Process control by optical emission spectroscopy during growth of a-C:H from a CH₄ plasma by plasma-enhanced chemical vapour deposition

During the growth of a-C:H thin films for tribological applications, the characteristic optical emission from a CH₄ plasma was used to estimate growth conditions such as the degree of dissociation of the feed gas, the deposition rate and the presence of impurities. Films were fabricated with various flow rates of CH₄. Their thickness, mass density and hydrogen content were determined by a combination of X-ray and neutron reflectivity measurements. Dissociation of the feed gas is determined relatively by monitoring the integrated peak intensity around the CH₄ 31 nm band head as a function of the gas flow. Above a certain flow rate the intensity saturates, since the deposition process is limited by the power input. At low flow rates a large fraction of the feed gas is dissociated and the deposition is limited by the supply of feed gas. A relationship was found for the intensity of the CH₄ 31 nm line as a function of discharge pressure, self-bias and r.f. power. The intensity of the CH₄ 31 nm emission line was found to be proportional to the deposition rate at constant pressure and the self-bias. This provides a method for in situ monitoring of the film growth rate.

Impurities of N₂ can be detected during argon plasma cleaning by the presence of characteristic emission lines at a variety of wavelengths. We used the broad peak around the 337.13 nm N₂ band head. From small admixtures of N₂ in argon we found that levels down to 15 vppm (parts per million by volume) were detectable.

During plasma cleaning, the emission from the OH radical at 306.4 nm indicated that H₂O was initially present in the discharge. The OH signal typically vanished during the cleaning cycle, which indicates that it was due to adsorbed water on the inner surfaces of the vacuum chamber and not an impurity in the process gas. The initial OH intensity was dependent on the ultimate vacuum prior to the plasma cleaning. A correlation was found between the vanishing of the OH line and the appearance of characteristic emission lines from sputtered electrode material.

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