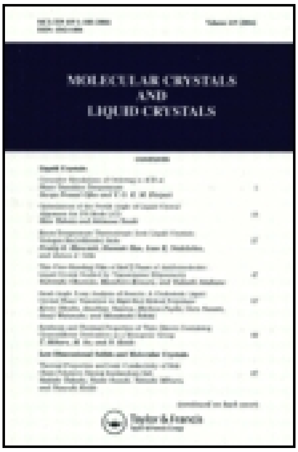

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The Properties of Amorphous Silicon Thin Film Solar Cell Fabricated by Intrinsic Layer's Structure and Materials

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The hydrogenated amorphous silicon and hydrogenated amorphous silicon-gemanium alloys have been prepared by the PECVD method. Hydrogenated amorphous thin film solar cells consisted of P-a-Si:H/I-a-Si:H(a-Si:H, a-SiGe:H, a-Si:H/a-SiGe:H superlattice) / N-a-Si:H structure. Solar cells were fabricated with thickness 200 nm of intrinsic layer, while the thicknesses of p- and n-layer were fixed to 30 nm and 60 nm respectively. UV-Vis Spectrometer analysis of a-Si:H and a-SiGe:H thin films optical bandgap were 1.77, 1.12–1.71 eV. Conversion efficiencies were a-Si:H (1.36%), a-SiGe:H (3.11%) and a-Si:H/a-SiGe:H superlattice (4.52%).

Keywords a-Si:H; a-SiGe:H; a-Si:H/a-SiGe:H; thin film solar cell; superlattice; PECVD

Introduction

Plasma enhanced chemical vapor deposition (PECVD) has become the most common technique used in the deposition of hydrogenated amorphous silicon material for semiconductor device applications. Amorphous silicon and alloys have attracted interesting as low cost high efficiency solar cells. A-SiGe:H have been of much interest for the production of efficient solar cell, the optical bandgap of alloys can be easily turned to match the solar spectrum. Among these alloy materials, a-SiGe:H has been explored extensively for photovoltaic applications as the narrow bandgap absorber. The a-SiGe:H alloys were investigated as an optoelectronic material with a lower bandgap than the a-Si:H, which allows for an increase of the utilization of the solar spectrum at long wavelengths and the stabilized efficiency of solar cells [1,2]. Semiconductor superlattices [3,4] were fabricated from the alternating layers of two semiconductors and exhibit many interesting transport and optical properties.

In this study, we fabricated an a-Si:H p-i-n solar cell using PECVD. We also compared with the conversion efficiency of the a-Si:H, a-SiGe:H and a-Si:H/a-SiGe:H superlattice thin film solar cells that were fabricated in material and structure by the intrinsic layer.

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Table 1. Deposition Conditions of PIN Solar Cell.

Parameter	a-Si:H	a-SiGe:H	Superlattice	P-a-Si:H	N-a-Si:H
Gas	SiH_4/H_2	$SiH_4/H_2/GeH_4$	SiH_4/GeH_4	SiH_4/B_2H_6	SiH_4/PH_3
Flow rate (*sccm*)	100/100	100/100/30	100/20	100/30	100/10
R.F. power (*W*)	100	100	50	100	100
Temperature (°*C*)	250	250	250	250	250
Working pressure (*mTorr*)	750	750	500	750	750
Thickness (*Å*)	2000	2000	2000	300	600

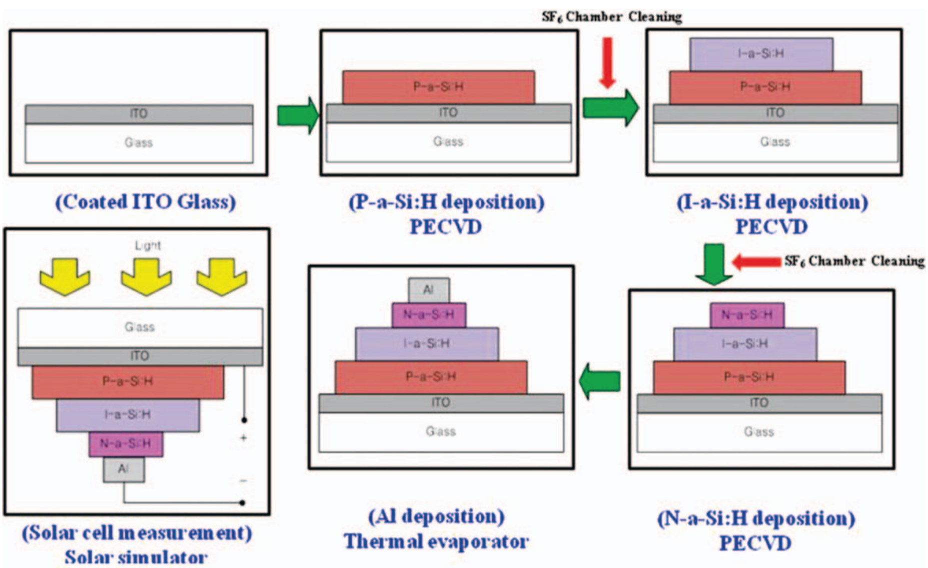


Figure 1. The Process flow of a PIN thin film Solar Cell.

