Perimeter Recombination in Thin Film Solar Cells

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Extended Abstract

Surface recombination has a profound effect on the performance of a solar cell, at the illuminated surface reduces its photocurrent and along the cell's perimeter increases its dark current. The perimeter recombination increases considerably the dark current particularly for small area solar cells where the perimeter to area ratio is important. Perimeter recombination current has two components, the first is due to recombination at the surface that intersects the space-charge layer while the second originates recombination at the surface of quasi-neutral regions.

Recombination at the depleted layer surface has a $2kT$ character and is treated in the present work in a similar way to that of the bulk, using the model of Sah, Noyce and Shockley. The electric field at the surface is different from that of the bulk because of the presence of surface states. The density of surface states at the GaAs surface is known to be very high and distributed across the entire forbidden energy band gap. However the Fermi level could be assumed pinned near mid gap throughout the structure. We suggested that at the surface the potential varies linearly and the electric field is uniform along the surface [1]. Using this simple model we were able to obtain an analytical form of the perimeter current that yielded values of the product of the characteristic length by the surface recombination velocity (L_sS_0) that agreed well with reported experimental values, Fig.1.

The recombination current outside the space-region is of two-dimensional nature, it represents lateral diffusion of minority carriers at the boundary of the space-charge region close to the perimeter. This current is calculated by solving numerically the two-dimensional continuity equation at the base, the contribution of the emitter is negligible. An effective surface recombination (S_e) was introduced to account for intrinsic surface recombination along with the effect of the bend bending caused by the charged states. This current is of kT character at low biases but tends towards $2kT$ behaviour at higher biases. A value of $S_e = 1\times10^7$ cm/s is found to give better result, Fig.2.

We found that at low bias the ideality factor of the total perimeter (Fig.3) current is about 2, thus the recombination inside the depleted layer surface is dominant. Whereas at higher bias the ideality factor sharply decreases to around 1 that corresponds to the kT character of the perimeter current associated with recombination at the quasi-neutral base surface.

The calculation demonstrates that perimeter component of the dark current is very important, Fig.4. It affects seriously the performance of small area solar cells. As the ratio of perimeter to area (P/A) is increased the perimeter current acquired significant proportions, thus the expected $2kT$ current due to bulk deep levels existing in the depletion layer is two to three orders of magnitude too small to account for [1,2].

References

[1] A. Belghachi, Modelling of perimeter recombination in GaAs solar cells, Microelectronics Journal **36** (2005) 115-124.

[2] S. P. Tobin, S. M. Vernon, C. Bajgar, S. J. Wojtczuk, M. R. Melloch, M. S. Lundstrom, K. A. Emery, Assessment of MOCVD- and MBE- Grown GaAs for High-Efficiency Solar Cell Applications, IEEE Trans. Electron Devices **37** (2)(1990) 469-475

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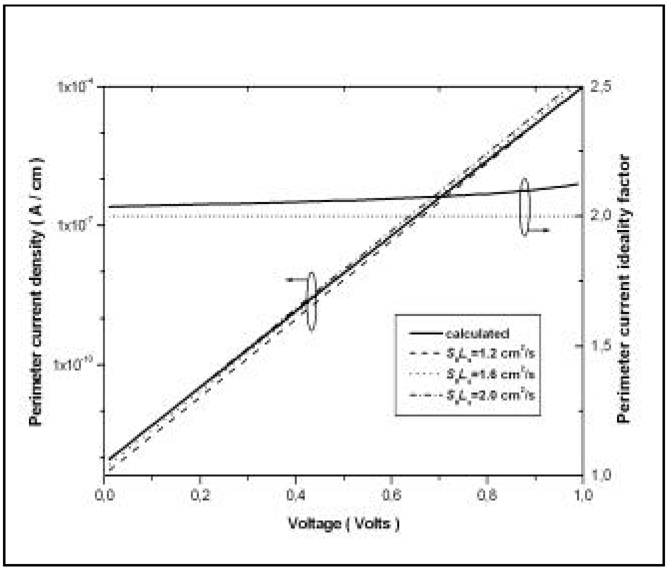

Fig.1: current vs. voltage characteristics and current ideality factor of perimeter recombination current at the space-charge region surface. Comparison is made with the equation:

$I_P = e n_i S_0 P L_s \exp\left(\frac{eV}{2kT}\right)$ using three values of the product $S_0 L_s$.

