_+$) 1, 2, 3, and 4 correspond to B = 0, 3, 5, and 7 kG, respectively.

Injection produces, even in weak magnetic fields, a current density that is variable over the cross section of the sample and causes appreciable transverse currents to flow in the regions near the contact[1]. If the sample thickness is comparable with or less than the Debye screening length L_D, then the injected-carrier concentration, distributions and consequently both the longitudinal and transverse currents can change at $E_s \neq 0$ in the entire sample. This changes the injection conductivity of the semiconductor. It is also necessary to take into account here the changes of the hole and conduction mobilities, which depend on E_s in the space-charge region. We note that under definite conditions these effects are appreciable also in the case considered above, when $\ell \lesssim L_{eff}$.

We shall call the change of the injection conductivity of a semiconductor in a magnetic field and in an external electric field perpendicular to the semiconductor surface the "magnetosensitive injection-field effect" (MIF effect). This effect was investigated in p-Si with $\rho \simeq 20 - 100$ kΩ-cm and $\tau_h \simeq 200 - 800$ μsec. The samples were prepared from plates 100 - 300 μ thick in the form of planar p^+-p-n structures. Aluminum was used for the p^+-p junction and an Au + Sb alloy for the p-n junction. The distance d between the junctions was varied such that the ratio d/L_{eff} ranged from 1 to 12. The sample surface was coated,

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[1] This phenomenon was not taken into account before in the quantum analysis of the magnetodiode effect [5, 7].

after suitable treatment, with an SiO_2 layer ∿1 μ thick. A field electrode was then sputtered over the region between the injecting contacts on the SiO_2 layer and was used to produce a field E_s. The measurements were made in a cyrostat in the temperature interval 100 - 500°K and in magnetic fields up to 8 kG. The dc current-voltage characteristics (CVC) of the structures were registered with an automatic x-y recorder, and the ac characteristics were recorded with a "characterograph."

The figure shows the CVC families of a typical sample at different values of B and different field-electrode potentials V_g relative to the anti-barrier junction. The magnetic field perpendicular to the current lines flowing through the structure had two directions. In one of them (B_+) the injected carriers were deflected towards the semiconductor surface with the field electrode, and in the other (B_-) they were deflected in the opposite direction. It follows from an analysis of the figure that the injection conductivity of the semiconductor depends strongly on V_g at both directions of B. The magnetosensitivity γ_V first increases with increasing negative V_g, reaches a maximum, and then decreases, ranging from 2 to 7 V/kG. The maximum of γ_V was observed in this sample at $V_g \simeq -30$ V for both directions of B. We note that while the observed relations agree qualitatively, their effect differs quantitatively for the different magnetic-field directions. The CVC of the sample varies more strongly in the field B_- than in the field B_+. The curves of the figure show also that with increasing negative V_g all the families of the CVC shift towards lower voltages, and this shift is larger in the field B_+ than in B_-. The magnetosensitive injection-field effect is observed also at the opposite polarity of V_g and also when the control voltage is applied relative to another contact. The MIF effect and its dependence on V_g are also influenced by illumination of the sample with visible light through a transparent field electrode. The MIF effect was also observed in Si samples doped with impurities having deep levels (Ni and others), and in silicon structures with S-shaped CVC (when $E_s \neq 0$, changes take place in γ_V, in the region of negative resistance on the CVC, and elsewhere).

In conclusion we note that the experimental results agree qualitatively with the concepts advanced above in the case when $\ell \lesssim L_{eff}$. The observed MIF, besides being of independent interest, can also serve as a basis (in analogy with [4]) for the development of a new method for investigating the rate of surface recombination as a function of ψ_s, and also for the development of different magnetosensitive semiconducting devices with field electrodes.

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OPTICAL DETECTION OF DYNAMIC POLARIZATION OF NUCLEI IN SEMICONDUCTORS

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Much research has been performed by now on optical pumping of spin-polarized electrons in semiconductors [1 - 6]. In these experiments, the spin-oriented carriers were excited from the valence band into the conduction band by absorption of circularly-polarized light. The most convenient for the detection of the spin orientation of the electrons is an optical method [2, 3] with investigation of the recombination-luminescence polarization. For III-V crystals, the selection rules for interband transitions yield a simple connection $S = 0.5P$ between the degree of circular polarization of the luminescence (S) and the degree of stationary orientation of the electrons (P) at the bottom of the conduction band. We have investigated, also by an optical method, a number of effects that arise when the electron spins interact strongly with the magnetic moments of the nuclei in the crystal.

As is well known, electron-nucleus collisions can be accompanied by mutual spin flip. In the case when the electrons are strongly polarized, the electron orientation becomes transferred to the nuclei by such collisions, i.e., dynamic polarization of the nuclei takes place. Such a phenomenon was first observed by Lampel [1] and revealed by the increase of the nuclear-magnetic resonance signal from a silicon crystal illuminated by circularly polarized light. Such a dynamic polarization of nuclei can be revealed also by the change of the degree of stationary orientation of the electrons, i.e., by optical means (by the luminescence polarization).

Let us examine the differential equations describing the relaxation processes of oriented electrons in a crystal (for simplicity we assume that the magnetic moments of the nuclei are equal to ±1/2):

$$\frac{dN_\pm}{dt} = I G_\pm - \frac{N_\pm}{T} - \frac{N_\pm - N_\mp}{2T_s} - (N_\pm n_\mp - N_\mp n_\pm)\frac{W}{2}$$

$$\frac{dn_\pm}{dt} = -\frac{n_\pm - n_\mp}{2\tau_s} + (N_\pm n_\mp - N_\mp n_\pm)\frac{W}{2}. \qquad (1)$$

Here $N_\pm$ and $n_\pm$ are the densities of the electrons and nuclei with the corresponding spins, I is the intensity of the exciting light, G the probability of producing an electron with different spin orientation upon absorption of circularly polarized light, T the lifetime of the nonequilibrium electron, and T_s and τ_s the spin-lattice relaxation times of the electrons and the nuclei. The last terms in the equations take into account the mutual spin flips of the electrons and of the nucleus, and W is the probability of such a flip upon collision. The solution of the equations in the stationary case yields

$$P = P_0\left[1 + \frac{T}{T_s} + \frac{T}{T_n}(1 - f)\right]^{-1}. \qquad (2)$$