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# Mechanism of Anomalous Photoinduced Transient Current Peak in Amorphous Silicon Thin-Film Transistor

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# Mechanism of anomalous photoinduced transient current peak in amorphous silicon thin-film transistor

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The photoinduced transient current from an amorphous silicon thin-film transistor is computed and the mechanism described in terms of trap-state filling dynamics. The direction of the current flow and the location of the transient peak depends strongly on the distributions of donorlike and acceptorlike trap states in the neighborhood of the dark Fermi level. We show that the transient current can flow in the same direction as in the crystalline transistor, as well as in the opposite direction. There is also an interesting cross-over behavior in which the transient current flows out of the drain terminal as a pulse of positive charge, and then immediately reverses its direction. There is a broadening effect of the transient peak by a simultaneous switch on of the gate voltage. The transient peak typically occurs at $10^{-4}$ s and an example is provided. The transient current can be greatly diminished by switching the gate voltage long before illumination, or by doping the channel either partially or completely.  [S0021-8979(97)07909-7]

## I. INTRODUCTION

Hydrogenated amorphous silicon ($a$-Si:H) thin-film transistors (TFTs) have been widely used for active-matrix liquid crystal displays for years. Illumination of the liquid crystal in these displays is achieved by using a fluorescent backlight. Thus, the performance of $a$-Si:H TFT will be greatly affected under backlight illumination as compared to its performance in a dark situation. With backlight, photoinduced electron-hole pairs are added into the carrier transport in the amorphous silicon layer. Several authors[1–5] have investigated the reduced on-off current ratio under illumination and the photoconductivity of amorphous silicon. Hepburn *et al.*[6–8] first investigated the transient discharge current of TFT under illumination. Their experimental method involved tying together the source and drain terminals to measure the discharge current after first turning on the gate voltage. The variation of the amount of discharge is related to the density of interface dangling bonds and the instability mechanism of the transistor. Their experimental method was subsequently employed by Fortunato *et al.*[9–13] to study space charge photomodulation. Their transient photocurrents, induced by turning a light on and off, were measured when a gate voltage was applied.

In this work, we will describe the existence and the basic mechanism of an anomalous photoinduced transient current. We want to emphasize that the transient peak in an $a$-Si:H TFT can be an anomalous one because the current can be in the opposite flowing direction as compared to that of a crystalline field-effect transistor. The connection between the transient current flowing direction after the light is turned on and the trap-state filling dynamics is clearly presented here for the first time. This can be easily proved when there is no applied gate voltage. There is a broadening effect of the transient current peak when an additional gate voltage is applied. Fortunato and his collaborators[9–11] have concentrated on such a gate voltage effect in terms of space-charge modulation. Here, we present our findings from the trap-state filling dynamics and the trap-state distributions when the gate voltage is absent, or when the gate voltage is simultaneously switched on. We note that various mechanisms can cause a transient current peak. For example, a different kind of transient current peak that is totally due to source-drain dopings has been studied by Hack *et al.*[2] However, such a transient peak is not photoinduced as we have investigated here.

First, let us clarify the current flowing direction of transient photocurrent. In the simplest situation of a perfect crystalline silicon field-effect transistor, instead of an amorphous silicon one, under uniform illumination and with no applied voltage, it is obvious that photogenerated electron-hole pairs will eventually diffuse equally left and right out to the source and drain terminals. At steady state, the total current on each terminal is zero, since there are equal amounts of electron and hole currents coming out of each side. However, it is easy to see that, because electron has higher diffusion constant, electrons will arrive at the source or drain terminal sooner than the holes. Thus, the drain current will exhibit a peak and the source current will have a similar peak in the opposite direction. This is shown in Fig. 1 for the drain current of a crystalline silicon transistor. The drain current, $I_d(t)$, consists of electron component, $I_n(t)$, hole component, $I_p(t)$, and displacement current, $I_{dis}(t)$. $I_{dis}(t)$ is shown to be very small at all times. $I_n(t)$ starts from zero and rises at a slope to a steady-state value, roughly at the transit time, $t_n = \ell^2/4D_n$, where $\ell$ is the channel length, and $D_n$ the electron diffusion constant. Similarly, $I_p(t)$ reaches its steady state value at time, $t_p = \ell^2/4D_p$, where $D_p$ is the hole diffusion constant. Since $D_n > D_p$, the drain current will have a "positive peak" located at time equals to $1/2(t_p + t_n)$, indicating that there is a pulse of positive charge flowing "into" the drain terminal at that time. For $\ell = 10\ \mu$m, this peak current occurs at $10^{-8}$ s for the silicon transistor as shown in Fig. 1. If the crystalline silicon material is replaced by a hydrogenated amorphous silicon, it is easy to believe that, because the electron and hole mobilities are two orders of magnitude smaller than the crystalline ones, the corre-

