Triple-Junction a-Si Solar Cells Deposited With Improved Intrinsic Layers

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ABSTRACT

Triple-junction a-Si/a-SiGe/a-SiGe solar cells are fabricated in our laboratory using a multi-chamber, load-locked PECVD system. By improving intrinsic layers, doped layers and using bandgap graded buffer layers for a-SiGe component cells, we improved our triple-cell performance and achieved a 12.71% initial efficiency and a 10.7% stable efficiency after 1000 hours of 1-sun light soaking. Samples sent to NREL for independent measurements show 11.8% total-area, or 12.55% active-area initial efficiency.

1. Introduction

This paper describes our recent progress in a-Si PV research, funded through NREL Thin Film Partnership Program. One of the objectives of this research is to develop and improve high-efficiency triple-junction solar cells. The general approach and experimental details were described in an earlier paper [1] and will not be repeated here. The device structure is SS/Ag/ZnO/n-i(bottom-a-SiGe)-p/n-i(middle-a-SiGe)-p/n-i(top-a-Si)-p/ITO.

2. Fabrication of Improved Component Cells

Several approached were taken to improve the performance of top, middle and bottom component cells, as described in our recent reports [2]. First, we deposited all of the i-layers with high H dilutions, which are slight below the dilution level at which the material starts to show signs of microcrystalline formation. Second, we improved the p-layer deposition by optimizing the deposition pressure and rf power. Third, we incorporated bandgap graded buffer layers [3] for the bottom and middle a-SiGe cells. With these approaches, the performances of the component cells are improved. Table 1 shows the performance of improved top, middle and bottom cells on bare stainless steel substrate (SS) and on Ag/ZnO back-reflector coated stainless steel substrates (BR). These performances are much improved from our previously reported results [1]. The devices were put under one-sun light for 1000 hours at 50 ^oC for stability test. The stability result is also shown in Table 1.

3. Fabrication of Triple-Junction a-Si Solar Cells

With a careful analysis of the light spectrum of our solar simulator, we improved the current matching among component cells. After incorporating improved component cells into our triple-cell fabrication, we achieved the fabrication of a-Si/a-SiGe/a-SiGe triple cells with 12.7% initial efficiency. Figure 1 shows the IV curve of the 12.7% triple cell, GD585. The performance for the triple cell is V_{oc}=2.29V, J_{sc}=8.34 mA/cm^2, FF=66.5% and the initial efficiency is 12.7%.

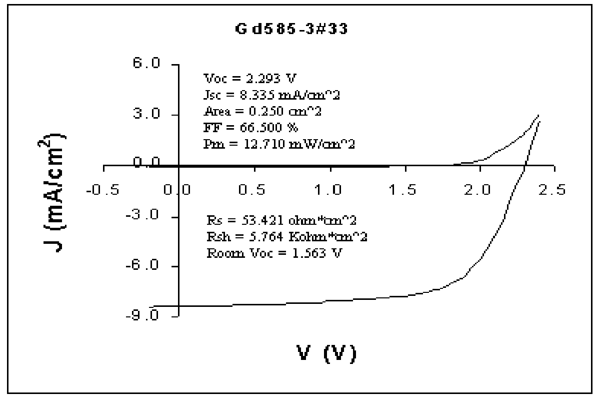

Figure 1 IV curve of a UT fabricated triple cell, showing 12.7% initial, active-area efficiency.

Figure 2 shows the quantum efficiency curves of the component cells in this triple cell. At the top of Figure 2, we show the calculated short circuit currents of the component cells under both UT simulator and the AM1.5 global spectrum. Since the Xenon lamp spectrum does not match exactly the AM1.5 global spectrum, different short circuit currents were obtained when being calculated using different spectrums. It should also be pointed out that the top cell current was calculated with wavelength longer than 370 nm. Therefore, the actual current should be larger than the current of shown in the figure for top cell by about 0.3 mA/cm^2 according to our estimate.

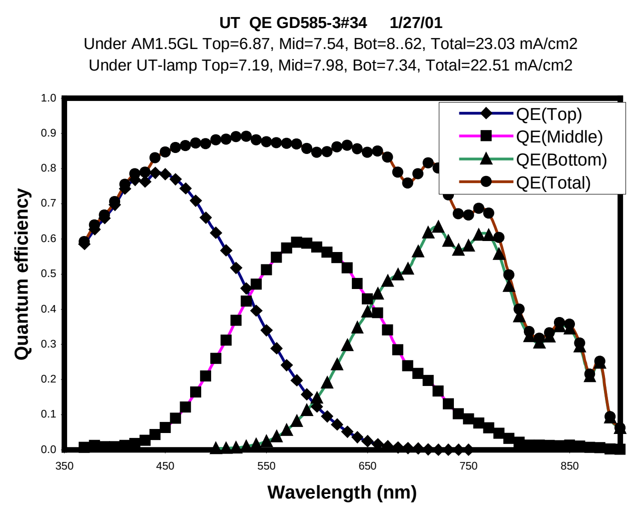

Figure 2 Quantum efficiency curve of 12.7% cell (GD585) showing the QE for top, middle and bottom cells. The figure also shows the short circuit current under UT simulator and AM1.5 spectrum.

