Mechanism of Oxygen Contamination in PECVD a-Si:H Films

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The presence of impurities in the active layers of semiconductor films has a deleterious effect on the performance of TFTs. Reducing the amount of an impurity present in the first stage of depositing an a-Si:H film is of a primary concern in the fabrication of poly-Si TFTs. Although results have been reported of many studies of the impurities incorporated in the PECVD of a-Si:H films[1][2], there have been few studies that examined a real target. Using our CVD system[3], O atoms in a deposited film, the fatal impurity atom, were only several hundredths in content of the typical value. We also identified residual O sources and identified a mechanism for the contamination.

Details of the reactor were reported elsewhere[3]. The background pressure and the minimum outgas rate from the reactor wall at room temperature were 7×10^{-8} Torr and 1.2×10^{-7} Torr l/s, respectively. The quality of the SiH_4/H_2 source gas mixture was 5N-up. The pipes between the gas cylinders and the reactor were of the EP grade without a gas purifier. The other conditions were: total gas pressure of 150 Pa, SiH_4 gas flow rate of 100 sccm, H_2 gas flow rate of 400 sccm, and substrate temperature of 280° C, respectively. Figure 1 shows the O atom depth profile for a film successively deposited four times with different RF powers, i.e., at different deposition rates without breaking vacuum. The minimum O content, 1.4×10^{17} atoms/cm^3, was several hundredths in magnitude of that deposited by a conventional PECVD system.

We identified the residual gas composition by using a quadrupole mass spectrum (QMS) analyzer under vacuum conditions. The dominant ion currents had mass numbers 17(OH), 18(H_2O) and 28(N_2 dominant), and were proportional in magnitude to the reactor outgas rate, as shown in Fig. 2. The HO-related signal seems to come from H_2O in the analyzer, and thus the dominant O source was concluded to be H_2O. H_2O molecules can be chemisorbed on a clean Si surface and OH radicals generated in plasma can also be adsorbed with much higher sticking probability. Since they are the origins of O atoms in the film, the O content in the film should be a linear function of the reciprocal deposition rate with an offset, as shown in Fig. 3. This feature was confirmed experimentally. There are dense N_2 molecules in the reactor but they are chemically activated only in plasma. Thus, the N content in the film is independent of the deposition rate, as shown in Fig. 3.

In conclusion, we reported successfully depositing a high-purity a-Si:H film having O content as low as 1.4×10^{17} atom/cm^3. We described a mechanism of the oxygen contamination in PECVD a-Si:H films. This research was supported by NEDO and METI.

[1] Tsai, C.C. et al: J. Non-Cryst. Solids **66** p. 45 (1984)

[2] Kamei, T. et al.: J. Vac. Sci. Technol. **A17**, p. 113 (1999)

[3] Hiramatsu, M. et al.: IDW2002 proceedings (to be published)

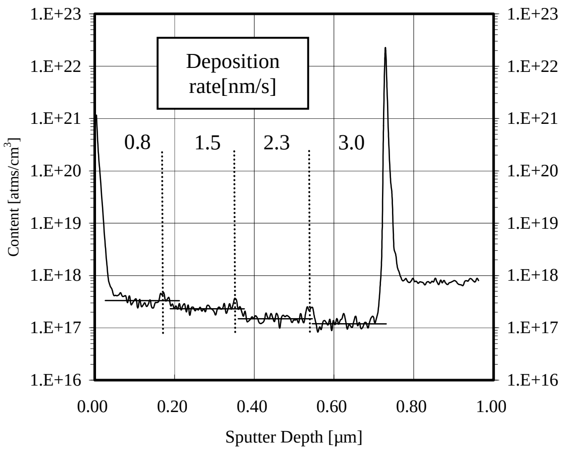

Fig. 1. SIMS profile of a stacked structure where the layers were deposited at various plasma powers corresponding to deposition rates of 0.8, 1.5, 2.3, 3 nm/sec, respectively.

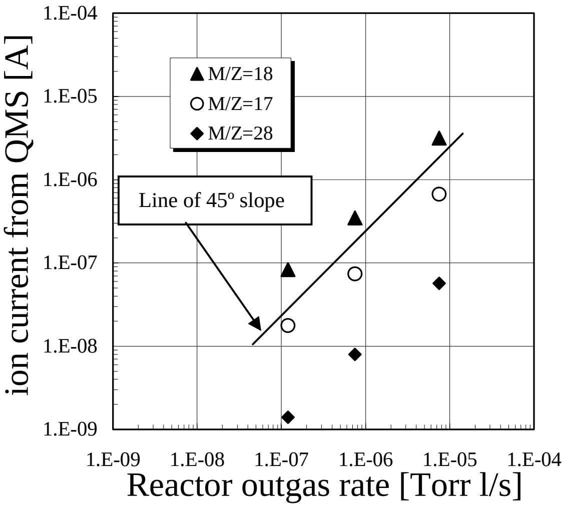

Fig. 2. Ion current from QMS (mass number is 18,17,28) versus outgassing rate. The ion current is linear to the outgassing rate.

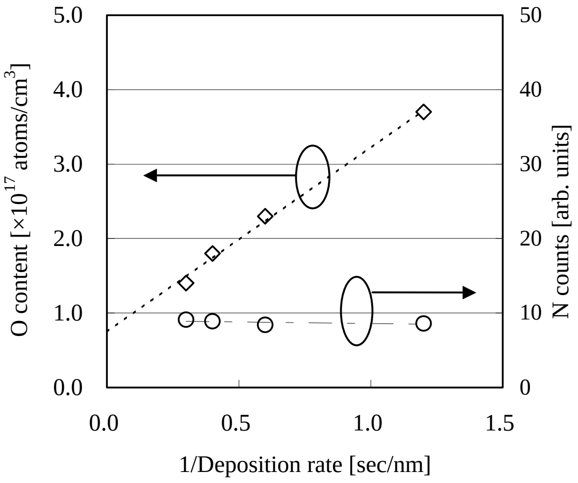

Fig. 3. Oxygen content as a function of the reciprocal deposition rate of a-Si:H. The nitrogen ion counts from the same layers by SIMS are inserted.