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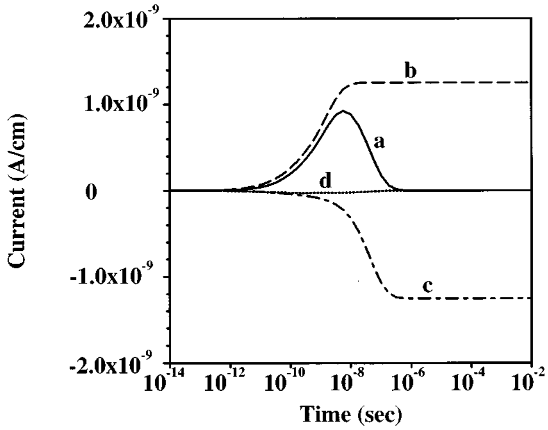


FIG. 1. Transient terminal drain current and its components: Curve a, $I_d$, total drain current, curve b, $I_n$, the electron component; curve c, $I_p$ the hole component, and curve d, $I_{\mathrm{dis}}$, the displacement current component. The decompositions of $I_d$ into $I_n$, $I_p$, and $I_{\mathrm{dis}}$ are shown throughout the remaining figures.

sponding drain current peak will also have a positive value at a location that is simply moved down two orders of magnitude in the time scale. Such an intuition is incorrect. In amorphous silicon material, the amount of trap states in the band gap is so large that the dominant time scale is the trap-state filling time, and not the transit time, as one of us and his collaborators has shown earlier.[14–17] Depending on trap-state distributions, it is possible for the hole current to rise to its steady state value earlier than that of the electron current. Thus, the total drain current, $I_d(t)$, actually exhibits a ''negative'' peak, indicating that a pulse of positive charge flows ''out'' of the drain terminal. We will provide a detailed discussion of this anomalous transient current peak that can exist only in disordered semiconductors. By changing the amount of trap states and their altered distributions due to sample preparation methods, we show that the drain current peak can change its flow direction from positive to negative. This change is closely related to the amount of acceptorlike and donorlike trap states in the neighborhood of the Fermi level before the light is turned on. In addition, we have discovered the existence of an interesting cross-over behavior (Sec. IV). In Sec. II, we describe our computation scheme and in Sec. III we describe the geometries of $a$-Si:H TFT used for the computation. Since the transient current peak location is at a measurable time scale of $10^{-4}-10^{-6}$ s range, a realistic $a$-Si:H TFT device is modeled and transient current is computed for future experimental verification. From such an experiment, one can correlate the sign of the transient current peak with the distribution of the midgap trap states of the deposited amorphous silicon thin film.

## II. GENERAL COMPUTATION METHOD FOR PHOTOINDUCED TRANSIENT CURRENT IN DISORDERED SEMICONDUCTORS

Here we outline the method to compute transport of carriers in a disordered semiconductor which is characterized by the existence of a large amount of donorlike and acceptorlike trap states continuously distributed in the band gap. The occupation function, $f(x,y,E,t)$, of those trap states, which is a function of our two-dimensional variables, $(x,y)$, and trap-state energy level, $E$, at time, $t$, is the center part of our computation. From Simmons–Taylor statistics,[18] the time evolution of the occupation function satisfies

$$\frac{\partial f}{\partial t}=\nu\sigma_n n(1-f)-e_n f+\nu\sigma_p p f-e_p(1-f), \tag{1}$$

where $n(x,y,t)$ is the electron concentration and satisfies a proper time-dependent electron continuity equation.[15] $\sigma_n(\sigma_p)$ is the electron (hole) trap-state capture cross section, $\nu$ is the thermal velocity, and $e_n(e_p)$ is the electron (hole) emission rate from the trap-state level, $E$, to the conduction (valence) band. Similarly, the hole concentration, $p(x,y,t)$, satisfies a proper time-dependent hole continuity equation. In addition, the large amount of space charge, $\rho(x,y,t)$, can be decomposed into the following terms:

$$\rho(x,y,t,)=q(p-n+N_d^+-N_a^-+N_{dt}^+-N_{at}^-), \tag{2}$$

where

$$N_{dt}^+=\int_{Ev}^{E_c}D_{dt}(E)(1-f)dt \tag{3}$$

is the trap charge from the donorlike trap-states of density, $D_{dt}(E)$, and

$$N_{at}^-=\int_{Ev}^{E_c}D_{at}(E)f dt \tag{4}$$

is the trap charge from the acceptorlike trap states of density, $D_{at}(E)$, and $N_a^+$ and $N_a^-$ are the usual ionized dopants from donors and acceptors.

