Decay kinetics of persistent photoconductivity in semiconductors

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Kinetic studies of the decay of persistent photoconductivity can decide between competing interpretations. This paper is concerned with the temporal decay of excess conductivity after illumination for low temperatures and spatial carrier separation. The initial decay is rapid since closely spaced carriers recombine; later decay is retarded. Analytic expressions are derived for various trap profiles. Epitaxial GaAs and interfaces of $Al_xGa_{1-x}As$-GaAs heterostructures are investigated; the results agree with theory, which predicts a decay essentially logarithmic in time.

I. INTRODUCTION

Many semiconductor structures exhibit a persistent conductivity after photoexcitation has terminated.[1,2] This persistent photoconductivity (PP) indicates long lifetimes. Recombination is impeded at low temperatures; heating restores the equilibrium. The phenomenon of PP has attracted renewed attention, especially for compounds and semiconductor alloys. $Al_xGa_{1-x}As$ exhibits persistence,[3] useful for adjusting the density of a two-dimensional electron gas.[4] Persisting charge causes undesirable back-gating effects in field-effect transistors.[5]

Several origins for recombination-preventing barriers may be assumed.[6] Earlier[2] it was concluded that PP indicated nonhomogeneity of the material. Potential barriers separate charge and thus delay recombination. An effective-medium theory[7] describes such disordered samples. A prolongation of lifetimes by adjacent junctions was observed in *n-i-p-i* doping superlattices.[8,9] Potential barriers lead to PP by *macroscopic separation* of electrons and holes, as demonstrated with well-defined samples.[10,11] One carrier type, e.g., holes, could be localized at traps in the substrate, while the electrons remained free in the *n*-type epitaxial layer.[10,11] A quantitative explanation for the buildup kinetics was shown to depend upon the spatial distribution of the traps. Trap distribution can be determined by PP;[12] other experiments were performed on GaAs,[13] InP,[14] and Si.[15]

A different explanation assumes photons to liberate carriers out of deep-lying centers, which undergo a *lattice relaxation.* Such relaxation in polar materials causes shifts between absorption and emission.[16] This idea had been suggested for PP in CdS (Ref. 17) and was then applied to $Al_xGa_{1-x}As$, introducing the concepts of the *DX* center.[18,19]

Yet another possibility for a restricted recombination of the excess carriers is a *separation in k space.* Deep levels have been assumed to be associated with subsidiary minima of the conduction band. After photoionization, the carriers thermalize into the lowest valley—often the Γ minimum—from whence they may not be able to return to the original level.[20–22]

A clarification of the processes involved for each experimental situation is important. Modulation doping,[23] transport in two-dimensional channels,[24] and device properties of field-effect transistors or of high-electron mobility transistors[25] with a two-dimensional channel[26] are affected by PP. The prevailing deep center in liquid-encapsulation-grown GaAs, termed *EL2*, also shows characteristic long-time photo aftereffects, to be understood for improving materials technology.[26–28] Interpretation of the photoquenching of *EL2* presently involved lattice relaxation.[29] However, a correlation of *EL2* and dislocations[30,31] suggests that barriers cylindrically surrounding charged dislocations[6] may also extend lifetimes.[28] Recently, the interpretation of PP by *DX* centers in GaAs has again been based upon effects of subsidiary minima.[32,33]

Experimental distinction between the various models is not easy.[6] Compositional and dopant fluctuations can often not be excluded; such fluctuations cause potential barriers. Attempts to distinguish between the models of macroscopic versus atomistic barriers have been made for $Al_xGa_{1-x}As$ by removing the junction-causing substrate or by spectroscopic techniques.[34] Magnetotransport measurements and variations of the illumination wavelength led to proposing a superposition of several causes for PP.[35,36] The presence of fluctuations in semiconductor mixed crystals has recently been demonstrated to be appreciable or dominating.[37]

This paper is concerned with the spatial separation of the photogenerated charges. One type of carrier is trapped, the other remains free and causes excess conductivity. The separation is assumed to be accomplished by potential barriers; such barriers may arise at surfaces, interfaces, junctions, or fluctuations of composition or doping. Drift and diffusion separate the pairs; a specific spatial profile of trapped charges is built up. The temporal decay of PP depends on this profile and its recombination with the free carriers. Fast decay involves closely spaced pairs. Distant partners recombine slowly. The translation of this spatial variable into the experimentally observable temporal decay is our main theme.

