Mol. Cryst. Liq. Cryst., Vol. 532: pp. 15/[431]–20/[436], 2010

ISSN: 1542-1406 print/1563-5287 online
DOI: 10.1080/15421406.2010.497096

Taylor & Francis
Taylor & Francis Group

The Optical Properties of a-Si:H/a-SiGe$_x$:H Superlattice Structure to Apply Intrinsic Layer in Solar Cell

JIN-EUI KIM, JAE-WON SHIN, WON-HO SON, AND SIE-YOUNG CHOI

School of Electrical Engineering & Computer Science, Kyungpook National University, Sankyuk-dong, Bu-gu, Daegu, Republic of Korea

The hydrogenated amorphous silicon (a-Si:H) and hydrogenated amorphous silicon-germanium (a-SiGe:H) alloys have been prepared by the plasma enhanced chemical vapor deposition (PECVD) method. The films were grown on corning #1737 glass from the gas mixture of silane and germane. Superlattice thin films consisted of a-Si:H/a-SiGe:H multilayer structure. The UV-VIS Spectrometer analysis of a-SiGe$_x$:H alloys and superlattices thin films showed that the bandgap absorption spectra of a-SiGe$_x$:H alloys shift to lower photon energy with an increase in the GeH$_4$ flow rate [0–300 sccm] and various a-Si:H [2−10 nm]/a-SiGe$_x$:H [2 nm] thickness. The optical bandgap had decreased by between 1.24∼1.71 eV in regards to a-SiGe:H and superlattice thin films.

Keywords a-Si:H/a-SiGe:H; optical bandgap; PECVD; solar cell; superlattices

Introduction

a-SiGe:H alloys were investigated as an optoelectronic material with a lower bandgap than 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 [1,2]. It was a possible to control the optical bandgab in a-SiGe:H alloys to lower energy by adding Ge to the alloys. Numerous studies on the characteristics of the a-SiGe:H alloys with respect to the Ge content have already been performed. The semiconductor superlattice structures fabricatied from the alternating layers of two semiconductors, exhibit many interesting transport and optical properties that are associated with quantum size effects. The semiconductor superlattices were based on the pioneering work of L. Esaki and R. Tsu [3], the band gap of many semiconductor superlattices including a-Si:H/a-C:H, a-Si:H/a-SiN:H [4], a-SiH/a-SiN$_x$, a-Si:H/a-SiO$_x$, a-Si:H/a-Ge:H, CdSe/SeTe, a-Si$_3$N$_4$:H/a-Si:H, a-C:H superlattice where the band gap were tailored by changing deposition conditions [5,6].

Address correspondence to Prof. Sie-Young Choi, School of Electrical Engineering & Computer Science, Kyungpook National University, Sangyuk-dong, Buk-gu, Daegu 702-701, Korea (ROK). Tel.: (+82)53-940-8618; Fax: (+82)53-950-6837; E-mail: sychoi@ee.knu.ac.kr

Table 1. Deposition conditions of a-Si:H and a-$SiGe_x$:H thin films

Parameter	a-Si:H	a-$SiGe_x$:H
Gas	SiH_4/H_2	$SiH_4/H_2/B_2H_6$
Flow rate (sccm)	100/100	100/100/0∼300
r.f. power (W)	50	50
Substrate temperature (°C)	250	250
Working pressure (mTorr)	750	750

This study investigated the optical properties of the a-$SiGe_x$:H and the a-Si:H/a-$SiGe_x$:H superlattice structure's thin films in order them in the solar cell as intrinsic layer.