As mentioned in the introduction, there are three time derivatives: $\partial f/\partial t$ from Eq. (1); $\partial n/\partial t$ from the continuity equation of electrons; and $\partial p/\partial t$ from that of holes. It is $\partial f/\partial t$ that dominates the transport process. Since $\partial f/\partial t$ determines the trap-state filling time and $\partial n/\partial t$ or $\partial p/\partial t$ determines the transit time, we conclude that transient current is determined by the trap-state filling process. The three time-dependent differential equations for $n(x,y,t)$, $p(x,y,t)$, and $f(x,y,E,t)$ are solved numerically along with the corresponding Poisson equation whose space charge term, $\rho(x,y,t)$, is given by Eq. (2).[15] Essentially, we compute the free electron and hole concentrations from the photogeneration and from the dark concentrations with or without applied voltages. Carriers are drifted and diffused along the channel as governed by the two continuity equations. In the process, carriers go through the multiple trapping processes as governed by the dynamics of the occupation function in Eq. (1). This in turn changes a local electric field, as governed by the corresponding Poisson equation, which in turn changes the local free electron and hole concentration as specified by the two continuity equations. The numerical values of $n,p$, electric potential, and $f$ are solved iteratively for a given time. The results presented here are computed using Semicad.[19] We first tested this Semicad program against our own written, but slower program, in which we published our

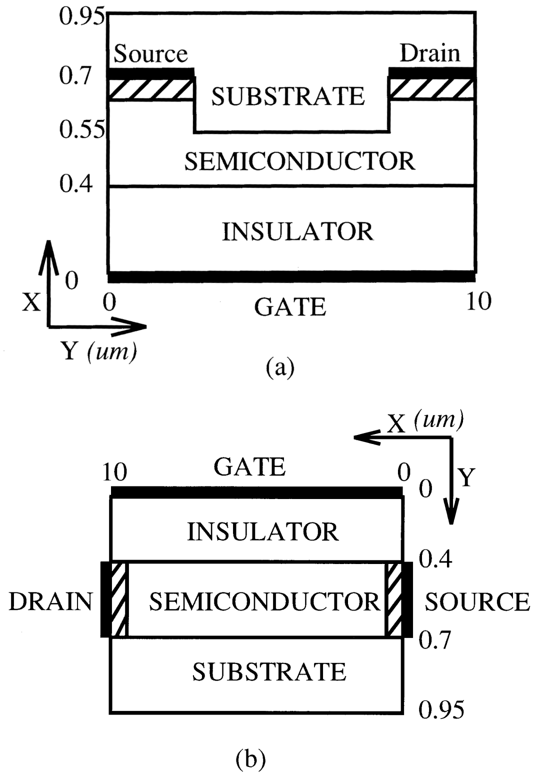


FIG. 2. Device geometries investigated: (a) shows a realistic $U$-shaped geometry of $a$-Si:H TFT with source and drain dopings indicated by the two shaded areas, (b) shows a rectangular geometry of $a$-Si:H TFT. In the computation $l=10$ $\mu$m (channel length), $\mu_n=20$ cm$^2/V-S$ and $\mu_p=0.2$ cm$^2/V-S$ are used.

earlier results.[14–17,20] The agreements are quite good and the Semicad program is a lot more efficient in computing time, even though the program is not yet perfect.

## III. DEVICE GEOMETRIES

We have investigated two basic geometries. A realistic $U$-shaped $a$-Si:H TFT with source-drain dopings is shown in Fig. 2(a). However, for our basic understanding of photoinduced transient current peak, a rectangular amorphous silicon layer with no source-drain dopings, shown in Fig. 2(b), is more important and is investigated first. The additional geometrical bending of the channel and the doping of the source/drain regions slightly modify the results from that with a rectangular geometry. These effects are discussed separately in the later cases. The gates are drawn at the bottom on top of a substrate to reflect one of the popular deposition processes.

## IV. PHOTOINDUCED TRANSIENT SOURCE AND DRAIN CURRENTS

The basic physics of photoinduced transient currents can be easily obtained using a simple rectangular geometry as shown in Fig. 2(b). Since those transients depend strongly on the distributions of donorlike and acceptorlike trap states, we have used three different sets of those densities of trap states from three available and typical data.[3,15,19,21,22] They are shown in Fig. 3 where curves a, b, and c correspond to high,

