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Negative Ions in Dual-Frequency Capacitively Coupled Fluorocarbon Plasmas[1]

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Dual-frequency capacitively coupled plasmas in fluorocarbon-based gases are widely used for etching SiO_2-based dielectric films in integrated circuit manufacture. We have studied a customized 2 + 27 MHz industrial etch reactor, running in Ar/O_2 with c-C_4F_8 or CF_4 gas mixtures at pressures in the region of 50 mTorr (6.6 Pa). Negative ions could play an important role in this type of plasma. The presence of negative ions will modify the positive ion flux arriving at a surface, and may even reach the surface and participate in etching. We have measured the electron density using a microwave hairpin resonator [1] and the positive ion flux with an ion flux probe [2]: the ratio of these two quantities varies strongly with gas chemistry and gives evidence for the presence of negative ions [3]. For example, by varying the flow of c-C_4F_8 in an Ar/O_2 mixture this ratio shows evidence of high electronegativity for high c-C_4F_8 flowrates. We have also measured the negative fluorine ion, F^-, density directly by high-sensitivity cavity ring-down absorption spectroscopy [4] in the wavelength range 340 to 360 nm to determine the density of absorbing F^- ions from the known photo-detachment cross-section. The F^- densities were seen to reach values in the 10^{11}cm^{-3} range, giving electronegative fractions, $\alpha = n_-/n_e$, of up to ≈ 15 when used in conjunction with the hairpin probe measurements. We acknowledge financial assistance from Lam Research Corporation.

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