II. PREVIOUS RESEARCH

Recent investigators of PP (Refs. 38 and 39) emphasized two observations: (i) the nonexponential decay of photoeffects after illumination, and (ii) asymptotic,

essentially time-independent persistence. Observation of nonexponential decay in $Al_xGa_{1-x}As$ is unexpected from a microscopic model of a barrier by lattice relaxation, since one expects simple kinetic laws, such as a monomolecular dependence. Other observers have attributed two characteristic decay times to the nonexponential dependence, thus alluding to two different mechanisms of recombination.[40]

Earlier papers rationalized nonexponential recovery. Radiation-damaged semiconductors, such as Ge and Si, show PP, interpreted[41,42] with clusters of deep levels, surrounded by spheres or cylinders of compensating space charge of polarity opposite to the majority carriers. Gregory[42] derived a formula for nonexponential time dependence. Spatial carrier separation by macroscopic barriers lowers these barriers, consequently changing the volume available for conduction.[19,11] This volume is usually enhanced at the expense of a shrinking space-charge layer.[10] A treatment was given by Vul and coauthors[13] for the changes of barriers during illumination (decrease) and after illumination (recovery). Schubert and Ploog[22] investigated PP decay in $Al_xGa_{1-x}As$ on GaAs, observed a nonexponential law, and explained it with recombination via tunneling through the barriers. A numerical fit was made for this purpose; the more recent analysis[39] shows that a simplified analytical expression can be substituted, which deviates slightly from a logarithmic law.

III. THEORY

A. General solution

Consider an n-type thin conducting layer (e.g., by epitaxy) on an insulating, trap-containing substrate.[10] The persisting electrons in the layer, ($x<0$), recombine with the spatially removed trapped holes in the substrate ($x>0$), and thus reduce PP. Here we neglect (a) thermal excitation of holes out of traps and (b) thermal surmounting of the barrier.

The recombination rate R is

$$R=(\Delta n/\tau_0)\exp(-2x/a)\,, \tag{1}$$

where Δn is the excess persistent electron density and τ_0 is a lifetime for vanishing spatial separation. The electrons have a Bohr radius a; their wave functions overlap with the localized wave functions of the holes. This overlap depends on the distance x of the holes from the electrons. Equation (1) is known in the theory of transition probabilities between donor-acceptor pairs[43] with a similar distance-dependent recombination.[44,45] Tunneling, leading to recombination between the free electrons and localized centers, obeys a similar law.[22,39] Equation (1) is thus fairly general.

During PP buildup, holes enter the substrate with a diffusion length L.[10] Near the layer/substrate interface all traps may be occupied by holes, but as the distance from the interface increases, the hole density decreases. Such a hole distribution can be described with a spatial Fermi function:

$$p_0\equiv p(x,t=0)=Z\{1+\exp[(x-x_f)/L]\}^{-1}\,, \tag{2}$$

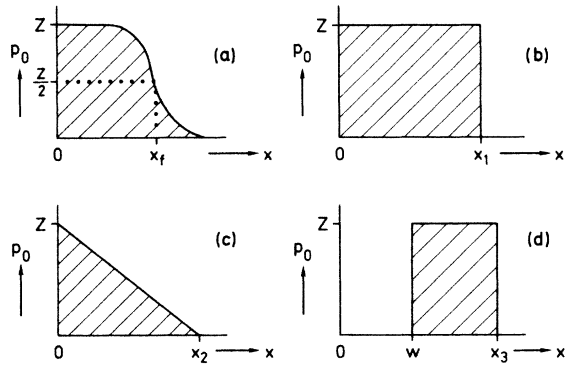

FIG. 1. Possible persistent trapped-hole distributions at time $t=0$ after illumination: (a) Spatial Fermi hole distribution; see Eq. (2); (b) rectangular distribution; (c) triangular distribution; and (d) shifted rectangular distribution; between the recombining carriers exists a zone of width w without any trapped charge.

where Z is the volume density of hole-capturing traps in the substrate ($x>0$). The parameter x_f is the distance at which half of the traps are occupied by holes. A simple exponential is obtained from Eq. (2) by setting $x_f=0$; such a form applies for nonsaturating illumination. The time $t=0$ indicates the termination of illumination. Figure 1(a) shows this profile. Simpler hole distributions approximate typical situations, such as a rectangular [Fig. 1(b)], triangular [Fig. 1(c)], and a shifted rectangular distribution [Fig. 1(d)], having a trap-free buffer of thickness w.