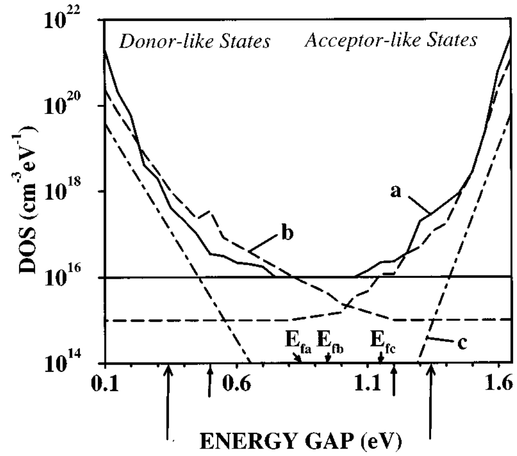


FIG. 3. Densities of donorlike and acceptorlike trap-state distributions in amorphous silicon used in the numerical simulation: curves; a, high density of trap-state distributions (see Ref. 3): b, medium density of trap-state distributions (see Ref. 19); c, low density of trap-state distributions (see Ref. 15). The dark Fermi levels are indicated by $E_{\mathrm{fa}}$, $E_{\mathrm{fb}}$, and $E_{\mathrm{fc}}$. The range of partial filling due to illumination are indicated by short arrows for a fluorescent light illumination and by long arrows for sunlight illumination.

medium, and low densities of trap states, respectively. The high density of trap states in Fig. 3, curve a is studied first to illustrate the negative photoinduced transient current peak as mentioned in the introduction.

### A. Case (1): Uniform illumination with no applied voltage

Under uniform and continuous illumination, the occupation function, $f(x,y,E,t)$, at any location will change from a Fermi-distributionlike function to a function that exhibits partial fillings of donorlike and acceptorlike states in the midgap. This is illustrated in Fig. 4 for a position at the top midchannel. The dark Fermi level is at $E=0.85$ eV. Under the illumination, the energy range of partial fillings, at $f=0.65$, is from $E=0.5$ eV (hole trap quasi-Fermi level) to $E=1.2$ eV (electron trap quasi-Fermi level). The energy

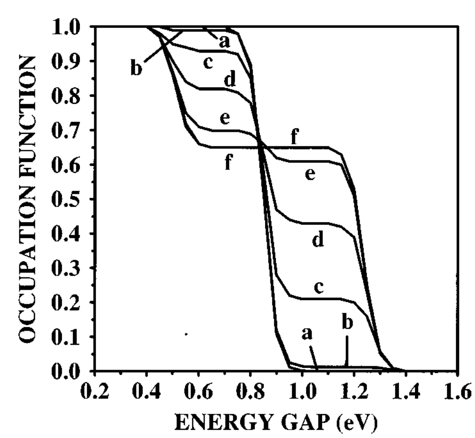


FIG. 4. Occupation function at the top midchannel location under a fluorescent light illumination with no applied voltage: High density of trap states of Fig. 3, curve a is used. Each curve is for a different time: curves; a, $10^{-14}$ s; b, $10^{-4}$ s; c, $1\times10^{-3}$ s; d, $3.2\times10^{-3}$ s; e, $10^{-2}$ s; and f, $10^{-1}$ s to steady state.

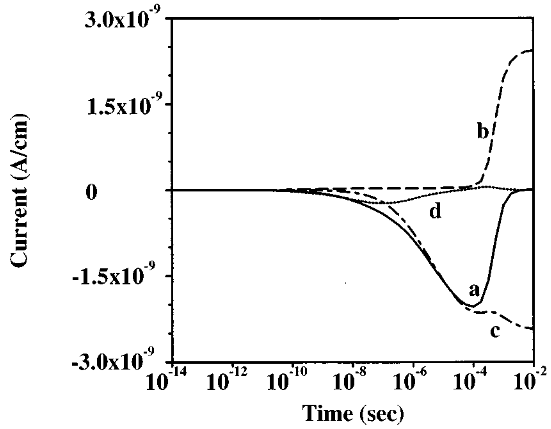


FIG. 5. Terminal drain current and its components: curves; a, is equal to $I_d$; b, is equal to $I_n$; c, is equal to $I_p$; and d, is equal to $I_{\text{dis}}$. High density of trap states in Fig. 3. curve a is used. This figure can be compared to the corresponding crystalline silicon transistor of Fig. 1. Note that the drain current, $I_d$, is in the opposite flowing direction and that the displacement $I_{\text{ds}}$ is always small.

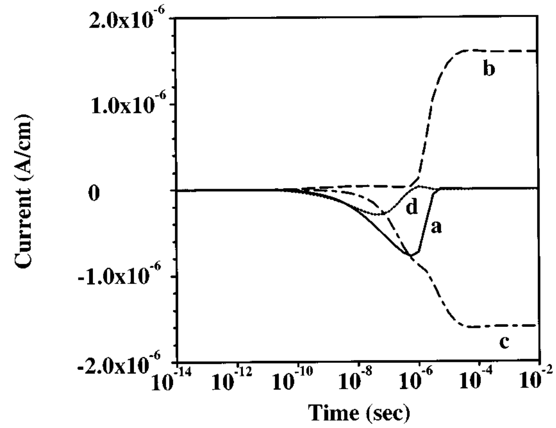


FIG. 6. Terminal drain current, $I_d$, and its components: a, $I_d$; b, $I_n$; c, $I_p$; and d, $I_{\text{dis}}$. The high density of trap states in Fig. 3, curve a is used. Compared to Fig. 5, we note that when the illumination intensity is increased, the value of the transient current peak is larger and the location of the current peak is moved to the left of time scale because more electron-hole pairs are generated to fill the trap states.

