Report on Visit to Ruhr-University Bochum by International Training Program

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I had been dispatched to Ruhr University Bochum Germany from 1 Oct. to 29 Nov. by International Training Program (ITP) and had studied in the research group of Prof. Uwe Czarnetzki. Then I would like to report about this dispatch.

Ruhr University Bochum and Bochum

Bochum is a city in North Rhine-Westphalia, western Germany. Four hundred thousand people live in it. It is located east of the Rhein. It is one of industrial city of Ruhr industrial area. Though the city had been developed until 19 century as a coal mine city, the coal mines all closed until 1970. Afterward an instauration by attracting of the automobile engineering, the finance industry and the new constriction of universities was worked out. One of the closed coal mine is used as a museum, we can know about appearance at that time.

Ruhr University Bochum is a state university in Bochum. The university was established in 1962. It was first establishment of university in West Germany since World War II. The university is located south of Bochum center station which is center of Bochum city. It takes ten minutes by subway from center station to the university. The university has twenty departments and the number of students is thirty four thousand, the number of staff is five thousand. Natural environment still remains around the university. People can concentrate on studying and researching due to the quiet atmosphere. Despite natural environment, the campus life is not inconvenience because people can access the center of city by subway. Furthermore there is shopping center named Uni-Center, therefore a living around the university is easy. I had lived in the apartment to which it takes fifteen minutes to walk from university for two months. I had lived comfortably because I could drop in Uni-Center on my way home from the university.

Research group

The research group of Prof. Uwe Carnetki belongs to physics department and Center for Plasma Science and Technology (CPST). The group carries out basic research of plasma. In the group plasma diagnostics is conducted using optical methods such as optical emission spectroscopy, laser induced fluorescence, absorption spectroscopy and Thomson

Figure 1 German Coal Mine Museum.

Figure 2 Campus of Ruhr University.

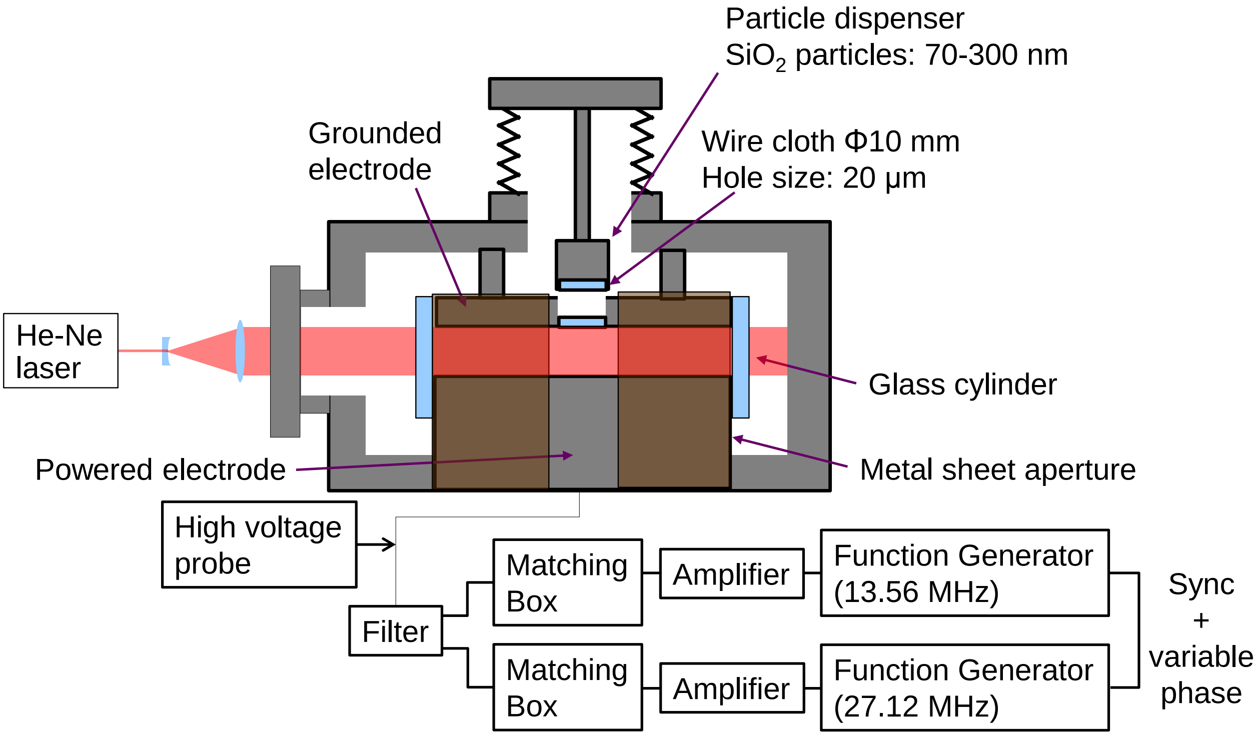

Figure 3 Experimental setup.

scattering. In this time I had studied about controlling transfer particles in plasma using electrical asymmetry effect and measurement of particles using laser scattering.

