The Numerical Simulation of the Constant Photocurrent Method (CPM) in Hydrogenated Amorphous Silicon

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1. Introduction

Optical absorption coefficient studies are often used to understand the generation-recombination processes and used to characterize the densities of gap states in hydrogenated amorphous silicon (a-Si:H) [1,2]. The sub-gap optical absorption spectrum is widely determined using the constant photocurrent method (CPM) [3]. This technique consists of adjusting and measuring the incident flux $\phi(h\nu)$, a necessary factor to keep the photocurrent (or photoconductivity) constant at each photon energy. The method was first proposed in 1975 by Grimmeis and Lebedo [4] for oxygen-doped GaAs samples, and was applied some years later to a-Si:H by Vanecek *et al.* [5].

In this work, we report numerical simulation of CPM technique. Thus the optical absorption coefficient is derived. Moreover, we calculate the optical coefficient absorption from the convolution method, which takes into a count the all optical transitions between the initial occupied states and final unoccupied states of the density of states (DOS) in a-Si:H [6]. The standard density-of-states of a-Si:H is used. The continuity of the density of states and their derivations are imposed between the parabolic extended bands and band tails. In our calculation, all optical transitions and all possible electronic exchanges between different states are considered. The transitions between localized states are neglected. We presented a comparison between the optical absorption coefficient calculated from convolution method and the CPM-derived one. The observed differences between the two spectrums are explained using a description of the free charge densities.

2. Main results of the simulation

For a typical set of a-Si:H microscopic parameters [2], we present in Fig. 1, the optical absorption coefficient spectrum $\alpha_{conv}(h\nu)$ obtained by the convolution method and the CPM-derived one. Also, we see in Fig. 1 the Cody plot for the determination of optical gap E_{CD}. We remark that the two spectrums are identical for high energies and in Urbach region. Differences arise in the lower energies corresponding to deep defect states absorption. α_{CPM}, which underestimates α_{Conv} for photon energies below 1.2 eV. Also, we can remark that a light difference appears in the energy range of 1.2 eV-1.5 eV.

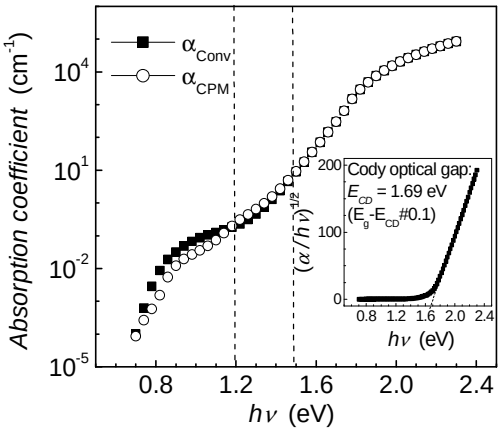

Fig.1: Comparison of the CPM-derived optical absorption coefficient and optical absorption spectrum obtained by convolution integral.

In order to understand the origin of this difference, we report in Fig. 2 the evolution of free charge densities. We can remark that the concentrations n and p of free electrons and holes are constant for photon energies above 1.5 eV. Though, we remark for the energy range of 1.2 eV-1.5 eV that the concentration n increases and that the concentration p decreases when the photon energies decreases. These variations are inverted for energies $h\nu < 1.2$ eV.

More explanations are given in a detailed paper, where the photon energies dependence of the charge densities and their recombination rates are presented.

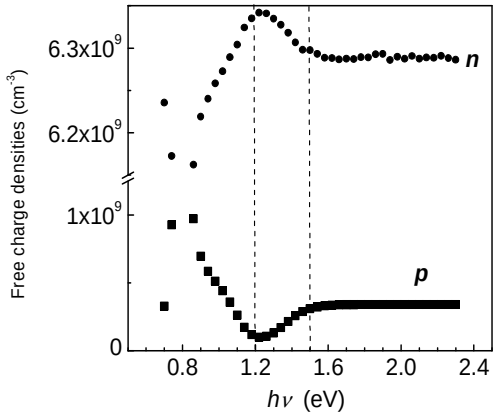

Fig.2: Calculated free charge densities in the CPM simulation.

3. Conclusions

In this paper, we have presented a simulation of the CPM-derived optical absorption coefficient and the optical absorption coefficient calculated by the convolution of density of states in the intrinsic a-Si:H. We have developed a numerical simulation in volume taking into account all optical transitions between the localized states and the parabolic states using the standard DOS model of a-Si:H.

Our CPM simulation results show clearly that the absorption coefficient α_{conv} and the CPM-derived α_{CPM} are identical for energies $h\nu > 1.5\,\mathrm{eV}$. The difference appears in the energy range $h\nu < 1.5\,\mathrm{eV}$. We have seen in the previous description of the free charge densities that n and p are not constant in the same energy range.

References

[1] H. Okamoto, H. Kida and Y. Hamakawa, Philos. Mag. **B49**, 231 (1984).
[2] T. Smaïl and T. Mohammed-Brahim, Philos. Mag. **B64**, 675 (1991).
[3] I. Sakata, M. Yamanaka, S. Numase and Y. Hayashi, J. Appl. Phys. **71**, 4344 (1992).
[4] H. G. Grimmeis and L.-A. Lebedo, J. Appl. Phys. **46**, 2155 (1975).
[5] M. Vanecek, J. Kocka, J. Stuchlik and A. Triska, Sol. Stat. Comm. **39**, 1199 (1981).
[6] W. B. Jackson, S. M. Kelso, C .C. Tsai, J. W. Allen and S.-J. Oh, Phys. Rev. **B31**, 5187 (1985).