ELECTRON-HOLE DROPS IN UNIAXIAL-DEFORMED GERMANIUM

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It is shown that exciton and exciton-complex motion in pure germanium can be observed directly by investigating low-temperature photoluminescence under conditions of nonuniform uniaxial compression. It is demonstrated experimentally that at temperatures between 4.2 and 1.8°K exciton complexes in a nonuniform deformation field possess a much greater mobility than free excitons do. Such complexes were observed in the experiments to move about 4 mm. They were also observed to "evaporate" under uniform uniaxial deformation conditions. The effect possesses a strong positive temperature dependence. At low temperatures and at a sufficiently high level of optical excitation, condensation of excitons involving formation of electron-hole drops[10] should be possible in germanium. Another conceivable model is the formation of exciton molecules in these conditions. The experimental data can satisfactorily be explained by assuming condensation of excitons into "liquid" electron-hole drops. The experimental results on movement in a nonuniform deformation field can satisfactorily be explained by the exciton molecule model only if the diffusion length of the exciton molecule is about 1.5 mm at T = 1.8°K, which is not consistent with available experimental data[9].

THE influence of uniaxial deformation on the recombination radiation spectra of pure germanium and silicon were investigated in[1-3]. A nonmonotonic character of the variation, with changing pressure, of the position of the line $\mathscr{E}_d$, ascribed to emission of electron-hole drops (EH drops) was observed in[1]. It was shown that the pressure P_{cr} up to which $\mathscr{E}_d$ is practically independent of P is different for different crystallographic directions of the crystal[2]. P_{cr} itself is determined by the splitting of the degenerate valence band of Ge and by the relative displacement of the four valleys of the absolute minimum of the conduction band. It was also noted that in the presence of non-uniform pressure (for example, when thin samples are used), the position of $\mathscr{E}_d$ deviates strongly with increasing pressure from the position at uniform deformation. This was attributed to the motion of the EH drops in the field of the nonuniform deformation. A strong variation of the intensity of the $\mathscr{E}_d$ line was obtained in the same experiment[1].

In the present investigation we measured the position of the $\mathscr{E}_d$ line and of the free-exciton emission line $\mathscr{E}_e$ under conditions of uniaxial deformation for samples of special shape with specified deformation gradients, as functions of the temperature, of the applied deformation, and of the position of the region of generation of nonequilibrium carriers on the sample. The position of the $\mathscr{E}_d$ line, its half-width, and the emission intensity, were investigated as functions of the temperature for the case of uniform deformation in greater detail than in[2]. The purpose of the present study was to prove experimentally that exciton complexes undergo macroscopic displacements in a non-uniform uniaxial deformation field, and to obtain certain quantitative estimates of their mobility under these conditions.

EXPERIMENTAL PROCEDURE AND RESULTS

We investigated germanium with residual impurity concentration less than 10^{13} cm^{-3}. The measurements were performed in a special optical helium cryostat at temperatures from 1.8 to 5°K. The optical-excitation source was an Ne-He laser of wavelength 1.15 μ and approximate radiation power 40 mW. Samples of cubic and special shape were oriented in the [110] direction accurate to 2°. The plane-parallel orientation of their bases was monitored with an optimeter.

Uniaxial pressure was applied to the samples by a lever system. The lever force was transmitted through a moving rod to a polished steel plunger. The plunger moved in a steel cartridge, on the bottom of which the sample was located. The effect of the pressure on the free and interacting excitons was investigated by analyzing the spectra of the low-temperature photoluminescence from the sample.

A. Uniform Deformation

To study the behavior of the excitons and EH drops under conditions of uniform uniaxial deformation, we used samples of cubic shape.

Figure 1 shows the dependence of the position of the maxima $\mathscr{E}_e^{max}$ of the free-exciton emission lines and $\mathscr{E}_d^{max}$ of the EH drops on the pressure applied in the [110] direction. We see that the $\mathscr{E}_e$ line shifts linearly in the entire interval of applied pressures, just as in[4],

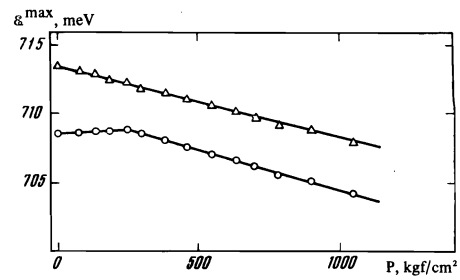

FIG. 1. Plots of $\mathscr{E}_d^{max}(P)$ (○) and $\mathscr{E}_e^{max}(P)$ (△) for the case of uniform deformation, T = 3°K.

owing to the decrease of the forbidden-band width. The position of the $\mathscr{E}_d$ line remains practically unchanged in the pressure interval 0 to ~ 250 kgf/cm^2 (P_{cr}). When higher pressures are applied, the variation of $\mathscr{E}_d$ is parallel to that of $\mathscr{E}_e$.

