Физика

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Illumination-Induced Degradation of a-Si:H Solar Cell Parameters

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Hydrogenated amorphous silicon is found to be a leading candidate for the fabrication of low cost solar cells. However presently there are two main factors that limit the large scale applications of a-Si:H solar cells as power sources. One of the central technological obstacle is the low conversion efficiency of the cells. The other obstacle for the large scale technological application of a-Si:H solar cells is degradation of critical material properties under the light exposure.

In our experiments we have performed light soaking tests on pinpin structure samples to see if the stability of a-SI:H solar cells is improved in comparison with the stability of pin structures.

The pattern of light induced degradation, i.e. the degree of degradation of a-Si:H pinpin solar cell parameters was studied on different i-layer thickness using high intensity (∼10 AM 1.5) illumination. It was found that stacked cells do not show a uniform degradation pattern as in the case of single junction solar cells. In particular, the degradation in short-circuit current Isc of stacked cells shows a big difference for thick (∼500 nm) and thin (∼400 nm) pinpin cells. It was found the degradation of the stacked cells with thick bottom layers exhibit a degradation pattern similar to that of single junction cells, i.e. the degradation in efficiency comes from the fill factor and the short circuit current, while open circuit voltage being degraded slightly. The degradation in short circuit current of cells with thin bottom layers is negligibly small.

Key words and phrases: pattern of degradation, solar cells, fill factor, efficiency, short circuit current, open circuit voltage, photo-degradation, multi-junction cells.

1. Introduction

During the past few years amorphous silicon alloys have become a viable material for inexpensive solar cells. But their application is still limited because of degradation observed under sunlight exposure. Many efforts have been made by several research groups to come up with new a-Si alloys which are less prone to light induced degradation. Stacked, multijunction solar cells are thus thought to be the most promising technology to obtain a-Si solar cells with high reliability and high efficiency [1]. Consequently, significant progresses have been made towards the improvement of the initial conversion efficiency as well as the light instability. Yet, for more reduction in the degradation of a-S based alloys or for the design of better structures that are less sensitive to the photo-degradation, a good understanding on the degradation behaviour of the cell is inevitable.

In the present work, we report the pattern of light induced degradation of a-Si:H pinpin solar cell parameters (I_{sc}, V_{oc}, FF) for different i-layer thickness, where i-layer thickness of the stacked cell is the sum of the i-layer thicknesses of the top cell (i_1)

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and the bottom cell (i_2). In particular, the degradation behaviour of I_{sc} has been presented for the different thicknesses.

2. Experimental

The samples were prepared by plasma enhanced chemical vapour deposition (PECVD) technique in a commercial 3-chamber PECVD system on a 10×10 cm^2 glass substrate. The stacked cells have the structure: glass/SnO_2 /p(C)/buffer/i/n/p/i/n/Ag. The area of the cell is 1×1 cm^2.

The light soaking tests were done under open circuit condition using high intensity ($\sim$10 AM1.5) illuminations obtained from WACOM solar simulator. During light exposure tests the temperature of the cells was kept at 50°C. On the other hand, the I-V characteristics of the cells were measured under standard test conditions (AM1.5, 25°C).

3. Results and Discussion

In single junction solar cells the degradation in efficiency (h) mainly comes from fill factor (FF) and partly from short circuit current (I_{sc}), while open circuit voltage (V_{oc}) being the less affected parameter [2, 3]. However, in pinpin structure solar cells, we do not observe such a uniform degradation pattern as it is evident from Fig. 1 and Fig. 2. Of course, similar to the pin structure, the degradation in efficiency of all stacked cells mainly comes from fill factor. But the decrease in short circuit current of stacked cells under illumination depends on the type of the cell under consideration. In some stacked cells (Fig. 1) the degradation in short circuit current I_{sc} is very small, almost negligible, while in others (Fig. 2) the degradation in I_{sc} is quite significant as in the case of single junction solar cells.

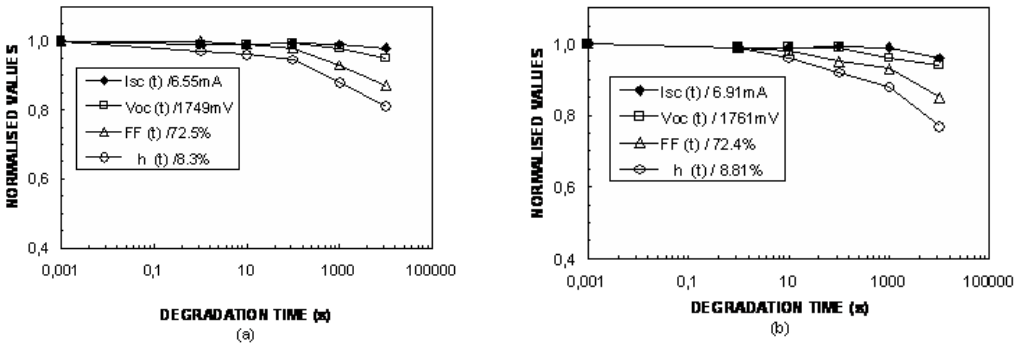

Figure 1. Light induced degradation of thin ($\sim$400 nm) a-Si:H pinpin solar cells with i-layer thickness: (a) i_1=43 nm, i_2=325 nm; (b) i_1=51 nm, i_2=325 nm. The light exposure tests were done under open circuit condition at 50°C

A closer look at the degradation behaviour of the stacked cells reveals that those cells with thick bottom layers (Fig. 2) exhibit a degradation pattern similar to that of single junction cells, i.e. the degradation in efficiency comes from the fill factor and the short circuit current while open circuit voltage being degraded slightly. On the other hand, those cells that have relatively thin bottom layers show a different degradation pattern as shown in Fig. 1, i.e. the degradation in short circuit current is negligibly small. This difference in degradation pattern, especially the difference in the degradation of I_{sc}, may be due to the current limitation of stacked cells.

