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Light-Induced Effects in a-Si/a-Si Two-Stacked Tandem Junction Solar Cells*

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A-Si/a-Si two-stacked tandem junction solar cell submodules were optimized on the textured SnO2 substrate. The highest module efficiency of 9.3% was obtained. The light-induced degradation of a-Si two-stacked tandem junction solar cells was simulated by using two types of degradation models (bond-breaking model and hole trapping model). In each case, the initial degradation of the tandem type cell can be well simulated. By optimizing the device parameters by using the computer simulation and adopting these results for the cell fabrication,the stable tandem type submodule of less than 3% degradation after 100h sunlight irradiation will be obtained.

1. INTRODUCTION

We have previously reported high-efficiency and high-stability a-Si/a-Si two-stacked tandem junction solar cells having an efficiency of 11.2 % for a 1 cm^2 area cell and an 8.9 % module efficiency for a 100 cm^2 area submodule[1,2]. Although the stability of tandem type cells is better than that of single junction cells, the light-induced degradation cannot be neglected. Realistic modeling of the light-induced changes in a-Si solar cells is required in order to increase our understanding of the light-induced degradation mechanism and to optimize device parameters to improve the stability.

Recently, a precise device simulation program was developed in the Konagai laboratory at Tokyo Institute of Technology[3,4]. We have made some modification of this program in order to optimize the cell design and to forecast the light-induced changes in tandem type cells. In this paper, we will introduce an optimized 100 cm^2 area two-stacked tandem type submodule with a high performance and also the results of the optimization of the tandem type cell to improve the stability.

2. FABRICATION OF THE TANDEM TYPE SUBMODULE

The submodules were glass/textured SnO_2/p-i-n/B.L./p-i-n/Ag structures, where the p, i, and n, layers were boron-doped a-SiC:H, i-a-Si:H, and phosphorous-doped μc-Si:H, respectively, fabricated in a separate chamber system and B.L. is a blocking layer. The thickness of each layer was optimized for the textured substrate.

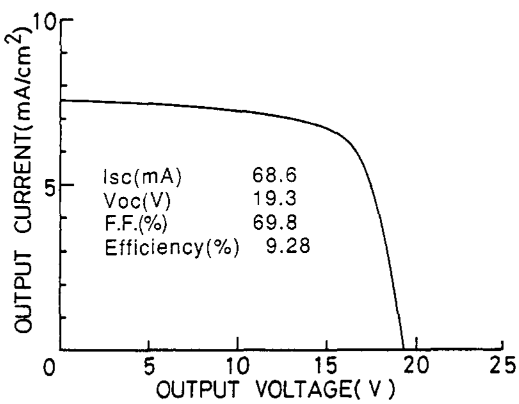

Figure 1
V-I characteristics of the 100 cm^2 area tandem type submodule with the highest efficiency.

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The optimum top i-layer thickness of the tandem type cell deposited on the textured substrate was slightly thicker than that deposited on the flat substrate. This means that the absorption of long wavelength light is enhanced by the textured SnO_2 substrate. The optimum thicknesses of the top and the bottom i-layers were 72 and 400 nm, respectively. The patterning processes were also optimized for the textured SnO_2 substrate. Electrical properties were measured under 100 mW/cm^2 simulated AM1 illumination. Fig.1 shows the V-I characteristics of the submodule with the highest efficiency prepared so far.

3. OPTIMIZATION OF TANDEM TYPE CELLS

Several models have been proposed to describe the light-induced degradation of a-Si solar cells[5,6,7]. Among these models, two types of calculation were carried out to simulate this. In the first calculation, we assumed that the D-state density increased through band-tail recombination.

Fig. 2 shows the calculated light-induced changes of efficiency for the single and tandem type cells. Light-induced changes of the top and the bottom cells are also shown in Fig. 2. From this figure it is clear that the stability of the tandem type cell is superior to that of the single junction cell, and this agrees with our experimental results[8]. It is also clear that the stability of the top cell is superior to that of the bottom cell. Fig. 3 shows the calculated D-state density profile after 20 h degradation. The D-state density in the top i-layer increases in almost the same manner as in the bottom i-layer. This means that the top i-layer shows light induced degradation, but because of the high electric field in this layer, the top cell shows almost no change. Next, we have calculated the light-induced degradation of a-Si solar cells by using a hole-trapping model; in this case it was assumed that the D-state density increased only by a hole-trapping process. The result of this calculation showed that the degradation of the tandem type cell is 13% lower than that of the single junction cell, which is very similar to the result of the first calculation.