Experimental and Measurements

The improvement of a-SiGe:H thin film alloys continues to be an important aspect of a-Si:H based solar cell technology. The plasma enhanced chemical vapor deposition (PECVD) technique was employed under varying growth conditions to explore the parameter space between pure a-Si:H and a-SiGe:H. The a-Si:H and a-$SiGe_x$:H layers were deposited consequently on the glass substrate by using the 13.56 MHz plasma enhanced chemical vapor deposition (PECVD) at 250°C without breaking the vacuum. The working pressure was 700 mTorr and the RF power was 50 W. Tables 1 and 2 shows deposition conditions of the a-Si:H, a-SiGe:H and a-Si:H/a-$SiGe_x$:H superlattices structure's thin films. The a-$SiGe_x$:H and superlattice layer 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 rates varied in the range of 0−300 sccm. The optical properties of the films were measured by UV-VIS Spectrometer analysis. Alpha-Step was used to measure the thickness of the a-Si:H and a-SiGe:H thin films. The layer thickness of the a-Si:H and a-$SiGe_x$:H thin films were 5000 Å and a-Si:H [2–10 nm]/a-SiGe:H [2 nm], respectively, while superlattices thin films were 5000 Å, respectively. The deposition rate of the a-SiGe:H and superlattice thin films were 1 Å/Sec. Figure 1 shows the structure of the superlattice with respect to the solar cell. The superlattice structure consisted of alternating layers of a-Si:H and a-$SiGe_x$:H. The superlattice film's layer thickness consisted of 1–10 nm.

Table 2. Deposition conditions of a-Si:H/a-$SiGe_x$:H superlattices structure thin films

Parameter	a-Si:H	a-$SiGe_x$:H
Gas	SiH_4/H_2	$SiH_4/H_2/B_2H_6$
Flow rate (sccm)	20/35	20/35/6∼22
r.f. power (W)	40	40
Substrate temperature (°C)	250	250
Working pressure (mTorr)	500	500
Film thickness (nm)	2, 5, 10	2, 5

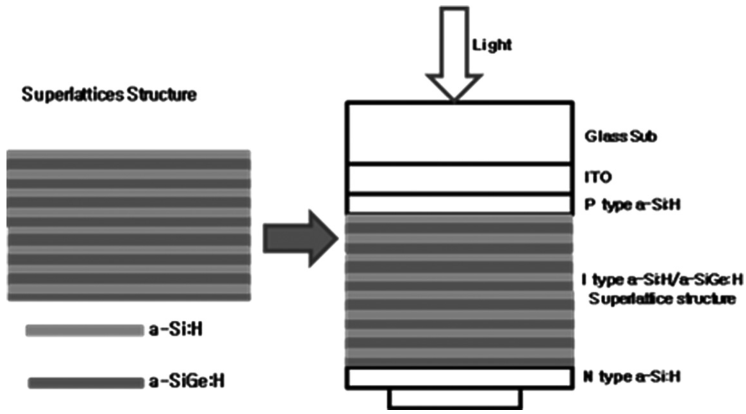

Figure 1. The superlattices structure of the intrinsic layer for a solar cell.

Results and Discussion

The a-SiGe:H has attractive features because of the possibility of changing the optical bandgap of these material with composition to matching the solar spectrum.

Figures 2 and 3 shows the transmittance spectra and optical bandgap of a-SiGe$_x$:H thin films of different GeH_4 flow rate obtained by UV-VIS spectrometer. Transmittance of the a-SiGe$_x$:H films had been observed as shifting from low to high in wavelength according to increase GeH_4 flow rate.

The optical bandgaps were calculated from the result of optical tranmittance spectra. The absorption coefficient and optical bandgap was calculated according to the Eqs. (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,