Research

Recently nano-particle composite films are attracting much attention as light emitting devices, sensors and solar cells due to their properties significantly different from conventional films [1,2,3]. The films can be produced using plasma processing. Nano-particles, radicals and ions are produced in plasma gas phase. The properties of such films depend on the size of nano-particles and on the ratio of the nano-particle. Therefore controlling particles in plasma is necessary to control the properties of films and realize a high deposition rate of nano-particle composite films.

The research group of Prof. Uwe Czarnetzki suggested the method of controlling a dc self bias. It is based on the electrical asymmetry effect (EAE): if one electrode is driven at a fundamental frequency and its second harmonic with variable phase between the two voltage waveforms, a dc self bias develop as a function of the phase angle even in a geometrically symmetric capacitively coupled frequency discharge with equal electrode surface areas [4]. Ion energy and flux at the electrode surface can be controlled separately. In our work, we focus attention on the transfer of nano-particles as a application of EAE. There are some forces that exert nano-particles in plasma. They are ion drag force, electrostatic force, coulomb repulsive force, thermophoretic force, gas viscous force and gravity. It was reported that using amplitude modulation of the discharge voltage, nano-particles can be transported, during the modulation period, from the plasma/sheath boundary region near the powered electrode to near the grounded electrode [5]. Transport of nano-particles will be controlled by controlling electrostatic force which exert nano-particles using EAE. Then, establishment of controlling transport of nano-particles using EAE is object of this research.

Figure 3 shows the experimental setup. Two synchronized function generators were used to generate the phase locked 13.56 and 27.12 MHz voltage waveforms. The phase angle between these harmonics can be adjusted via the frequency generators. Each voltage waveform was then amplified individually by an amplifier and matched individually. Behind each matchbox a filter blocked the other harmonic.

Behind the filters the two voltage waveforms were added and applied to the bottom electrode. The gap between the electrodes were 3 cm. The plasma is shielded from the outer grounded chamber walls by a glass cylinder. As a first step, SiO2 particles were induced to Ar plasma to confirm that EAE can operate in the plasma in which particles exist and particle can be transported using EAE. The particles were induced to plasma from particle dispenser which was placed above top electrode via the mesh. To obtain information about transport of nano-particles, we observed their transport using a two-dimensional laser-light scattering method. For the method, a sheet beam of He-Ne laser light of 15 mW at 632 nm was passed parallel to the electrodes. The height of the sheet beam was 3 cm. The intensity of light scattered by nano-particles was detected with an ICCD camera equipped with an interference filter.

Firstly, optical equipment to measure particle was constructed. We adjusted optical axis to make sheet beam be 3 cm. Afterward we tried to detect particles in Ar plasma, however we couldn't detect particles. As we thought the cause was that there were a few particles in plasma, the size of mesh hole was optimized. Then particles which resided at the plasma/sheath boundary region near the powered electrode could be detected.

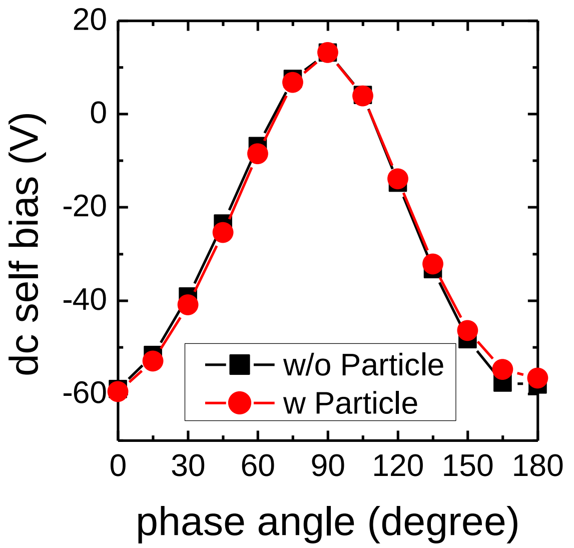

Figure 4 Dc self bias as a function of phase angle

Secondly, we confirmed that the dc self bias could be controlled using EAE. Figure 4 shows the dc self bias as a function of phase angle. The dc self bias was measured by high voltage probe. As phase angle increased from 0° to 90°, the dc self bias changed from -59 to 13.2 V with or without particles. Therefore, It was demonstrated experimentally that the dc self bias can be controlled using EAE also in the plasma which particles exist.