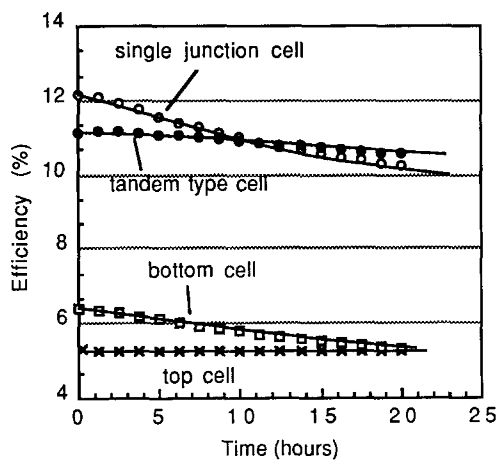

Figure 2
Calculated light-induced changes of tandem and single junction cells. The top and bottom i-layer thicknesses are 50 and 460 nm, respectively. The i-layer thickness of the single junction cell is 500 nm.

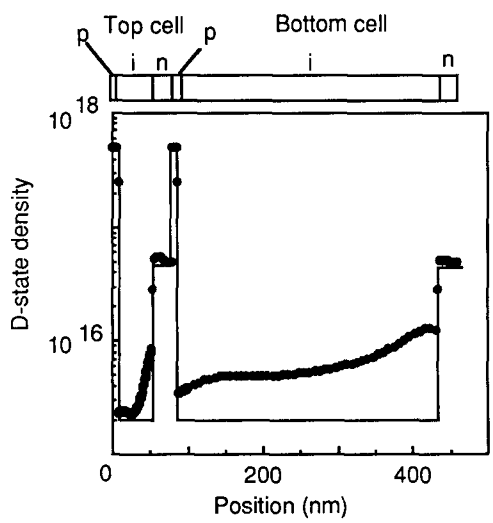

Figure 3
Calculated D-state density in the tandem type cell.

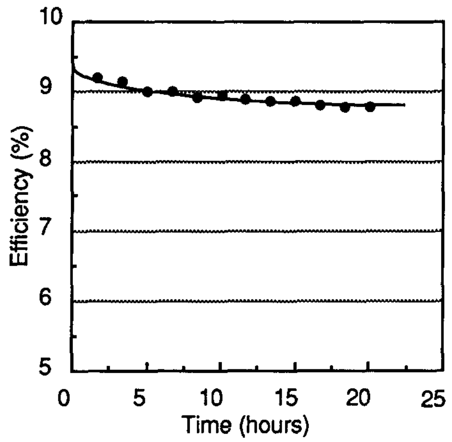

Figure 4
Light-induced degradation of the tandem type cell.

The experimental results of initial degradation are shown in Fig. 4[1]. The tandem type cell showed about 5% degradation after 20 h of 100 mW/cm^2 simulated sunlight irradiation. The experimental data is not very different from the calculated result. Although the thermal recovery factor is not taken into account in our calculations, initial and relatively

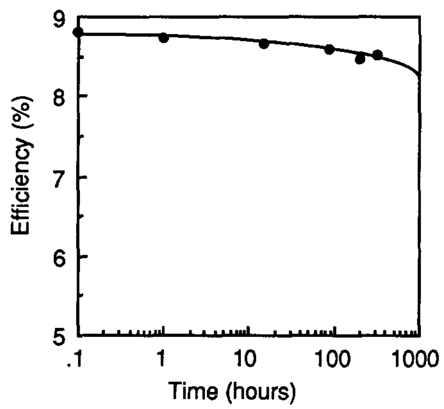

Figure 5
Light-induced degradation of an optimized 100 cm^2 area tandem type submodule.

short-time degradation can be simulated because of the low thermal recovery rate at room temperature. We roughly estimate the stability of the tandem type cells by using computer simulation. To optimize the device parameters, we calculated the light-induced degradation of several cells of having different device parameters. By adopting these results to cell fabrication, an optimized 100cm2 area two-stacked tandem type submodule was fabricated that shows a small degradation of less than 3 % after 100 h of 100 mW/cm^2 simulated sunlight irradiation. Fig. 5 shows the light-induced degradation of this submodule

4. SUMMARY

A 100 cm^2 area tandem type submodule having 9.3% efficiency was obtained by using a textured SnO_2 substrate and optimized device parameters.

The stability of the a-Si two-stacked tandem junction solar cell could be simulated using two types of degradation models. In both cases the stability of the tandem type cell is satisfactorily simulated.

By adopting the computer simulation results to cell fabrication, a stable submodule having less than 3% degradation after 100 h sunlight irradiation could be obtained.

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