range of this partial filling depends on illumination intensity. If sunlight is used, the energy range of partial filling is from $E = 0.35$ to 1.35 eV. In our calculations, a fluorescent light spectrum is simulated at a black-body radiation of temperature at 2000 °K. Sunlight spectrum is simulated at a black-body radiation of temperature at 6000 °K. By observing Fig. 3, curve a at the energy range of partial fillings, we note that there are more electrons to be filled than holes in the trap states because the density of acceptorlike trap-states is much larger than that of the donorlike trap-states in the midgap range. Thus the acceptorlike trap states filling time, $\tau_{nt}$, is longer than the donorlike trap-state filling time, $\tau_{pt}$. The result is that the electron current, $I_n(t)$, will rise later than the hole current, $I_p(t)$. This is exactly the opposite situation of the corresponding crystalline silicon case. The difference in the two trap-state partial-filling times results in a transient current peak. The slope of the current rise of $I_p(t)$ $[I_n(t)]$ is clearly related to the donorlike (acceptorlike) trap-state distribution. Thus the shape of the transient peak is asymmetrical. This is shown in Fig. 5 from an illumination by a fluorescent light. At this low light intensity, the photoinduced electron concentration is approximately $10^{13}$ $\text{cm}^3$. The result corresponding to that of an illumination from sunlight is shown in Fig. 6. The steady-state photoelectron concentration is $10^{15}$ $\text{cm}^3$ and the transient current is consequently higher. For a comparison the transient current of crystalline silicon is shown earlier in Fig. 1. Note that from Figs. 1, 5, and 6 the component of displacement current is always very small. If the amount of trap states is low, as in the case of Fig. 3, curve c, the transient current peak becomes positive as in the crystalline case, except that the location of the current peak is moved down two orders of magnitude in time scale as shown in Fig. 7. In this case, more hole trap states are to be filled than the electron trap states in the midgap. If the medium amount of trap states as in Fig. 3, curve b is used, the transient current exhibits an interesting cross-over behavior. This is plotted in Fig. 8 for comparison. The locations of electron and hole current rise times, $\tau_{nt}$ and $\tau_{pt}$, and the slopes of those rises determine the cross-over transient. Thus, we clearly show that there is a correlation of transient current peaks with the distributions of donorlike and acceptorlike trap states in the midgap.

### B. Case (2): Uniform illumination with simultaneous switch-on of source-drain voltage

When a source-drain voltage of the TFT is switched-on simultaneously with the illumination, the steady-state current will be nonvanishing. This deviates from the condition of $I_n(t=\infty)=I_p(t=\infty)$ at the zero-bias situation because now there are net electrons flowing into the drain terminal. In this case, the value of the $I_n(t)$ component will increase and the $I_p(t)$ component will be less negative at the steady state in order to accommodate this condition.

If the source-drain voltage is positive, the Fermi level will shift towards the valence band, indicating that less elec-

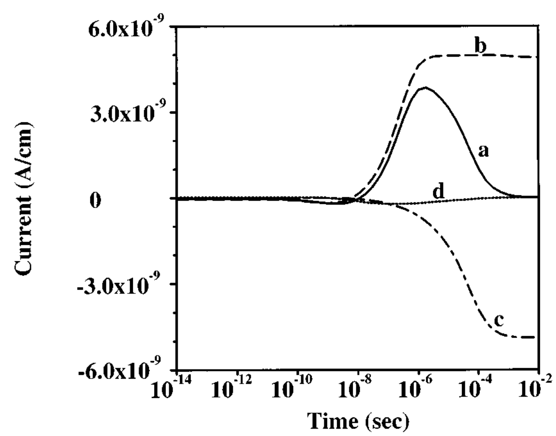


FIG. 7. Terminal drain current, $I_d$, and it's components: curves; a, $I_d$; b, $I_n$; c, $I_p$; and d, $I_{\text{dis}}$. The low density of trap states in Fig. 3, curve c is used. Note that the transient current peak is positive which is opposite to the sign in Fig. 5. In addition, the location of the transient peak is two orders of magnitude longer as compared to that of Fig. 1 of the crystalline case.