The shaded areas in Fig. 1 represent hole charge equal to the initial excess sheet density of electrons $\Delta(nd)$:

$$\Delta(nd)=\int_0^\infty p(x,t=0)dx \quad \text{at } t=0\,. \tag{3}$$

The density n and the width d can be measured as the product nd by the Hall effect; both n and d *can vary*.[10]

For times $t>0$, carriers recombine, reducing $\Delta(nd)$ and thereby the excess photoconductivity $\Delta\sigma$ (see Fig. 2).

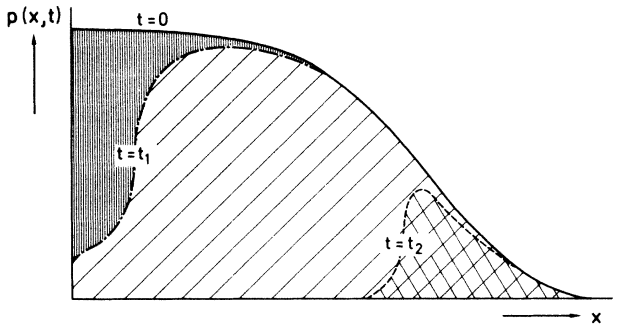

FIG. 2. Trapped-hole volume density $p(x,t)$ in the substrate as a function of position x for times $t=0$, $t=t_1$, $t=t_2>t_1$ after illumination switch off at $t=0$. The shaded area represents charge having recombined up to time $t=t_1$; the hatched area is the charge that still remains at t_1. The cross-hatched area is the charge that remains at $t_2>t_1$, where the decay is very slow, because of the large distance from the interface.

Close carriers recombine first; the hatched and crosshatched areas of Fig. 2 display the distribution of holes remaining at $t_2 > t_1 > 0$; the decreasing excess conductivity $\Delta\sigma(t)$ is given by

$$\Delta\sigma d = \mu_n e \Delta(nd) = \mu_n e \int_0^\infty p(x,t)dx \ , \tag{4}$$

where e and μ_n are charge and mobility of the electrons at $x < 0$. The rate of disappearance of hole charge is obtained by multiplying $p(x,t)$ with the x-dependent recombination probability of Eq. (1):

$$dp/dt = -[p(x,t)/\tau_0]\exp(-2x/a) \ . \tag{5}$$

Integration of Eq. (5) and substitution into Eq. (4) yield

$$\Delta(nd) = \int_0^\infty p(x, t=0)\exp[-(t/\tau_0)\exp(-2x/a)]dx \ . \tag{6}$$

B. Sharp-front assumption

Each situation requires substitution of the appropriate initial profile $p(x, t=0)$ into Eq. (6). Even simple profiles demand numerical solutions, since the exponential integral $E_i(\exp x)$ arises. Such evaluation presents no difficulty. We want, however, to elucidate the physics and thus resort thus resort to simplifying assumptions. Consider in Fig. 3 the quantity

