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Effects of Nanoparticle Inclusion on Properties of Si Films Deposited by Plasma CVD
プラズマCVDで成膜したSi薄膜へのナノ粒子含有の効果

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We have investigated effects of nanoparticle inclusion on properties of a-Si:H films and mc-Si:H films using the multi-hollow discharge plasma CVD method. Minor deposition species (nanoparticles in this study) modify considerably properties of a-Si:H films and mc-Si:H films.

1. Introduction

A-Si:H and mc-Si:H films are dominant materials for thin film solar cells. These films are widely deposited by plasma CVD. Nanoparticles are often formed in such CVD plasmas and may modify properties of films [1-7]. Here we report effects of nanoparticle inclusion on properties of a-Si:H films and mc-Si:H films.

2. Experimental

Multi-hollow discharge plasma CVD reactor consists of one powered electrode and a pair of grounded electrodes to generate plasma as shown in Fig. 1[3]. 60MHz voltage was applied to the electrode to sustain the discharges in the holes in the electrodes.

Pure SiH_4 or H_2+SiH_4 was supplied to the reactor. The total pressure and gas flow rate were 0.5-2 Torr and 15-150 sccm, respectively. The substrate holder was set vertically or perpendicularly to the gas flow. The substrate temperature (T_S) was 250°C. Information on chemical bonds in films was obtained by FTIR. Crystallinity (X_C) was determined with a Raman spectroscope (Jasco, NRS-3100). Deposition rate (R_d) was obtained as film thickness divided by deposition time.

3. Experimental results and discussion

3-1. a-Si:H films

First, we study effects of amorphous Si nanoparticle inclusion on properties of a-Si:H films. Figure 2 shows FTIR spectrum of nanoparticles formed in pure discharge plasmas. While SiH and SiH_2 bonds exist in nanoparticles, SiH_2 bonds have larger absorption.

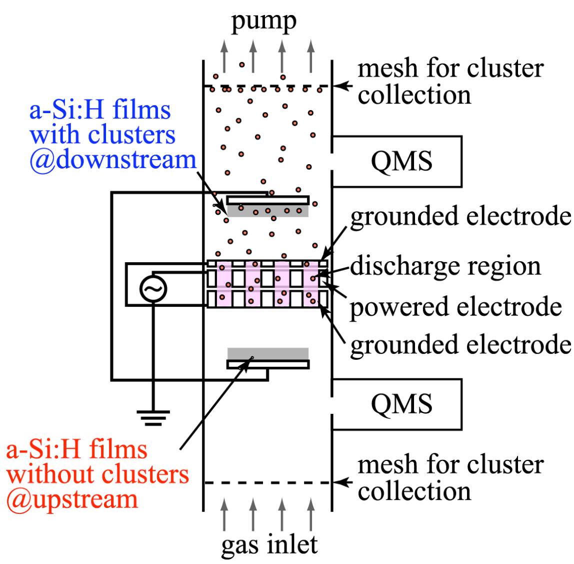

Fig. 1. Schematic diagram of a multi-hollow discharge CVD reactor.

Figure 3 shows FTIR spectra for a-Si:H films deposited in the downstream region and in the upstream region. The films in the downstream region have predominant SiH absorption and small SiH_2 one, while the films in the upstream region only have SiH absorption. The films in the downstream region contain nanoparticles of 1% in volume fraction, whereas the films in the upstream region do not contain them (<0.01% in volume fraction). These results suggests that SiH_2 bonds are originated from nanoparticle inclusion. Such nanoparticle inclusion brings about light induced degradation of a-Si:H films, because SiH_2 bonds are weaker than SiH ones. This consideration is consistent with the fact that the films in the upstream show little light induced degradation, whereas the films in the downstream region show significant light induced degradation.

