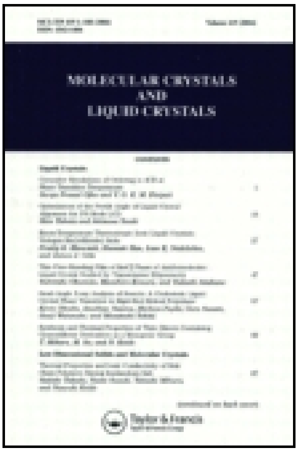

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The Properties of a-Si:H p-i-n Solar Cell by Intrinsic Layer's Thickness

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The hydrogenated amorphous silicon p-i-n solar cells have been deposited on indium tin oxide glass by using the PECVD. Solar cells were fabricated with various thicknesses [50–300 nm] of the i-layer, while the thicknesses of the p- and n-layer were fixed to 25 nm and 50 nm, respectively. The solar simulator shows the highest value of short-circuit current density and efficiency that are of 6.32 mA/cm^2 and 1.36%, respectively for the solar cell with a thickness of 200 nm and the open-circuit voltage is the highest value when thickness of the i-layer is 150 nm.

Keywords: a-Si:H; PECVD; intrinsic layer; solar cell

Introduction

Since the initial success of doping hydrogenated amorphous silicon(a-Si:H) by using the glow-discharge technique in 1975 [1], the use of amorphous silicon and its alloys as semiconductor materials have been largely proposed. The development of the first thin film a-Si:H solar cells was reported by D. E. Carlson and C. R. Wronski in 1976 [2]. The hydrogenated amorphous silicon (a-Si:H) which is fabricated in the form of a thin film has large photoelectric conductivity under AM1 (Air Mass 1:100 mW/cm^2) and it has about 10 times the optical absorption rate as compared with the crystal silicon in the visible spectrum. In addition, it has an advantage that it can be fabricated in a low temperature atmosphere under 300°C, be easily automated, and at a lower cost. Traditional solar cell is a p-n junction. The light irradiates the junction and produces electron-hole pairs, and then the charges will be driven out by an electric field in the depletion region. An intrinsic layer was added between the p and n to enlarge the depletion region so that the solar cell efficiency could be increased [3,4]. Amorphous silicon has since the beginning attracted a great deal of interest because of its capability of being deposited on large areas at a very low cost when compared with crystalline silicon.

In this study, we fabricated an a-Si:H p-i-n solar cell using PECVD. In a-Si:H p-i-n solar cell, thickness of i-layer plays an important role in generation electron-hole pairs. So we investigated the characteristics of the a-Si:H p-i-n solar cells that were fabricated in various thicknesses of the intrinsic layer.

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Experimental & Measurements

The a-Si:H thin film were deposited using 10% SiH_4 gas mixture diluted with He as a gas source by 13.56 MHz PECVD. Table 1 shows the deposition condition of the p-i-n solar cell. The substrate temperature and the working pressure were kept at 250°C and 0.75 torr respectively. The radio frequency (RF) power during the film deposition process was set to be 100 W for the dopant layer and 150 W for the intrinsic layer. The total gas flow of the p-a-Si:H layer was SiH_4 of 100 sccm and B_2H_6 of 30 sccm. The total gas flow of the i-a-Si:H layer was SiH_4 of 100 sccm and H_2 of 100 sccm. And, the total gas flow of the n-a-Si:H layer was SiH_4 of 100 sccm and PH_3 of 20 sccm. Solar cells were fabricated by applying different intrinsic layer thicknesses [50–300 nm], while the thicknesses of p- and n-layers were fixed to 25 nm and 50 nm respectively. All of the solar cells were fabricated on top of corning glass coated with ITO, based on the p-i-n structure as shown in Figure 1. Al was used as an electrode and 2000 Å were deposited by a thermal evaporator. The film's thickness was measured by an α-Step analysis. A semiconductor-parameter analyzer (HP4155A) was employed to measure the dark current-voltage (I-V) characteristics of the solar cell. The absorptance of the i-layer with various thicknesses was measured by a UV/VIS/NIR spectrometer, as depicted in Fig. 2. The efficiency of solar cells were measured by a standard solar simulator equipped with a xenon flash and an AM 1.5G filter.

