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Radio-Frequency Plasma Probes[1]

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The utility of radio-frequency probes for diagnosing low-temperature plasmas has recently been extended through the use of a network analyzer to measure the small-signal, complex probe impedance Z_{ac} as a function of applied frequency and dc bias. To interpret the results, account must be taken of the gas pressure, the plasma density, the applied frequency, and the applied magnetic field if any. In this talk four different models are presented for use in different regimes. At high gas pressure, $\mathrm{Re}(Z_{ac})$ is shown to give n_{e0}/ν, where n_{e0} is the ambient electron density and ν is the electron-neutral collision frequency. At low pressure $\mathrm{Re}(Z_{ac})$ gives not only n_{e0} but also $n_e(r)$ within the sheath immediately outside the probe, the plasma potential, and the electron energy distribution and temperature. Magnetized plasmas can be treated by adding an external inductance in series with the probe and operating above the upper hybrid frequency; alternatively, rf voltage can be applied between two closely-spaced planar electrodes oriented either parallel or perpendicular to the field. As will be shown, rf probes not only provide more information than Langmuir probes, but the data is easier to analyze and generally less affected by noise. Additional advantages include the following: decreased sensitivity to secondary electron emission, ions, plasma flow, and high-energy beams; clear and unequivocal determination of n_{e0}, even in magnetized plasmas; direct utility at high pressure; multiple checks on the results; and the ability to operate in reactive and depositing gases.

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