Digest of Tech. Papers *The 14th Conf. (1982 International) on Solid State Devices, Tokyo*

C-5-1 CHARACTERIZATION OF AMORPHOUS SILICON SOLAR CELLS

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As is now widely recognized, photovoltaic performances of amorphous silicon (a-Si) solar cells are not uniquely settled by their design and fabrication conditions, but significantly affected by uncontrollable contaminations, thermal history, ion or electron damage and prolonged light irradiation during and/or after whole the cell fabrication processes. Accordingly, for achieving high efficiency together with sufficient reliability and reproducibility, it is an essential matter to identify in what manner the physical parameters dominating the performances are influenced by the above violating factors. In this paper, we will make it clear through combining a series of systematic experimental examinations on various type of a-Si solar cells with their theoretical analyses based upon the variable minority carrier collection model.[1)]

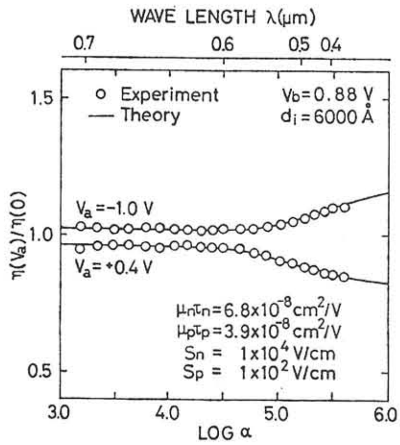

Fig. 1 Calculated results on normalized collection efficiency spectra $\eta(V_a)/\eta(0)$ as a parameter of $\mu_n\tau_n+\mu_p\tau_p$.

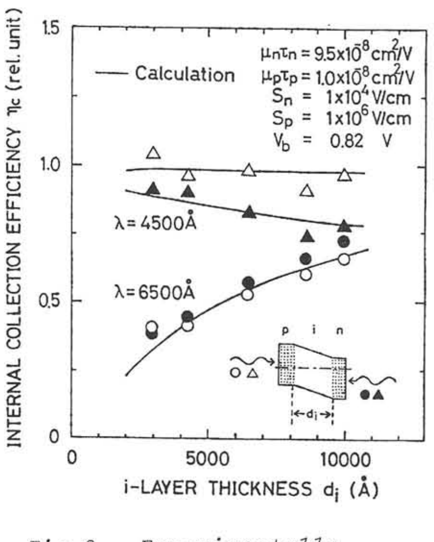

Fig 2 Experimentally obtained collection efficiency as a function of i-layer thickness and theoretical curves for them.

Figure 1 shows an absorption coefficient dependence of the biased collection efficiency $\eta(V_a)$ normalized by the short circuit collection efficiency $\eta(0)$, that is $\eta(V_a)/\eta(0)$. The a-Si solar cell used for the measurement is a SnO_2/p-i-n/Al type one exhibiting a conversion efficiency of 6.5% under AM 1 illumination. An excellent fitting is obtained between the experimental results plotted by open circles and theoretically calculated curves with choosing the physical parameters as inserted in the figure. The $\mu\tau$ products of both electron and hole are evaluated on the order of $10^{-8}cm^2/V$ and the effective surface recombination velocities at p/i and n/i interfaces $S_n\cdot\mu_n$, $S_p\cdot\mu_p$ can be estimated at 10^4cm/sec and 1cm/sec when μ_n and μ_p are assumed as 1 and $0.01cm^2/V\cdot sec$, respectively.

Figure 2 demonstrates the active i-layer thickness dependence of collection efficiency in the case of p-side and n-side illumination for the monochromatic light wavelengthes, 4500Å and 6500Å. As can be seen in the figure, a considerably good coincidence is found between experimental plots and theoretical curves which were drawn with the physical parameters determined through the above mentioned method. These results confirm us of a validity to determine the physical parameters through analizing $\eta(V_a)/\eta(0)$ spectra in the presented way.

Table 1 Photovoltaic performances and several physical parameters in various types of s-Si solar cells.