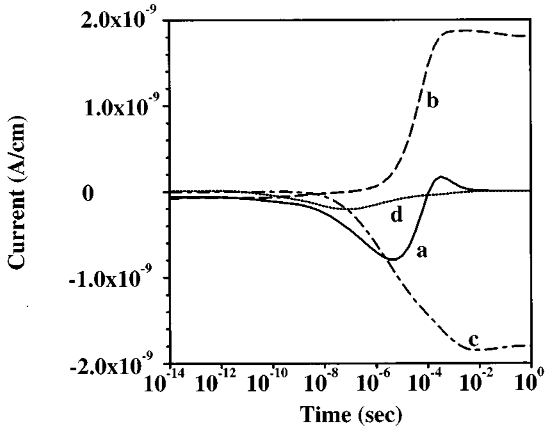


FIG. 8. (a) Terminal drain current, $I_d$, and its components: curves; a, $I_d$; b, $I_n$; c, $I_p$; and d, $I_{\rm dis}$. (b) Terminal source current, $I_s$, and its components: curves; a, $I_s$; b, $I_n$; c, $I_p$; and d, $I_{\rm dis}$. The medium density of trap states in Fig. 3, curve b is used. Note that the transient current exhibits an interesting cross-over behavior.

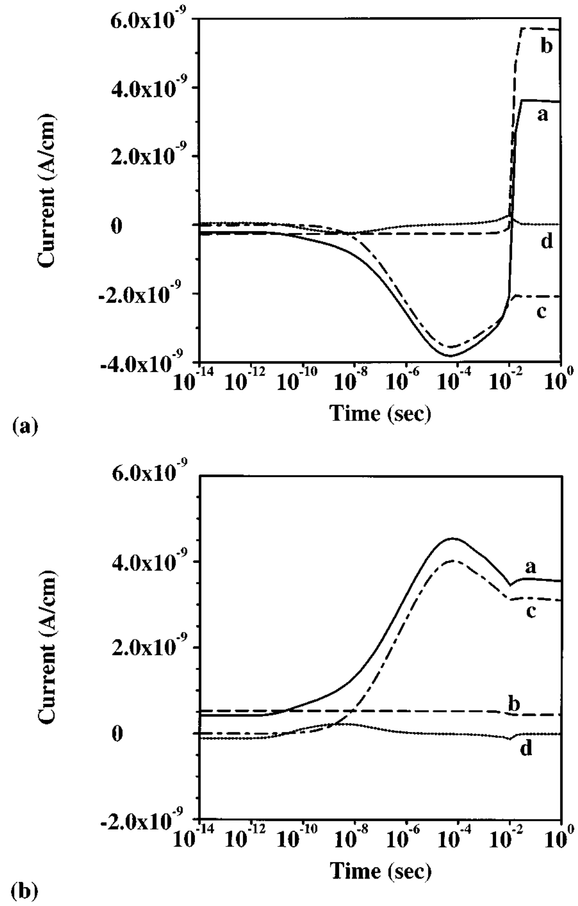


FIG. 10. Effect of source and drain dopings on $I_d$ and $I_s$. (a) is for terminal drain current, $I_d$, and its components: where curves: a, $I_d$; b, $I_n$; c, $I_p$; and d, $I_{\rm dis}$. (b) is for terminal source current, $I_s$, and its components: where curves; a, $I_s$; b, $I_n$; c, $I_p$; and d, $I_{\rm dis}$. Here $V_D = 5$, $V_G = 10$ V, and the source/drain doping level is at $10^{15}$ cm$^{-}$. The high density of trap states in Fig. 3, curve a is used. Note that $I_s$ peak is larger than $I_d$ peak.

tron trap states and more hole trap states are to be filled. Thus, the $I_p(t)$ curve will rise at a later time and the $I_n(t)$ curve will rise at an earlier time. This results in a reduction of the drain transient current peak. At $V_D = 0.1$ V, the transient current peak is still visible. This peak will exhibit a cross-over behavior at $V_D = 0.2$ V. As $V_D$ is increased to 1 V, the peak becomes positive. At $V_D = 5$ V, the current is totally determined by the electron component and thus no transient peak is observable. In Fig. 9, we show the transient drain currents for both positive and negative $V_D$.

### C. Case (3): Effect of additional source/drain dopings

We note that the amount of electron density in the channel is of the order of $10^7$ cm$^{-3}$ from Fig. 3, curve a, and the photogenerated electron concentration is in $10^{13}$ to $10^{15}$ cm$^{-3}$ range. If the amount of electron concentration is further increased through doping or through an earlier applied gate voltage, then the effect of photogenerated electron-hole pairs become less pronounced as one would expect.

