The experimental and numerical investigations of electron characteristics in 2 MHz and 13.56 MHz inductively coupled hydrogen plasmas

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RF inductively coupled hydrogen plasmas are widely used in a broad range of technology areas, including fusion, positive ion sources, negative ion sources, plasma etching, and other semiconductor processing. The electron characteristics are investigated in 2 MHz and 13.56 MHz inductively coupled hydrogen discharges with an expansion region. The influences of gas pressure, radio frequency of the power source, RF power and the number of the antenna coil turns on the electron energy probability function (EEPF), electron density, electron temperature and RF power transfer efficiency have been presented. The measured EEPFs in the driver region of the discharge evolve from a three-temperature Maxwellian distribution to a Maxwellian distribution as the pressure increases. Different characteristic frequencies calculated based on the measured plasma parameters show that stochastic heating of electrons dominates at pressures lower than 0.3 Pa and it has to be considered for pressures lower than 1.0 Pa, while Ohmic heating dominates at higher pressure. Furthermore, the EEPFs as a function of the total energy evolve from the identical shape to discrete shapes with axial position and pressure, indicating a transition of electron kinetics from nonlocal to local regimes. This can be explained by the calculated electron energy relaxation length. The RF power transfer efficiency increases with increasing the number of the antenna coil turns, while it first increases and then decreases with the increase of gas pressure at 2 MHz discharge. The axial distribution of the electron density exhibits a bell-shaped profile in the discharge driver region, while it decreases monotonically in the expansion region. And the electron temperature is almost constant along the axial direction in the discharge driver region, while it declines monotonically in the expansion region. In addition, there is no frequency dependence of axial resolved EEPFs, electron density, and electron temperature in high power deposition discharges (1.5 kW).

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