Electron temperature diagnosis of CF_4/O_2 plasma based on fluorine atomic corona model by tomographic optical emission spectroscopic measurement

Yuya Yamashita[(*)1,2], Kenta Doi[3], Tetsuji Kiyota[4], Shuhei Watanabe[1], Kazuki Shimatani[1], Wataru Kikuchi[1], Yuchen Ye[1], Atsushi Nezu[5,6], and Hiroshi Akatsuka[6,1]

[1] *School of Engineering, Tokyo Institute of Technology, 2-12-1-N1-10 Ookayama, Meguro-ku, Tokyo, Japan*

[2] *Research Fellow DC, Japan Society for the Promotion of Science*

[3] *Institute of Advanced Technology, ULVAC, Inc., 1220-1 Suyama, Susono-shi, Shizuoka, Japan*

[4] *Strategic Planning Department, ULVAC, Inc., 2500 Hagisono, Chigasaki-shi, Kanagawa, Japan*

[5] *Open Facility Center, Tokyo Institute of Technology, 2-12-1-N1-10 Ookayama, Meguro-ku, Tokyo, Japan*

[6] *Institute of Innovative Research, Tokyo Institute of Technology, 2-12-1-N1-10 Ookayama, Meguro-ku, Tokyo, Japan*

[(*)] yamashita.y.an@m.titech.ac.jp

1. Introduction

In recent years, there has been an increasing number of reports on plasma position profile diagnostics by tomographic optical emission spectroscopic (OES) measurement [1-2]. Simultaneous measurement of all lines of sight is essential for *in-situ* measurement of position profiles. We have previously reported electron temperature and density diagnosis for Ar plasma based on tomographic OES measurement and collisional radiative model [2]. In this study, we report an attempt to diagnose the positional distribution of electron temperature T_e by tomographic emission spectroscopy in CF_4/O_2 inductively coupled plasma which is frequently used for etching.

2. Experiment

CF_4/O_2 plasma was generated by an inductively coupled plasma system (chamber inner dimensions Φ177.5 x H 211.8 mm (largest part), bias stage outer diameter 291 mm) as shown in Fig.1. The total pressure was set at 1.0 Pa (constant), the O_2 partial pressure p_{O2} = 0 - 25% of the total pressure, and the radio frequency (RF) power P_a = 50 - 400 W (antenna, 13.56MHz) and P_b = 0 - 100 W (stage bias, 12.5MHz). The cross section was observed 12 mm above the Si wafer by 34 lines of sights as shown in Fig.2. A multichannel spectrometer (UV-M135A, Horiba, Ltd.) was used to simultaneously measure the line-of-sight dependence of the spectral radiance $L_{air}(\lambda)$ at the atmospheric side of the window [3].

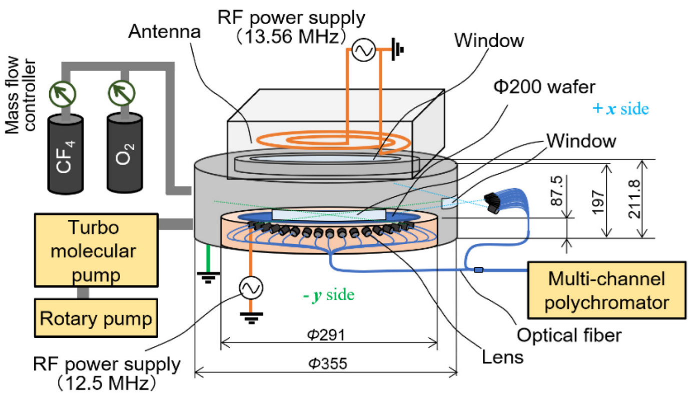

Fig. 1: The experimental setup.

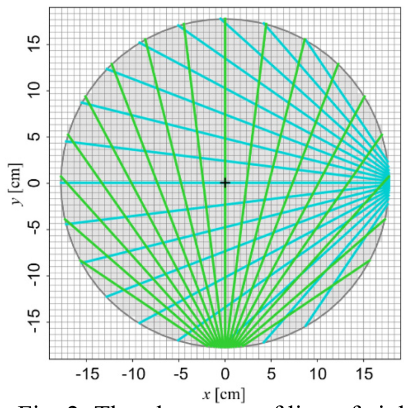

Fig. 2: The placement of line-of-sight.

