Report on Visit to The University of Texas at Dallas by International Training Program

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I conducted the study of plasma diagnostics by using the Langmuir Probe, Floating Probe, MWI (Micro Wave Interferometer) in The University of Texas at Dallas. My duration of stay was 2 months (November 19, 2012 to January 21, 2013). I was studying with Dr. Matthew Goeckner and researchers of his group.

Introduction of The University of Texas at Dallas and Dallas

Dallas is the city of commerce and industry and is located north of Texas, USA. It is developed as the hub for transportation from time immemorial, and even today, it is active as the nerve center of money and economy. The population of the urban area of Dallas and Fort Worth is over five million, and it is the greatest number of broad urban area.

I conducted the collaborative work at the International Center for Advanced Materials Processing of The University of Texas at Dallas which is located in Richardson, Texas, USA. It was founded as Graduate Research Center of the Southwest which is the part of the research institute of Texas Instruments in 1961. In 1969, as the graduate university which took in only graduate students of doctor's course, it became the university which is accepted as the one of the Texas University System. After that, it started to take in first-year students and it reaches the 40th anniversary of opening and the 20th anniversary of starting to take in first-year students. It is very young university. In the best college of 2011 in "U.S. News & World Report", it was ranked as "Tier-1". It was developed as the type of the research university since its inception for being the previous incarnation of Texas Instruments research institute. Recent its development is brilliant, its research expenditure became 8.5 million dollars August, 2010. The expenditure increased over 60 % in the last 4 years. The research centers of nanotechnology, space science, computer security, behavior science and brain science receive very good reputations.

Fig.1 The University of Texas at Dallas

Life in Dallas

I stayed a residence hall on the university's property until first half of January. The house is large and there are basic home electric appliances like a kitchen things, refrigerator and sofa. I went to the supermarket, restaurants and the station near my house by bus.

We have the meeting every Wednesday in my group. They conducted the experimental tests and read the literature outside of meeting hours. At the weekly-meeting a few people report on progress by using slides. At the monthly-meeting everyone in the group reports on progress and presents future goals. Each one often went to the room of Dr. Goeckner and discussed the research outside of meeting hours.

Fig.2 Basketball game

I did sightseeing in the city on holidays. There are Dallas Museum, The Sixth Floor Museum which is about the time John F. Kennedy was taken a bullet, the basketball game and the ice hockey game and learned the history of Dallas and the culture of American.

Research Work

Research theme was "Plasma Diagnostics with Langmuir Probe, Floating Probe and Microwave Interferometer and their Comparison".

I set the equipment of Langmuir Probe and Microwave Interferometer but they didn't work well. I couldn't measure the values with them so I only introduce the method of them.

Langmuir Probe is very popular method of plasma diagnostics which can exactly measure the regional plasma density, electron temperature and so on. The minim probe is inserted in the plasma. It is impressed electric voltage against the reference electrode. The current is measured and it is desired the current-voltage characteristics. The probe current is obtained as a sum of an electron current and an ion current. In the area of negatively-biased deeply the probe current is an ion saturation current because electrons can't penetrate it. The value of it is expression (1).

$$I_{is} = -0.605 e n_0 \left(\frac{\kappa T_e}{m_i}\right)^{\frac{1}{2}} S \qquad (1)$$

The other way, in the area of positively-biased deeply the probe current is an electron saturation current because ions can't penetrate it. The value of it is expression (2).

$$I_{es} = (n_0 e \langle v_e \rangle / 4) S \qquad (2)$$

In the middle area the electron current is

$$I_e = \frac{e n_0 \langle v_e \rangle}{4} S e^{e(V_s - V_p)/\kappa T_e} \qquad (3)$$

$$\log I_e \propto e(V_B - V_p)/\kappa T_e \qquad (4)$$

and increases in an exponential fashion. The logarithmic value $\log I_e$ of an electron current against an electric voltage V_B becomes a straight line and the inverse of its line gradient gives κT_e. The plasma density is measured from the electron temperature and an ion saturation current or an electron saturation current.

Floating probe is the method of plasma diagnostics of measuring regional plasma density and the electron temperature. Fig.3 is the circuit diagram of the probe. The electric voltage is applied from the signal source and the voltage applied at the current sensing resistor is measured with differential AMP. The current is separated from each component with fast Fourier transformation. The electron temperature and the plasma density are measure with the ratio of their currents.

