Effects of Si cluster incorporation on properties of microcrystalline silicon thin films

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Abstract : Hydrogenated microcrystalline silicon (μc-Si:H) films have attracted much attention as materials of the bottom-cells in Si thin film tandem photovoltaics due to their low bandgap and excellent stability against light soaking. However, in PECVD, the source gas SiH_4 must be highly diluted by H_2, which eventually results in low deposition rate. Moreover, it is known that high-rate μc-Si:H growth is usually accompanied by a large number of dangling-bond (DB) defects in the resulting films, which act as recombination centers for photoexcited carriers, leading to a deterioration in the device performance. During film deposition, Si nanoparticles generated in SiH_4 discharges can be incorporated into films, and such incorporation may have effects on film properties depending on the size, structure, and volume fraction of nanoparticles incorporated into films.

Here we report experimental results on the effects of nonoparticles incorporation at the different substrate temperature studied using a multi-hollow discharge plasma CVD method in which such incorporation can be significantly suppressed in upstream region by setting the gas flow velocity high enough to drive nanoparticles toward the downstream region [1, 2]. All experiments were performed with the multi-hollow discharge plasma CVD reactor at RT, 100, and 250oC, respectively. The gas flow rate ratio of SiH_4 to H_2 was 0.997. The total gas pressure P was kept at 2 Torr. The discharge frequency and power were 60 MHz, 180 W, respectively. Crystallinity Xc of resulting films was evaluated using Raman spectra. The defect densities of the films were measured with electron spin resonance (ESR). The defect density of fims deposited in the downstream region (with nonoparticles) is higher defect density than that in the upstream region (without nanoparticles) at low substrate temperature of RT and 100^{o}C. This result indicates that nanoparticle incorporation can change considerably their film properties depending on the substrate temperature.

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