

The relation between stress and photoluminescence of hydrogenated amorphous silicon nitride films

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Hydrogenated amorphous silicon nitride (a-SiN_x:H) films are attracted increased interest with respect to wide applications in silicon-device and their process technologies, such as gate insulator, passivation layer in thin-film transistor, and membranes for e-beam or X-ray lithography masks. Plasma-enhanced chemical vapor deposition (PECVD) method is usually employed to produce the a-SiN_x:H films. In the a-SiN_x:H film's applications, the remaining stress must be controlled in the deposition process to form free-standing films by preventing from cracks.

In this paper, we demonstrate the results on the relationships between the stress and structure or optical properties such as photoluminescence (PL), optical band gap and refractive index of a-SiN_x:H films. We found that the PL spectrum were clearly correlated with the stress of deposited a-SiN_x:H films. We propose that the PL measurement is a very useful to estimate the stress and its distribution of the a-SiN_x:H films in very small points of 1 μm without any destruction.

A-SiN_x:H thin-films were deposited at both 150°C and 350°C on single-crystal silicon (c-Si) substrates using SiH₄-NH₃ mixtures in H₂ at a pressure of 1 Torr by PECVD. Total and SiH₄ gas flow rate are set to be constant at 262 sccm and 5 sccm, respectively. The stress, PL, optical band gap, and refractive index were investigated as a function of the NH₃ flow ratio in the range of 0.95-15.3 % in the gas phase. The stress of deposited films was measured by wafer curvature method using Tencor model FLX-2320. The PL spectra were measured by using Renishaw 2000 micro-Raman spectrometer. The 325 nm emission line from an He-Cd laser was used to excite the luminescence.

Increased tensile stress subsequent to a reduction in the compressive stress was observed with increasing NH₃ gas flow ratio, as shown in Fig. 1. It was found that very low value of the stress less than 300MPa was observed in the range of 5-8% of NH₃ flow ratio. Rutherford backscattering spectroscopy (RBS) determined the stoichiometric composition of the all a-SiN_x:H films prepared in this study to be x=1.33. Figure 2 shows FT-IR spectra of a-SiN_x films. The intensity of N-H bonds increased with increasing NH₃ flow ratio. These results show that the stress of a-SiN_x:H films are caused by not the composition of SiN_x but affected by the incorporated N-H bonds. Figure 3 shows PL spectra of a-SiN_x:H films deposited as a function of the flow ratio of NH₃ in total flow rate. Very strong PL was observed in the a-SiN_x:H films which have compressive stress, on the other hand, the tensile-stressed a-SiN_x:H films exhibited weak PL.

The peak of the PL spectra was range from 1.9 to 2.2eV in energy, and its position shifted toward lower energy with decreasing the amount of NH₃ in the gas phase. We conclude that both the PL intensity and its peak position strongly relates with the stress of the a-SiN_x:H films.

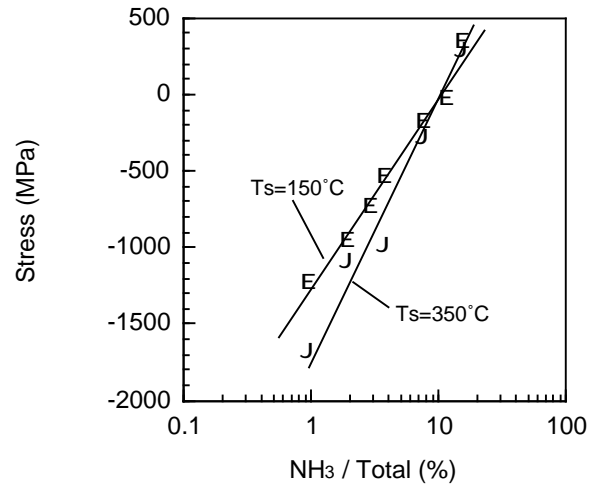


Fig. 1 Stress of deposited a-SiN_x:H films.

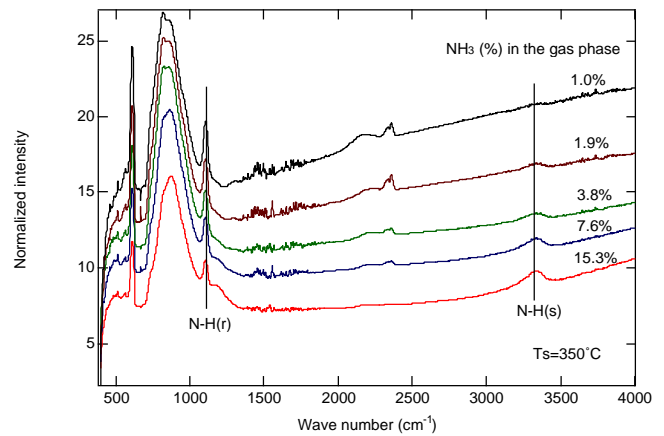


Fig. 2 FT-IR spectra of deposited a-SiN_x:H films.

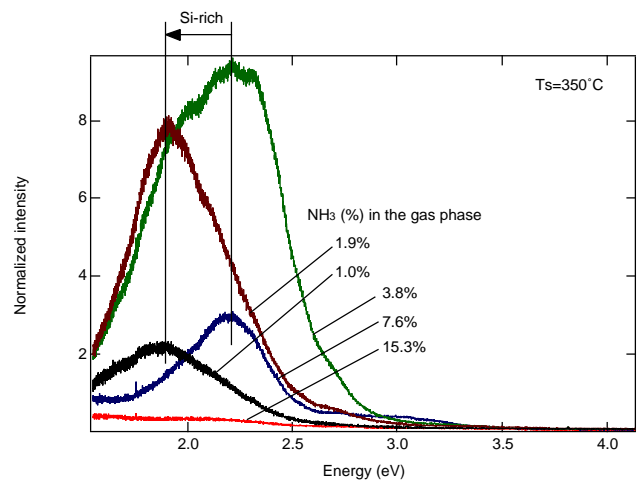


Fig. 3 Photoluminescence of deposited a-SiN_x:H films.