REVIEW ARTICLE

Comprehensive analysis of chlorine-containing capacitively coupled plasmas

Gerhard Franz
Munich University of Applied Sciences, D-80335 Munich, Germany

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Capacitively coupled discharges of strongly reactive atmospheres containing mixtures of boron trichloride (BCl_3) and chlorine (Cl_2) are investigated employing spatially resolved Langmuir probe measurements, and three probes that are spatially integrating methods: optical emission spectroscopy (OES), self-excited electron resonance spectroscopy (SEERS), and impedance characteristics of the discharge. The analysis covers the pure gases including some mixtures, discharge pressure, and rf power over nearly two orders of magnitude, and their impact on important plasma parameters of "first order," such as plasma density, plasma potential, electron temperature, temperature of the plasma bulk, electron collision rate with neutrals, and actual rf power coupled into the discharge. From these, other properties (electrical conductivity, capacitance, plasma bulk resistance, sheath resistance, and its electrically defined thickness) can be derived. Since the methods are partially complementary, a mutual control of the obtained data is made possible, and we finally obtain a self-consistent model for capacitive coupling connecting data obtained with electrical and optical probes. Compared to electropositive discharges of inert atomic gases (Ar) and molecular gases (H_2), which are used as calibration standard for BCl_3 and Cl_2, the electron plasma density n_e is definitely lower, whereas the electron temperature T_e is significantly higher, which would be expected by electron attachment to the electronegative molecules—at least at higher discharge pressures. Furthermore, we compared values for T_e and n_e obtained with OES and SEERS, respectively, and with the Langmuir-probe system. The agreement in electron plasma density and electron temperature for Ar is surprisingly good, despite the fact that the electron energy distribution would be described with two temperatures. For argon plasma, the variation of the calculated dc conductivity for nearly pure capacitive coupling either from impedance measurements or SEERS is within 30%. This is a result of uncertainties in current path rather than principal faults of the various methods. For the reactive, molecular gases, however, the results vary significantly. These data serve to determine several derived properties. Among these, are the sheath thickness, which is compared with optical and electrical data, and the conductivity of the plasma bulk. As they are derived from simultaneous, but independent measurements, they confirm the relative simple model of an electropositive discharge (argon and argon/krypton), and stress the difficulty to describe plasmas consisting of electronegative constituents (Cl_2, BCl_3, and their mixtures) which is due mainly to a pressure-dependent transition from stochastic to ohmic heating and from electropositive to electronegative behavior. © *2005 American Vacuum Society.* [DOI: 10.1116/1.1894725]