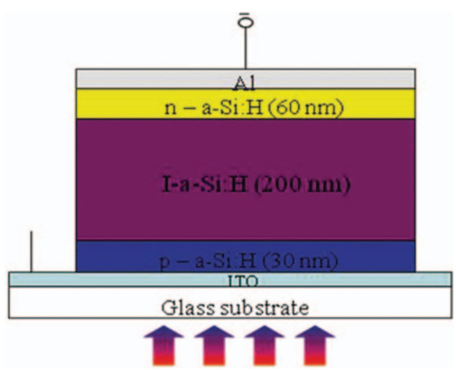


Figure 2. Schematic of the PIN a-Si:H solar cell on a glass superstrate.

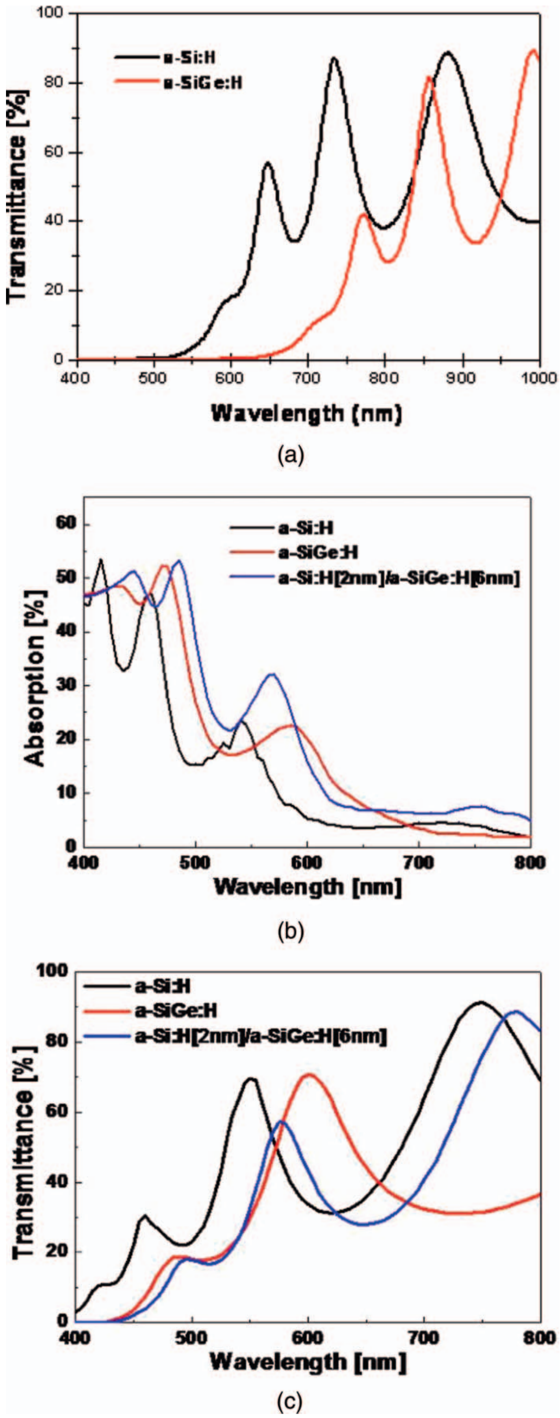
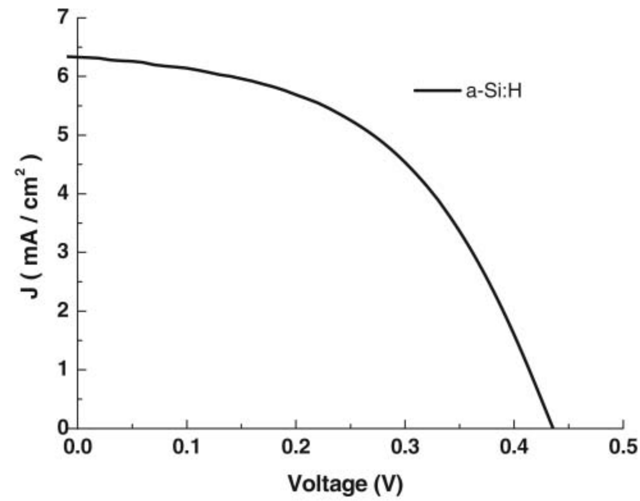
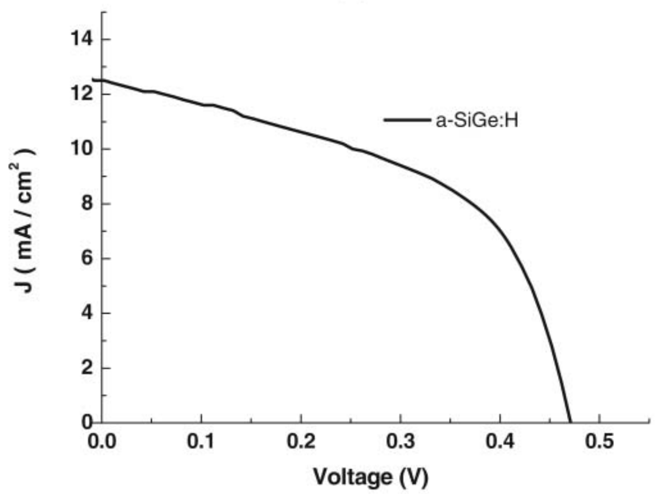