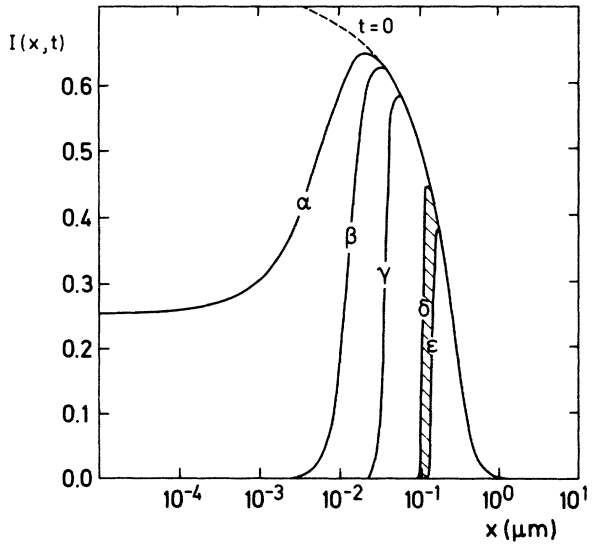

FIG. 3. Integrand function $I(x,t)$ of Eq. (7) versus distance x from the layer-substrate interface for different times t after illumination switch off. Logarithmic scale chosen for x to visualize time evolvement. Dotted curved for $t=0$: curve α, $t = 1.1\times10^{-9}$ s; curve β, $t = 1.1\times10^{-8}$ s; curve γ, $t = 10^{-6}$ s; curve δ, $t = 1$ s; curve ϵ, $t = 10^3$ s. Notice the sharping of the demarcation between the remaining and already recombined trapped charge, which is given by the curves β to ϵ. Notice further the very small motion of this front between δ and ϵ, which represents the temporal range of observation between $t = 1$ to 1000 s. The hatched area is proportional to the charge recombining between 1 and 1000 s.

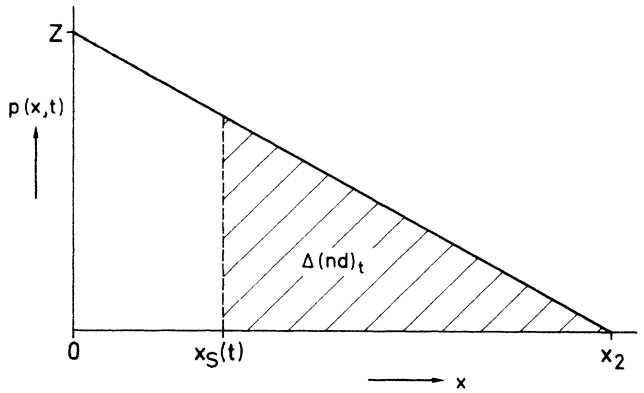

FIG. 4. Triangular hole distribution function. Distance $x_s(t)$ represents the moving front. Up to a time t after illumination switch off, all holes between 0 and $x_s(t)$ have recombined and the area under the curve between $x_s(t)$ and x_2 is equal to the remaining persistent charge (hole sheet density) at time t.

$$I(x,t) = \{1+\exp[(x-x_f)/L]\}^{-1} \times \exp[-(t/\tau_0)\exp(-2x/a)] \ , \tag{7}$$

the integrand of Eq. (6) with Eq. (2). The receding charge front is shown in Fig. 3 for a logarithmic length scale. After a period of a few τ_0, the separation between recombined charges and remaining charges becomes a sharp front. (A similar model was used for luminescence.[43]) At time t all carriers of lifetime $t+\tau_0$ are assumed to have recombined. The front is at x_s, where $\tau_0\exp(-2x_s/a)$ equals $t+\tau_0$, thus

$$x_x(t) = \tfrac{1}{2}a \ln[1+(t/\tau_0)] \ . \tag{8}$$

The integral of Eq. (6) can now be considerably simplified:

$$\Delta_s(nd) = \int_{x_s}^\infty p(x, t=0)dx \ . \tag{9}$$

This approximation is valid for many experimental cases. First, the small τ_0 ($\tau_0 \approx 10^{-9}$ s for GaAs) means that data for PP are only obtained for $t \gg \tau_0$, where the approximation holds. Secondly, $L > a$, being typically $L \approx 10^{-5}$ to 10^{-4} cm and $a \approx 10^{-6}$ cm in GaAs.[10] This fact is decisive for the occurrence of PP since the charge to be trapped can extend much more deeply into the substrate than a few Bohr radii; therefore, distant regions are reached where the recombination rate is so slow as to be observable for times $t/\tau_0 > 10^{12}$ or even *far beyond.*

These considerations of validity imply a critical value Z_c to cause persistence:

$$Z_c = \gamma Q/a \ , \tag{10}$$

where γ is a quantum efficiency producing pairs by an incident photon[10] and Q is the cumulative dose of photons per unit area.[10] If Z exceeds Z_c, and the traps have reasonably large capture coefficients, then all holes generated by the illumination dose Q are stored so close to

the interface that they recombine within τ_0 after illumination; no persistence is obtained.