There is a well-established consensus among photovoltaic specialists [4, 5] that the output current of stacked solar cells is limited by the lowest current among the

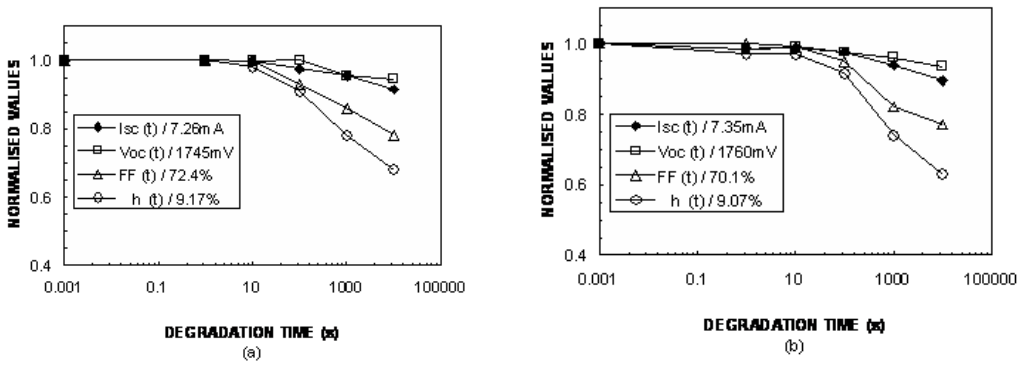

Figure 2. Light induced degradation of "thick" (500 nm) a-SiH pinpin solar cells with i-layer thickness: (a) i_1=59 nm, i_2=430 nm;(b) i_1=59 nm, i_2=540 nm. The light exposure tests were done under open circuit condition at 50°C.

component cells. Thus, in those stacked cells, whose current is limited by the top cell, the degradation in short circuit current should be negligible since the large electric field present in the top cell (which has a thickness of $\sim$ 60 nm) sweeps away the electron-hole pairs created in the layer before they can recombine and create light induced defects in the layer. However, if the current is limited by the bottom cell, the degradation in I_{sc} as well as the degradation pattern of the stacked cell as a whole resembles that of single junction solar cells. Thus, we may conclude that the degradation in I_{sc} of stacked cells is limited by that component (top or bottom) of the tandem structure which has a smaller output current.

4. Conclusion

Unlike single junction solar cells, the pattern of light induced degradation of a-Si:H pinpin solar cell parameters is dependent on the i-layer thickness of the cell. In particular, the degradation of I_{sc} is found to be negligible for thin cells, while it is significantly large for thick ones. This may be explained by the fact that the degradation in I_{sc} of stacked cells is limited by the top cell or the bottom cell, which has a smaller output current. Thus, to design a stacked cell with minimum degradation in I_{sc}, one needs to adjust the output current in such a way that the current of the top cell is dominant.

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Фотоиндуцированная деградация параметров солнечных a-Si:H фотоэлементов

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В результате многочисленных исследований было установлено, что гидронизированный аморфный кремний являетса наиболее подходящим материалом для изготовления недорогих солнечных фотоэлементов. Однако, широкому практическому применению фотопреобразователей на основе этого материала мешают их низкий коэффициент полезного действия и быстрая деградация параметров фотоэлементов под действием солнечного излучения. Влияние солнечного излучения на параметры фотопреобразователей проверяется как на многослойных, так и на однослойных pin структурах при различных интенсивностях света. Сравнивается стабильность параметров многослойных структур с однослойными.

В работе изучалось влияние освещения на параметры гетероструктурных солнечных фотоэлементов на основе гидронизированного аморфного кремния. В экспериментах было установлено, что механизм деградации параметров pinpin структур отличается от механизма деградации параметров pin структур при толщине нижнего слоя более 400 нм. Было обнаружено, что при толщине нижнего слоя менее 400 нм заметного отличия в механизмах деградации не наблюдалось. Обсуждается механизм деградации параметров могослойных фотоэлементов. Предполагается, что в случае толстого нижнего слоя фотоэлемента коэффициент полезного дейсвия определяется как фактором заполнения, так и током короткого замыкания. Деградация токов короткого замыкания в солнечных фотоэлементах с тонким нижним слоем незначительна.

Ключевые слова: характер деградации, солнечные фотоэлементы, коэффициент заполнения, эффективность, ток короткого замыкания, напряжение разомкнутой цепи, фотогенерация, многослойные фотоэлементы.