Optical Emission Spectroscopy Signal Analysis for Predicting Deposition Characteristics of Silicon Nitride in Plasma Enhanced Chemical Vapor Deposition

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Optical emission spectroscopy (OES) is a non-invasive tool that enables plasma monitoring without affecting the plasma state. It operates by analyzing light emitted from excited atoms or ions within the plasma. This analysis provides information about the chemical composition and energy state of the plasma thus allowing for the prediction of process results.[1] Researchers have conducted studies analyzing OES signals during deposition process to predict deposition characteristics such as growth rate, film thickness, uniformity. However, research on predicting the refractive index, which is one of the important deposition characteristics, has been limited. In this study, the deposition rate and refractive index of silicon nitride (SiN_x) were predicted using OES signal analysis in plasma enhanced chemical vapor deposition (PECVD) with trisilylamine (TSA), NH_3, and N_2 gases. The deposition rate was correlated with the I_{N2+}/I_{N2} and I_{Ha}/I_{Hb} line ratio, which can estimate the electron temperature, as the deposition rate is influenced by the electron temperature that activates dissociation and ionization.[2] The refractive index determined by the N/Si ratio in SiN_x film was correlated with the ratio of SiH and NH radicals in the plasma transferred to the film.[3] The relative radical densities were investigated using the I_{SiH}/I_{N2} and I_{NH}/I_{N2} line ratios, known as actinometry, after demonstrating the overlap of electron energy distribution function (EEDF) and excitation cross sections. The deposition rate (R^2 = 0.85, MAPE = 3.66%) and refractive index (R^2 = 0.95, MAPE = 0.27%) investigated in linear regression analysis showed very high prediction accuracy.

Reference

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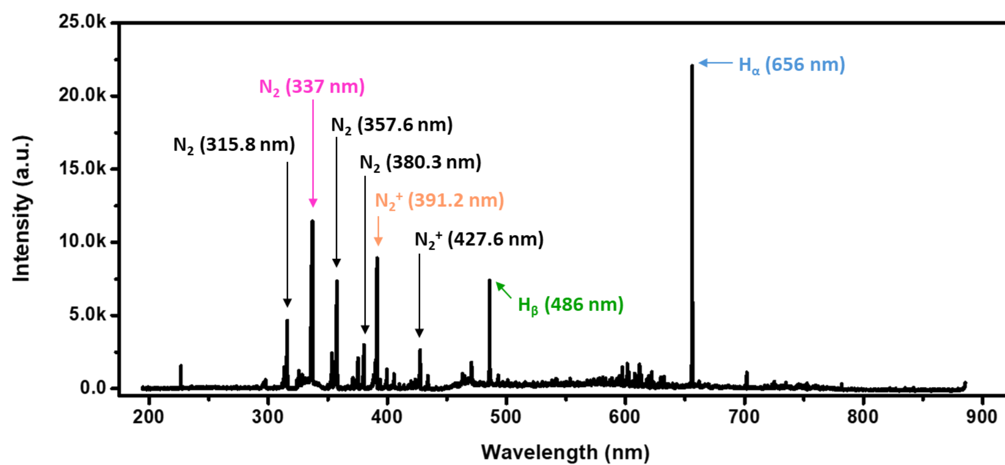

Figure 1. Plasma emission spectra monitored by OES

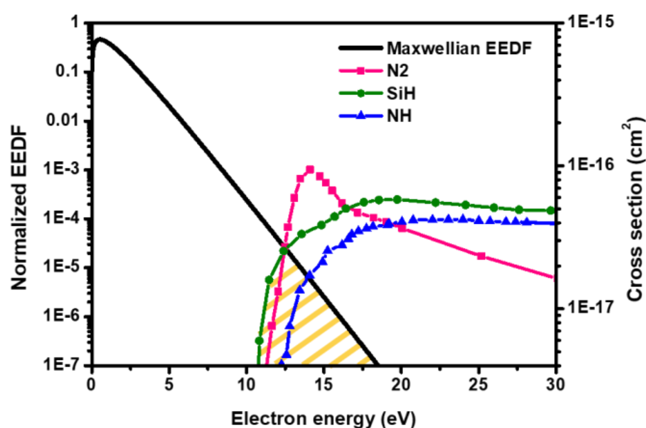

Figure 2. Overlap of EEDF and excitation cross section for NH, SiH, N_2

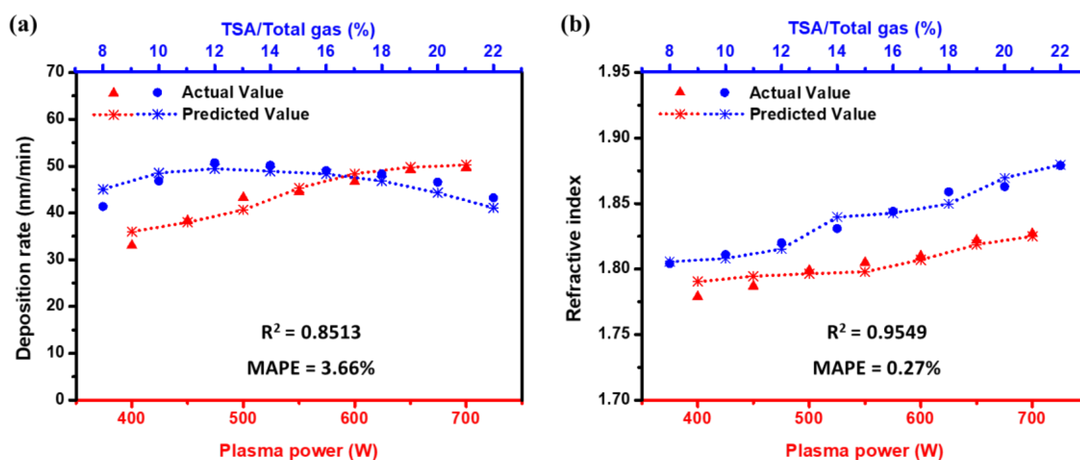

Figure 3. Comparison of actual values with the predicted values in (a) deposition rate and (b) refractive index