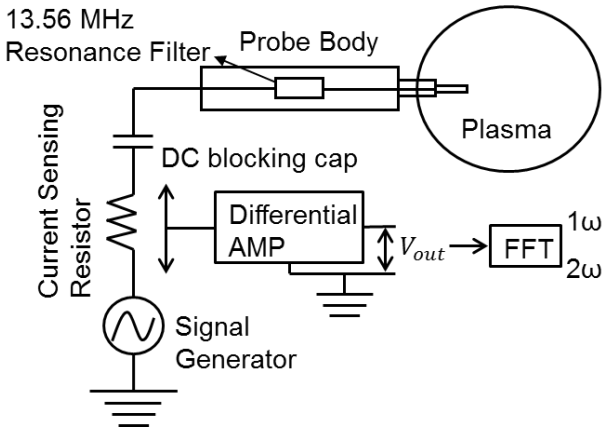

Fig.3 Floating probe configuration diagram

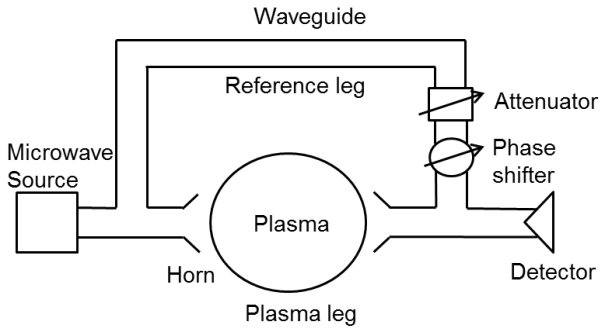

Fig.4 Microwave Interferometer configuration diagram

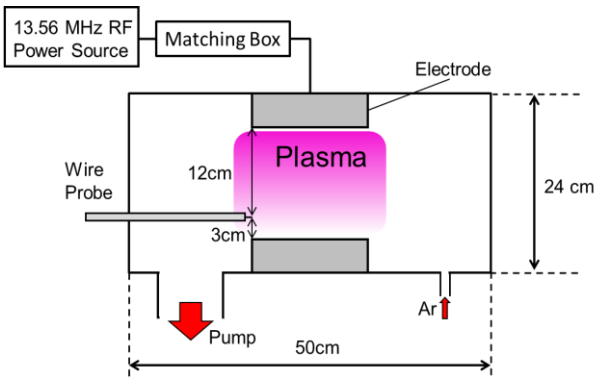

Fig.5 Experimental setup

Microwave interferometer is the method of plasma diagnostics of the plasma density and the electron temperature. It has the merit of non-invasive diagnostics against the plasma but measures only average plasma density of microwave propagation channel. Fig.4 is the diagrammatic illustration of its equipment. The plasma density and the electron temperature are measured by connecting the phase variation of the propagation channels without the plasma and with the plasma, the propagation coefficient and the plasma frequency.

Fig.5 shows diagrammatic illustration of experimental equipment. There are two electrodes in the cylindrical chamber and the under electrode is grounded. The high-frequency power source of 13.56 MHz is applied to the upper electrode and the Capacitively Coupled Plasma is generated and is measured. The gas is Ar and its flow rate is 10 sccm. The distance between the electrodes is 15 cm and the probe is inserted 3 cm apart from the under electrode. The plasma density and the electron temperature are measured for the probe sweeping parallel direction against the electrode.

The results of the plasma density with floating probe are fig.6 and fig.7. The transverse origin of the graph is the center of an electrode and the position of 80 mm is the edge of an electrode. Fig.6 shows the plasma density graph depending on the power as the constant pressure. Fig.7 shows the plasma density graph depending on the pressure as the constant power.