Some triple cells fabricated at UT were sent to NREL for independent measurements. Table 2 shows the measurement for GD585 measured at NREL and UT, which agree with each other very well. The small difference in the J_{sc} and FF is because UT's simulator is slightly insufficient in the red, leading to a lower FF and a higher J_{sc}. The total-area η measured by NREL for GD585-3#33 is 11.8% (12.55% active-area), as shown in Figure 3.

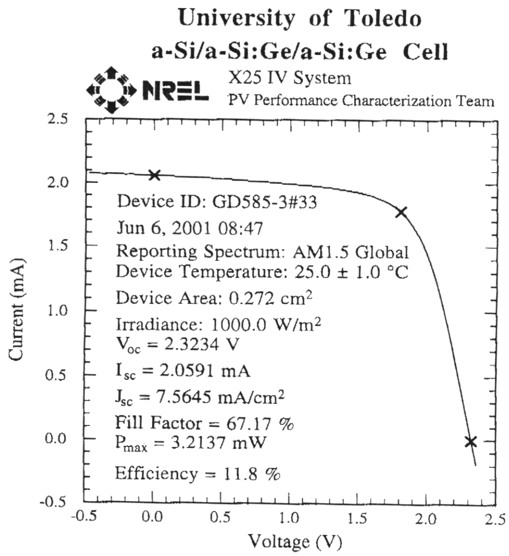

Figure 3 IV curve of GD585 measured at NREL, showing 11.8% initial, total-area efficiency.

We have conducted light soaking stability tests for these UT fabricated triple-junction solar cells [2]. After 1000 hours of one-sun light soaking at 50 C, these triple cells degrade around 11-12% and show stable active-area efficiency above 10.5% with the highest stable efficiency (active area) at 10.7%, shown in Fig. 4. The achievement of 10.7% stable efficiency is a significant improvement from our previously fabricated triple junction solar cells.

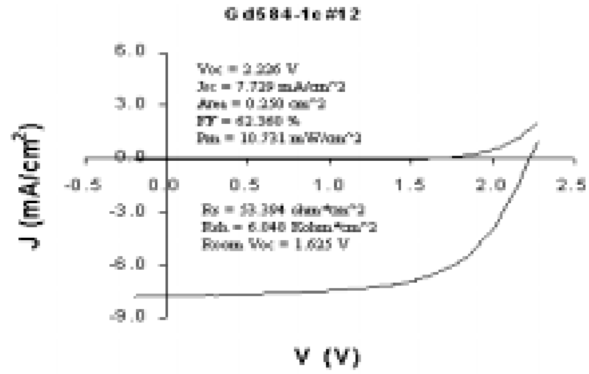

Figure 4. I-V curve of a triple cell showing 10.7% stable η.

4. Summary

Incorporating improved component cells into triple cell fabrication, we achieved triple-junction a-Si/a-SiGe/a-SiGe solar cells with 12.7% initial active-area efficiency. NREL measurements for these cells show 11.8% initial total-area efficiency (12.55% active-area efficiency). After 1000 hours of light soaking, these triple cells stabilized at efficiencies of 10.5-10.7%, with a degradation of 11-12%.

Acknowledgment –-We would like to thank researchers at ECD, United Solar, NREL and UT CdTe group for collaborations and assistance. Work supported by NREL Thin Film Partnership Program ZAF-8-17619-14.

References

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2. A.D.Compaan and X.Deng, U. of Toledo 3rd and 4th quarterly reports during Phase 3, to NREL TFPP (2001).
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Table 1 IV performance of top, middle and bottom component cells before and after 1000 hours of light soaking with 1 sun intensity at 50 °C.

Cell Number	Cell Type	Subs		Voc (V)	Jsc (mA/cm²)	FF (%)	η (%)	Degradation (%)
Gd550-1	Top	SS	Initial	1.00	9.49	71.61	6.77	
			Stable	0.98	9.20	66.66	6.01	11.23
Gd572-2	Middle	BR	Initial	0.80	18.95	65.51	9.97	
			Stable	0.78	19.63	54.14	8.29	16.85
Gd575-2	Bottom	BR	Initial	0.62	22.85	60.96	8.57	
			Stable	0.62	22.94	52.44	7.41	13.54

Table 2 IV data for GD585 measured at UT, USSC and NREL.

Cell#	V_{oc} (V)	I_{sc} (mA)	FF (%)	Active area (cm²)	Active-area η (%)	Total area (cm²)	Total-area η (%)	Measurem't Lab
UT585-3#33	2.293	2.084	66.50	0.25	12.71			UT
UT585-3#22	2.286	2.046	66.35	0.25	12.41			UT
UT 585-3#33	2.3234	2.0591	67.17	0.256	12.55	0.272	11.81	NREL
UT 585-3#22	2.3191	2.0331	66.14	0.255	12.41	0.271	11.68	NREL