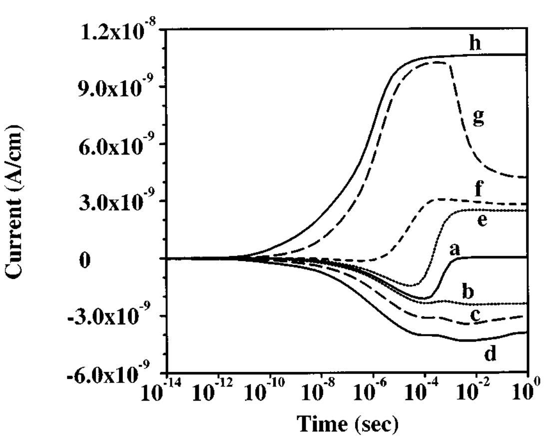


FIG. 9. Transient terminal drain current, $I_d$, as function of time. This is computed under a fluorescent light illumination with a simultaneous switch on of an applied source-drain voltage. The high densities of trap states in Fig. 3, curve a is used. Each curve is for a different applied source-drain voltage: curves; a, $V_D = 0$; b, $V_D = 0.1$; c, $V_D = 1$; d, $V_D = -5$; e, $V_D = 0.1$; f, $V_D = 0.2$; g, $V_D = 1$; and h, $V_D = 5$ V. Note that the transient current peak is destroyed under a high source-drain voltage.

If the two small regions near both source and drain are doped, as in a typical TFT indicated in Fig. 2(a), the transient current peak will be reduced. At the doping level of $10^{15}$ cm$^{-3}$, the transient peaks are as shown in Figs. 10(a) and 10(b) at the drain and source terminals. At this low doping level, the effect of dopings on the transient current is small. As the doping level is increased further, the transient photocurrent peak will gradually vanish. In this situation, the high electron concentration from doping starts to dominate the whole transport process if we compare the amount of photogenerated electron-hole pair concentration with that of electron concentration from the doping.

### D. Case (4): *U*-shaped TFT with source/drain dopings

Since *a*-Si:H TFT is typically fabricated with a *U*-shaped channel as in Fig. 2(a) with source/drain dopings for their better static current–voltage characteristics, we compute the transient current peak for the device shown in

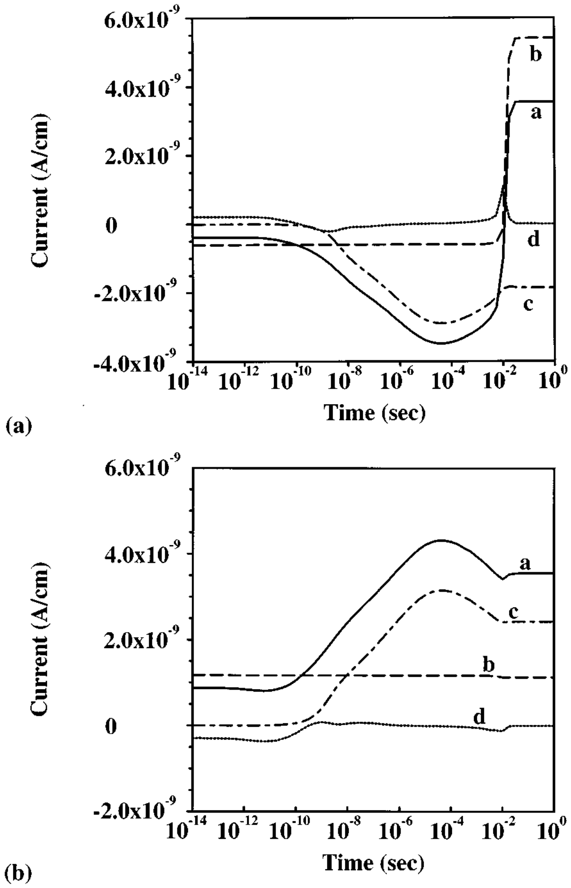


FIG. 11. Drain and source terminal currents calculated from the $U$-shaped device geometry of Fig. 2(a). (a) is terminal drain current $I_d$ and its components: where curves; a, $I_d$; b, $I_n$; c, $I_p$; and d, $I_{\mathrm{dis}}$. (b) is for terminal source current $I_s$ and its components: where curves; a, $I_s$; b, $I_n$; c, $I_p$; and d, $I_{\mathrm{dis}}$. Here $V_D=5$, $V_G=10$ V, and the source/drain doping level is at $10^{15}$ cm$^{-3}$. The high density of trap states in Fig. 3, curve a is used.