Figure 3. Transmittance spectra of the a-Si:H and the a-SiGe:H thin film. (a) UV-Vis Spectrometer analysis (b), (c) Essential Macleod Simulation analysis.



(a)



(b)

Figure 4. Current-voltage of a-Si:H and a-SiGe:H thin film solar cell.

Experimental & Measurements

The a-Si:H and a-SiGe:H layers were deposited consequently on the glass substrate by using the 13.56 MHz plasma enhanced chemical vapor deposition (PECVD) [5,6] at 250°C without breaking the vacuum. The working pressure were 700, 500 mTorr and r.f power were 100, 50 W. Table 1 shows deposition conditions of the a-Si:H, a-SiGe:H and a-Si:H/a-SiGe:H superlattices structure's thin films. The a-Si:H and a-SiGe:H films were deposited using a mixture of SiH_4 (SiH_4 diluted in 10% He) and GeH_4(GeH_4 diluted in 10% H_2). The GeH_4 flow rate was 30 sccm. B_2H_6 and PH_3 flow rate were 30 and 10 sccm. Figures 1 and 2 shows process flow and Schematic of the PIN a-Si:H solar cell and superstrate structure.

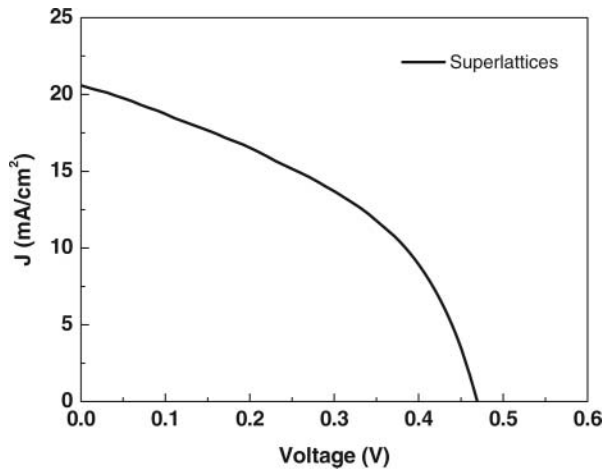


Figure 5. Current-voltage of a-Si:H/a-SiGe:H superlattices thin film solar cell.

We used coated ITO[12 Ω/cm^2] glass. The film's thickness was measured by an α-Step analysis. a-Si:H and a-SiGe:H film's thickness were 2000 Å. The deposition rates of the a-Si:H, a-SiGe:H and superlattices thin films were 3.5 Å /Sec, 3.7 Å /Sec and 1 Å /Sec, respectively. P type a-Si:H and n type a-Si:H thin film layer's thickness was 300 Å, 600 Å, respectively. The optical properties of the films were measured by UV-Vis Spectrometer analysis. Thin film solar cell's external parameter were measured by the solar simulator under AM 1.5.

Results and Discussion

Figure 3(a) shows the transmittance spectra of a-Si:H and a-SiGe:H thin films obtained by UV-Vis Sectrometer. The spectral responses of thin film was measured 400 ~ 800 nm range. The spectrum's peak of the a-SiGe:H thin film had a blue shift more than a-Si:H film's spectra. Figure 3 (b), (c) transmittance and absorption results of a-Si:H, a-SiGe:H and a-Si:H/a-SiGe:H superlattice thin film using Essential Macleod Simulation. Superlattice thin film's transmittance were lower than a-Si:H and a-SiGe:H. From this result, Superlattice thin film's absorption were better than a-Si:H and a-SiGe:H.