For our experiments on GaAs, we numerically estimated the errors introduced by the sharp-front approximation. These do not exceed 2%. The approximation underestimates removal of distant charge and overestimates removal of close charge.

C. Individual cases

1. Spatial Fermi distribution

The spatial Fermi distribution, see Fig. 1(a) and Eq. (2), applies to moderate trap densities Z which can be saturated with holes to $x \approx x_f$ by a sufficient dose Q. It will usually be difficult to obtain a unique set of fit parameters if these are not known from other independent experiments. Meaningful determinations of the parameters τ_0, a, L, Z, and x_f require a broad range of times t, such as from $t/\tau_0 \approx 1$ to 10^{14} to obtain data in regimes where there will be noticeable deviations from a simple logarithmic decay.

Most experiments on PP thus far have been limited to the regime of several seconds to several hours, hence the name persistent photoconductivity; we suggest that future experiments must extend the time scale. In Fig. 3, the charge removal between curve $\delta(1=1$ s) and $\epsilon(t=1000$ s) is indicated by the hatched area, which shows what a small total removal arises. One can use here a simpler approximation such as a rectangle or a triangle. Our experiments have an advantage which effectively extends our range of observation, since we can measure buildup[10] and indeed know the conditions for $t=0$.

2. Rectangular distribution

With rectangular distribution [see Fig. 1(b)], all traps are initially filled to a depth x_1, as in samples having a thin layer of uniform trap doping Z after a saturating dose Q. Equation (6) can be solved numerically. The sharp-front approximation of Eqs. (8) and (9) leads to

$$\Delta\sigma(t) \sim \Delta(nd) = Z[x_1 - x_s(t)]$$
$$= Zx_2 - \tfrac{1}{2}aZ \ln[1+(t/\tau_0)] \, . \tag{11}$$

Equation (11) is a good approximation for many experimental situations. Since $Zx_2 = \Delta(nd)$ for $t=0$, one can simplify further for $t \gg \tau_0$:

$$\Delta\sigma(t) = \Delta\sigma(t=0) - A \ln(t/\tau_0) \, , \tag{12}$$

where the constant A is a measure for the photoconductance lost within a time τ_0.

3. Shifted rectangular distribution

For shifted rectangular distribution, see Fig. 1(d). Such a model applies to structures with charge-free regions separating the electrons from holes. Epitaxial samples with pure, trap-free buffer layers or wide junction regions are experimental realizations. We have with the sharp-front assumption

$$\Delta(nd) = (x_3 - w)Z, \quad x_s(t) \le w \tag{13a}$$
$$= [(x_3 - x_s(t)]Z, \quad x_s(t) > w \, , \tag{13b}$$

which results in

$$\Delta(nd) = (x_3 - w)Z, \quad x_s \le w \tag{14a}$$
$$= x_3 Z - \tfrac{1}{2}aZ \ln[1+(t/\tau_0)], \quad x_s > 1 \, . \tag{14b}$$

For times $t < \tau_0[\exp(2w/a) - 1]$, there is essentially no PP decay yet, then a logarithmic decay begins. This case can thus be treated with a shift in time scale that can be so large that a true persistence without any reduction of the photoconductivity may be observed; the effective lifetime is now $\tau_0 \exp(2w/a)$.