Cell Structure	J_{sc}(mA/cm^2)	V_{oc}(V)	FF	η(%)	V_b(V)	$\mu_n\tau_n$(cm^2/V)	$\mu_p\tau_p$(cm^2/V)	S_n(V/cm)	S_p(V/cm)	d_i(Å)
SnO_2/p-i(6000Å)-n	12.0	0.83	0.65	6.47	0.88	6.8×10^{-8}	3.9×10^{-8}	10^4	10^2	5941
SnO_2/p-i(10000Å)-n	12.8	0.79	0.58	5.78	0.87	1.2×10^{-8}	5.2×10^{-8}	10^4	10^2	9382
SnO_2/p-i-n/ITO	-	-	-	-	0.82	9.5×10^{-8}	1.0×10^{-8}	10^4	10^6	6500
p-SiC(CH_4,B:0.1%)/i-n	13.0	0.87	0.61	6.92	0.98	1.6×10^{-9}	3.4×10^{-8}	$10^{4.5}$	10^2	6000
p-SiC(CH_4,B:0.2%)/i-n	13.2	0.83	0.69	7.49	0.93	1.2×10^{-8}	3.0×10^{-7}	10^5	10^2	6000
p-SiC(C_2H_4:35W)/i-n	11.8	0.89	0.64	6.69	1.01	2.6×10^{-8}	1.8×10^{-8}	10^5	10^2	6457
p-SiC(C_2H_4:70W)/i-n	11.2	0.87	0.63	6.16	1.00	1.8×10^{-8}	1.6×10^{-8}	10^6	10^2	5334
ITO/p-i-n/SS	9.5	0.69	0.59	3.83	0.76	1.1×10^{-9}	6.2×10^{-9}	10^6	10^4	5047
ITO/p-i(B)-n/SS	4.3	0.79	0.39	1.31	0.85	3.4×10^{-9}	3.4×10^{-10}	10^6	10^4	5246
ITO/n-i-p/SS	8.7	0.84	0.62	4.53	0.91	5.2×10^{-9}	1.7×10^{-10}	10^4	$10^{4.5}$	4982
ITO/n-i(B)-p/SS	6.6	0.75	0.47	2.32	0.83	1.3×10^{-9}	3.6×10^{-11}	10^4	$10^{4.5}$	4310
ITO/n-ip(graded)/SS	8.8	0.83	0.60	4.40	0.89	9.6×10^{-9}	3.8×10^{-10}	10^4	$10^{4.5}$	5568

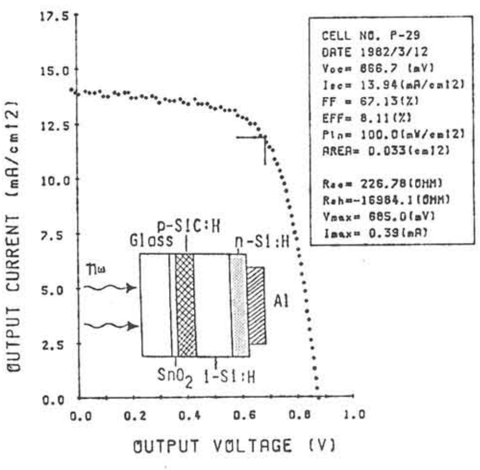

Fig. 3 J-V characteristics of a SnO_2/p a-SiC/i-n a-Si/Al solar cell.

Here, we will summalize in table 1, the fundamental physical parameters $\mu_n\tau_n$, $\mu_p\tau_p$, S_n and S_p derived in various types of a-Si solar cells. Several results found are written down in the following. Inclusion of Boron atoms(phosphrus atoms) into the i-layer during the plasma depositon reduces $\mu\tau$ products, paticularly $\mu_p\tau_p(\mu_n\tau_n)$. Deposition of ITO front electrodes inevitably decreases $\mu\tau$ products and increase the surface recombination velocity($S_p{\cdot}\mu_p$, $S_n{\cdot}\mu_n$) owing to ion or electron damage which the a-Si layers are suffered. The interface at p a-SiC/i a-Si has larger $S_n{\cdot}\mu_n$, however, which is successfully saved by the enhanced built-in potential due to the heterojunction effect. In this type of solar cell, we have obtained 8.1% conversion efficiency under AM 1 illumination as shown in Fig. 3.

We will make detailed discussions on the correlationship among the cell structure, fabrication conditions and process, fundamental physical parameters and resulting photovoltaic performance. Moreover, we will mention about the stability of the cell performance against thermal history and prolonged light irradiation from the standpoint of the corresponding variations of the physical parameters.

Reference

1) S. Nonomura, H. Okamoto, H. Kida and Y. Hamakawa: The 3rd Photovoltaic Sci.& Eng. Conf. in Japan (1982) to be published.