Results and Discussion

Figure 3 shows the dark I-V curve for a-Si:H p-i-n solar cell. Figure 4 shows the absorptance spectra of the i-layer a-Si:H films with various thickness. The spectral responses of devices were measured in the 400~800 nm range. The absorptance of the i-layer with a thickness of 100 nm is lower than one of 200 nm and 300 nm in the wavelength range from 600~800 nm, specifically. As i-layer film is thick, we verified that absorptance was improved. Figure 5 shows the V_{oc}, J_{sc}, fill factor (FF), and efficiency (η) of an a-Si:H p-i-n solar cells as a function of the different i-layer thickness under AM 1.5 illumination. V_{oc} was decreased slightly with the i-layer thickness in the range of 150~300 nm. J_{sc} was increased until 200 nm and continued to decrease, after it was optimized at the i-layer thickness of 200 nm. If thickness of i-layer is thin, J_{sc} is decreased by less light absorption, whereas V_{oc} increased with built-in field in p-n junction. On the contrary to this, if thickness of i-layer is too thick, light is absorbed effectively. But, V_{oc} decreased with built-in field in p-n junction, also J_{sc} decreased by recombination of collected carrier. The FF is in general the most sensitive parameter to bulk recombination losses, as it is related to the bias dependence of this loss

Table 1. Deposition Conditions of p-i-n Solar Cell

Parameter	p-a-Si:H	i-a-Si:H	n-a-Si:H
Gas	SiH_4/B_2H_6	SiH_4/H_2	SiH_4/PH_3
Flow rate (sccm)	100/30	100/100	100/20
R.F. power (W)	100	150	100
Temperature (°C)	250	250	250
Working pressure (Torr)	0.75	0.75	0.75c
Thickness (nm)	25	50–300	50

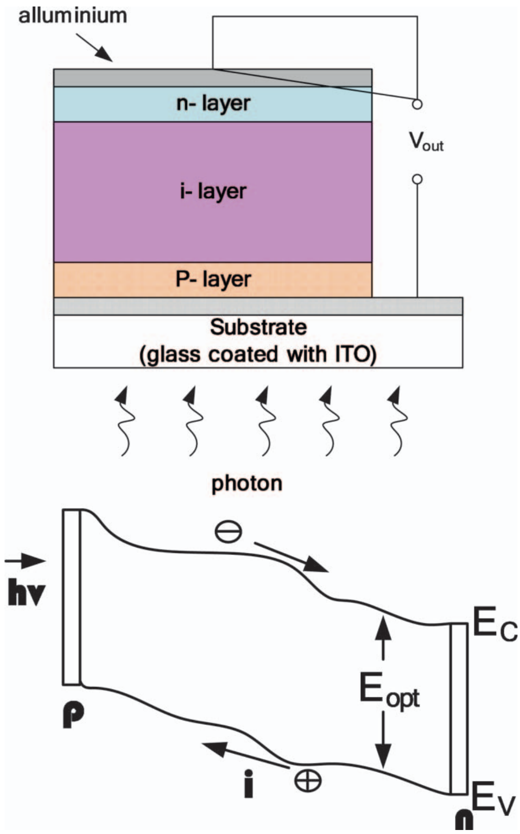

Figure 1. Structure and energy band diagram of the p-i-n solar cell.

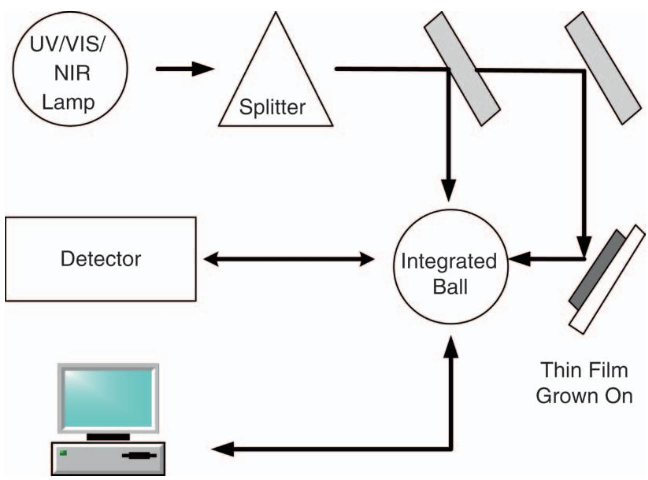

Figure 2. The setup of UV/VIS/NIR spectrometer for measuring absorptance of i-layer films.