4. Triangular distribution

For triangular distribution (see Fig. 4), the initial charge here is

$$p(x, t=0) = (Z/x_2)(x_2 - x), \quad x \le x_2 \tag{15a}$$
$$= 0, \quad x > x_2 \tag{15b}$$

and

$$\Delta(nd) = (Z/x_2)[x_2 - x_s(t)] \, , \tag{16}$$

when the sharp-front approximation of Sec. III B is applied. One then obtains

$$\Delta(nd) = K - \tfrac{1}{2}Za \ln[1+(t/\tau_0)]$$
$$+ Z^2(4K)^{-1} \left[\frac{a}{2}\right]^2 \ln^2[1+(t/\tau)] \, , \tag{17}$$

where K is $\Delta(nd)$ for $t=0$. The second term accounts for the deviation from the simple logarithmic decay law of Eq. (11); the steadily decreasing number of trapped charges encountered by the advancing front $x_s(t)$ makes the decay steadily slower. The same general trend is observed for the case of the Fermi distribution, as discussed in Sec. III C 1. Many experimental curves indeed show such deviations from the simple logarithmic law, thus indicating the expected spatially decreasing trapped charge. All these cases ought then be treated by Eq. (17), which represents a closer approximation, or with a numerical fit by Eq. (6).

D. Theoretical refinements

The cases treated are one-dimensional models, particularly appropriate for thin epitaxial films with plane interfaces. Similar treatments can be found for spherical geometries demanded by inclusions or inhomogeneities in doping and composition or cylindrical geometry for dislocations. These cases can be treated with the same basic model.

Well-defined structures and accurately controlled spatial charge profiles could be used to test the physical details of the recombination and to investigate if laws other than the simple exponential ansatz of Eq. (1) are valid, such as a dipole interaction or other, more refined treatments of wave-function overlap and carrier capture, as

well as details of the potential in the semiconductor.

Our treatise holds for low temperatures since a stationary trapped charge is assumed. Finite temperatures release charge and transport it toward $x=0$, i.e., closer to the excess electrons. This transport accelerates the motion of the front, thus accelerating decay. Other transport, such as impurity-band conduction, hopping, or tunneling, can arise even at low temperatures, especially for large trap densities. This is also neglected here and would also accelerate PP decay.

The illumination dose influences PP and its buildup[10] and decay. The cumulative photon input determines the initial distribution $p(x, t=0)$. Consider the Fermi profile, where an enhanced dose extends x_f to greater depth. A larger $p(x, t=0)$ results and consequently a larger excess conductivity. The decay rate $d\Delta(nd)/dt$ remains unaffected as long $x_s(t)$ traverses regions of saturated traps. The remaining long-time storage will be larger because of the enhancements at greater depths. Decay curves for PP at various input illumination doses should thus be parallel curves, such as a family of parallel lines in a $\Delta\sigma$-versus-log(t) plot. The same holds for wavelength dependences, which can be converted into dose dependences by considering the efficiency of creating carriers via band-to-band or band-to-defect optical transitions. Photons with energies below the gap energy can create electron-hole pairs by two-step excitation involving traps, which has been observed not only in defect-rich materials but also in high-purity GaAs.[46]

The theory presented here indicates an essentially logarithmic time decay of the light-induced excess conductivity. This result explains why the observed PP decay is usually *not* exponential. Expectation of a law $\Delta(nd)\sim\exp(-t/\tau_e)$ is unjustified. It is unrealistic to attribute several lifetimes τ_e to force fit the decay of PP by assuming different physical mechanisms of recombination. Assumption of a spread in energies and cross sections of traps are also artificial. Rapid and slow decay result from identical physical mechanisms, but involve different spatial separations.

Nonexponential relaxation is a common phenomenon, first described by Kohlrausch.[47] The time-extended exponential $\exp[(-t/\tau_0)^\gamma]$ is often used to fit experimental data, where τ_0, $0<\gamma<1$, and a prefactor provide three adjustable parameters for this Kohlrausch relaxation, now of renewed interest.[48] Our data can likewise be fitted, but without physical significance.[49]

Observations of a logarithmic decay strongly suggest a spatial separation. Microscopic models, such as those assuming large lattice distortions with concomitant atomistic barriers, predict recombination rates to be governed by monomolecular or possibly bimolecular reaction kinetics.

IV. EXPERIMENTAL

A. Technique

Our measurements are performed with an automated apparatus[10] in the van der Pauw configuration.[50] The sample is immersed in He gas in a cryostat. Light from a tungsten halogen lamp is filtered and transmitted through a quartz fiber onto the sample. The contacts are shielded against light by masks.