Figure 2 shows the change in the intensities of the emission lines of the EH drops (I_d) and of the free excitons (I_e) as functions of the applied pressure at different temperatures. At T = 1.8°K, the intensity of the $\mathscr{E}_d$ line decreased by only a factor of 2. However, at 3 and 4.2°K the intensity ratio $I(P = 0)/I(P = P_{cr})$ was ~ 10 and ~ 30, respectively. We see that the emission intensity changes most strongly in the pressure interval from 0 to P = 250 kgf/cm^2. The free exciton emission line intensity I_e approximately doubles in the same pressure interval.

The pressure dependence of the half-widths $\Delta\mathscr{E}_d$ and $\Delta\mathscr{E}_e$ of the EH drop and free-exciton emission lines at temperatures 1.8 and 4.2°K respectively are shown in Fig. 3a. The line width $\Delta\mathscr{E}_d$ decreases in the pressure interval from 0 to 250 kgf/cm^2 and reaches ~ 2.3 meV. With further increase of the load on the sample, $\Delta\mathscr{E}_d$ remains practically constant. The relatively large spectral width of the gap (~ 1.5 meV) did not make it possible to investigate the variation of $\Delta\mathscr{E}_e$ in the employed pressure range.

B. Non-uniform Deformation

The behavior of the free and interacting excitons was investigated with samples of special shape (Fig. 4). In a sample of this shape one can produce a smooth deformation gradient over the height with the maximum stress in the central region of the sample. The samples were 8 mm high, and the ratio of their base area to the central-section area was ~ 1.5.

Figure 5 shows the variation of the energy position of $\mathscr{E}_d^{max}$ as a function of the applied pressure following optical excitation of the central (Section A) and lower (Section B) parts of the sample at 1.8°K. The dash-dot line corresponds to the position of the maximum of the exciton emission line as measured under uniform pressure. As seen from the figure, the change of $\mathscr{E}_d^{max}(P)$ hardly differs from the case of uniform deformation when the non-equilibrium carriers are excited in Section A. When the carriers are excited in Section B of the sample, the behavior of $\mathscr{E}^{max}(P)$ does not differ in any way from the preceding case when $P < P_{cr}$. When $P > P_{cr}$, however, the $\mathscr{E}_d^{max}(P)$ dependence becomes stronger than in the case of uniform deformation. Such a behavior of $\mathscr{E}_d^{max}(P)$ allows us to assume that at the instant of irradiation the investigated objects are situated in the crystal in a location where the pressure differs appreciably from the pressure in the excitation region. Recalculation of part of the curve of Fig. 5 for the region $P > P_{cr}$ to the central part of the sample (for details see the next section) results in good agreement with the $\mathscr{E}_d^{max}(P)$ relation for the case when the crystal is excited in Section A. An exception is the region $P \sim P_{cr}$.

The changes of the EH-drop emission-line shape (T = 1.8°K) when the carriers are excited in Section B of the sample at pressures 0, 300, and 600 kgf/cm^2 are shown in Fig. 6. For convenience in the analysis, all three maxima of the lines are made to coincide at an energy corresponding to the position of the maximum of the EH drop emission line in the undeformed crystal.

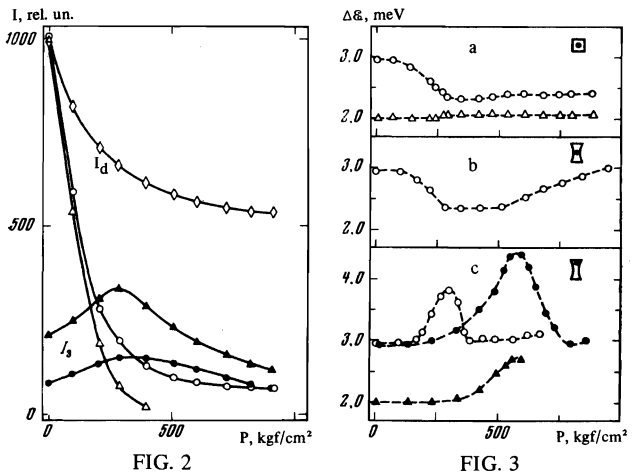

FIG. 2

FIG. 3

FIG. 2. Plots of line intensities I_d and I_e at different temperatures: Δ, ▲–4.2; O, ●–3; ◇–1.8°K.

