

Suppression of HOS molecules incorporation in a-Si:H films fabricated by plasma CVD

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1. Introduction

Thin film hydrogenated amorphous silicon (a-Si:H) solar cells have several advantages over other solar cells, such as low cost, flexible and lightweight features. They are, therefore, promising to be a power source for the “Internet of Things” devices. One of the important issue to use a-Si:H solar cells for IoT devices is suppression of light-induced degradation. By Raman spectroscopy, we have succeeded in detecting Si-H₂ bonds in cells which are responsible for the light-induced degradation [1,2]. A-Si:H solar cells are most commonly fabricated using SiH₄ plasmas. Incorporation of clusters and higher-order silane (HOS) molecules formed in the plasmas is the main origin of Si-H₂ bonds in films [3]. We have significantly reduced such clusters and HOS molecules incorporation by adopting the multi-hollow discharge plasma CVD (MHDPCVD) method together with a cluster eliminating filter [4]. However, the films still contains many Si-H₂ bonds. Here, we report a deposition method that further suppresses clusters and HOS molecules incorporation.

2. Experimental

We deposited undoped a-Si:H films (I-layer) on B-doped Si films (P-layer) by the MHDPCVD method with the cluster eliminating filter. Pure SiH₄ gas fed into the reactor at 84–147 sccm. The total pressure was 0.08 Torr. The discharge frequency and power were 110 MHz and 20 W respectively. The substrate temperature was 170 °C. The thickness of I-layer was 20 nm. Measurements of the I_{SiH₂}/I_{SiH} ratio were carried out with a Raman spectroscopy (JASCO, NRS-3100) equipped with a HeNe laser ($\lambda = 632.8$ nm). The scan time was 100 s and the cumulative number of measurement was 3 times. The diameter of the probe laser was 1 μ m. We deconvoluted Raman spectra around 2000–2090 cm⁻¹ of a-Si:H films into two peaks corresponding to Si-H bonds (2000 cm⁻¹) and Si-H₂ bonds (2090 cm⁻¹) and eventually obtained I_{SiH₂}/I_{SiH} [5].

3. Results and discussion

In order to investigate more suitable film deposition conditions, we have evaluated the SiH₄ gas velocity and diffusion velocity of clusters and HOS molecules. First, we derive the gas residence time τ_g as follows:

$$\tau_g = \frac{n_h}{n_f} = 1.11 \times 10^{-1} \times \frac{1}{FR}, \quad (1)$$

where n_h is the number of gas molecules in hollows, n_f is the number of the molecules supplied to the hollow per second and FR is SiH₄ gas flow rate. SiH₄ gas velocity v_g is expressed as follows:

$$v_g = \frac{z}{\tau_g} = 1.8 \times FR, \quad (2)$$

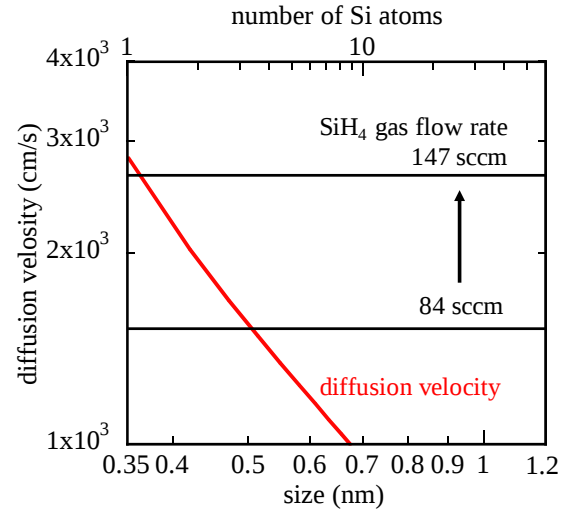


Fig 1. Relation between gas velocity and diffusion velocity.

Where z is the hollow length. In addition, diffusion velocity of clusters and HOS molecules v_d is expressed as follows:

$$v_d = \frac{D}{\lambda}, \quad (3)$$

where D is diffusion coefficient and λ is characteristic diffusion length. Figure 1 shows the relation between gas velocity and diffusion velocity. For 84 sccm, gas velocity is 15.1 m/s and clusters above 0.5 nm can be driven to downstream region. For 147 sccm, gas velocity is 26.5 m/s and HOS molecules above 0.36 nm can be driven to downstream region. By increasing the SiH₄ gas velocity from 15.1 to 26.5 m/s, we succeeded in suppressing incorporation of HOS molecules into the films. Eventually, I_{SiH₂}/I_{SiH} decreased to one third at 26.5 m/s as compared with that at 15.1 m/s.

Acknowledgements

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