The n-type GaAs epitaxial layers are grown by liquid-phase epitaxy on semi-insulating Cr-doped GaAs substrates. They have cloverleaf or rectangular shapes. Ohmic contacts are achieved by alloying with tin. The n-type (Al,Ga)As samples are grown by molecular-beam epitaxy (MBE) on semi-insulating GaAs substrates. The samples have cloverleaf or rectangular shapes; Ohmic contacts were made by alloying with indium. Some specimens have (AlGa)As or GaAs buffer layers. To measure the decay of PP, we illuminate with a sufficient photon dose to saturate the PP, or with an intermediate dose.

B. Results and interpretations

Figure 5 shows results for GaAs at $T=50$ K for two photon doses. The density $\Delta(nd)$ decays fast at the beginning and approaches an almost steady state with an extremely low rate of decay where the conductivity is considerably larger than in the dark virgin state $(nd)_0$ prior to illumination. All GaAs samples display similar results independent of dose. A change of dose Q results in a parallel shift of the $\Delta(nd)=f(t)$ curves; see Fig. 5. A similar shift has been observed in $Al_xGa_{1-x}As$ samples.[38] The interpretation is given in Sec. III D.

Figures 6 and 7 give results for two $Al_xGa_{1-x}As$/GaAs samples at 4 K. The PP decay is geometry dependent. The thickness of the layers and presence or absence of undoped buffer layers determine decay, as expected for spatial carrier separation by barriers. Sample A (of Fig. 6) with a narrow buffer layer displays a logarithmic decay. Sample B of Fig. 7, however, has no measurable decay, although its PP is about 30% of dark conductivity. This sample had a buffer, as was discussed in Fig. 1(d) and Sec. III C 3. This buffer between the free electrons

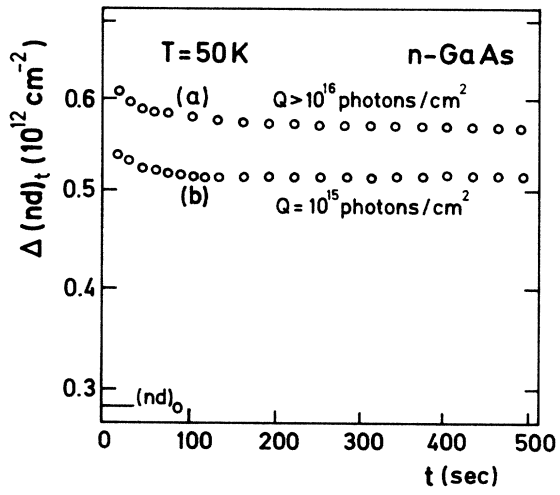

FIG. 5. Experimental persistent electron density $(nd)_t$ as a function of time t after illumination switch off for an n-GaAs sample at $T=50$ K. Curve A measured after illuminating with a total photon dose $Q>10^{16}$ photons/cm^2, to get saturation. Curve B after illumination with a smaller photon dose $Q=10^{15}$ photons/cm^2. A parallel shifting of the decay curves results. The electron density $(nd)_0$ is measured before illumination.

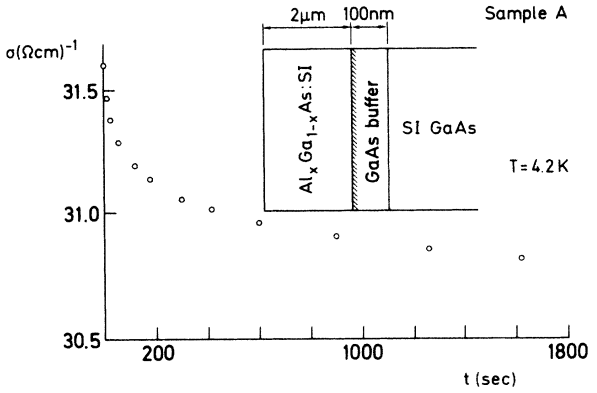

FIG. 6. Persistent photoconductivity σ as a function of time after switching off the illumination for $Al_xGa_{1-x}As$ sample A, ($x=0.34$), at temperature $T=4.2$ K. The sample structure is described in the inset. The PP decay is logarithmic. The two-dimensional electron gas occurs in the hatched area. (SI denotes semi-insulating.)

