

**Amorphous &
Microcrystalline
Semiconductor
Devices**

**Volume II:
Materials and Device
Physics**

Jerzy Kanicki ▼ Editor

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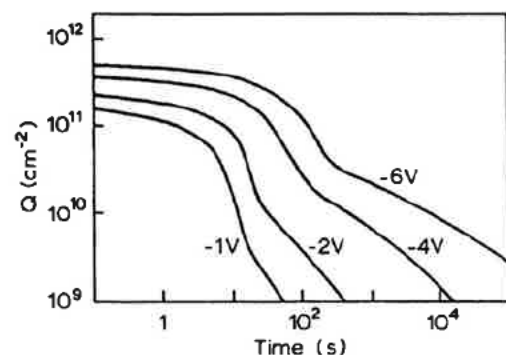


Figure 8.16 Time dependence of excess charge in a-Si:H after switch-off to different gate voltage. Two components in curve are uniform emission and approach to equilibrium (Figure 8.15). From: [139].

by a second component, which extends to much longer times. These two components correspond to the two processes of charge emission and charge redistribution shown in Figures 8.15(a) and 8.15(b) [139]. These two components can also be identified in experimental results [144].

8.5.3 Photoconductivity

A further phenomenon in which the band bending plays an important role is the photoconductivity of the transistors. Figures 8.17(a), 8.17(b), and 8.17(c) illustrate band bending, electron and hole concentration profiles, and flux of carriers, respectively, all calculated with a complete model for uniformly absorbed illumination [145]. The rate-limiting step in the electron hole recombination rate is given by the capture of the minority carrier at the recombination center. Because the hole concentration is less than the electron concentration everywhere, the hole profile in Figure 8.17(b) can be directly interpreted as the distribution of the recombination. As is apparent, the recombination rate increases away from the interface. The effect of this is a net flux of photogenerated electrons and holes away from the interface. The carriers then recombine near the back surface, where the concentration of holes (and thus the recombination rate) is high. Under negative voltage the same effect will occur, with an exchange of roles between electrons and holes. The flux, however, will still be away from the interface.

The photocurrent is undesirable in the TFTs because it reduces the on/off ratio of the transistor and thus the ability to act as an efficient switch; yet, in active

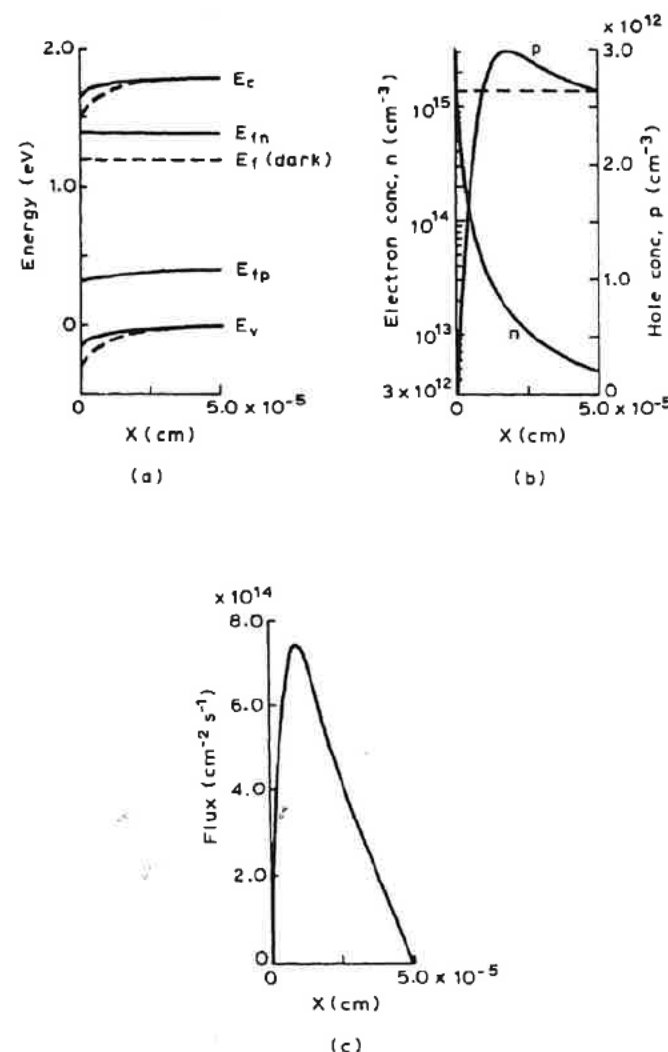


Figure 8.17 Photofield effect: (a) Band-bending in dark (dashed lines) and under illumination (full lines). (b) Electron and hole concentration profiles under illumination. (c) Steady-state flux of electrons and holes perpendicular to gate insulator interface. From: [145].

matrix displays, illumination of the transistors cannot be avoided completely. The photosensitivity of the TFT itself must be controlled without altering the basic parameters such as prethreshold slope and mobility, in other words, without affecting the gate insulator interface. From the above physics it is clear that this can be achieved by (1) thinning the a-Si:H layer to reduce optical absorption and (2) placing efficient recombination centers at the back interface to suck the photo-generated holes and electrons away from the interface. This is precisely what happens in B-type transistors when they are thinned down to 100 Å [25].