$$\alpha = -(1/d)\ln T(\lambda) \tag{1}$$

$$\alpha = A(h\upsilon - E_{opt})^{1/2}/h\upsilon \tag{2}$$

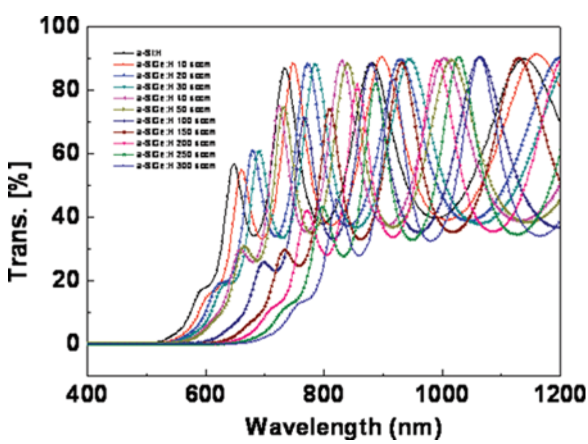

Figure 2. Transmittance spectra of the a-Si:H and the a-SiGe$_x$:H films in GeH_4 flow rate.

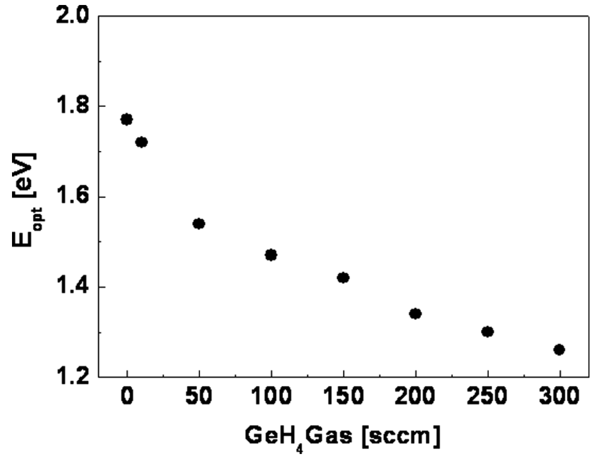

Figure 3. The optical bandgap of the a-Si:H and the a-$SiGe_x$:H films in GeH_4 flow rate.

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 equation from hυ versus (αhυ), in which (hυ) denotes the photon energy.

The optical bandgap had decreased while the GeH_4 flow rates were increasing. The bandgap were decreased from 1.24 to 1.71 eV with a correspondingly increase in the GeH_4 flow rate.

Figures 4 and 5 shows the transmittance spectra of the a-Si:H/a-$SiGe_x$:H superlattice thin films. Figure 6 shows the optical bandgap with respect to superlattice thin films. Superlattice thin films consist of two types: Type I was prepared GeH_4 flow rate of a-$SiGe_x$:H, and the thickness were fixed at a-Si:H [5 nm]/a-$SiGe_x$:H [5 nm]. Type II was varied in a-Si:H thickness [10-2 nm] and the thickness of a-$SiGe_x$:H were fixed [2 nm]. The optical bandgaps of type I were 1.23~1.25 eV, and those of type II were 1.6~1.71 eV.

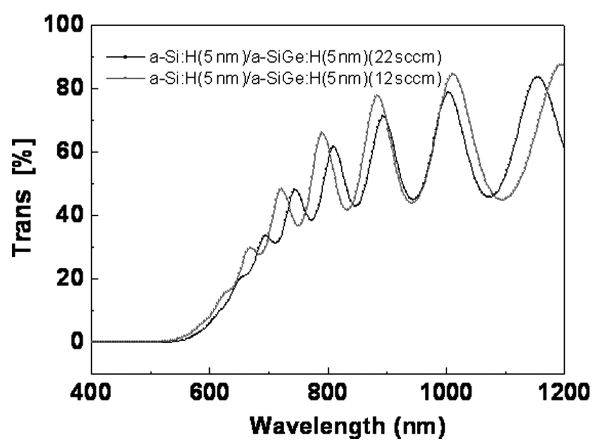

Figure 4. Transmittance spectra of the a-Si:H/a-$SiGe_x$:H superlattice films in different GeH_4 flow rate.

