Electronegativity and negative ion kinetics in O_2 ICP during E-H transition

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Important plasma species, e.g., density of electrons, negative atomic oxygen ions, singlet metastable and ground state molecular oxygen as well as the electron and gas temperature were quantified using comprehensive plasma diagnostics. In particular, the negative ion kinetics was evaluated taking into account the O^- particle balance equation with the relevant rate constants from literature. During the E-H transition a continuous reduction of the electronegativity was observed over two orders of magnitude.

1. Introduction

Oxygen plasmas have been widely studied in experiment and simulation as a model system for electronegative plasmas. Furthermore, oxygen is used as reactive plasma processing gas in low or atmospheric pressure discharges to produce atomic oxygen and ozone as well as secondary reaction products in gas phase, e.g., OH, H_2O_2, NO_x. The interaction of these reactive species with materials is applied in plasma surface processing, e.g., surface oxidation/functionalisation, degradation and plasma etching. Here, we investigated experimentally inductively coupled radio frequency plasmas (RF ICP) in pure oxygen at low pressure using comprehensive plasma diagnostics. The changing plasma parameters during the E-H transition were systematically studied and the underlying species kinetics, in particular the negative ion kinetics, was evaluated.

2. Experimental

The configuration of the RF ICP at 13.56 MHz consists of a plane double spiral antenna of about 120 mm in diameter with 2.75 windings. The RF power up to 500W or coil voltage of about 8 kV was coupled to the centre connection, whereas the ground potential was applied at the two opposite ends of the coil. The coil was installed in a quartz cylinder immersed in the cylindrical vacuum vessel, [1].

The installed plasma diagnostics includes electric probe measurement, 160 GHz Gaussian beam microwave interferometry, emission and absorption spectroscopy, phase resolved optical emission spectroscopy (PROES) as well as laser photo detachment experiment, [2, 3].

3. Results

All plasma parameters, e.g., electron density and temperature, reveal a continuous E-H transition for pressures lower than 35 Pa. Here, a hybrid (E/H) mode was observed, that means the capacitive and inductive electron heating appears simultaneously in the RF cycle. The negative atomic oxygen ion density was determined by laser photo detachment experiment and the rate equation calculation. The electronegativity $\alpha=n_{O^-}/n_e$ during the E-H transition decreases from about 20 in the E-mode to 0.1 in the H-mode, see Fig.1.

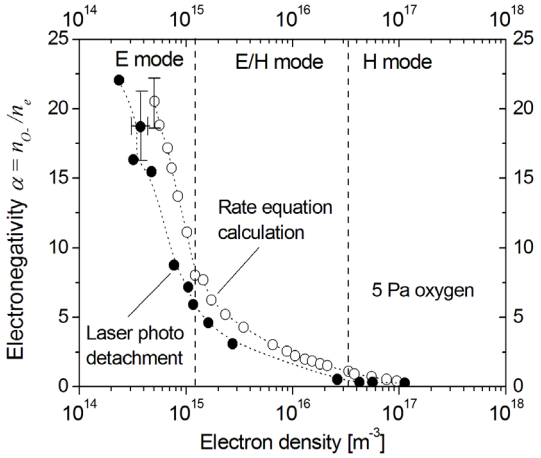

Figure 1: Electronegativity vs. electron density during E-H transition from O^- laser photo detachment experiment and O^- rate equation calculation.

The rate equation calculation for the negative atomic oxygen ion provides the dominant reaction channels for O^- generation and loss, respectively. These are for the E/H and the H mode the dissociative electron attachment reaction with $O_2(X)$ and $O_2(a^1\Delta)$ as well as the ion-ion recombination and the detachment with atomic oxygen.

4. References

[1] Th. Wegner, C. Küllig, J. Meichsner Contrib. Plasma Phys. **55** (2015) 728

[2] Th. Wegner, C. Küllig, J. Meichsner, Plasma Sources Sci. Technol. **26** (2017) 025006

[3] Th. Wegner, C. Küllig, J. Meichsner, Plasma Sources Sci. Technol. **26** (2017) 025007