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TRANSIENT PHOTOCONDUCTIVITY AND SCHOTTKY BARRIER PROFILE DETERMINATION IN a-Si:H

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Abstract.- Carrier drift studies on submicron thick a-Si alloys sandwiched between blocking metal and injecting contacts reveal anomalous behavior. Using a pulsed external field and a tuneable-pulsed, nano-second laser, we observe that the transient photo current cannot be explained by the current response of a sheet of drifting charges. The non-drift contributions appear to originate from the time dependent relaxation of the Schottky barrier as a result of the photo excitation. This effect is more obvious in the small forward bias (±1.0 volts) mode, when a reversal of the photo response is obtained. Also, we have devised a novel technique to determine the junction potential profile. This is done by measuring the external field required to null the initial photo current as a function of the excitation wavelength (hence, the penetration depth).

We address the question of the discrepancy between the reported drift mobility values between thin (<1μm) and thick (>1μm) samples in a-Si alloys (1). Recently our results (2) of transient photo-current measurements in thin a-Si:H:F films showed a non-transport component in the photo response. These signals may easily be mistaken as bona fide transient pulses and from which one would derive erroneous values for the mobility. In the present paper we analyze similar data in Silane samples. Also, we will report on the results of simple measurements which yield the potential profile in the Schottky barrier between a metal contact and a-Si:H. These data were obtained via the technique discussed by Datta and Silver (3).

The details of our photo-injection and transient measurements have been described in reference (2). Briefly, the carriers were created by laser excitations of about 6 nS duration at 10 Hz in a sub-micron thick a-Si:H (RF deposited) layer sandwiched between blocking metal and injecting contacts. For the drift experiment the laser wave length was chosen to be 500nm, but for potential profiling the wave length was varied between 450nm and 600nm, in a number of convenient discrete steps. The photon flux was adjusted such that the initial peak signal varied directly with the light intensity.

Fig. 1 shows the transient signals for a-Si:H. The top curve is the response for 1.0V, and the middle curve is that for 0.5V. Both these pulses have the general appearance of the previously reported drift signals by Tiedje (1), namely a relatively flat top followed by a fast decay. The break or knee of the curve, is normally taken to mark the arrival of the drifting charges at the collecting electrode. The slow initial rise is universally observed in these materials and is due to a slow release of carriers from near surface traps, Silver (4). The lowest curve is a re-plot of Tiedje's 1.0V data for a 3.5 μm thick a-Si:H sample. Notice, that on an absolute time scale the results of our measurements are the same as those obtained by Tiejje; notwithstanding, the almost 9:1 ratio in the specimen thickness. In point of fact, to date all laboratories have reported almost identical transit times even though the thickness of the samples differed by 15 to 1. We do not believe this is a coincidence. As we have discussed in detail in reference (2), the photo-response cannot be solely due to a "drifting sheet" of charges. This is true, despite the
fact that the apparent transient time varies inversely with the applied voltage. The non-transport component of the transient pulse is more apparent when observed under small forward bias. Fig. 2 shows the response for 1.3 volts forward bias. Here we see the strange reversal in the photocurrent, just as was seen in a-Si:H:F. The presence of this unfamiliar phenomena in a-Si:H as in a-Si:H:F cannot be explained in a simple drift model, because neither the amplitude nor the time of reversal, scales correctly with the applied field. We conclude, that the dominant contribution to the photo-response in thin samples results from a space charge re-orientation due to the photo-excitation within the Schottky barrier. Since the space charge relaxation pulse width is insensitive to the sample thickness, a "constant time" would be inferred and therefore, the deduced mobility will appear to increase with \( L^2 / V \) instead of decreasing with thickness as predicted via dispersive transport (5).

This interpretation is reinforced by the results recently reported by Nielson et al. (1). They observed an increase in the apparent drift mobility in a-Si:H, ranging from \( 10^{-2} \text{cm}^2/\text{Vsec} \) for \( L = 1 \mu \text{m} \) to \( 1.2 \text{ cm}^2/\text{Vsec} \) for \( L = 7.5 \mu \text{m} \). These are in agreement with the results and discussions presented above. The more recent interpretation of dispersive transport in a-Si, is in terms of an exponential distribution of traps (6,7). This model too predicts an apparent mobility which either remains constant or decreases with thickness, depending upon the sample temperature. Thus, one is hard pressed to interpret Nielson's data (1) except through an extraneous near surface space charge contribution.

As a part of our studies, we found that we could experimentally determine the potential, or the internal field profile of the junction between the blocking contact and the amorphous insulating film. In the light of the role of the junction response in the transient drift mobility measurement in these systems, it is appropriate to report on some recently obtained potential profile data in a-Si:H. As discussed in detail in reference (3), the physical basis of this measurement is to null the initial photo-current \( J(t=0^+) \), by varying the applied forward bias for a given
Absorption depth of the incident pulsed light. Where

\[ J(t=0^+) = \frac{e}{L} \int_0^L (\mu_n + \mu_p)n(x) E(x)dx \] ...... 1

In equation 1, \( e \) is the electronic charge, \( \mu_n \) and \( \mu_p \) are the electronic and hole mobilities respectively, \( n(x) \) the excess free carrier density. \( E(x) \) is the total field, which for short voltage pulse times, is:

\[ E(x) = E_i(x) - \frac{V}{L} \] ...... 2

Where \( E_i(x) \) is the required internal field and \( V \) the applied pulsed external voltage across the sample of thickness \( L \). The photo generated free carrier density is:

\[ n(x) = n_0 e^{-ax} \] ...... 3

Where \( a \) is the absorption coefficient; therefore the \( J(t=0^+) \) is zero for an external field \( V(\alpha) \) null when:

\[ \frac{L}{L} \int_0^L (E_i(x) - \frac{V(\alpha) \text{null}}{L}) e^{-ax} dx = 0 \] ...... 4

Since \( a \) is a function of the excitation wave length, by varying the wavelength of the laser light say \( m \) times, one obtains \( m \) integral or functional equations the type:

\[ \frac{V(\alpha_k)}{L} \int_0^L E_i(x) e^{-ax} dx = 0 \] ...... 5

where \( k \) runs from 1 to \( m \). Modeling \( E_i(x) \) by a functional form containing at most \( m \) parameters the \( m \) equation (of the type 5) may be inverted to obtain a reasonable estimate for \( E_i(x) \). We found that our data could be best fitted to an analytic form shown below,

\[ E_i(x) = E_0 e^{-\beta x} \] ...... 6
In Fig. 3 we show the experimental data for the $V_{\text{null}}$ vs Laser wave length. The solid curve is the model fit of predicted $V_{\text{null}}$ for equation 6 with $E_o = 7 \times 10^4 \text{v/cm}$ and $S^{-1} = 600 \text{ A}^\circ$. It appears that these are reasonable values and yield a Schottky barrier potential of around 0.4v.

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References: