Numerical Modeling of the DC and AC-CPM for the Determination of Density of Gap-States Distribution in Hydrogenated Amorphous Silicon- Ultra High Frequency Effect

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1. Introduction

Sub-band gap absorption coefficient of amorphous semiconductors can provide useful information on their electronic transport and optical properties. It can be used to infer the spectral distribution of the density of gap states D(E) of these materials. Many methods [1-3] have been applied in order to determine D(E), but the sensitivity of each technique is not the same in the different regions of the band gap. The aim of this paper is, using constant photocurrent method (CPM) in dc and ac regimes especially at ultra high frequency, to investigate band gap states in the lower and the upper half of the band gap of a-Si:H in order to have a full picture in the whole band gap. For this reason, we have developed a code program to simulate the dc and ac-CPM sub-band-gap optical absorption coefficient. This numerical simulation includes all possible thermal and optical transitions between a parabolic extended states and gap states, which consist of an exponential tail state assumed to be either acceptor-like or donor-like and a midgap state assumed to be amphoteric and described by defect pool model of Powell and Dean [4].

2. Main results

Fig. 1 illustrates the simulated dc-CPM and ac-CPM $\alpha(h\nu)$ spectrum at several frequencies (from 100Hz to 10^{13}Hz), showing a considerable differences in the Urbach edge region as the frequency increases and the saturation of the ac $\alpha(h\nu)$ above 100 Hz in the defect region below about 1.35eV is achieved.

Fig. 2 illustrates the simulated dc-CPM and ac-CPM $\alpha_n(h\nu)$ spectrum at several frequencies (from 100Hz to 10^{13}Hz), showing no difference in the Urbach edge region as the frequency increases and saturation of the ac $\alpha_n(h\nu)$ above 100 Hz in the defect region below about 1.35eV is achieved.

Fig. 3 illustrates the simulated dc-CPM and ac-CPM $\alpha_p(h\nu)$ spectrum at several frequencies (from 100Hz to 10^{13}Hz), showing significant differences in the Urbach edge region as the frequency increases and the saturation of the ac $\alpha_p(h\nu)$ above 100 Hz in the defect region below about 1.35eV is achieved.

Fig. 4 illustrates the reconstructed $D(E)$ from $\alpha(h\nu)$, $\alpha_n(h\nu)$ and $\alpha_p(h\nu)$ spectra with dc-CPM and ac-CPM at 10^{12}Hz**,** showing a most reliable recovery in the case of the 10^{12} Hz ac-CPM.

Fig. 5 illustrates the reconstructed $D(E)$ from $\alpha(h\nu)$, $\alpha_n(h\nu)$ and $\alpha_p(h\nu)$ spectra with ac-CPM at two frequencies, 100Hz and 10^{12}Hz**,** showing a most reliable recovery in the case of ultra-high frequency 10^{12} Hz ac-CPM.

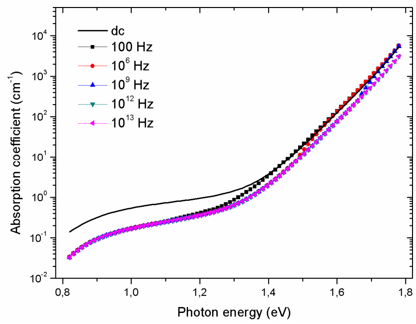

Fig.1.

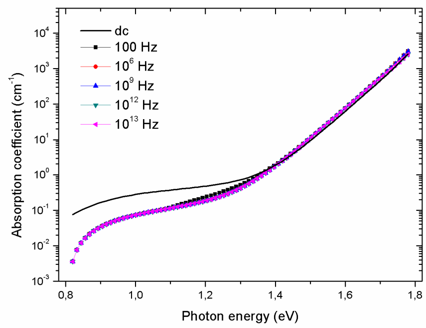

Fig.2.

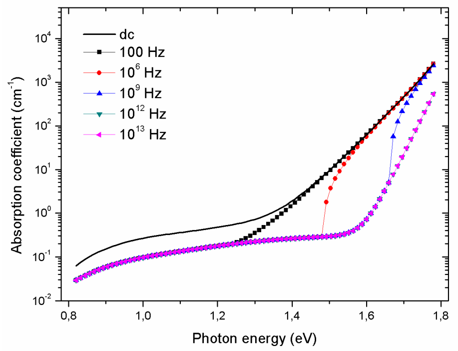

Fig.3.

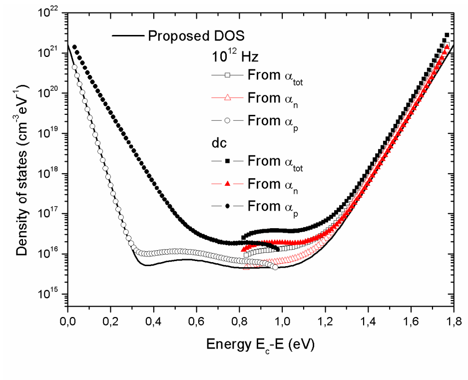

Fig.4.

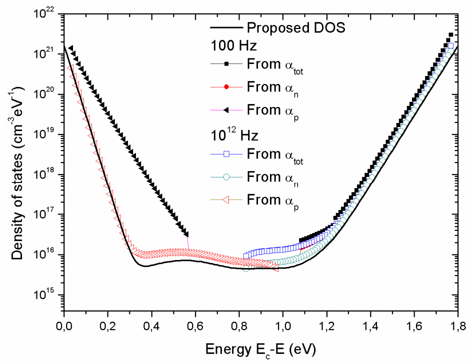

Fig.5.

3. Conclusion

In order to obtain more information about the density of states distribution within the gap of a-Si:H as a typical amorphous semiconductors, we have developed a numerical model to simulate the sub-band-gap absorption spectra in dc and ac modes and taking into account all possible optical and thermal transitions between extended and localized states. The entire $D(E)$ distribution could reliably be determined by deconvolution of both absorption coefficient spectra $\alpha_n^{ac}(h\nu)$ and $\alpha_p^{ac}(h\nu)$ at high frequency. Our simulations reveal that the dc-CPM and the ac-CPM at ultra-high frequency yield optical absorption spectra with significant differences, not only below the Urbach edge, as for low frequency ac-CPM, but also in the Urbach edge. The reliability to infer the $D(E)$ distribution by deconvolution of both $\alpha_n^{ac}(h\nu)$ and $\alpha_p^{ac}(h\nu)$ spectra at ultra-high frequency is demonstrated.

References

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