FIG. 3. Plots of the half-widths $\Delta\mathscr{E}_d(P)$ and $\Delta\mathscr{E}_e(P)$ at 4.2 and 1.8°K. a–Uniform deformation: O–$\Delta\mathscr{E}_c$ at 1.8°K, Δ–$\Delta\mathscr{E}_e$ at 4.2°K; b–nonuniform deformation: O–$\Delta\mathscr{E}_d$ at 1.8°K with section A illuminated (see Fig. 4); c–nonuniform deformation: ●–$\Delta\mathscr{E}_d$ at 1.8°K, ●–$\Delta\mathscr{E}_d$ and ▲–$\Delta\mathscr{E}_e$ at 4.2°K with section B illuminated.

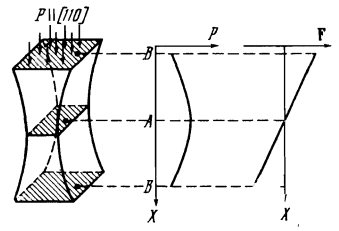

FIG. 4. Shape of sample with specified deformation gradient; approximate distribution of the pressure P over the height of the sample; distribution of the force F acting on the particles over the height of the sample.

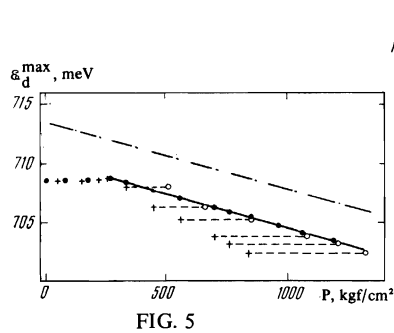

FIG. 5

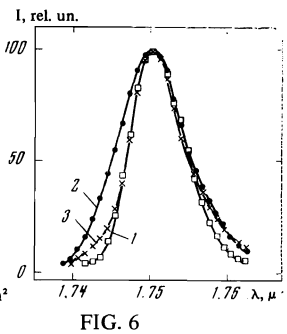

FIG. 6

FIG. 5. Plots of $\mathscr{E}_d^{max}(P)$ at T = 1.8°K: O–section A illuminated; +–section B illuminated, O–section B illuminated and pressure recalculated for section A.

FIG. 6. EH drop emission line shape vs. pressure. Case of non-uniform deformation, T = 1.8°K. Generation region of non-equilibrium carriers in Section B: □–P = 0; O–P = 300 kgf/cm^2; X–P = 600 kgf/cm^2.

It is seen from the figure that at P = 300 kgf/cm^2, i.e., P ~ P_{cr}, the short-wave edge of the emission line undergoes an appreciable change. With further increase of the load on the sample (P = 600 kgf/cm^2), however, the EH drop emission line resumes practically its initial shape.

Plots of $\Delta\mathscr{E}_d$ against the applied pressure at T = 1.8 and 4.2°K with the carriers excited in the central and lower parts of the sample, are shown in Figs. 3b and 3c. For Section A, the variation of $\Delta\mathscr{E}_d(P)$ in the pressure interval from 0 to 500 kgf/cm^2 has the same character as in the case of uniform deformation. When the load is increased, however, a gradual increase in the half-width of the EH-drop emission line is observed. When the carriers are excited in Section B, the $\Delta\mathscr{E}_d(P)$ plot has a maximum in the pressure region P ~ P_{cr}.

The plots of $\mathscr{E}_d^{max}(P)$ and $\mathscr{E}_e^{max}(P)$ obtained under conditions of non-uniform deformation at different temperatures are shown in Fig. 7. It is easily seen that the deviation of the $\mathscr{E}_d^{max}(P)$ curve from the similar plot for the case of uniform deformation occurs at different pressures if the sample temperature is varied. Thus, at T = 1.8°K this deviation is observed already at pressure P ~ P_{cr}, whereas at T = 4.2°K it is observed only at P ≈ 500 kgf/cm^2. A similar picture is observed also for the position of the maximum of the half-width of the $\mathscr{E}_d$ line as a function of the sample temperature (Fig. 3c). As to the behavior of $\mathscr{E}_e^{max}(P)$ under the same excitation conditions, its character at pressures P > P_{cr} is similar to that of $\mathscr{E}_d^{max}(P)$, but with smaller slopes.

To investigate the behavior of the free excitons in a non-uniform deformation field in the absence of EH drops, we plotted $\mathscr{E}_e^{max}(P)$ at 4.2 and 5°K (Fig. 7a). (The dependence of the position of $\mathscr{E}_e^{max}(P)$ at 5°K was similar to the dependence at 4.2°K.) No noticeable deviation of the $\mathscr{E}_e^{max}(P)$ curve from that given in[2] for the case of uniform deformation was observed in the pressure range from 0 to 1200 kgf/cm^2.

The plot of the intensity I_d vs P in the case of non-uniform deformation, when the excitation spot is in Section B of the sample, is a rather complicated curve (Fig. 8). The region where the intensity decreases sharply has two nearly exponential sections with different arguments. As seen from Fig. 8, the more rapid decrease of the intensity begins at P ~ 300 kgf/cm^2, i.e., just when the deviation of $\mathscr{E}_d^{max}(P)$ from the case of uniform deformation begins. Another feature that distinguishes the $I_d(P)$ plot from the case of uniform deformation is a certain increase of the intensity at high pressures.

DISCUSSION OF RESULTS

A. Case of Uniform Deformation

As shown in[2], two different regions are observed in the behavior of the line $\mathscr{E}_d^{max}$ as a function of the uniaxial compression: the region of low pressures P < P_{cr}, when the position of $\mathscr{E}_d^{max}$ is practically independent of the pressure, and the region P > P_{cr}, when $\mathscr{E}_d^{max}$ shifts in accordance with the decreased width of the forbidden band with changing pressure (Fig. 1). The dependence of the width of the emission line $\mathscr{E}_d$ shown in Fig. 3a correlates well with the dependence of $\mathscr{E}_e^{max}$ on P. At P ≳ P_{cr}, which amounts to ~ 250 kgf/cm^2 when the compression is along the [110] axis, the line width decreases to 2.3 meV. When this pressure is reached, the separation Δ between the two pairs of valleys of the conduction band amounts to approximately 2 meV[4], corresponding to the Fermi energy $\mathscr{E}^F$ for the electrons in the drop[2]. When P > P_{cr} and $\mathscr{E}^F$ < Δ, the electrons previously in four equivalent valleys fill only two of the valleys of the conduction band, the energies of which decrease. An increase of the electron kinetic energy leads to an increase of the internal "pressure" in the drop. The need for maintaining the attraction and repulsion forces equal is equivalent to an increase in the equilibrium volume of the drop, and consequently to a decrease of the average particle density in the drop. The emission line width, being a quantity representative of the average density of the particles in the drop, decreases. The equilibrium censity n_0 of the particles in the drop, with a deformation P ∥ [110] applied, has been estimated in[5] at 1.75×10^{17} cm^{-3}.

An important experimentally observed quantity characterizing the equilibrium in the system consisting of the drop and the exciton gas system is the emission intensity. In such a two-phase system (neglecting the free carriers), the equilibrium can shift towards the excitons, depending on the value of the energy gap $\mathscr{E}_e - \mathscr{E}_d = \Delta\mathscr{E}$ and of the temperature. In other words, the decrease of the intensity of the $\mathscr{E}_d$ line can be explained as being due to "evaporation" of the excitons from the drop, i.e., to a decrease in the total number of particles in the drop. From the plot in Fig. 2 it is seen that the free-exciton emission intensity increases in the pressure interval from 0 to P_{cr}, since the equilibrium shifts toward the exciton side when $\Delta\mathscr{E}$ is decreased. We see that at 4.2°K the $\mathscr{E}_d$ line intensity decreases by an approximate factor of 30, and the $\mathscr{E}_e$ line intensity increases by only approximately two times. This points out once more the large ratio (~ 20) of the quantum yields of the drops and excitons.[1)] We note that this fact is quite difficult to explain from the point of view of the exciton molecule.

