22P037-P

Mass Spectrometry of the Atmospheric Pressure Plasma Jet
大気圧プラズマジェットの質量分析

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Plasma phenomena which are produced under the atmospheric pressre region have been studied. To measure the particle components and the ion energy spectrum, mass analyzer with energy filter was prepared, and which was installed in the original three sets of differential pumping system. It was observed that measured ion energy specrums and the number of counted particles strongly depend on the electric potential differences between orifices which are installed in each pumping stage. Moreover, it was obviously observed that the pressure in the first pumping stage decreases in the case with the plasma jet. This possible cause will be presented at the meeting by showing the Schlieren high-speed imaging.

1. Introduction

It was obviously found that the pressure decreases in the case with the plasma. This cause will be presented at the meeting by showing the Schlieren high-speed imaging.
The plasma production under atmospheric pressure has been studied for the purpose of applying to new medical instruments [1], combustion improvement [2], material surface processing, and so forth. To understand the discharge phenomena under atmospheric pressure plasma, it is very important to measure the components such as neutral particles, excited particles, ions. However, the components of the atmospheric pressure plasma were not studied in detail, because the components immediately changes due to the interaction with high pressure ambient gases. Under this background, we have tried to measure mass species and the energy of each particle, usually which is not easy under the atmospheric pressure region.
In the present study, we have prepared an original differential pumping system to guide the plasma components from the atmospheric pressure region to a mass analyzer under high vacuume region through three set of orifices. Voltage biasing effects on these orifices are studied during inhaling the plasma jet components.

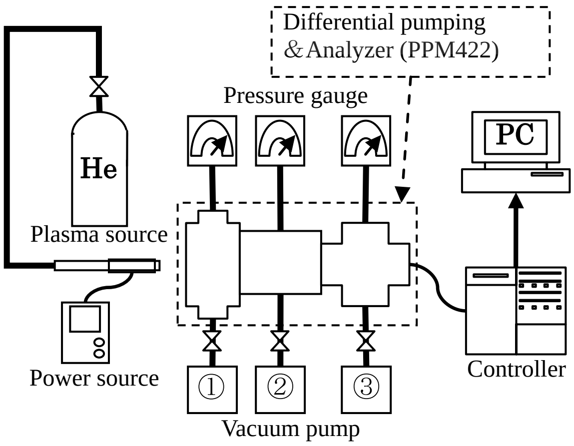

Fig.1. Mass spectrometry system.

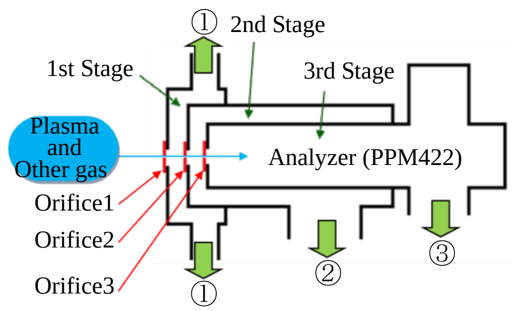

Fig.2. Differential pumping system.

2. Mass spectrometry system

Fig. 1 shows the mass spectrometry system. The main components of this system are composed of a plasma source and a mass analyzer (Pfeiffer: PPM422) which is installed in three-staged of differential pumping system. In the present experiments, we have measured helium (He) gas plasma and argon (Ar) gas plasma which are produced by the dielectric barrier discharge.

Fig. 2 shows the schematic diagram of the differential pumping system. This system is divided into three regions by three orifices (orifice 1; ϕ =0.1or1.0mm, orifice 2; ϕ =0.4mm, orifice 3; ϕ =0.1or1.0mm). The material of those orifices is stainless steel. First stage (①) are evacuated using a scroll pump, and second and third stages (② and ③) are evacuated using a rotary pump and turbo-molecular pump. Here, the orifice 3 installed between second and third stages is the entrance aperture of the analyzer tube. PPM422 can be operated under the lower pressure range than 10^{-2} Pa. Therefore, the atmospheric pressure plasma is introduced into the analyzer region through the each pressure of ① 10^{1}, ② 10^{-3}, and ③ 10^{-6} Pa. In addition, it is possible to apply voltages to each orifice independently. It is possible for PPM422 to measure the energy spectrum of each particle using an electrostatic energy filter.