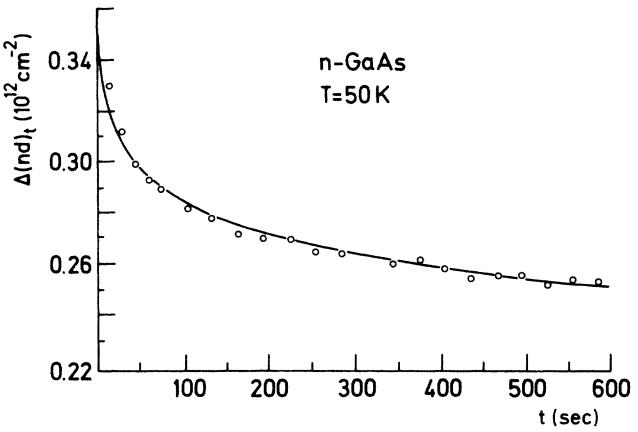

FIG. 8. Persistent electron density $\Delta(nd)_t$ as a function of time; sample at a temperature $T=50$ K. Points are measured, solid line is theory from Eq. (11).

and the trapped holes thus leads to immeasurably long lifetimes, as predicted.

As merely one example, we show a quantitative fit with theory for a GaAs sample in Fig. 8. The rate of decay, as given by Eq. (11), depends on the product of Bohr radius a times trap volume density Z, also on τ_0. Using the values of $a=10^{-6}$ cm (as calculated in a hydrogenic model with the electron effective mass), $\tau_0=1.1\times10^{-9}$ s (from luminescence experiments), and $Z=5\times10^{-16}$ cm^{-3}, we obtain a good fit to the experimental points.

The more complicated heterostructure samples have not yet enabled us to present a reliable quantitative fit. These samples have many competing recombination channels because the charge is stored in more than one region of the heterostructure. An additional complication in the measurements of the decay of PP is generally ignored although it plays a role especially in heterostructures. The electrical contacts on the external layer are not usually confined to the top layer only, but they penetrate into the substrate. The existence of such transport paths via the contacts is hinted at only for the buildup of PP in Ref. 36, where it is stated that the electrons in the conduction band of $Al_xGa_{1-x}As$ that are excited from DX centers move through the alloyed indium contacts into the GaAs channel. An observation shows the likelihood of such a recombination channel: A van der Pauw conductivity measurement on $Al_xGa_{1-x}As$ samples yields faster decay than a conductivity measurement. In the van der Pauw measurement,[50] voltages are alternately applied on different contact pairs providing recombination through the contacts.

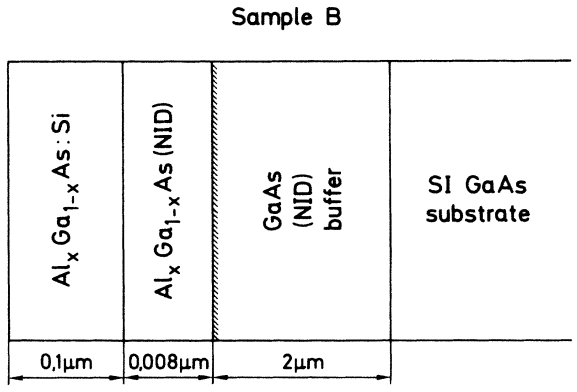

FIG. 7. Schematic of an $Al_xGa_{1-x}As$ sample B ($x=0.30$) with thick buffer layer between the conductivity area and the GaAs substrate. This sample shows PP of about 30% of dark conductance, but *no* measurable decay as expected from the large distance between the recombining charges. The two-dimensional conduction occurs in the hatched area. (NID denotes "not intentionally doped.")

V. CONCLUSION

Persistent photoconductivity can be caused by a separation of photogenerated charge carriers at macroscopic potential barriers. This model predicts specific decay rates after termination of the illumination. An essentially logarithmic decay is most characteristic and distinguishes this model from others, where charge is separated in wave-vector space or in configurational coordinate space.[6] This characteristic logarithmic decay rate has been observed in layered structures of compound semiconductors.

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