B. Case of Non-uniform Deformation

In[1] we reported observation of an anomalous behavior of $\mathscr{E}_d^{max}$ under uniaxial compression conditions. When a pressure equal to P_{cr} was reached, the $\mathscr{E}_d$ line has a stronger dependence on P than $\mathscr{E}_g$ or $\mathscr{E}_e$, and the slope varied with the geometry of the sample (i.e., with the degree of non-uniformity of the deformation) and with the temperature. It was suggested that the stronger dependence of $\mathscr{E}_d$ on P is due to motion of the EH drops in the non-uniform deformation field.

Indeed, the deformation changes the width of the forbidden gap in the semiconductor. It follows therefore that the energy of the electron-hole pair depends on the applied stress ϵ_{ik} in first approximation:

$$\mathscr{E}(\varepsilon_{ik}) = \mathscr{E}_0 + \frac{\partial\mathscr{E}}{\partial\varepsilon_{ik}}\varepsilon_{ik} + \ldots = \mathscr{E}_0 + D_{ik}\varepsilon_{ik}, \quad (1)$$

where D_{ik} is the summary deformation potential of the electron and the hole. An EH drop with volume V is therefore acted upon in the field $\epsilon_{ik}(r)$ of non-uniform deformation by a force

[1)]The quantum yield of EH-drop emission was measured in [6,7] and found to equal 50–100%.

$$\mathbf{F} = Vn_0 D_{da} \operatorname{grad} \varepsilon_r, \quad (2)$$

where n_0 is the equilibrium concentration in the drop[2)]. Thus, the EH drops should move, under the influence of the force **F**, into the region of maximum deformation, with a velocity **v**,

$$\mathbf{v} = \frac{D_r \tau_p}{M} \operatorname{grad} \varepsilon_r. \quad (3)$$

Here M is the mass of the electron-hole pair, and τ_r is the momentum relaxation time of the EH drop as a whole.

The most convenient geometry for direct observation of particle motion in a non-uniform deformation field is possessed, in our opinion, by the sample indicated in Fig. 4. The cross section area of such a sample depends quadratically on the height of the section, and the maximum deformation is reached at the center of the sample. The height distributions of the pressure in the sample and of the force acting on the particle are shown schematically in Fig. 4. Obviously, such a distribution of the deformation gradient makes it possible to obtain uniformly decelerated motion of a particle produced, say, at the edges of the sample, with the particle moving towards the center, which acts like a trap from which the particles can no longer escape. The path traversed by the particles to the center (i.e., the dimensions of the sample) was chosen on the basis of an estimate[8] of the velocity of the EH drops in the non-uniform deformation field, and on the basis of the experimental data on the lifetimes of the drops[6]. The thus-chosen time of flight τ_f of the drops was as a rule shorter, at the employed deformation gradients and temperatures, than the lifetime τ_0 of the drops, so that the radiation of the drops could be observed from the central part of the sample. Two series of experiments were performed, in which the region of generation of non-equilibrium carriers was moved over the sample and the laser beam could be focused either on the central part of the sample (Section A), or on its end (Section B); the distance from the illuminated spot to the edge of the sample did not exceed a fraction of a millimeter).

Having on hand data on the pressure dependence of $\mathscr{E}_e^{max}$ and $\mathscr{E}_d^{max}$ for the case of uniform deformation, we can determine the place in the sample where the main emission takes place. When the central part is illuminated, the points of the experimental plot $\mathscr{E}_d^{max} = f(P)$ coincide almost always with the data obtained for the case of the uniform deformation. Thus, when the central region of the sample is illuminated, the drops radiate from the same region, since the stress there is maximal and the gradient is practically equal to zero. The pressure dependence of the width of the $\mathscr{E}_d$ line duplicates first the dependence of $\mathscr{E}_d$ on P for uniform samples, but at $P > 500$ kgf/cm^2 the line broadens somewhat. It can be assumed that at such high pressures the sample becomes bent in its thin central section, and this gives rise to the appearance of sections with larger stresses than the average in the central section.

As already indicated, when section B of the sample is illuminated, the $\mathscr{E}_d^{max}(P)$ plot deviates at $P > P_{cr}$ from $\mathscr{E}_d^{max}(P)$ for the case when the section A is illuminated, and has a larger slope. When the pressures were recalculated relative to the central section (i.e., when a coefficient k = 1.4—1.5, equal to the ratio of the areas of the central section of the end surface, was introduced), the points fitted quite satisfactorily the $\mathscr{E}_d^{max}(P)$ plot for the central section. This allows us to conclude unequivocally that the deformation gradient has caused the drops to move from the point of their formation into the central part, i.e., an approximate distance of 4 mm. At $\tau_f \gtrsim \tau_0$, the cloud of drops stretches over the sample, and since the entire sample is focused on the slit of the monochromator (at least in height), one registers in this case the broadened emission line of the EH drops situated in different sections of the sample with different pressures.

