Extended Abstracts of the 2014 International Conference on Solid State Devices and Materials, Tsukuba, 2014, pp402-403

Pulsed Plasma Deposited a-SiCx:H p-i-n Solar Cells

Yeu-Long Jiang*, Da-Jhe Huang, Tai-Chao Kuo

Graduate Institute of Optoelectronic Engineering and Department of Electrical Engineering, National Chung Hsing University, Taichung 40227, Taiwan, Republic of China
*Phone: 886-4-22840688#223, E-Mail: yljiang@nchu.edu.tw

Abstract

Hydrogenated amorphous silicon carbide (a-SiC$_x$:H) p-i-n solar cells were fabricated by pulsed plasma. The carbon content in a-SiC$_x$:H films were effectively controlled by fixed the plasma turn-off time (t_{off}) and altered the plasma turn-on time (t_{on}). Increasing t_{on} dissociates more carbon contents in the a-SiC$_x$:H films, resulting in the increasing of the optical bandgap (E_g) but reducing the absorption coefficient (α) and the refractive index (n). Correspondently, for a-SiC$_x$:H solar cells with i-layer deposited by increasing t_{on}, the open-circuit voltage (V_{oc}) is increased, but the short-circuit current density (J_{sc}) and fill factor (FF) are reduced, and the energy transfer efficiency is effectively reduced. Combining a buffer layer at p/i interface deposited by high t_{on} and the bulk of i-layer deposited by low t_{on} can increase the V_{oc} and maintain the high value of J_{sc}.

1. Introduction

In this work, pulse-PECVD [1-4] was used to deposited a-SiC$_x$:H p-i-n solar cells. By changing t_{on}, the dissociate rates of SiH_4 and CH_4 were changed to prepared a-SiC$_x$:H films with various amounts of carbon contents. The optical properties of p/i buffer and i-layer of the a-SiC$_x$:H p-i-n solar cells were controlled by t_{on}, and their changes on the I-V characteristics of the a-SiC$_x$:H p-i-n solar cells were investigated.

2. Experimental

The a-SiC$_x$:H films and solar cells were deposited on glass and Asahi U-type substrates by pulsed plasma [4]. The SiH_4 and CH_4 flow, RF peak power, pressure and substrate temperature were fixed at 50 SCCM, 1.5 SCCM, 12 W, 1.0 Torr, and 210 ^{O}C. The t_{off} was fixed at 20 ms and the t_{on} was changed from 5 to 40 ms. The E_g, α and n of a-SiC$_x$:H films were measured by a J.A.WOOLLAM M-2000 Spectroscopy Ellipsometer. The I-V characteristics of a-SiC$_x$:H solar cells were measured by a SAN-EI Electric XES-40S1 solar simulator.

3. Results and discussion

Fig. 1 shows the E_g of the a-SiC$_x$:H films prepared by changing ton from 5 to 40 ms. The E_g is increased from 1.701 to 1.765 eV. High t_{on} raises the dissociation probability of CH_4, the incorporation of more carbon atoms into films, resulting in the increasing of E_g.

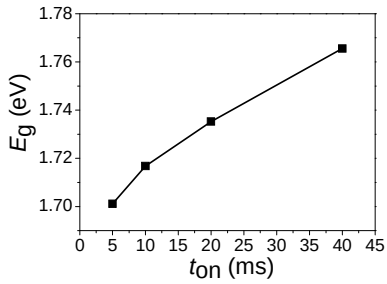

Fig. 1 The E_g of the a-SiC$_x$:H films deposited by changing t_{on} from 5 to 40 ms.

Fig. 2 displays (a) α and (b) n of the a-SiC$_x$:H films deposited by altering t_{on}. As the t_{on} increased from 5 to 40 ms, the α is gradually decreased which is the result of gradual decreasing of E_g. The n is also decreased which indicates that the increasing of carbon contents reduce the density of the films [5].