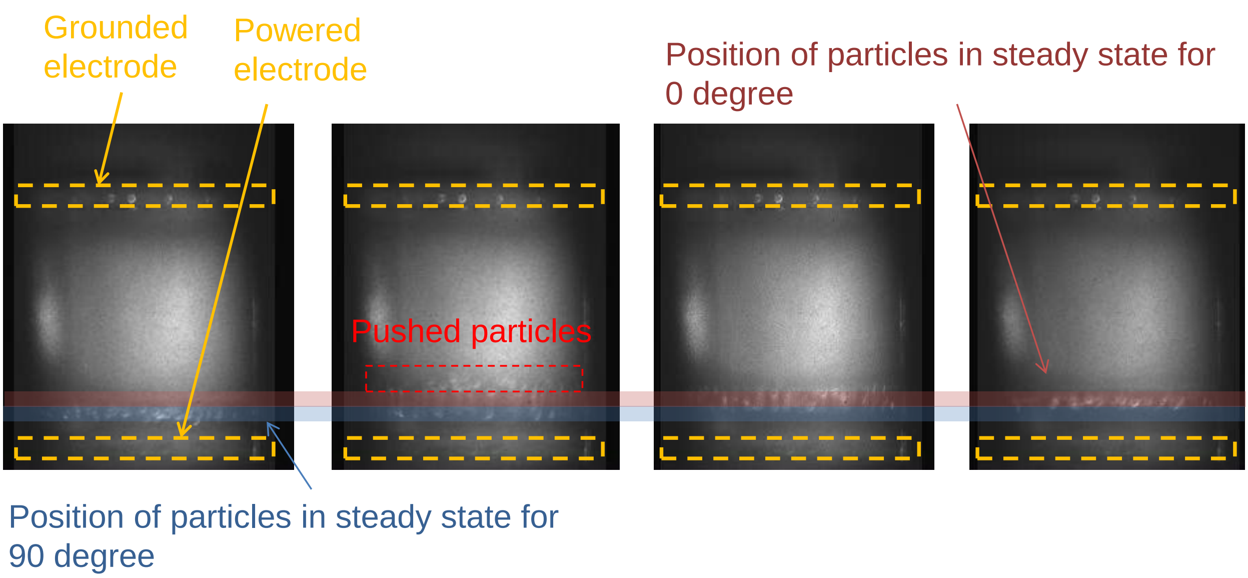

Figure 5 Two-dimensional images of laser light scattered intensity.

Figure 5 shows two-dimensional images of laser light scattered intensity as the phase angle changed from 90° to 0°. This time, we couldn't figure out the timing of switching because the function generator and ICCD camera couldn't be synchronized. It was observed that particles which resided the plasma/sheath boundary region near the powered electrode were pushed toward the upper grounded electrode and resided at the static state for 0°. However it wasn't observed that particles reach near the upper grounded electrode like the reference.

In this experiment, only bigger particles (several μm) than the size of induced particles (70-300 nm) could be detected. The reason may be that particles become massed together.
As controlling the nano-particles is required in reactive plasma, it is necessary to induced particles to plasma without their becoming massed together. Additionally, low laser power (15 mW) may be one of the reasons. As function generators and ICCD camera we used couldn't be synchronized, it is necessary to make a program to synchronize them. In future, they will be improved and more detailed controlling particles and observation of them will be done. Furthermore fabrication of nano-particles using reactive plasma and controlling transport of them based on the obtained result.

As mentioned above, every experience that I've had in this program such as study, discussion with students or professor in English, and life in a foreign country, will help me to promote my study in Japan and international understanding between Germany and Japan. This stay in Germany gave me an irreplaceable two months.
Finally, I deeply appropriate professors in Nagoya University and Ruhr University Bochum, and all of person who assisted this program.

Reference

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