22P054-P

Plasma Source in an Ion Beam System with Low Energy and High Current Density
低エネルギー高電流密度イオンビームシステムにおけるプラズマ源の開発

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The coaxial shunting arch plasma gun has been developed as a plasma source for the ion source of the ion beam injector. Carbon plasma has been successfully generated from solid material without methane gas by the plasma gun. The duration of the plasma gun discharge is 5 msec. We installed a RF generator and an antenna to sustain the plasma generated by the plasma gun. A long time plasma generation is achieved by the plasma gun and by the RF discharge.

1. Plasma gun

The ion beam source has been developed for a new type of the deposition system for diamond and other carbon materials in AIST. Pure carbon plasma source is required for the plasma source of the ion beam. Gun type plasma source can generate a plasma without any carrier gas and is adopted as the pure carbon plasma source of the ion beam. The access port of the ion chamber is limited to size of the ICF-34 flange port to make the cusped magnetic field in side of the ion chamber. The coaxial shunting arch plasma gun has been designed as a plasma source [1]. The surface of the plasma gun except the insulation between the inner and outer electrode is made by the graphite in order to avoid the influx of impurities into the ion beam. The shunting bar, the conductor bridging between the inner and the outer electrodes, is made by a Plastic Formed Carbon (PFC) in order to make it's the impedance higher than the impedance of the discharge current pass. A certain amount of input energy is consumed in the shunting bar. Figure 1 a) shows the discharge voltage and the current of the plasma gun for 600 V charging voltage of the pulse forming network (PFN). The pulse duration and the typical impedance of the PFN are designed 2.4 ms and 0.039 Ohm respectively. The waveform of the gun current shows the flat top phase is same with the designed pulse duration. Figure 1 b) shows the discharge impedance estimated from the gun voltage and the gun current and the CI line (247.8 nm) emission from the plasma gun. The designed impedance of the PFN is same order with the plasma discharge impedance. The CI line emission shows the carbon plasma is generated during the plasma gun discharge.

2. RF source installed on the cusp field chamber

The RF generator (2.45 GHz, 1 kW, IDX Inc., MHA-10AHSB) is installed on the ion chamber.

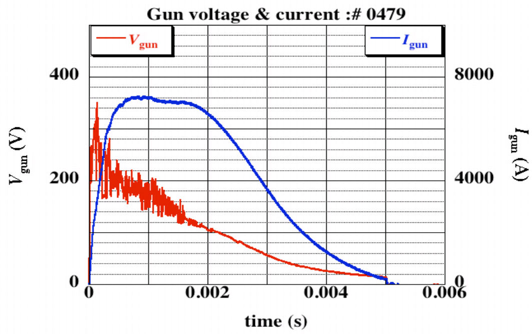

Fig 1 a). The discharge voltage (red line) and the discharge current (blue line).

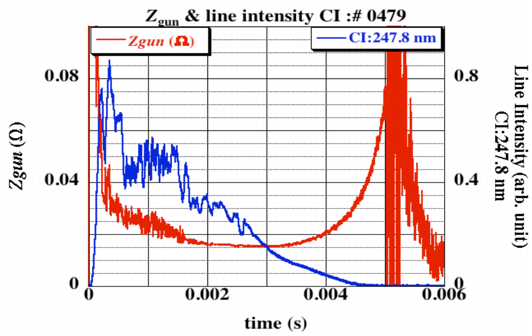

Fig 1 b). The discharge impedance (red line) and the line intensity of CI (247.8 nm).

Figure 2 shows the experimental setup. The size of the access port is limited, and the tapered coaxial waveguide is designed to downsize the coaxial waveguide to ICF-34 from ICF-70. Hydrogen gas is not used for the ion beam source, and the hydrogen embrittlement of copper can be avoided. The coaxial waveguide and the antenna can be made by copper. The tapered coaxial waveguide is installed inside of the access port in order to insulate heat flux to the access port from the waveguide. The cylindrical copper conductor of the waveguide is connected to the water cooler at the bottom of the tapered coaxial waveguide. The 1/2 or 1/4 wavelength antenna is installed on the coaxial waveguide. We used the copper antenna in this paper. The carbon antenna is also prepared. The plasma can be generated by the microwave and electron cyclotron resonance (ECR) in the cusped magnetic field. We usually apply 200 W of the RF power to sustain the plasma.

