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SUMMARY OF Ph.D. DISSERTATION

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Title

Numerical Modeling of the Effect of Ar Metastables on the Plasma Maintenance and the Production of Atomic Oxygen Radicals in an Inductively Coupled Plasma

Abstract

In this study, a numerical simulation of an inductively coupled plasma (ICP) by using the relaxation continuum (RCT) model was performed to clarify the effect of Ar metastables on the plasma maintenance through the stepwise ionization. A model considering the reactions of neutral radicals in an ICP in O_2/Ar was established to investigate the number densities of atomic oxygen radicals and their production mechanism in detail.

Chapter 1 summarizes the background and the objective of the present study.

Chapter 2 describes the detail of the RCT model which expresses a low-temperature and high-density ICP. A schematic of the ICP and external conditions considered in the present study are described. The governing equations of the RCT model including the electron energy relaxation equation which expresses the relaxation phenomena of the electron energy in non-equilibrium plasmas are presented. Numerical techniques, boundary conditions, and decision method of electron swarm parameters are also explained.

In chapter 3, periodic steady-state plasma structures in ICP in pure Ar are presented and a comparison with experimental results is made to confirm the validity of the present modeling. The plasma structures in high-density ICP in Ar under several conditions are calculated to discuss the mechanism of the plasma maintenance. The stepwise ionization is found to be the dominant mechanism of the plasma maintenance under high pressure conditions (> 50 mTorr). The plasma density exhibits a hysteresis property with the decrease of the dissipated power.

Chapter 4 describes the production mechanism of atomic oxygen radicals by the RCT model considering the reactions of neutrals (and ions) in the gas phase and the surface reactions on the chamber wall in highly Ar-diluted O_2 plasma. Atomic oxygen radicals are predominantly produced through the dissociation of O_2 molecule and the density is up to 10^{14} cm^{-3} through the iterative reactions of the excitation and quenching under the present conditions. Ar metastable density has the maximum at 1 % of the O_2 fraction at 100 W of the dissipated power. However, effect of Ar metastable on the atomic oxygen production is negligibly small due to the electron quenching in the present ICP.

Chapter 5 summarizes the results of the present study.