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E. A. Konorova and S. F. Koslov. Diamond Detector for Nuclear Radiation.

In spite of the progress made in germanium and silicon detectors for nuclear radiation, there are fields of application where the diamond detector has definite advantages because of its high chemical and thermal stability. The counting properties of diamond have been the subject of a rather large number of investigations[1-3]. These investigations, however, did not lead to the development of a diamond detector—an instrument suitable for practical use.

Natural diamonds are insulators with resistivity 10^{14} ohm-cm and higher. Electric fields up to 10^6 V/cm still produce no breakdown of the crystal. The carrier mobility is large and amounts to 1550 cm^2/V-sec for holes[4] and 2000 cm^2/V-sec for electrons[5]. These properties of diamonds are very favorable for its use as a radiation detector.

However, the use of very strong electric fields is limited by the dependence of the mobility on the field, as in other valent crystals. According to[5,6], the electron drift velocity in diamond reaches its limiting value $10^7 \pm 0.2 \times 10^7$ cm/sec at room temperature in a field of approximately 2×10^4 V/cm. This circumstance was not taken into account in any of the published papers on the counting properties of diamonds, and therefore the treatment of the experimental results was not always satisfactory. Since the electron and hole lifetimes in diamond exceed in very rare cases 10^{-8} sec[5], the maximum depth of the work in the region of the detector is limited to 200—300 μ.

An essential shortcoming of diamond detectors is the polarization of the crystal, since the very low electric conductivity prevents the electric equilibrium from becoming reestablished inside the crystal within the time between pulses. Known methods of eliminating the polarization by heating, illumination, or applying an alternating field are not suitable and have little efficiency. To avoid polarization, we have proposed to use an injecting contact on the side of the diamond opposite to the irradiated side[7]. In the vicinity of such a contact there is maintained an equilibrium of the field and the charge. When this equilibrium is violated by the captured carriers, say electrons produced in the crystal following ionization by the registered radiation, their neutralization is effected by the hole current from the contact (space-charge-limited current).

Sample No.	Thickness, mm	Working voltage	Counting efficiency, %	Energy resolution, %	ε_α*), eV
1	0.15	400	100	5	15.6
2	0.16	600	100	5	15.4
3	0.21	600	100	8	16.2
4	0.27	400	100	9	16.1
5	0.14	600	100	8	16.3
6	0.20	300	100	4	15.9
7	0.20	400	100	10	16.2
8	0.19	200	100	15	16.2
9	0.13	400	100	15	16.6
10	0.40	600	100	5	16.2

*ε_α—energy necessary to produce a pair of carriers, calculated from the momentum at the maximum of the curve of the amplitude distribution.

After overcoming many difficulties connected with the development of injecting contacts for diamond, the selection of crystals with necessary lifetime, and others, we have constructed 10 diamond detectors. The properties of these detectors were investigated by registering 5.5-MeV α particles from a $Pu^{238-242}$ source. The obtained results are summarized in the table, the data in which pertain to room temperature.

The working area of the detectors ranged from 2 to 10 mm^2.

The operation of the detectors was investigated by registering particles in the temperature range 300—1000°K. Up to 490—550°K, the properties of the detector remained essentially unchanged, but at higher temperatures, the amplitude of the pulses and the counting efficiency decreased, but the count continued in some cases up to 1000°K.

At the present time we can point out the following fields of application of diamond detectors for nuclear radiations: 1) registration of short-range particles (α particles, protons) at increased temperature, 2) registration of short-range particles in aggresive media—in acids and alkalis, 3) registration of low-energy β particles at room temperature and at increased temperatures, and also in active media (for example, the radiation of tritium in biological objects).

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I. V. Karpova, S. G. Kalashnikov, O. V. Konstantinov, V. I. Perel', and G. V. Tsarenkov. Recombination Waves in Compensated Germanium.

The paper presents data on the observation and investigation of a new type of electric instability in semiconductor plasmas, called recombination waves (RW). The existence of RW was theoretically predicted in[1], where it was shown that waves of carrier density

and of the limiting electric field can be self-excited in semiconductors containing deep traps in the presence of an external electric field. Subsequently[2,3], the properties of RW were investigated in greater detail. Unlike other known types of electric instability in semiconductors, the excitation of RW is not connected with heating of the plasma and with the occurrence of negative differential conductivity; nor does it require an external magnetic field. However, no RW were observed experimentally until recently. We have observed electric instability in compensated germanium crystals[4], and the properties of this instability make it possible to interpret it as RW excitation.

The current oscillations were observed in n-type crystals in which the recombination centers were manganese atoms. The manganese was compensated by antimony in such a way that the upper level ($E_c - 0.37$) eV was partly filled with electrons. The contacts were made by fusing indium or tin to which 1% antimony was added.

