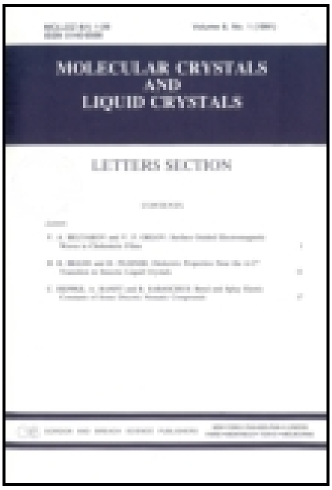

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Characteristics of a-SiC:H/a-SiGe:H/a-Si:H Thin Film Solar Cells Enhanced by CH_4 Flow Rates Controlling in P-Layer

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We fabricated a a-SiC:H / a-SiGe:H / a-Si:H thin film solar cell by adjusting CH_4 flow rate in order to absorb long wavelength of solar spectrum without stacked structures such as triple junctions. The a-SiC:H, a-SiGe:H and a-Si:H layers with sheet resistance 7∼8 ohm/sq were deposited on indium tin oxide (ITO) glass by 13.56 MHz radical-assisted plasma-enhanced chemical vapor deposition (RA-PECVD). The working pressure and substrate temperature were 750 mTorr and 250°C, respectively. The a-SiC:H films for p-layer thickness of 300 Å were deposited using 10% CH_4 diluted in H_2. The thickness of a-SiGe:H for i-layer corresponded to 2000 Å. The n-layer was fabricated using 1% PH_3 in diluted H_2. The optical properties of these films were measured by UV-VIS spectrophotometer. The thickness of the film was estimated by FE-SEM were observation. The various values of Jsc, Voc, FF and conversion efficiency were evaluated by the solar simulator.

Keywords a-SiC:H; a-SiGe:H; thin-film solar cells; PECVD; amorphous silicon

Introduction

In recent years, with the interest of developing several new energy resources to deal with the exhaustion of fossil fuel, solar cell is one of the most important research interests [1]. In addition to crystalline structured bulk type solar cell of high efficiency, there are many researches going on including organic type and thin film type. Although thin film a-Si:H solar cell has advantages of simple structure and cheap fabrication price, its efficiency is low [2]. These amorphous based devices have intensively researched for high absorption coefficient in the visible range of the solar spectrum and are able to fabricate the low-cost and low temperature using the PECVD. Among these alloy materials, the a-SiGe:H alloys has been explored extensively for photovoltaic application as the narrow bandgap absorber than that of the a-Si:H, which allows an increase of the utilization of the solar spectrum at a long wavelength and the stabilized efficiency of solar cells [3–8]. To overcome this problem, we improved transmittance ratio by depositing a-SiC:H using CH_4 gas as a p-layer. As a result of, we achieved

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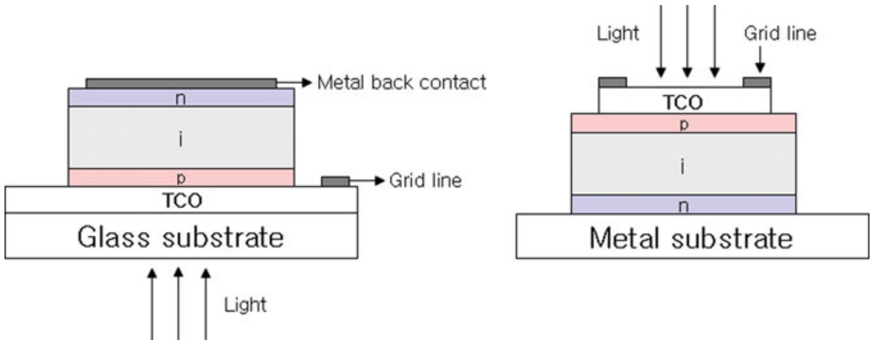

Figure 1. The structure of the p-i-n solar cell.

improved transmittance ration by depositing a-SiC:H suing CH_4 gas for p-layer. Moreover, we anticipate that these results will affect to raise cell performance. Also, we achieved improved efficiency of solar cell by absorbing maximized light to light absorption layer.