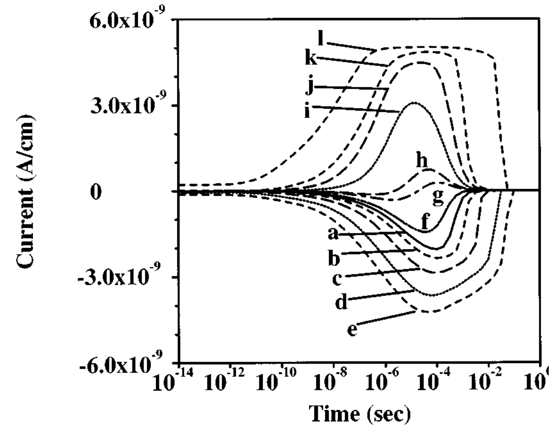


FIG. 12. Transient terminal drain current, $I_d$, as function of time. Each curve is for a different applied gate voltage: curves; a, $V_G=0$; b, $V_G=0.2$; c, $V_G=1$; d, $V_G=5$; e, $V_G=15$; f, $V_G=-0.1$; g, $V_G=-0.18$; h, $V_G=-0.2$; i, $V_G=-0.3$; j, $V_G=-0.5$; k, $V_G=-1$; and l, $V_G=-15$ V. Note that an interesting cross-over behavior occurs at $V_G=-0.18$ V in curve g.

Fig. 2(a). This is shown in Fig. 11 for simultaneous switch-on of source-drain voltage, $V_D=5$ V, and gate voltage, $V_G=10$ V. The source/drain doping level is set at $10^{15}$ cm$^{-3}$. Here we show that the transient peak is measurable experimentally at $t=10^{-4}$ s, using the high density of trap states in Fig. 3, curve a. As mentioned in Case (3), this transient current peak will disappear at a higher source/drain doping level, of about $10^{18}$ cm$^{-3}$. As the doping level is increased, the $I_n(t)$ component is increased and the $I_p(t)$ component is decreased, so that $I_d \approx I_n(t)$ is reached at high doping level.

### E. Case (5): Simultaneous switch-on of gate voltage and illumination

Simultaneous switching-on of a gate voltage with the illumination will bring additional carriers into the channel when electron-hole pairs are being generated by illumination. If the gate voltage is positive, additional electrons will be pulled into the channel from the drain terminal. Thus, the rise time for the electron component current, $I_n(t)$, flowing ''out'' of the drain terminal is delayed. The gradual Fermi-level shift towards the conduction band also implies that less holes are to be filled. Thus, the rise time for the hole-component current, $I_p(t)$, will be shortened. The net result is that the higher the gate voltage, the broader and larger the transient-current peak. This is shown in the lower half of Fig. 12. If the gate voltage is negative, then holes will be pulling into the channel and the Fermi level will be shifting towards the valence band. Thus, less electron trap states are to be filled. Hence, $I_n(t)$ rise time is shortened, and $I_p(t)$ rise time is delayed and is now later than that of $I_n(t)$. The net result is that the transient drain current peak is now positive. This is shown in the upper half of Fig. 12. It is interesting to note that when the gate voltage is small, e.g., $V_g \approx -0.18$ V, there is cross-over behavior as shown in Fig. 8. Partial filling in this situation is at $f = 0.5$. This is again due to two different slopes of the electron and hole current rise times as we discussed earlier. However, in this case, the transient-current peak is not purely photoinduced because a transient gate current is also included.

Thus, here we show that, instead of using different samples to change trap-state distributions, the transient current peak can also be manipulated by applying a gate voltage in a nonpure photoinduced method. We note here that if the gate voltage is switched on long before the illumination, then there is already a significant amount of negative (positive) carriers present in the channel when the gate voltage is positive (negative). The higher the amount of carriers present due to a gate voltage as compared to the amount of photogenerated electron-hole pairs, the greater the reduction of transient drain current peak. This makes the transient current peak less observable experimentally. This is indeed the situation as was investigated by Fortunato and his collaborators.[9–13] Doping the whole channel or partly near source and drain regions will have a similar effect on the photoinduced transient current as in the case from an applied gate voltage. When the amount of carriers present in the channel is greater than that of photogenerated electron-hole pairs, there is no longer meaningful photoinduced transient current peaks.

## V. CONCLUSION

We show that photoinduced transient current peaks are associated with differences in times required for the partial filling of donorlike and acceptorlike trap states in the amorphous silicon layer. If the density of the acceptor trap states is greater than that of the donorlike states in the midgap region, it is possible to have a transient current peak located two orders of magnitude longer on the time scale, as well as in the opposite current direction when it is compared to that from crystalline silicon. The shape of this transient current peak is asymmetrical, reflecting trap-state distributions near the midgap. If the trap-state distribution is altered, we show that it is possible to have a photoinduced transient current similar to that from crystalline silicon in the current flow direction. However, the transient current peak will occur at a time that is two orders of magnitude longer. In between, there exists an interesting cross-over behavior. This transient current peak will be broadened under a simultaneous switch on of an applied gate voltage, because the amount of hole trap states to be filled is reduced and that of electron trap states is increased. Doping the source and drain regions or doping the whole channel will reduce the role of electron-hole generation from illumination and wipe out the observability of a photoinduced transient current peak. This is also true when a gate voltage is turned on long before the illumination. The transient current peak from a realistic device occurs at approximately $10^{-4}$ s.

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