S10-2

Diagnostics and Modeling of Microplasmas
マイクロプラズマの診断とモデリング

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Optical emission spectroscopy (OES), laser absorption spectroscopy (LAS) and laser Thomson scattering (LTS) methods have been applied to the diagnostics of dynamic behaviors of microplasmas in a PDP cell. A method is also being performed for analyzing accumulated charges on the surface by using Pockels effect. In the simulation parts, a phenomenon of electron bunching in laser produced plasma has been analyzed by a particle code. Phenomena in super critical fluid plasma are also being analyzed theoretically.

1. Introduction

Properties of microplasmas can be characterized not only by their down sizing from mm to μm but also by their relatively high plasma densities which range over 10^{13} cm^{-3} in collision dominant atmospheres. In addition, the plasma-wall interaction becomes important, given that the charges accumulated on the surface can strongly affect the discharge and plasma behaviors. Diagnostics and modeling should aim to clarify those specific properties of microplasmas. Several measurements have been performed using spectroscopic methods, only by which such small spaces can be accessible. Simulations in fluid and particle codes have also been developed. An overview of those approaches in our subgroup of the MEXT microplasma project will be introduced.

2. Diagnostics

2.1. Dynamic behaviors of excited species

Excited Xe atoms in unit PDP discharge cell has been diagnosed by optical emission spectroscopy (OES) and laser absorption spectroscopy (LAD) for their spatiotemporal behavior. A special cell structure of realistic scale was developed for the three-dimensional observation, and the effect of the auxiliary third-electrode was investigated for the improvement of the production efficiency of excited atoms as shown in **Fig. 1 [1]**. Another diagnostics has been performed on an integrated structure of microplasmas to realize a large area plasma source operated at around atmospheric pressure for various material processing. In addition to the LAS measurements, a mm-wave transmittance technique is used for the estimation of electron density n_e.

2.2. Measurements of plasma parameters

Laser Thomson scattering（LTS）technique has been used by Uchino *et al* to measure directly n_e and electron temperature T_e profiles in a plasma of PDP-like discharge [2]. The spatial resolution of LTS has been improved to be around 50 μm, and the measurements have been performed at heights as close as 60 μm from the electrode surface. The configuration of the electrodes used in this study were similar to those of sustain electrodes of coplanar ac-PDPs. Coplanar electrodes of 1 mm in width were built up on a glass substrate of 50

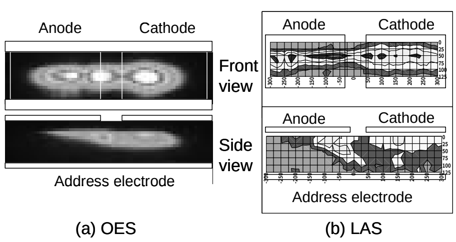

Fig. 1 Spatiotemporal behavior of excited Xe*(2p, 1s) atoms in PDP discharge by 3D observation.

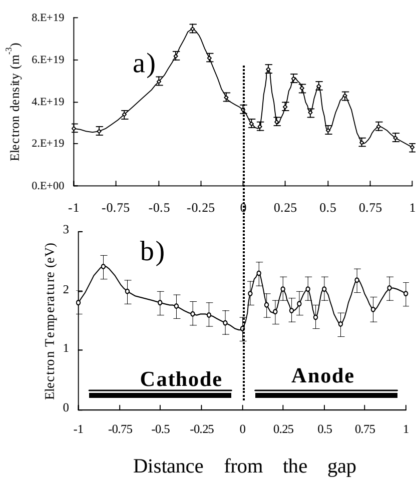

Fig.2 (a) Electron density and (b) electron temperature in PDP-like discharge measured by LTS.

mm in length and 2 mm in width. The LTS measurement was performed at a height of 100 μm above the electrode surface, because vertical distributions of n_e at almost all positions along the electrode had peaks at around this height for the discharge in the gas mixture of Ne/Ar (10%) at a pressure of 200 Torr. The results are shown in **Fig. 2**. From the figure, modulations in n_e and T_e are clearly observed above the anode side. Five striated peaks can be easily distinguished. The distances between the density and temperature peaks are 100-150 μm. It is noted that the modulation in T_e is out of phase from the modulation in n_e.