The observed instability had the following features: The spontaneous oscillations of the current occurred at temperatures close to room temperature, and existed in a relatively narrow interval of temperatures (several dozen degrees). The critical instability field was small and for the various samples it was in the range of a few dozen V/cm; this excluded noticeable heating of the plasma. The instability was observed only in the case of partial compensation of the upper manganese level, and did not occur if the antimony concentration exceeded double the manganese concentration. The current-voltage characteristics of the samples prior to the currents of the current oscillation were strictly linear. Near the threshold, the current oscillations had a noise character, but with further increase of the field they became regular. The frequency of the oscillations ranged from 0.1 to 1 Mhz and was independent of the crystal length. The amplitude of the oscillations was large; the depth of current modulation $(i_{max} - i_{min})/i_{max}$ reached 50–90%.

An investigation of the change of the potential in space and in time during the course of the oscillations, carried out with the aid of a moving clamped probe, has shown that the instability has a volume character. It was observed that the field oscillations occur only in a bounded region of the crystal, which is located at different distances from both electrons. Special experiments with samples of many different shapes have shown that the possible injection from the contacts does not play a principal role in the development of the instability. In exactly the same way, no noticeable influence of the surface finish of the crystal was observed.

The indicated singularities of the observed instability are in qualitative agreement with the theory of RW. To compare the theory with experiment also quantitatively, we calculated the critical field E_c, the corresponding oscillation frequency ω_c, and the temperature dependence of E_c. The initial equations, just as in[1-3], were the following: two continuity equations for the electrons and holes, the recombination-kinetics equation, and the condition div j = 0, where j is the density of the convection current. The calculations were performed in a linear approximation, i.e., only for threshold conditions of the instability development. By considering the behavior of the harmonic fluctuation of the carrier density and of the electric field in the form $\exp[i(kx - \omega t)]$, it is possible to find the values of the threshold the electric field $E_{thr}(k)$ (corresponding to a zero damping increment) and of the frequency $\omega(k)$ as functions of the wave number k. The critical instability field (E_c) was assumed equal to the minimum value of $E_{thr}(k_c)$, and the critical frequency (ω_c) was determined as a function of k_c.

The obtained expressions for E_c, ω_c, and k_c depend on the following: the equilibrium concentrations of the holes and electrons p_0 and n_0; the manganese concentration N; the hole and electron capture coefficients α_p and α_n at the upper level of the manganese; the equilibrium degree of filling of the upper level of the manganese with electrons at the experimental temperature, $f \equiv n_t/N$, where n_t is the concentration of the electrons at the indicated level. The values of p_0, n_0, and N were determined from the measured Hall constant and the electric conductivity. The capture coefficients α_p and α_n and their temperature dependences were known from[5]. The value of f was determined from an investigation of the temperature dependence of the Hall constant and of the electric conductivity. An interpretation of these data was difficult, since the upper level of the manganese lies near the center of the forbidden band. Nevertheless, the integral of the possible values of f could be determined.

A comparison of the calculated values of E_c and of the cyclic frequency ω_c with the experimental data shows satisfactory agreement. The table shows by way of illustration the results for one of the samples. The most intense current oscillations for this sample were observed at 313°K. At this temperature, the conductivity of the sample can be assumed to be intrinsic. It was found that $0.2 < f < 0.4$. The agreement between the theoretical and experimental values of E_c is obtained at f = 0.31, which corresponds to the center of the experimentally determined interval of possible values of f.

The calculated $E_c(T)$ dependence has shown that the development of instability in the investigated samples was possible only in a narrow temperature interval—near room temperature, for only in this case does the critical field have the required low value. This was precisely observed in the experiment.

The foregoing data demonstrate that the properties

Comparison of theoretical values of critical fields and frequency with experiment

T, °K	n_0, cm^{-3}	p_0, cm^{-3}	N, cm^{-3}	f	E_{theor}, cm^{-1}	E_{exp}, cm^{-1}	ω_{theor}, sec^{-1}	ω_{exp}, sec^{-1}	k_{theor}, cm^{-1}
313	$4.3 \cdot 10^{13}$	$4.3 \cdot 10^{13}$	$5 \cdot 10^{14}$	0.31	18	18	$2 \cdot 10^5$	$1 \cdot 10^6$	40

of electric instability, observed in germanium with partly compensated manganese, agree with the conclusions of the RW theory. Therefore, the occurrence of the described instability can be regarded as an experimental proof of the existence of RW.

The results of this paper are presented in greater detail in[6].

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Yu. M. Gal'perin, I. L. Drichko, Yu. V, Ilisavskii, and V. A. Kudinova, Possibility of Obtaining and Using the Effect of Amplification of Ultrasound by a Semiconductor in a Magnetic Field.