The a-Si:H and a-SiGe:H thin film's optical bandgap were calculated from the result of transmittance spectra. The absorption coefficient and optical bandgap were calculated according to following equations (1) and (2) method. The absorption coefficient α was calculated from a transmittance spectra obtained by the UV-Vis Spectrometer analysis using the following the equation,

$$\alpha = -(1/d)\ \mathrm{In}\ \mathrm{T}(\lambda), \quad (1)$$

$$\alpha = \mathrm{A}\left(\mathrm{h}\upsilon - \mathrm{E_{opt}}\right)^{1/2} / \mathrm{h}\upsilon \quad (2)$$

where d and T(λ) denote the thickness of the film and transmittance as functions of the photon wavelength, respectively. The optical bandgap (E_{opt}) was determined using an equation from hυ versus (αhυ), in which (hυ) denotes the photon energy. The a-Si:H film's optical bandgap was 1.77 eV and a-SiGe:H film's was 1.55 eV.

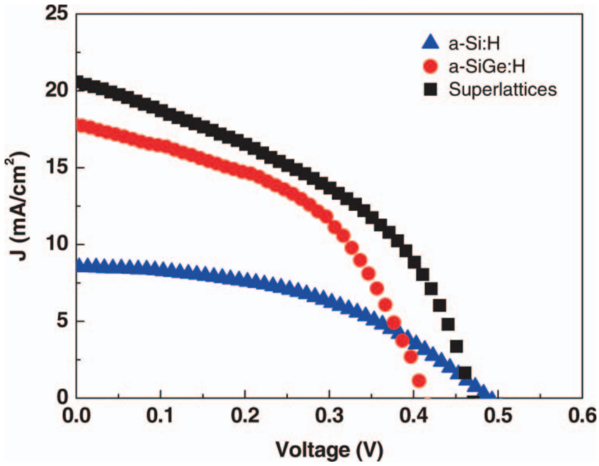


Figure 6. Current-voltage of a-Si:H, a-SiGe:H and a-Si:H/a-SiGe:H superlattices thin film solar cell.

Figure 4 shows the current-voltage characteristic of the a-Si:H and a-SiGe:H thin films solar cell set under AM 1.5 illumination. P-I-N layer's thickness were 30 nm [15–40 nm], 200 nm [50–300 nm] and 60 nm [15–80 nm]. Previously, a-Si:H thin film solar cell was optimized. Result of a-Si:H film's external parameters were $J_{sc} = 6.33$ mA/cm^{-2}, $V_{oc} =$ 0.44 V, FF = 0.5 and $\eta = 1.37\%$. a-SiGe:H thin film solar cell's external parameter was optimized at 1.55 eV. External parameters of the a-SiGe:H film was $J_{sc} = 15.1$ mA/cm^2, $V_{oc} = 0.44$ V, FF = 0.47 and $\eta = 3.12\%$.

Figure 5 shows the current-voltage characteristic of a-Si:H/a-SiGe:H superlattice structure thin film solar cell. The superlattice were consist of barrier[a-Si:H] and well[a-SiGe:H]. The superlattice thin film was consist of a-Si:H [2 nm]/ a-SiGe:H [6 nm] and Total 25 layers. The superlattice thin film solar cell's GeH_4 flow rate was 20 sccm. The a-SiGe:H film's External parameters measured were $J_{sc} = 22.01$ mA/cm^2, $V_{oc} = 0.48$ V, FF = 0.34 and $\eta =$ 4.52%.

Figure 6 shows the current-voltage characteristic of a-Si:H, a-SiGe:H and a-Si:H/a-SiGe:H thin films solar cell. Conversion efficiency were 2.1%, 3.2% and 4.52%. Superlattices thin film solar cell's external parameter were better than a-Si:H and a-SiGe:H.

Conclusion

Hydrogenated amorphous silicon and amorphous silicon germanium films prepared by plasma enhanced chemical deposition. We investigated the properties of the amorphous silicon thin films deposition by intrinsic layer's structure and materials. The a-Si:H film's bandgap was 1.77 eV and the a-SiGe:H was 1.55 eV. Conversion efficiencies were better with a-Si:H/a-SiGe:H superlattice [4.52%] thin film solar cell than a-Si:H[1.36%] and a-SiGe:H[3.10%].

Semiconductor superlattices was improvement electron mobility and optical absorption better than bulk condition. The superlattice structure thin film solar cell were remarkable improvement in collection efficiency in the short wavelength region was compared with conventional a-Si:H and a-SiGe:H thin film solar cell. The superlattice thin film solar cell were better than property in interaction of neighbor's well, quantum size effect and improvement of mobility by tunneling.

Acknowledgment

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