3. Analysis

Taking $L_{air}(\lambda)$ as input, the line-of-sight dependence of the spectral radiance at the vacuum side window was calculated, taking into account the Fresnel reflection due to window surface refraction and the line-of-sight shift [4]. Furthermore, the positional distribution of the spectral emission coefficients was reconstructed using a tomography spectral emission calculation program [2] based on the constrained regularization method [5]. From the emission coefficients of natural fluorine (F_I) lines, the excited level number densities of $3p^4\ 4D^{\circ}$ and $3p^2\ 2P^{\circ}$ of F_I : n_j and n_j' were calculated, respectively. The rate of electron collisional excitation from the ground level was calculated as a function of T_e and the cross section. Assuming coronal equilibrium, the elementary processes intervening in the relevant excited levels are the inflow by electron collisional excitation from the ground level to the relevant level and the outflow by spontaneous emission from the relevant level. Therefore, T_e was diagnosed by fitting the following equation:

$$f(T_e) = \sqrt{\left(\frac{\int_0^\infty \varepsilon\sigma(\varepsilon)\exp\left(-\frac{\varepsilon}{T_e}\right)d\,\varepsilon}{\int_0^\infty \varepsilon\sigma'(\varepsilon)\exp\left(-\frac{\varepsilon}{T_e}\right)d\,\varepsilon} - \frac{n_j\sum_i A_{ji}}{n'_j\sum_i A_{j'i}}\right)^2}, \qquad (1)$$

where ε is electron energy; $\sigma(\varepsilon)$ and $\sigma'(\varepsilon)$ are the electron collisional excitation cross section [6] of the transition from the ground level to $3p^4\ 4D^{\circ}$ and $3p^2\ 2P^{\circ}$, respectively; A_{ji} and $A_{j'i}$ are A coefficients from $3p^4\ 4D^{\circ}$ and $3p^2\ 2P^{\circ}$ to the ground level, respectively.

4. Results and Discussion

Figure 3 shows the dependence of T_e diagnostic results on P_b at p_{O2} = 20%. T_e at the center of the stage was lower than the outside. The asymmetry is considered due to the spiral shape of the edge of the antenna for inductive coupling or the placement of line-of-sights. Furthermore, an increase of T_e due to bias application was also observed. The dependence of the spectral emission coefficient and electron temperature on p_{O2}, P_a, and P_b, which are omitted for reasons of space limitation, will be discussed in my presentation.

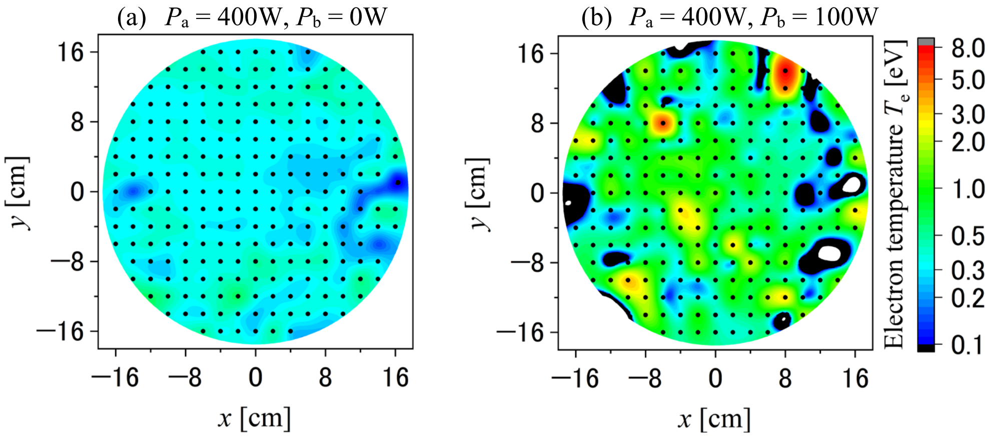

Fig. 3: The dependence of electron temperate on *x*-*y* position.

Acknowledgments

The authors thank Mr. Akira Kobayashi of the (then) Tokyo Institute of Technology for providing the initial version of the fluorine atom electron temperature analysis program based on the corona model. This work was supported by JSPS KAKENHI Grant Number JP23KJ0884.

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