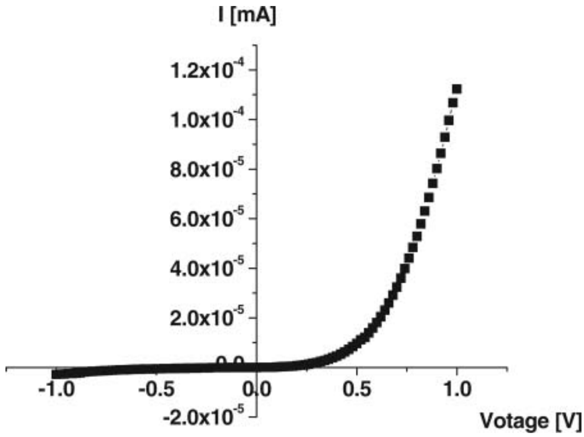

Figure 3. The dark I-V curve of p-i-n solar cell.

mechanism. In this result, the FF was optimized at the i-layer thickness of 200 nm. It was found that the best cell efficiency appears in the i-layer thickness of 200 nm.

The three parameters V_{oc}, J_{sc}, and FF are sufficient to calculate the energy-conversion efficiency η of the solar cell. It is defined by the ratio of maximum power that is extracted from the cell to the total illumination power. It is represented by the following equation,

$$\eta = \frac{FF \cdot V_{oc} \cdot I_{sc}}{\phi_{in}} \tag{1}$$

where ϕ_{in} is the total incident power of the photons. As another parameter influenced on the efficiency, there are shunt and series resistance. Significant power losses caused by the presence of a shunt resistance, R_{SH}, are typically due to manufacturing defects, rather than poor solar cell design. Low shunt resistance causes power losses in solar cells by providing an alternate current path for the light-generated current. Such a diversion reduces the amount of current flowing through the solar cell junction and reduces the

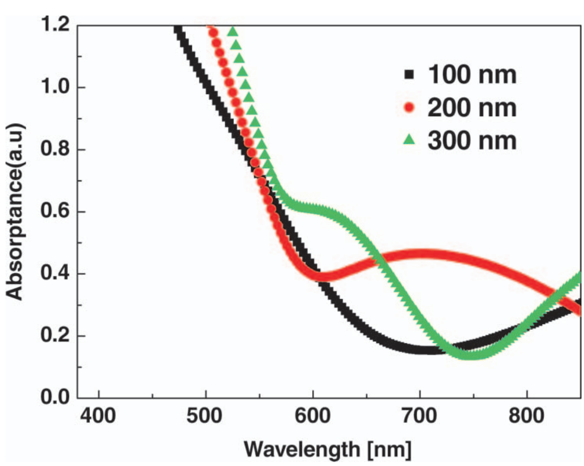

Figure 4. The absorptance spectra of i-layer a-Si:H films with various thickness.

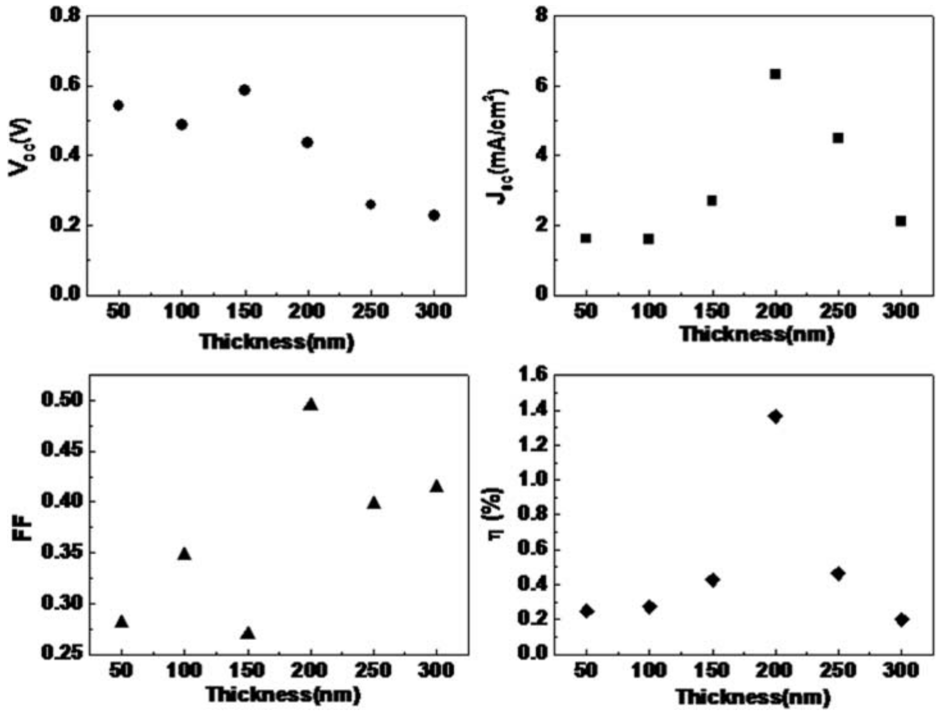

Figure 5. V_{oc}, J_{sc}, FF and efficiency under AM 1.5 illumination of a-Si:H p-i-n solar cells as a function of the various thickness of i-layer.

