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Time evolution of radical deposition rate and cluster amount

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For fabricating a large amount of high efficiency a-Si:H solar cells at a low cost, we need low light induced degradation (LID) of efficiency below 3% and a high deposition rate above 1nm/s. We have showed that 1) suppressing cluster incorporation in a-Si:H films leads to low LID and 2) suppressing cluster density in gas phase leads to a high radical deposition rate [1, 2]. Here we report time evolution of radical deposition rate and cluster amount measured in the downstream region of multihollow discharge plasma CVD reactor.

Experiments were carried out witha multi-hollow discharge plasma CVD reactor [1, 2].Pure SiH_4 was supplied to the reactor at a flow rate of 10 sccm. The gas flow velocity was 0.18 m/s. The pressure was 0.5 Torr. Discharge plasmas were sustained by 60 MHz voltage. The discharge power was 20 W. We measured the deposition rate due to radicals (DRradical) using quartz crystal microbalances (QCMs) with a cluster eliminating filter. QCMs were set at 20 mm below the lowest electrode in the downstream region. We measured the cluster amount in gas phase by a laser light scattering (LLS) method. LLS intensity is proportional to cluster density and sixth power of cluster size in the Rayleigh scattering regime. A sheet of laser beam was passed parallel to the electrodes and LLS intensity was measured with a high speed CCD camera.

Figure 1 shows the time evolution of DRradical and LLS intensity at 10 mm below the lowest electrode in the downstream region. The time evolution of LLS intensity can be divided into 3 periods. In the 1st period of $t < 4$ s, clusters nucleate and grow due to gas phase reactions, and hence the LLS intensity increases rapidly and becomes the highest at 4s. Then in the 2nd period of $4 s < t < 30$ s, cluster density decreases because the gas composition in plasma turns from pure SiH_4 into SiH_4+H_2 due to considerable dissociation of SiH_4. In the 3rd period of $t > 30$ s, a cloud of clusters extends from the discharge region to the QCMs. Because clusters absorb radicals in gas phase, they have significant influence on the radical deposition rate as shown in Fig. 1. At around 40 s, DRradical becomes highest and cluster incorporation in a-Si:H films is suppressed because clusters reside far from the deposition region. By applying these phenomena, we can deposit high quality films at a high deposition rate.

[1] S.Toko, et al., Jpn. J. Appl. Phys. 55 (2016) 01AA19.
[2] S.Toko, et al., Thin Solid Films 587(2015) 126.