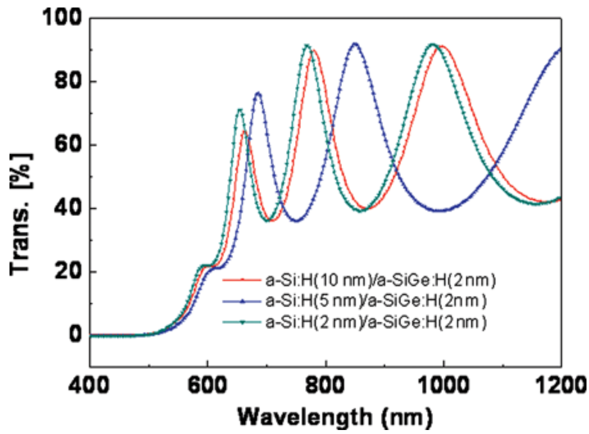

Figure 5. Transmittance spectra of the a-Si:H/a-SiGe$_x$:H superlattice films in different a-Si:H thickness.

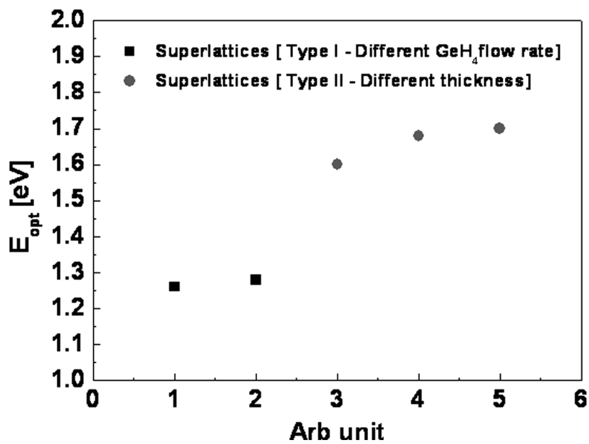

Figure 6. The optical bandgap of the a-Si:H/a-SiGe$_x$:H superlattice films in different GeH_4 flow rate and a-Si:H thickness.

We will make a solar cells, based on the result of the optical bandgap (E_{opt}) in a-Si:H/a-SiGe$_x$:H superlattice thin films.

Conclusion

This study has investigated the optical properties of the a-SiGe$_x$:H and superlattice films produced by the PECVD method. The transmittance and optical properties were measured by means of UV-VIS spectrometer analysis. The optical bandgap of the a-SiGe$_x$:H film had decreased linearly from 1.24~1.71 eV by increasing the GeH_4 flow rate and the superlattice thin films at 1.24~1.70 eV. It was known that optical bandgaps were controlled by the superlattice thin film's layer thicknesses or GeH_4 flow rates.

Acknowledgments

This work was supported by grant No. (R12-2002-055-01003-0) from the Basic Research Program of the Korea Science & Engineering Foundation.

References

[1] Yang, J., Banerjee, A., & Guha, S. (1997). *Mater. Res. Soc. Symp. Proc.*, *467*, 693.
[2] Terakawa, A., Shima, M., Kinoshita, T., Isomura, M., Tanaka, M., Kiyama, S., Tsuda, S., & Matsunami, H. (1997). In: *Proceedings of 14th European Photovoltaic Solar Energy Conference*, Barcelona, 2359.
[3] Esaki, L., & Tsu, R. (1970). *IBM J. Res. Dev.*, *14*, 61.
[4] Koinuma, H., Takano, A., & Sumiya, M. (1986). *J. Non-Cryst. Sol. Stat. Comm.*, *58*(6), 379.
[5] Ravi, S., Silva, P., Gehan A. J. Amaratunga, Charles N. Woodburn, Mark E. Welland, and Haq, S. (1994). *Jpn. J. Appl. Phys.*, *33*, 6458.
[6] Davis, C. A., Silva, S. R. P., Dunin-Borkowski, R. E., Amaratunga, G. A. J., Knowles, K. M., & Stobbs, W. M. (1995). *Phys. Rev. Lett.*, *75*(23), 4258.