Experimental and Fabrication of Solar Cell

We have fabricated the a-SiC:H / a-SiGe:H / a-Si:H solar cell by adjusting CH_4 flow rate using the RA/PECVD. All solar cells that were fabricated on the top glass, which was coated with an indium tin oxide (ITO) based on the P-I-N structure as shown in Fig. 1. We prepared p-a-SiC:H, i-a-Si:H (buffer layer), i-a-SiGe:H, and n-a-Si:H thin films for fabrication of amorphous silicon solar cells, as shown in Table 1. We also explored the effect of plasma treatment under the same CVD conditions. Indium tin oxide (ITO) glasses with 7 Ω/sq sheet resistance were employed as transparent electrodes for amorphous silicon solar cells. A conventional plasma enhanced chemical vapor deposition (PECVD) system was used

Table 1. Deposition conditions of p-a-SiC:H, buffer-a-Si:H, i-a-SiGe:H, and n-a-Si:H

Parameter	p-a-SiC:H	Buffer-a-Si:H	i-a-SiGe:H	n-a-Si:H
Gas	SiH_4(+90% He) / B_2H_6(+97% H_2) / CH_4(+90% H_2)	SiH_4(+90% He) / H_2	SiH_4(+90% He) / H_2 / GeH_4(+90% H_2)	SiH_4(+90% He) / PH_3(+99% H_2)
Flow rate (*sccm*)	10∼90 / 30 / 10∼90	100 / 100	100 / 100 / 60	100 / 20
rf power (*W*)	100	150	150	100
Substrate temperature (°C)	250	250	250	250
Working Pressure (*mTorr*)	750	750	750	750
Deposition time	1 *min* 48 *sec*	1 *min* 12 *sec*	10 *min* 48 *sec*	4 *min* 48 *sec*

to deposit the p-a-SiC:H, i-a-Si:H, i-a-SiGe:H, and n-a-Si:H films. Deposition conditions for a-SiC:H, a-SiGe:H, and a-Si:H in the p-i-n layer were summarized in Table 1. Firstly, A 300 Å-thick p-a-SiC:H thin film as an alternative window layer was deposited onto the ITO glass by introducing 30 sccm 97% B_2H_6 diluted in H_2, 90% CH_4 diluted in H_2, and 90% SiH_4 diluted in He with RF power of 100 W at 250°C and 750 mTorr. It should be noted that the ratio of CH_4 and SiH_4 gases was systematically adjusted (100 : 0 ∼ 0: 100 sccm). A 2000 Å-thick i-a-Si:H/a-SiGe:H optical absorption layer was deposited onto the p-a-SiC:H/ITO film by introducing 100 sccm SiH_4 and 100 sccm H_2 with RF power of 150 W at 250°C and 750 mTorr for i-a-Si:H and introducing 100 sccm SiH_4, 100 sccm H_2, and 60 sccm GeH_4 with RF power of 150 W at 250°C and 750 mTorr for a-SiGe:H. A 600 Å-thick n-a-Si:H thin film was deposited with introducing 100 sccm SiH_4 and 20 sccm 99% PH_3 diluted in H_2 with RF power of 100 W and 750 mTorr for p-i-n junction configuration. Finally, a 2000 Å-thick Al electrode was deposited by thermal evaporator. The designed a-SiC:H/a-SiGe:H/a-Si:H thin film solar cell was depicted in Figure 2, revealing that the pyramid shaped structure was formed with shadow masks.