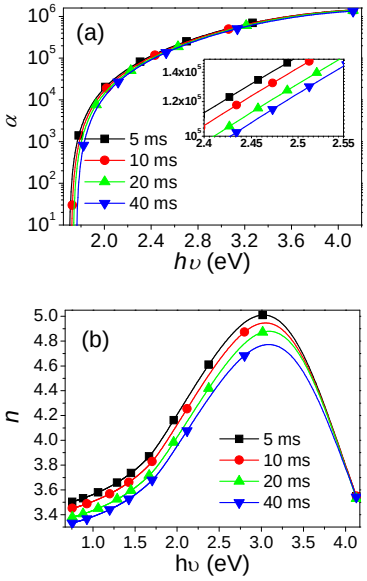

Fig. 2 The α (a) and the n (b) of the a-SiC$_x$:H films deposited with changing t_{on} from 5 to 40 ms.

Fig. 3 presents the I-V curves of the a-SiC$_x$:H p-i-n solar cells with i-layer deposited by changing t_{on}. The J_{sc} is substantially decreased, but the V_{oc} is increased, which are corresponded with the increase of E_g and the decrease of the α. The i-layer deposited with low t_{on} has high α, which can absorb more light intensity, resulting in high J_{sc}. However, due to has low E_g resulting in low V_{oc}. Conversely, that deposited with high t_{on} has low α, which can not ab-

sorb more light intensity, resulting in low J_{sc}. But, due to has high E_g resulting in high V_{oc} [6].

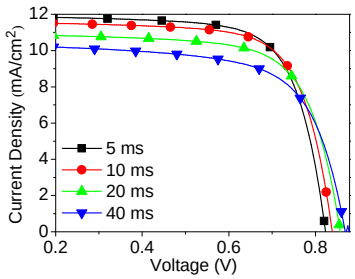

Fig. 3 The I-V curves of the a-SiC$_x$:H p-i-n solar cells with i-layer deposited by changing t_{on} from 5 to 40 ms

Fig. 4 shows I-V curves of the a-SiC$_x$:H solar cells without and with a buffer layer deposited by t_{on} of 20 ms at p/i interface and the bulk i-layer was deposited by t_{on} of 5 ms. Because the cell deposited by low t_{on} can obtain high J_{sc} but low V_{oc}, conversely, deposited by high t_{on} can obtain low J_{sc} but high V_{oc}. Combining a buffer layer at p/i interface deposited by high t_{on} and the bulk of i-layer deposited by low t_{on} can increase the V_{oc} and maintain the high value of J_{sc}. The V_{oc} of the a-SiC$_x$:H solar cell with the buffer layer is increased.

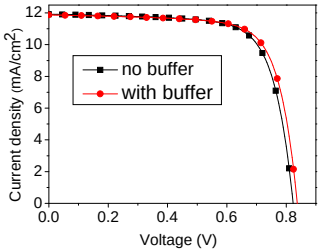

Fig. 4 The I-V curves of the a-SiC$_x$:H solar cells without and with a buffer layer at p/i interface.

3. Conclusions

Modulation of t_{on} can change the optical properties of E_g, α and n. Increasing t_{on} increases the E_g but reduces α and n of the a-SiC$_x$:H film. High E_g reduces the J_{sc} but increases the V_{oc} of the a-SiC$_x$:H p-i-n solar cell. Combining a buffer layer at p/i interface deposited by high t_{on} and the bulk of i-layer deposited by low t_{on} can increase the V_{oc} and maintain the high value of J_{sc}. The energy transfer efficiency of a-SiC$_x$:H p-i-n solar cell could be further improved by simply switch the t_{on} of pulse-wave modulated plasma from high to low for the p/i buffer layer and the bulk i-layer deposition.

Acknowledgements

We thank the financial support of the National Science Council.

References

[1] Y. Tawada, M. Kondo, H. Okamato, and Y. Hamakawa, Solar Energy Materials, vol.6, pp.299-315, 1982.

[2] Arun Madan, Scott Morrison, Hajime Kuwahara, Solar Energy Materials & Solar Cells, vol.59, pp.51-58, 1999.

[3] S. Morrison, Ujjwal Das, Arun Madan, Solar Energy Materials & Solar Cells, vol.76, pp.281–291, 2003.

[4] Yeu-Long Jiang, Pei-Tzong Shih, and Tai-Chao Kuo, Applied Physics Letters, vol.92, pp.101915-1-101915-3, 2008.

[5] G. Ambrosone, U. Coscia, S. Lettieri, P. Maddalena, C. Privato, and S. Ferrero, Thin Solid Films, vol.403, pp.349-353, 2002.

[6] B. Vet and M. Zeman, Thin Solid Films, vol.516, pp.6873–6876, 2008.