It is interesting to note here that thinning the a-Si:H layer also changes the nature of the (dark) off-current. When the film thickness is more than the parameter λ introduced above, the off-conductivity is determined by the bulk. For very thin a-Si:H layers there is no bulk however; all electrons are pushed out of the film and the off-conductivity drops far below the bulk conductivity. Therefore, thinning of a-Si:H layer also drastically increases the on/off ratio. This is also true for the short channel devices which, as discussed before, suffer from space-charge-limited currents in the off condition. Thinning the active layer in these devices means that the electron concentration remains controlled by the gate potential, thus keeping the on/off ratio high [84].

8.6 DEVICE STABILITY

8.6.1 Instability Mechanisms

We will now discuss the third regime in Figure 8.13, which is labeled " V_T instability." As shown, at long times after application of a gate voltage, the threshold voltage starts to change again. This shows that the characteristics of the amorphous silicon TFTs are not perfectly stable but instead show some change under prolonged application of a gate voltage. These changes are usually characterized by a shift in the threshold voltage, with little change in mobility. Two separate mechanisms have been found to contribute to this effect. One is the trapping of charge into the gate insulator nitride. This charge then acts as the fixed charge discussed in a previous section. The second contribution to instability comes from changes in the DOS of the amorphous silicon itself.

The two mechanisms contributing to the shift in threshold voltage are illustrated in Figure 8.18 for a positive bias stress situation. The charge trapping in the nitride gate insulator [135, 146], in which electrons are transferred from the amorphous silicon into silicon-dangling bond states in the silicon nitride, builds up a negative charge. This is a strongly field-dependent process that requires a relatively high field. At lower voltages, the trapped electrons in the silicon nitride act as a permanent charge sheet, causing an offset in the gate voltage.

In the creation of states [147–150], strained or weak Si-Si bonds break to form two dangling bonds. These two dangling bonds are prevented from recom-

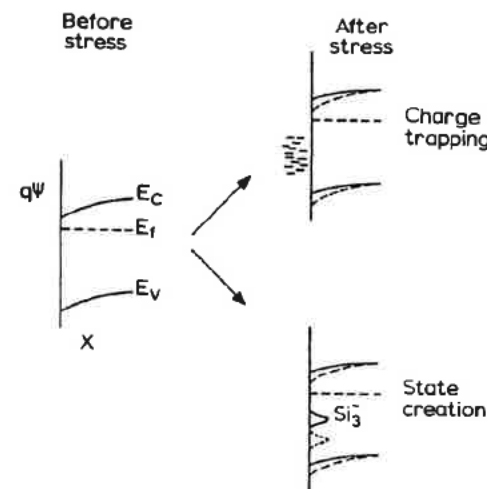


Figure 8.18 Charge trapping and state creation instability mechanisms. In charge trapping, band bending relaxes at fixed gate voltage; current correspondingly decreases due to accumulation of fixed charge in insulator. In state creation band bending relaxes similarly due to transfer of charge into created deep states.

binning by a hydrogen atom that moves in to passivate one of the two dangling bond defects. The result is a slight and negligible decrease in the density of tail states and an increase in the density of deep states. The electrons trapped in these states act as fixed negative charge for positive gate voltage if the dangling bonds created are located deep enough in the gap. As illustrated in Figure 8.18, their effect on surface band bending is then identified to that of the electrons in the nitride, that is, a reduction in band-bending, giving a decrease in source drain current. Because there is little change in field-effect mobility, this current decrease translates into a positive shift of the threshold voltage.

However, for negative gate voltage the two electrons on each created dangling bond can fall into the valence band and the dangling bonds will then act as positive fixed charge centers in contrast to the electrons in the nitride, which remain negative irrespective of gate voltage. This effect can be used to distinguish between the two instability mechanisms. Figure 8.19 shows current-gate voltage characteristics for a transistor that can sustain a hole channel for negative gate voltage [148]. For state creation (Figure 8.19(a)) the hole and electron branches move apart while, for charge trapping in the nitride (Figure 8.19(b)), both shifts have identical signs [148]. Figures 8.19(a) and (b) were both taken on the same device, which was annealed between the two experiments. In Figure 8.19(b) the trapping in the nitride