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Deposition of highly stable cluster-free a-Si:H films using a fast gas flow multi-hollow discharge plasma CVD method

高速ガス流マルチホロープラズマCVD法を用いた
高光安定クラスタフリーa-Si:H膜の作製

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We have deposited cluster-free a-Si:H films using a fast gas flow multi-hollow discharge plasma CVD method. To evaluate their quality as an I layer of PIN solar cells, we have measured Fill Factor (FF) of N-type c-Si/a-Si:H/Ni Schottky cells of such cluster-free a-Si:H films. Our films deposited at a rate of 0.51 nm/s show high initial FF of 0.556, high stable FF of 0.523, and quite low light induced degradation ratio of 5.93 %.

1. Introduction

Light-induced degradation of hydrogenated amorphous silicon (a-Si:H) has been an important issue for a-Si:H solar cells, because light exposure initially causes a reduction of the conversion efficiency of the cells due to the degradation [1]. During the deposition, amorphous silicon particles (clusters) in a size range below 10 nm are generated in the plasmas and they deposit into the films [2]. For conventional plasma CVD of a-Si:H films, clusters are generated in discharges and deposit into the films, and degrade efficiency and stability of the cells using such films. Reducing incorporation of the clusters is important for realizing highly stable a-Si:H solar cells of high efficiency [3]. It motivated us to deposit cluster-free a-Si:H films to realize stable a-Si:H solar cells of a high efficiency.

Recently, we have deposited highly stable a-Si:H films of 4.7×10^{15} cm^{-3} in stabilized defect density at a rate of 3 nm/s at substrate temperature Ts= 250°C by suppressing incorporation of clusters into the films [4,5]. The films show high stability against light exposure. In this study, we have deposited cluster-free a-Si:H films using the SiH_4 multi-hollow discharge plasma CVD method [4]. We report performance of Schottky solar cells using such cluster-free a-Si:H films.

2. Experimental

Experiments were carried out using a multi-hollow discharge plasma CVD reactor as shown in Fig. 1. Multi-hollow powered and two grounded electrodes had holes of 5mm in diameter were placed in a stainless-steel vessel. SiH_4 gas was fed from a gas inlet at a flow rate of 150 sccm and was pumped out through the electrodes. The gas pressure was 0.5 Torr. The discharge frequency and power were 60 MHz and 40 W, respectively. Cluster-free a-Si:H films were deposited on a N-type c-Si substrate set in the upstream region

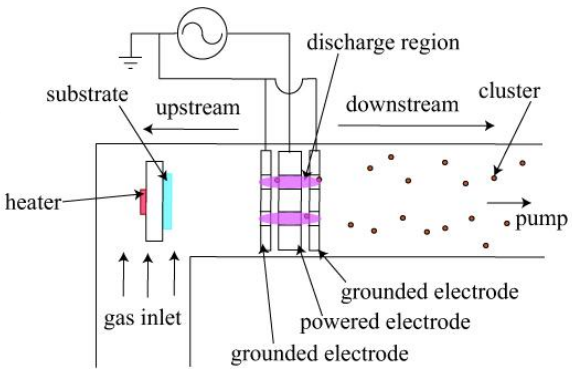

Fig.1. Multi-hollow discharge plasma CVD reactor.

from the discharges, because clusters generated in the discharges were driven toward the downstream region by gas flow. We deposited 605 nm films of a-Si:H at Ts= 250°C. The deposition rate was 0.51 nm/s.

FF was evaluated irradiating N-type c-Si/a-Si:H/Ni Schottky cells by irradiation of an AM 1.5 solar spectrum light of 100 mW/cm^2 (1 SUN) at Ts=30 °C. The stabilized FF was measured after 6 hours 40 min light soaking under conditions of 2.7 SUN irradiation and Ts=50°C.

3. Results and Discussion

Initial and stabilized J-V and P-V characteristic of the Schottky cell are shown in Fig. 2 and Table I. The fill factor (FF), maximum power (Pmax), open circuit voltage (Voc), short circuit current density (Jsc), series resistance (Rs), and parallel resistance(Rsh) are obtained from J-V curves of the Schottky cells. The initial and stabilized FF values of Schottky cell are 0.556 and 0.523, respectively. This degradation ratio is 5.93%. Initial Pmax of the cell was 0.859 mW/cm^2. Stabilized Pmax was 0.797 mW/cm^2 which was 7.21% lower than the initial one. Light soaking has little influence on Voc and the initial and stabilized Voc are 0.37 V. The initial and stabilized Jsc were 4.21 mA/cm^2 and 4.17 mA/cm^2, respectively. These results suggest that a-Si:H films with little light induced degradation can be deposited by suppressing the cluster incorporation.

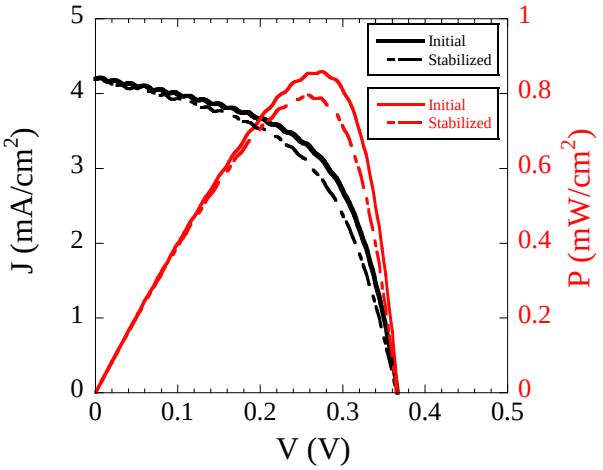

Fig. 2 Initial and stabilized J-V characteristic of Schottky solar cell. Conditions: SiH_4 150sccm, 0.5Torr, Frequency 60MHz, Ts 250°C, Electrode power 40W, 6h40min light soaking under conditions of 2.7 SUN and Ts 50°C.

Table I. Initial and stabilized characteristics of Schottky cell (FF, Pmax, Voc, Jsc, Rs, and Rsh) and degradation ratios of FFand Pmax values

Characteristics of Schottky cell	Initial	Stabilized	Degradation ratio
FF	0.556	0.523	5.93%
Pmax (mW/cm^2)	0.859	0.797	7.21%
Voc (V)	0.37	0.37	
Jsc (mA/cm^2)	4.21	4.17	
Rs (Ω cm^2)	15.5	19.6	
Rsh (Ω cm^2)	524	466	

4. Conclusions

We have examined characteristics of N-type c-Si/a-Si:H/Ni Schottky cells using cluster-free a-Si:H films deposited by the multi-hollow discharge plasma CVD method. Our films deposited at a rate of 0.51 nm/s show high initial FF of 0.556, high stable FF of 0.523, and quite low light induced degradation ratio of 5.93%. These results indicate that our method is useful to fabricate highly stable a-Si:H solar cells.

Acknowledgements

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