Observation of the standing wave effect in large-area, very-high-frequency capacitively coupled plasmas by using a fiber Bragg grating sensor and hairpin resonance probe

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Large-area capacitive discharges driven at very high frequencies have been attracting much attention due to their wide applications in material etching and thin film deposition. However, in the regime standing wave effect (SWE) becomes a major limitation for plasma material processing uniformity. In this study, a fiber Bragg grating sensor was utilized for the observation of SWE in a large-area capacitive discharge reactor by measuring the radial distribution of the neutral gas temperature T_g. The influences of the RF power and the working pressure on the radial profiles of T_g were studied. At a higher frequency (100 MHz) and a lower pressure (5 Pa), T_g presents a center-peaked radial distribution, indicating a significant SWE. As the RF power increases, the central peak of T_g becomes more evident due to enhanced SWE. By contrast, at 100 MHz and a higher pressure (40 Pa), the radial distribution of T_g shows an evident peak at the electrode edge and T_g decays dramatically towards the discharge center because the electromagnetic waves are strongly damped as they are propagating from the edge to the center. At a lower frequency (27 MHz), only edge-high profiles of T_g are observed for various pressures. For the sake of a comparison, a hairpin resonance probe was used to measure the radial distributions of the plasma density n_p under the same condition. The radial profiles of T_g are found to generally resemble those of n_p under various conditions. This is primarily due to the fact that the radial profile of the plasma density determines the radial profile of the ion flux into the sheath, which determines the collision frequency and momentum transfer between ions with neutral species, and consequently the heat efficiency of neutral gas. In other words, a higher neutral gas temperature corresponds to a higher plasma density and/or higher sheath voltage potential. Our experimental results suggest that the FBG sensor could be used to determine the local T_g in capacitive discharges.

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