The experimental data shown in Fig. 6 confirm the foregoing arguments. Indeed, the emission line shape varies with increasing pressure. We see that curve 2 is more symmetrical than curves 1 and 3, which were obtained in the two limiting cases: curve 1 at T = 0, when the EH drops emit while still at the location where they were produced; curve 3 corresponds to the pressure $P > P^*$, where P^* is a pressure such that the forces acting on the EH drops are sufficient to bring practically all the EH drops to the center of the sample within the lifetime τ_0, and cause their main emission to come from the centers.

We note that the emission line width shown in Fig. 3c also demonstrates the displacement of the particles.

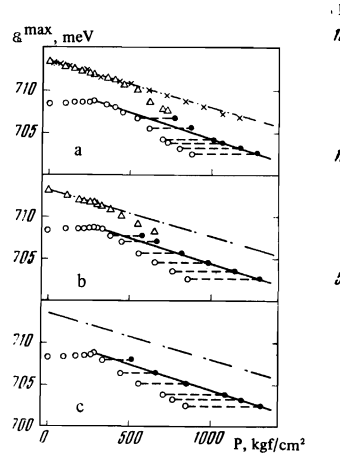

FIG. 7

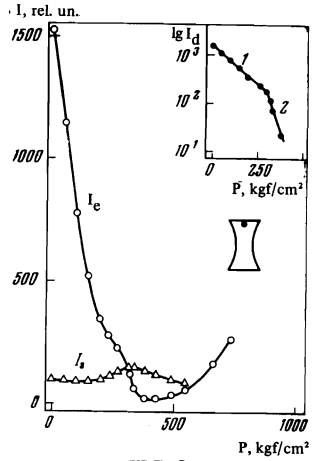

FIG. 8

FIG. 7. Plots of $\mathscr{E}_d^{max}(P)$(○) and $\mathscr{E}_e^{max}(P)$ (△) when Section B is illuminated, at temperatures 4.2 (a), 3 (b), and 1.8°K (c). ×—position of $\mathscr{E}_d^{max}(P)$ at T = 4.2°K in the absence of emission in the $\mathscr{E}_d$ line (lower excitation level); ○—$\mathscr{E}_d^{max}$ with P recalculated relative to the central section.

FIG. 8. Intensities of the $\mathscr{E}_d$ and $\mathscr{E}_e$ lines at 4.2°K for the case of non-uniform deformation with Section B illuminated. The right-hand corner shows the same relation, but with log I_c as the ordinate. Two different sections of the slope are seen: 1—at $0 < P < P_{cr}$ and 2—at $P > P_{cr}$; $P_{cr} \sim 300$ kgf/cm^2.

[2)] Strictly speaking, formula (2) should contain the true energy per particle pair in the drop. It is known from experiment, however (Fig. 1), that at $P > P_{cr}$ the measured energy per particle pair in the drop (which includes the particle binding energy and the surface-tension energy) varies with the deformation in exactly the same manner as $\mathscr{E}_g$ (the width of the forbidden gap), and this allows us to state that the expression (2) for F is exact for this range of pressures. It is precisely this pressure range, in which the drop motion changes, which we analyze below, for at $P < P_{cr}$ there is practically no motion of the drops.

The pressure interval in which the emission line again becomes narrower is different for the temperatures 1.8 and 4.2°K, as is also the quantity P* at which the points can be satisfactorily recalculated to fit the curve for the middle section (see Fig. 7). This agrees with the premises developed in[8], that the drop velocity has a temperature dependence connected with the analogous temperature dependence of τ_r. It must be stated that at $T \lesssim 1°K$ this dependence takes the form T^{-5}, but is close to linear in the temperature interval 4—2°K. It is seen from Fig. 7 that the drop velocity actually has a noticeable temperature dependence. Thus, at 4.2°K, the points can be satisfactorily recalculated (i.e., the drops emit from the central part of the sample) only at $P = 700$ kgf/cm^2, whereas at 1.8°K they can already be recalculated when $P = 400$ kgf/cm^2 is reached.