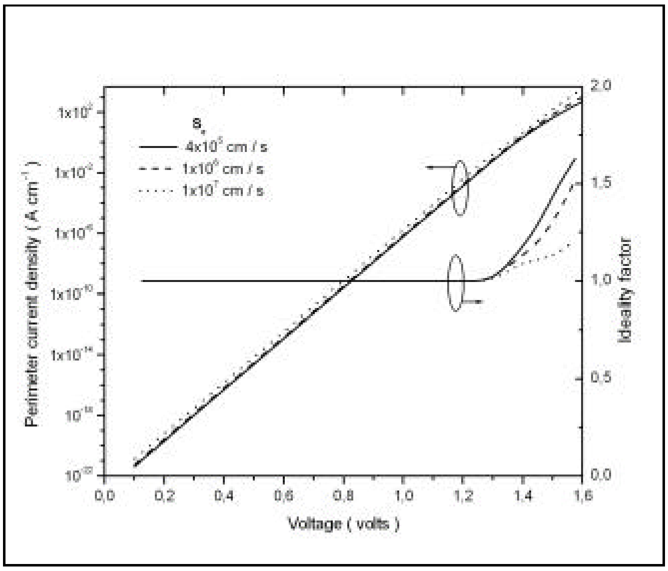

Fig. 2: current vs. voltage characteristics and current ideality factor of perimeter recombination current at the quasi-neutral base for different effective surface recombination velocities.

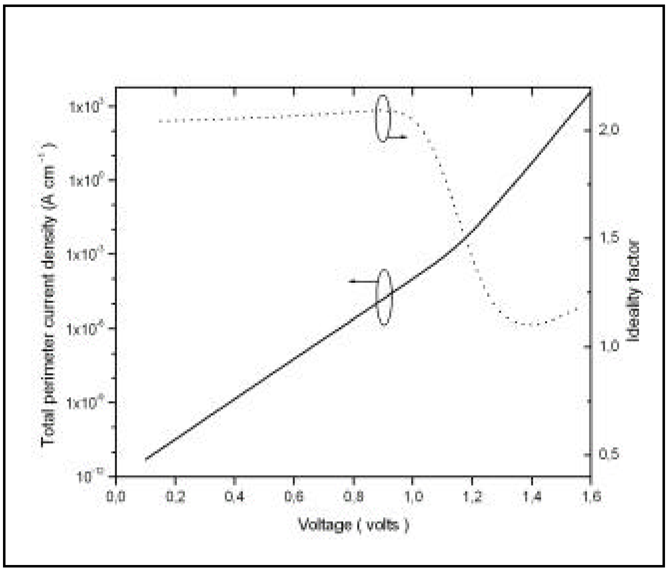

Fig. 3: current vs. voltage characteristics and ideality factor of the total perimeter recombination current. (Effective surface recombination velocity $S_e = 10^7$cm/s. at the quasi-neutral base).

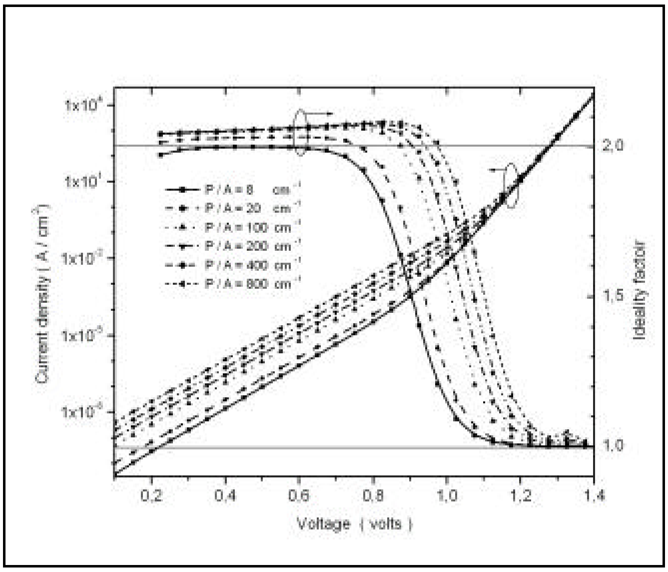

Fig. 4: dark current vs. voltage characteristics and current ideality factor of heteroface GaAs solar cell with different perimeter to area ratios (P/A). $P/A = 8$ cm^{-1} corresponds to the fitted data of Tobin et al. [2].