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High stabilized efficiency single and multi-junction thin film silicon solar cells

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Abstract

We present the study of high efficiency single and multi-junction solar cells, focusing on the stability against degradation under illumination. In both single and multijunction solar cells, the thickness of the a-Si:H absorber layer was varied over a wide range up to 790 nm. While single junction a-Si:H solar cells show reduced stability against prolonged light illumination with an increase in layer thickness, themultijunction solar cells are significantly more stable. In these cells the total thickness of the a-Si:H absorber layers (first and second sub-cells) can be significantly increased up to 790nm while keeping the degradation level low (below 13%) after 1000 hrs of light soaking. The possible origins of an improved stability against degradation are addressed in the paper.

*Keywords:*amorphous silicon, microcrystalline silicon, multijunction solar cells, light induced degradation

1. Introduction

Silicon thin film solar cells are known to suffer from degradation due to prolonged illumination. This degradation process, known as Staebler-Wronski effect [1], is considered as a major limiting factor for high efficiency devices and usually is associated with the stability of amorphous silicon (a-Si:H) absorber layers. It is widely accepted that that degradation kinetics in a-Si:Hsingle junction solar cells demonstrates a thickness dependency andan improved stability of a-Si:H solar cells could be achieved for thinner absorber layers [2-4]. A combination of sub-cells with

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amorphous/microcrystalline silicon (μc-Si:H) absorber layers or its alloys in multijunction solar cells allows for more efficient utilization of the sun spectrum. Various combinationsof thin-film silicon solar cells with a-Si:H, a-SiO_X:H, a-SiGe:H and μc-Si:H, absorber layershave been reported in multi-junction devices [5-9].Microcrystalline silicon is generally more stable against prolonged illumination [10], whereas the presence of a-Si:H absorber layers can reduce the efficiency of multijunction devices considerably under illumination.

Here we present the study of high efficiency single junction (a-Si:H absorber) and multi-junction (a-Si:H and μc-Si:H absorbers) solar cells, focusing on the stability against degradation under illumination. In the case of multijunction devices, a wide range of device architectures is considered: a-Si:H/μc-Si:H and a-Si:H/a-Si:H tandem solar cells, a-Si:H/μc-Si:H/μc-Si:H and a-Si:H/a-Si:H/μc-Si:H triple junction solar cells and a-Si:H/a-Si:H/μc-Si:H/μc-Si:H quadruple junction cells. Moreover, in order to obtain more insights into the degradation behavior, the total thickness of the a-Si:H absorber layers in both single and multijunction solar cells was varied over a wide range up to 790 nm. In the case of a-Si:H single junction solar cells, 300 nm was found to be an optimal absorber layer thickness resulting in high stabilized efficiency of 9.8% (12% relative degradation). Further increase in the thickness of the absorber layer results in the reduction of stabilized efficiency and stronger degradation (up to 30% in the case of 700 nm thick absorber layer). In contrast, in the case of multijunction solar cells, the total thickness of the a-Si:H absorber layers (first and second sub-cells) can be significantly increased up to 790nm while keeping the degradation level low (below 13%). The details of degradation behavior upon illumination and stability issues in single- and multijunction solar cells are compared and discussed in this contribution.

2. Experimental details

Single and multi-junction solar cells were prepared by PECVD at deposition temperatures of 185°C or below. In the case of multi junction devices, we have prepared a-Si:H/μc-Si:H and a-Si:H/a-Si:H tandem solar cells, a-Si:H/μc-Si:H/μc-Si:H and a-Si:H/a-Si:H/μc-Si:H triple junction solar cells and a-Si:H/a-Si:H/μc-Si:H/μc-Si:H quadruple junction cells. The matching of the current in the sub-cells of the multijunction devices was achieved by variation in the thickness of the absorber layer and by implementation of doped microcrystalline silicon oxide (μc-SiO_x:H) layers. Additional details on the preparation of solar cells can be found elsewhere [4, 9, 11, 12]. Table 1 presents an overview of individual layer thicknesses for multijunctionsolar cells studied here. The performance of the solar cells was evaluated by current-voltage (*J-V*) measurements under AM 1.5 illumination (intensity of 1000 W/m^2, class A spectrum). Degradation of solar cells was performed at 55 °C in open circuit condition with an intensity of 1000 W/m^2 (class B spectrum) over a period of 1000 hours.

Table 1.Layer sequence and thickness of multijunction solar cells, together with efficiency (η) in initial and stabilized (after 1000 hrs of light soaking) states and relative degradation in efficiency. A-D tandem junction, E-F triple junction and G quadruple junction cells.

	Junction 1		Junction 2		Junction 3		Junction 4		η	η	Δ η
		Thickness[nm]		Thickness[nm]		Thickness[nm]		Thickness[nm]	ini. [%]	stab. [%]	[%]
A	a-Si:H	350	μc-Si:H	1800					13.1	11.8	-10
B	a-Si:H	160	μc-Si:H	650					10.6	10.1	-5
C	a-Si:H	110	a-Si:H	400					11.3	9.6	-12
D	a-Si:H	90	a-Si:H	400					10.5	9.2	-13
E	a-Si:H	90	a-Si:H	700	μc-Si:H	1800			13.6	11.7	-13
F	a-Si:H	160	μc-Si:H	1200	μc-Si:H	1600			11.2	11.0	-3
G	a-Si:H	80	a-Si:H	400	μc-Si:H	1600	μc-Si:H	2300	13.2	12.6	-4