The emission intensity of the $\mathscr{E}_d$ line at 4.2°K has three sharply differing sections as functions of P. Whereas in the pressure interval up to P_{cr} the main contribution to the decrease of the intensity is made, just as in the case of uniform deformation, by "evaporation" (slope 1 in Fig. 8, where the data are plotted in a semilogarithmic scale), in the pressure interval $P_{cr} < P \leq P^*$ (where P* is the pressure at which the drops already emit from the central region of the sample) the decrease of the intensity is connected with the "runaway" of the drops into the region of maximum deformation (slope 2 in Fig. 8). When $P > P^*$, the line becomes narrower, and since Fig. 8 shows not the integral of the line but its amplitude, its value even increases somewhat.

Thus, the aggregate of the foregoing information offers convincing evidence that the exciton complexes move in the non-uniform deformation field.

We can determine the minimum particle velocity (the drift component) if we know the particle path (4 mm, the distance between sections A and B) and the lifetime ($\tau_0 = 2 \times 10^{-5}$ sec[6]). Then $v = 2 \times 10^4$ cm/sec.

We use formula (3) to estimate τ_r for a drop, where $D_{ik}\partial\epsilon_{ik}/\partial x$ is the force acting on a pair of particles in the drop and is equal to the change of the width of the forbidden band as a function of the pressure along the path of the particle from section B to section A. This quantity is obtained from the experimental data shown in Fig. 5. At T = 1.8°K, the + points can be fitted by recalculation to the $\mathscr{E}_d^{max}(P)$ plot for section A (indicated by the dashed lines) already at $P = 600$ kgf/cm^2. In this case $\mathscr{E}_d^{max}$ is equal to 707 meV. At this instant, the pressure at section B reaches ~ 430 kg/cm^2, i.e., $\mathscr{E}_d^{max}$ lies in the region of ~ 707.8 meV. Consequently, the difference in the width of the forbidden band is 0.8 meV. Then

$$F = D_{ik}\partial\epsilon_{ik}/\partial x = 3.2 \cdot 10^{-15} \text{ erg/cm}$$

when

$$\tau_r = vM/F = 6.3 \cdot 10^{-9} \text{ sec}$$

and $\tilde{\mu} = \tau_r/M$, the value of the effective mobility of the electron-hole pair in the non-uniform deformation field is equal to 6.3×10^{18} sec/g.

If we assume that the exciton complexes are exicton molecules, then, using the Einstein relation $D_b = \tilde{\mu}_b kT$ (where $\tilde{\mu}_b = \tilde{\mu}/2$), we find that at T = 1.8°K the diffusion coefficient is equal to 8×10^2 cm^2/sec, and the biexciton diffusion length is $L_b = \sqrt{D_b \tau_0} = 1.3$ mm.[3)] Consequently, the biexciton diffusion length should be three times larger than the exciton diffusion length ($L_e = 0.4$ mm[9]). This conclusion contradicts the experimental data of[9], where the diffusion length of the formations responsible for the "new" radiation is estimated to be at least one order of magnitude lower than the diffusion length of the exciton.

We note once more that in the entire investigated pressure interval (up to 1200 kgf/cm^2) we have observed no deviations of the behavior of $\mathscr{E}_e^{max}(P)$ of the free excitons under non-uniform deformation at 4.2 and 5°K from the case of uniform deformation (see Fig. 7a). The plots shown in Fig. 7 for the positions of $\mathscr{E}_e^{max}(P)$ are connected with excitons evaporated from the drop, i.e., with the exciton "bow" of the drop. The same holds for the width of the exciton line on Fig. 3c.

Summarizing the results, we can emphasize that the attempt to interpret the obtained data from the point of view of formation of a biexciton encounters considerable difficulties, whereas the electron-hole drop model[10] describes them quite satisfactorily.

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[3)]The application of the Einstein relation to EH drops obvioulsy yields values of μ_d, and hence of D_d, that are smaller than μ_b and D_b by a factor N/2 (where N is the number of carriers in the drop), since $\mu = v/F_\Sigma$, and $F_\Sigma = N\Sigma F$ (where F is the force obtained from experimental data, equal to 3.2×10^{15} erg/cm). The value of N should naturally depend on the drop dimension, i.e., on the temperature, excitation level, etc. A value $D_b \leq 1$ cm^2/sec is given in [9]. This agrees with our estimate if $N \sim 10^3 - 10^4$.

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