voltage from the solar cell. The effect of a shunt resistance is particularly severe at low light levels, since the will be less light-generated current. The loss of this current to the shunt therefore has a larger impact. In addition, at lower voltages where the effective resistance of the solar cell is high, the impact of a resistance in parallel is large. Series resistance in a solar cell has three causes. Firstly, it is the movement of current through the p-i-n junction

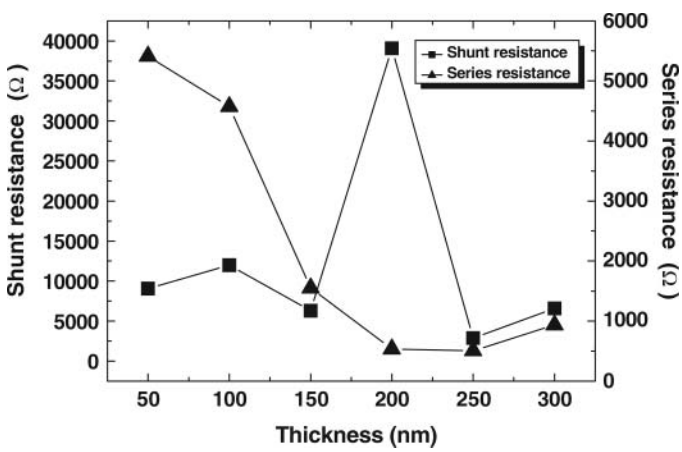

Figure 6. The shunt and series resistance change with the various thickness of i-layer.

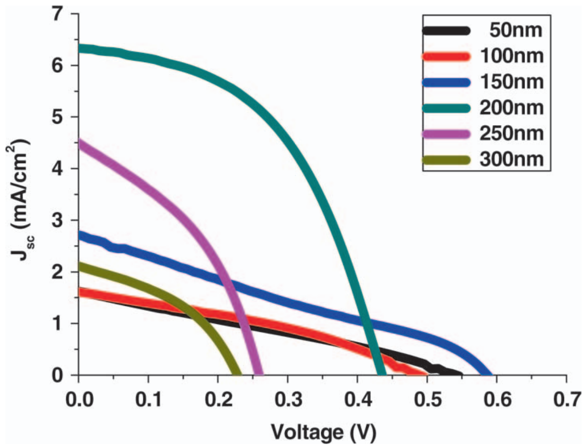

Figure 7. The photo J-V curves of fabricated p-i-n a-Si:H solar cells under AM1.5 illumination.

of the solar cell. Secondly, it is the contact resistance between the metal contact and the silicon, and finally the resistance of the top and rear metal contacts. The main impact of series resistance is to reduce the fill factor, although excessively high values may also reduce the short-circuit current.

Figure 6 shows the shunt and series resistance with various thickness of the i-layer. The shunt resistance was a peak at the i-layer thickness of 200 nm. And series resistance was decreased until 250 nm and continued to increase. In our research, fabricated solar cell has the best characteristics at the i-layer thickness of 200 nm.

Figure 7 shows the current-voltage characteristic of the solar cells under AM 1.5 illumination that resulted from this study. The best performance of short circuit current density (J_{sc}), fill factor (FF), and efficiency (η) are of 6.32 mA/cm^2, 0.49, and 1.36%, respectively for the solar cell having an i-layer thickness of 200 nm and an open-circuit voltage (V_{oc}) is the best performance for 150 nm. In this research, these parameters have been optimized to obtain the best thickness of an intrinsic layer for a solar cell application.

Conclusion

We have fabricated a-Si:H p-i-n solar cells with varying i-layer thicknesses from 50 nm to 300 nm by using the PECVD method. As a result of this experiment, we verified that the best characteristics of p-i-n solar cells are when the value of the open-circuit voltage (V_{oc}), short-circuit current density (J_{sc}), fill factor (FF), and efficiency (η) are 0.43 Volt, 6.32 mA/cm^2, 0.49, and 1.36%, respectively for the solar cell with a thickness of 200 nm. As i-layer is thick, it obtained better absorptance, through the UV/VIS/NIR spectrometer measurement. We will research to enhance solar cell efficiency through additional experimentation.

Acknowledgment

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