The electron temperature graph measured the plasma density at the same time is fig.8 and fig.9. Fig.8 shows the electron temperature graph depending on the power as the

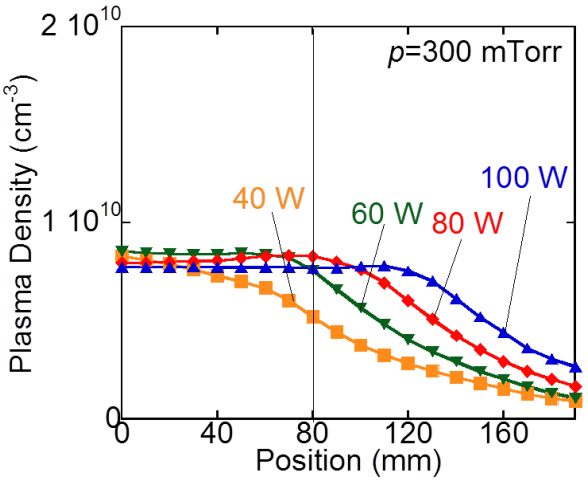

Fig.6 Plasma density (Power dependence)

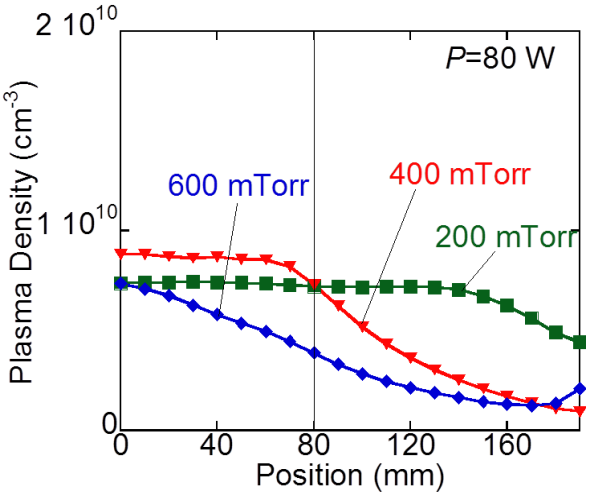

Fig.7 Plasma density (Pressure dependence)

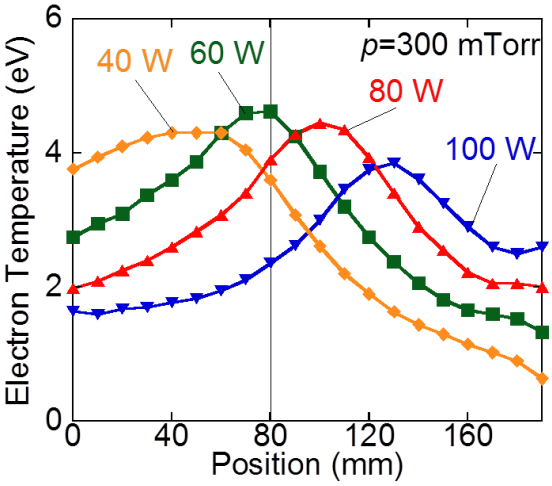

Fig.8 Electron temperature
(Power dependence)

constant pressure. Fig.9 shows the electron temperature graph depending on the pressure as the constant power. From fig.6 and fig.7, the plasma density is very uniform near the electrode center which is not depending on the pressure and the power and the electron temperature is the shape of having the peak and over 4 eV partly.

I think that the value is saturated because the plasma density appears to be too uniformly.

In a normal situation, I should inspect the circuit of the floating probe with calling for a report to the company. And I should compare the results to use other methods of plasma diagnostics but it took a long time to prepare the diagnostic devices. I couldn't get good results.

Finally, I would like to give heartfelt thanks to Prof. Hori, Prof. Toyoda, Plasma-Nano Technology Research Center, Dr. Goeckner, students in the University of Texas at Dallas and all staff who helps my visiting.

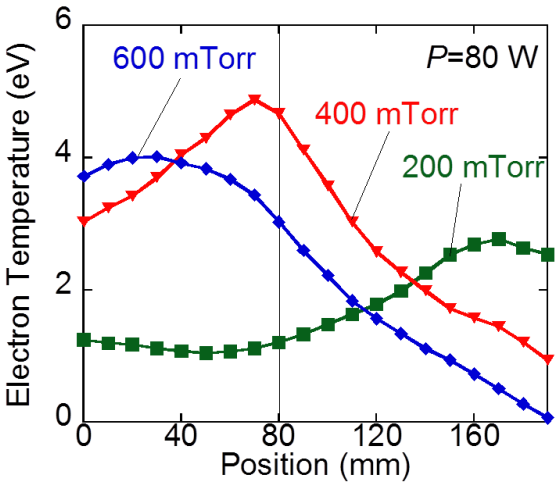

Fig.9 Electron temperature (Pressure Dependence)