Results and Discussion

The effect of ratio of CH_4 and SiH_4 gases on amorphous silicon solar cells performance was investigated. Optical transmittance and absorption spectra of the individual p-layer were

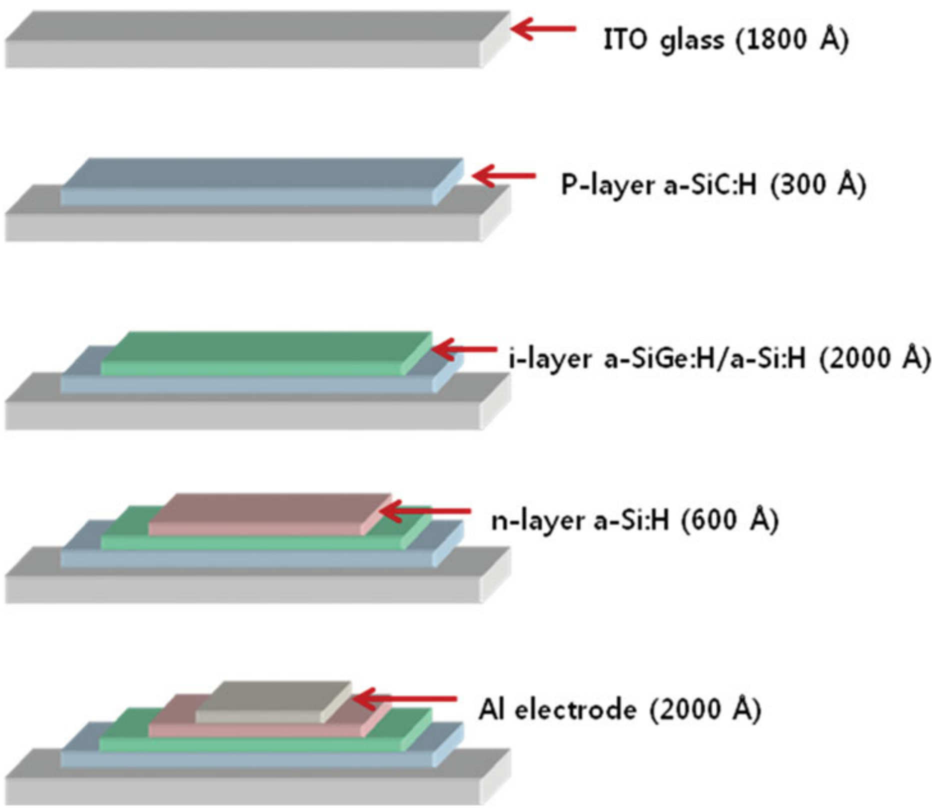

Figure 2. The structure of the a-SiC:H/a-SiGe:H/a-Si:H solar cell.

Table 2. UV/Vis/Nir spectrophotometer analysis deposition conditions

	SiH_4 (sccm)	B_2H_6 (sccm)	CH_4 (sccm)	Time (min)	RF power (W)	Wp (Torr)	Temp (°C)	Thick (Å)
			0					
			10					
p-layer			30					
	100	30	50	1′48″	100	0.750	250	300
			70					
			90					
			110					
			130					

examined by UV/Vis/NIR spectrometer. This result clearly reveals that light absorption was inversely proportional to CH_4 flow rate. The performance of a-SiC:H/a-SiGe:H/a-Si:H thin film solar cell was examined by solar simulator. The effect of ratio of CH_4 and SiH_4 gases on amorphous silicon solar cells performance was investigated. Optical transmittance and absorption spectra of the individual p-layer were examined by UV/Vis/NIR spectrometer. This result clearly reveals that optical light absorption was inversely proportional to CH_4 flow rate in Figure 3. The performance of a-SiC:H/a-SiGe:H/a-Si:H thin film solar cell was examined by solar simulator.

As CH_4 flow increased, the efficiency also increased (maximum efficiency at SiH_4 :CH_4 = 60 : 40 sccm), followed by a gradual decrease up to SiH_4 :CH_4 = 20 : 80 sccm. We suggested that the appropriate CH_4 injection can allow band gap widening of the p-layer, leading to increase in V_{oc}, J_{sc}, FF, and efficiency as show Figure 4. However, oversupply of CH_4 induces a low electrical conductivity, thereby the efficiency is substantially reduced. Also, reduced fill factor (FF) can be explained by the p/i band offset, the energy barrier of ITO glass and p-layer, and the electrical conductivity of p-layer. Figure 5 shows the external quantum efficiency (EQE) of the a-SiC:H/a-SiGe:H/a-Si:H solar cells as a function of the

