Improvement of Si network order of a-Si:H thin films by suppressing incorporation of HOS molecules

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With the rapid development of Internet of Things (IoT) technology, energy supply for IoT devices is an important issue. Hydrogenated amorphous silicon (a-Si:H) solar cells might power various IoT devices because they are cheap, flexible and lightweight. However, one of the biggest challenges to use a-Si:H solar cells for IoT devices is their low conversion efficiency. The large urbach tail slope in a-Si:H films causes a reduction of the efficiency due to a decrease in open circuit voltage (Voc) [1]. Improvement of Si network order of a-Si:H films has a strong impact on the reduction of urbach tail slope [2,3]. Recently, we found that Si network order of a-Si:H thin films was disorderded especially at the P/I interface and near the surface of a-Si:H films. Here, we have improved such Si network order by suppressing incorporation of higher-order silane (HOS) molecules into a-Si:H films.

We deposited undoped a-Si:H films (I-layer) on B-doped Si films (P-layer) by the multi-hollow discharge plasma CVD method with a cluster-eliminating filter [4]. Pure SiH_4 gas was fed at 84–147 sccm. The total pressure was 0.08 Torr. The discharge frequency and power were 110 MHz and 20W, respectively. The substrate temperature was kept at 170 °C. The thickness of I-layer is 20 nm. Raman spectra were measured with a Raman spectroscope (JASCO, NRS-3100) equipped with the second harmonics of Nd:YAG laser light (λ=532 nm). For the measurements, the exposure time was 100 s and the cumulative number of measurement was 3 times. We set a focus position at surface of I-layer and measured at seven positions of each sample [5].

Figure 1 shows the dependence of FWHM of 480 cm^{-1} peak in Raman spectra on SiH_4 gas velicity. With increasing velocity of SiH_4 gas from 1000 to 1750 cm/s, FWHM decreases from 65.9 to 65.0 cm^{-1}, and for SiH_4 gas velocity above 1750 cm/s, it is constant at 65.0 cm^{-1}. The results suggest that HOS molecules above 0.46 nm in size are driven to the downstream region for the high gas velocity conditions. Such high gas flow rate also reduces the gas residence time in the discharge space and suppresses the formation of HOS molecules. By increasing the velocity of SiH_4 gas from 1000 to 1750 cm/s, we succeeded in suppressing incorporation of HOS molecules into the films. Table 1 summarizes relation between film growth precursors and Si network order. The conventional method forms a-Si:H films using SiH_3 radicals, HOS molecules and clusters. In this study, we succeeded in suppressing incorporation of HOS molecules and clusters into the films and hence Si network order can be improved significantly.

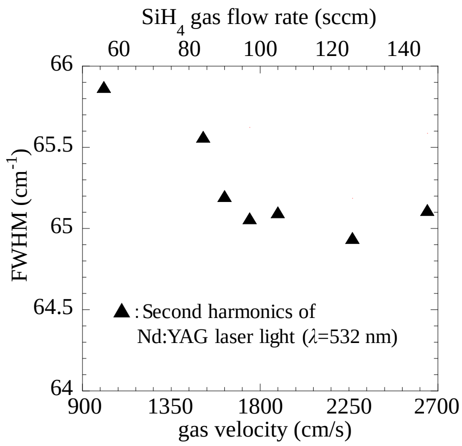

Figure 1. Dependence of FWHM of 480 cm^{-1} peak in Raman spectra on SiH_4 gas velocity.

Table 1. Relation between precursors of film growth and Si network order.

		SiH_3 radicals	higher-order silane (HOS)	clusters
conventional method		○	○	○
MHDPCVD method cluster eliminating filter	v_g(low)	○	○	✕
	v_g(high)	○	✕	✕
Si network order		**best**	**good**	**worse**

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