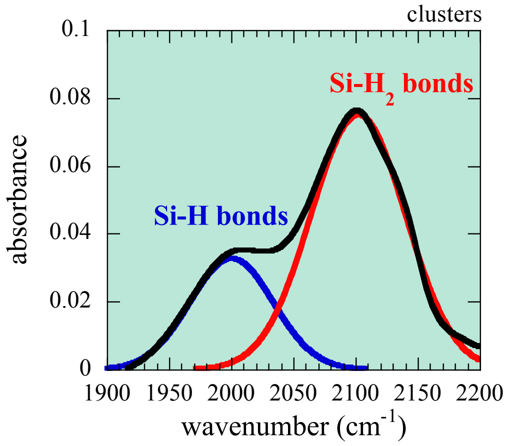

Fig. 2. FTIR spectrum of nanoparticles formed in pure discharge plasmas.

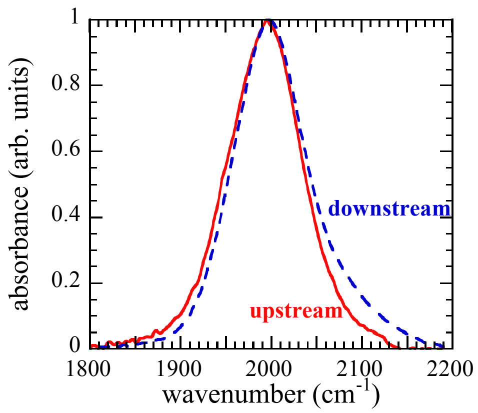

Fig. 3. FTIR spectra for a-Si:H films deposited in the downstream region and in the upstream region.

3-1. mc-Si:H films

Next, we study effects of crystalline Si nanoparticle inclusion on properties of mc-Si:H films. Nanoparticle inclusion has little effects on deposition rate and crystallinity. The volume fraction of (220) crystalline orientation crystals of the films without nano-particles is higher than that with nano-particles. A cross sectional SEM of mc-Si:H films deposited in the upstream region is shown in Fig. 4, while that in the downstream region is shown in Fig. 5. The film without nanoparticles has columnar gran growth, whereas the film with nanoparticles has inverted conical growth. Therefore, nanoparticle inclusion of 1% volume fraction considerably modifies the crystal grain growth in mc-Si:H films.

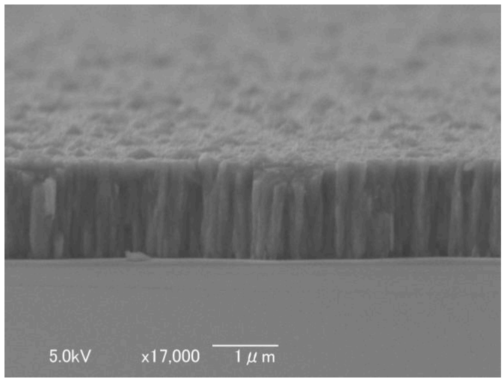

Fig. 4. A cross sectional SEM of mc-Si:H films deposited in the upstream region.

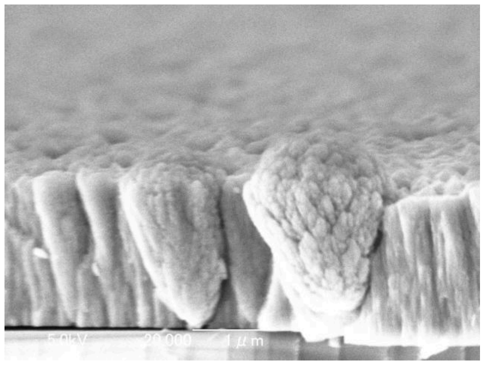

Fig. 5. A cross sectional SEM of mc-Si:H films deposited in the downstream region.

4. Conclusions

We have investigated effects of nanoparticle inclusion on properties of a-Si:H films and mc-Si:H films using the multi-hollow discharge plasma CVD method. Minor deposition species (nanoparticles in this study) modify considerably properties of a-Si:H films and mc-Si:H films.

Acknowledgements

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