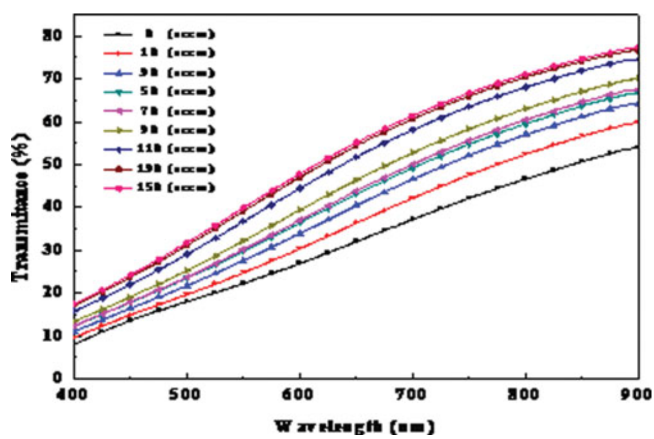

Figure 3. Transmittance characteristics of a-SiC layer with CH_4 flow rates.

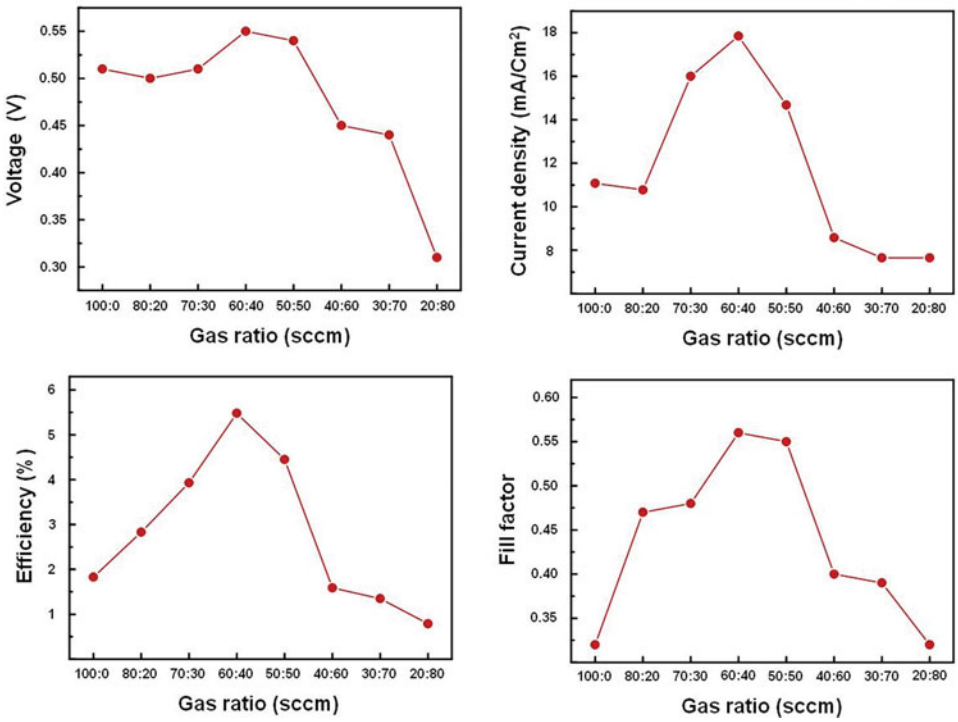

Figure 4. Characteristics of a-SiC:H/a-SiGe:H/a-Si:H solar cell with SiH_4:CH_4 flow rates.