As is well known, the coefficient of sound absorption by carriers moving under the influence of an external electric field in piezoelectric semiconductors is given by the expression

$$\alpha_{el} = \alpha_0 \frac{\gamma\omega\tau^0_M}{(1+\omega^2\tau_i^2)^2+(\gamma\omega\tau^0_M)^2} \text{ (dB/cm)},$$

$$\text{where } \alpha_0 = 4.34\frac{4\pi\beta^2}{\varepsilon\rho v_{ac}^2}\frac{\omega}{v_{ac}} = 8.68\frac{K^2}{2}\frac{\omega}{v_{ac}} \text{ (dB/cm)},$$

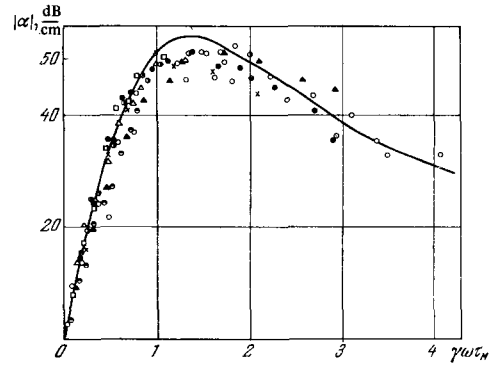
where β—effective piezoelectric coefficient in the sound propagation direction, ϵ—dielectric constant, v_{ac}—speed of sound, $\omega = 2\pi\nu$—its frequency, ρ—crystal density, $\tau_i = R_{sc}/v_{ac}$, R_{sc}—Debye screening radius, K—electromechanical coupling constant, $\tau^0_M = \epsilon/4\pi\sigma_q$—Maxwellian relaxation time, $\gamma = 1 - v_{dr}/v_{ac}$, where v_{dr} is the electron drift velocity. When $v_{dr} > v_{ac}$ we get $\gamma < 0$ and the absorption of sound gives way to amplification of the sound, as established by many experimental investigations.

When the constant magnetic field is turned on, the quantities τ^0_M and ϵ_{el} are replaced by

$$\tau_M = \tau^0_M \frac{1+\left(\frac{uH}{c}\right)^2}{1+\left(\frac{uH}{c}\right)^2\cos^2\theta} \quad \left(\cos\theta = \frac{qH}{qH}\right)$$

(u—mobility). In a strong (in the classical sense) transverse magnetic field, when $\cos\theta = 0$ and $(uH/c)^2 \gg 1$ we get $\tau_M = \tau^0_M (uH/c)^2$, i.e., the electronic sound absorption (or amplification) increases by a factor $(uH/c)^2$.

The authors investigated the influence of a transverse magnetic field on the absorption and amplification of sound with frequency 400—800 MHz in single crystals of n-InSb with $n \sim 10^{14}$ cm^{-3} and $u \sim 6 \times 10^5$ cm^2/V-sec at T = 77°K. A piezoelectric active shear wave, propagating in the [110] direction with poarization along [001] was used in the measurements. The measurements results at a magnetic field intensity $H \leq 8 \times 10^3$ Oe are in good agreement with the linear



Dependence of the amplification of sound in n-InSb on the parameter $\gamma\omega\tau_M$. Frequency f = 800 MHz, T = 77°K.

theory. This has made it possible to determine the constant of the electromechanical coupling ($K^2 = 1.4 \times 10^{-3}$). The constant was determined: 1) from measurements of sound absorption in a magnetic field under the conditions $(uH/c)^2 \gg 1$, $(uH/c)^2\cos^2\theta \ll 1$, and $\omega\tau_M \ll 1$; 2) from an analysis of the temperature dependence of the sound absorption in the magnetic field at its temperature interval 77—160°K; 3) from the value of the maximum and from the dependence of the electronic amplification coefficient α of the sound on the parameter $\gamma\omega\tau_M$, which is independent of either γ or H, or of the electron-scattering mechanism.

The figure shows the form of this dependence for the frequency f = 800 MHz. The main result of the work can be formulated as follows: 1) The influence of a magnetic field on absorption and amplification of sound was observed experimentally. 2) The amplification and absorption of the sound in magnetic fields up to 8×10^3 Oe is in good agreement with the linear theory. At 800 MHz, a gain on the order of 50 dB/cm was observed. 3) The piezoelectric coefficient was found to be $e_{14} = 0.08$ C/m^2. 4) The measurement of the absorption and amplification of the sound makes it possible to investigate the transverse conductivity of the semiconductors with large mobility in a magnetic field. 5) The obtained data show that the use of a transverse magnetic field makes it possible to increase the number of semiconducting materials in which appreciable sound amplification is observed.

A. A. Vedenov, A. M. Dykhne, and M. D. Frank-Kamenetskiĭ. Melting of DNA Molecules.

The DNA molecule consists of two right-hand helices of length $\gtrsim 10^5$ Å, with a pitch of 34 Å, wound one on the other in such a way as to produce a cylinder of 20 Å diameter, and secured with the aid of hydrogen bonds, by AT and GC pairs of bases (10 pairs or links per turn of the helix).

When heated to approximately 90°C (under so-called normal conditions, when one mole of NaCl is dissolved in one liter of water), melting (in other words, (denaturalization) of the DNA molecule takes place; some of the hydrogen bonds break, and in these places the two helices diverge and, being flexible, wind themselves in the solution into disordered coils. This divergence of the helices can be seen by depositing the