2.3. Diagnostics of plasma-surface interactions

The wall charges accumulated on the dielectric surface play an important role in a gas discharge, especially in dielectric barrier discharge (DBD). Sakurai *et al* have developed a technique to measure the wall voltage in a DBD using an electro-optic nonlinear crystal as follows [3]. One of the dielectric barriers was made by a z-cut KDP crystal with a rectangular cross section of 25 x 30 mm and a thickness of 2 mm. An actual discharge volume is 20 x 10 x 3 mm. A pure Ar gas was filled in the discharge space at a pressure of 3 Torr. A pulsed power supply was connected to metal conductors which were in contact with ITO. A laser beam with a circular polarization passes through the barrier discharge and the KDP in the direction normal to the surface. The polarization of transmitted laser beam changes due to a surface voltage on KDP. The dynamic behavior of the wall voltage due to accumulated charges is observed from a spatial and temporal measurement of the polarization change. An example of the results is shown in **Fig. 3**. The positions 0 and 10 mm indicate the edge of the conductor ITO and the end of discharge space based on a boundary, respectively. It is found that the discharge progresses in a local space at region from 2 to 6 mm during time from 6 to 6.5 μs. After the end of discharge, the charges accumulate on the KDP surface uniformly.

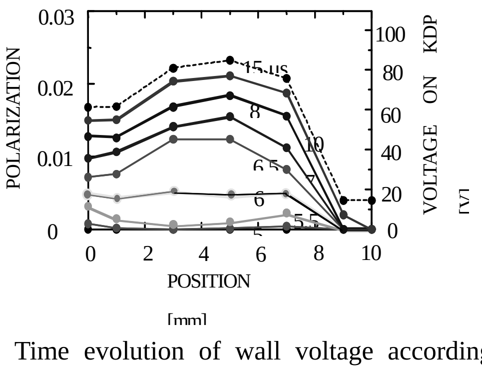

Fig. 3 Time evolution of wall voltage according to accumulated charge on cathode surface.

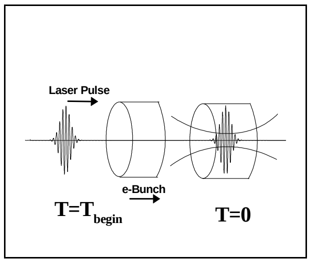

Fig.4 Mechanism of electron bunch compression and acceleration

3. Modeling

3.1. Modeling of micro bunch formation

A phenomenon of electron bunch generation was studied Kawata *et al* using a 3-dimensional particle simulation. A focused short pulse laser of TEM (1,0)+TEM (0,1) mode has two intensity peaks in the radial direction, so that the transverse ponderomotive force can trap electrons between the two peaks [4]. At the same time the longitudinal ponderomotive force accelerates electrons at the head of the laser pulse, when the laser is focused (see **Fig. 4**). When the electrons move to the laser tail, the laser diverges and the electron deceleration becomes relatively weak. Their numerical analysis demonstrated that electrons are effectively trapped by the laser potential well, and that at the same time the acceleration by the longitudinal ponderomotive force induces the electron bunch compression. This trapping and compression mechanism is unique: the electron bunch can be compressed to the scale of the laser pulse length. Thus, the electron bunch is confined well in transverse and compressed remarkably in longitudinal

3.2. Modeling of supercritical fluid (SFC) plasma

It was found by Terashima *et al* that the breakdown voltage drops drastically in CO_2 near the super critical condition. In order to explain this phenomenon theoretically, our theoretical groups are working on the modeling of the discharge. In the first step, clusters of CO_2 molecules are studied by Senda *et al* using quantum chemistry calculation to derive the cluster structures and ionization potentials of $(CO_2)_n$. In the second step, the electron swarm characteristics in SCF is studied by Hamaguchi *et al* by taking into account the quantum statistical fluctuation in the density which causes the electron channeling in SCF media.

References

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