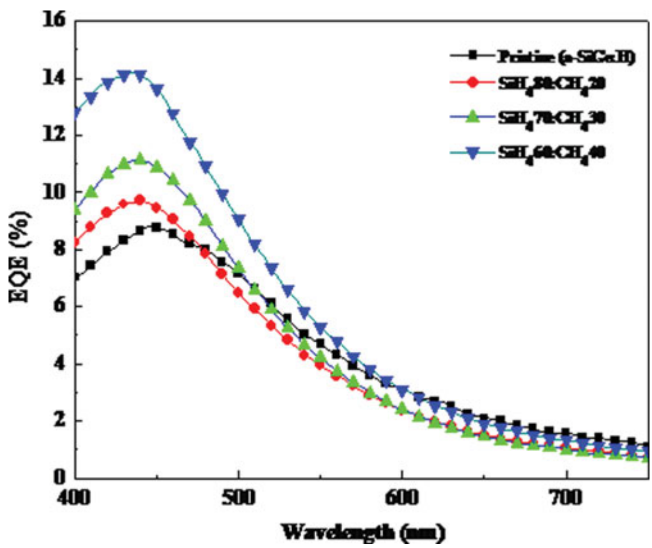

Figure 5. External quantum efficiency characteristics of the a-SiC:H/a-SiGe:H/a-Si:H solar cells with SiH_4:CH_4 flow rates.

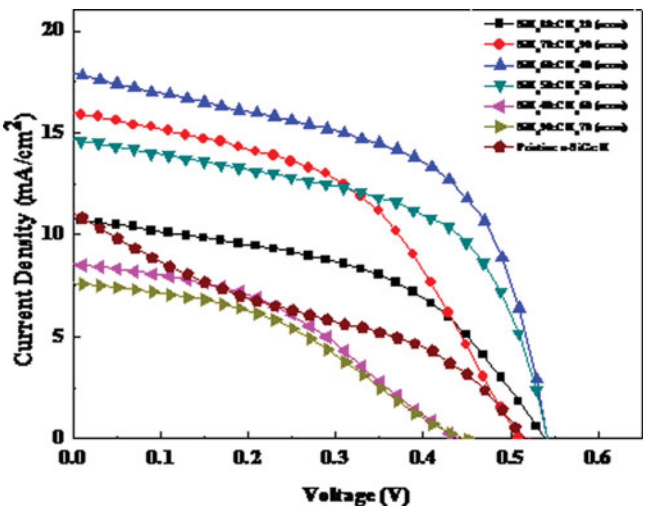

Figure 6. J-V characteristics of a-SiC:H/a-SiGe:H/a-Si:H solar cells with CH_4 flow rates.

flow rate of SiH_4/CH_4. The EQE is incident photon to converted electron ratio, which is highly related to J_{SC}. We observed that the EQE can be modulated by adjusting the flow rate of CH_4 and the EQE of the SiGe:H/a-SiGe:H/a-Si:H thin film solar cells was greater than that of a-SiGe:H thin film solar cells. Figure 6 reveals J-V characteristics of a-SiC:H/a-SiGe:H/a-Si:H thin film solar cells deposited by adjusting CH_4 gas for the p-layer. With increasing CH_4 flow rate, the VOC and JSC increased (maximum V_{OC} and J_{SC} at SiH_4 : CH_4 = 60 : 40 sccm), followed by a gradual decreased. As CH_4 flow increased, the efficiency also increased (maximum efficiency at SiH_4 : CH_4 = 60 : 40 sccm), followed by a gradual decrease up to SiH_4 : CH_4 = 20 : 80 sccm. We suggested that the appropriate CH_4 injection can allow band gap widening of the p-layer, leading to increase in V_{oc} and J_{sc}. However, the oversupply of CH_4 induces the potential barrier lowering, resulting in a decrease in V_{OC}.

Conclusions

In this study, we have investigated the optical properties and the J-V characteristics of the a-SiC:H/a-SiGe:H solar cells deposited using the PECVD method. It should be noted that the ratio of CH_4 and SiH_4 gases was systematically adjusted (100 : 0 ∼ 0: 100 sccm). Here, we estimated optimized condition for the ratio of gases (SiH_4 : CH_4 = 60 : 40 sccm), establishing that optimized cell efficiency was up to 5.48%, 0.55 V, 17.85 mA/cm^2, and Fill Factor of 0.56 at. This approach provides an effective methodology for band gap tuning of a p-layer for high-performance amorphous silicon solar cells without tandem and triple junction cells.

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