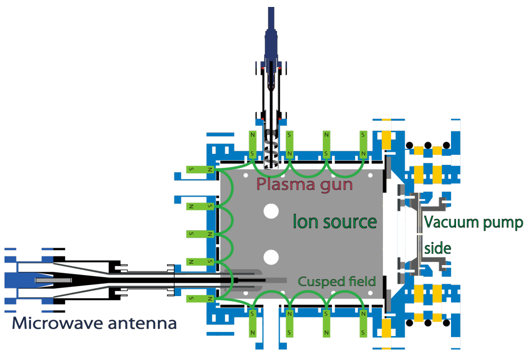

Fig 2. Experimental setup.

3. Combination discharge the plasma gun and RF discharge

The plasma gun can generate the carbon plasma without any hydrocarbon gas as shown in section 1. However, the pulse width is limited within the designed pulse width of the PFN. We apply the microwave to sustain the plasma generated by the plasma gun during the cycle of the gun discharge. The cycle of the plasma gun discharge is selectable. 10 seconds of the cycle is selected in this paper. The number of the cycles is limited to be 8 by the data acquisition. However, the purpose of the experiment is to optimize the plasma gun discharge, and the plasma cycle is enough for this purpose of the experiment. The microwave source is adjusted for the case that the ion chamber is filled with the steady Helium plasma, and the reflection of the microwave is reduced after discharging the plasma gun. The microwave is applied before the plasma gun trigger and is terminated after 8 cycles of the plasma discharges. Figure 3 a) shows the probe signal from double probe installed in the ion chamber. The plasma discharge is short, and the signal of the gun discharge is indicated as a spike signal within the green ellipse. Figure 3 b) shows the probe signal for a 6th single discharge of the plasma gun. The single discharge is limited within 5 ms. The effect of the microwave discharge is shown before the gun discharge and after a few milli-second from the gun discharge. After the RF turn-off, the plasma is also terminated. This indicates the plasma discharge can be sustained longer time. At the last, we note that the carbon is detected in the mass spectrum measured at another side of the vacuum pump from the ion chamber.

Acknowledgments

This study was financially supported by the Budget for Nuclear Research of the Ministry of Education, Culture, Sports, Science and Technology of Japan, based on the screening and counseling of the Atomic Energy Commission, and in part by the Japan Society for the Promotion of Science Core-to-Core Program 22001.

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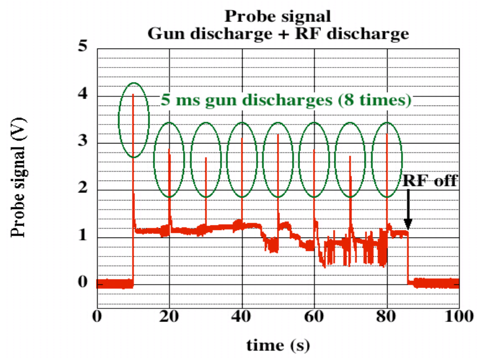

Fig. 3 a). The double probe signal.

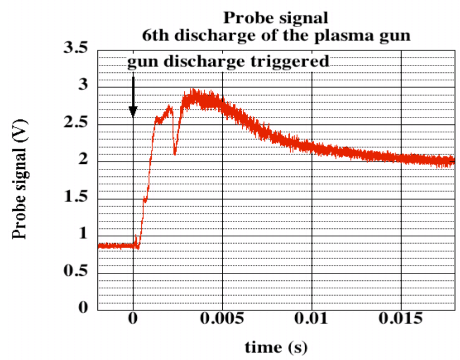

Fig. 3 b). The double probe signal for a single gun discharge.