3. Results and discussion

Fig. 3 and Fig. 4 show the energy distribution of the argon ion in Ar gas plasma. In these experimental series, following conditions are set. For Fig. 3 case, V_{b1} (bias voltage of the orifice 1) is set from -10 to -50 V, V_{b2} (bias voltage of the orifice 2) is set to 10 V, and V_{b3} (bias voltage of the orifice 3) is set to -10V. For Fig. 4 case, V_{b1} is set to a floating potential, V_{b2} is set to from 0 to 20V, and V_{b3} is set to 0V. As shown in Fig.3, it was observed that there were two peaks around the energy region of 0 and 10 eV. The peak value located around 10 eV increases, when the value of the V_{b1} becomes negatively large. Fig. 4 indicated that the amplitude of V_{b2} affected on the peak position of the ion energy distribution. Moreover, the maximum counts at the peak increased when the electric potential difference between orifice 1 and orifice 2 becomes large. This result suggests that particles in 1st stage are ionized by electrons and accelerated.

Fig.5 shows the dependency of 1st stage pressure on the distance between the nozzle of plasma device and orifice 1 with or without the plasma jet. It was obviously found that the pressure decreases in the case with the plasma. This possible cause will be presented at the meeting by showing the Schlieren high-speed imaging.

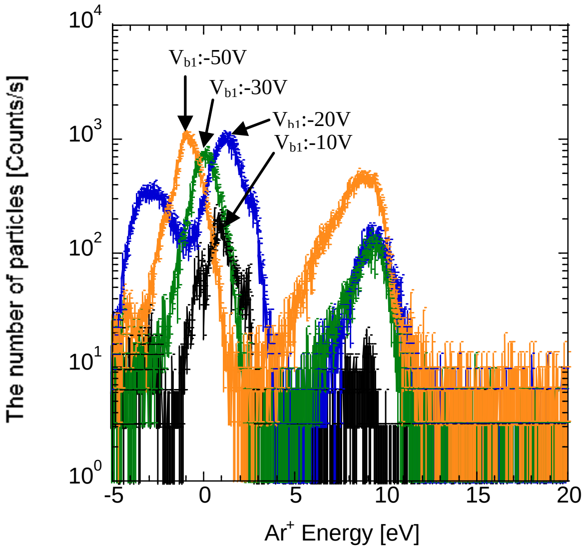

Fig.3. Ar^{+} energy spectrums Ⅰ

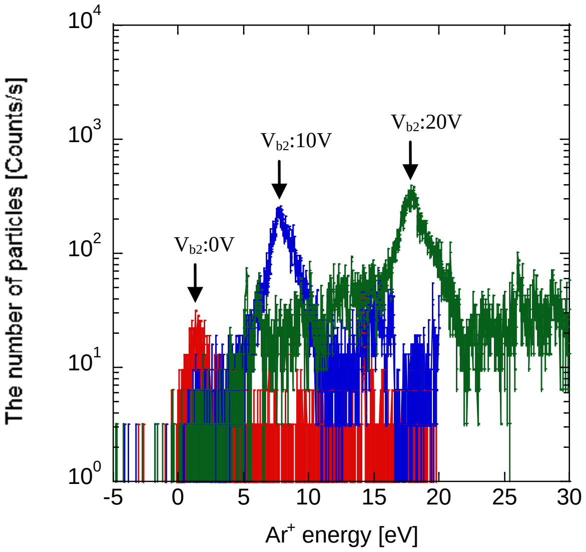

Fig.4. Ar^{+} energy spectrums Ⅱ

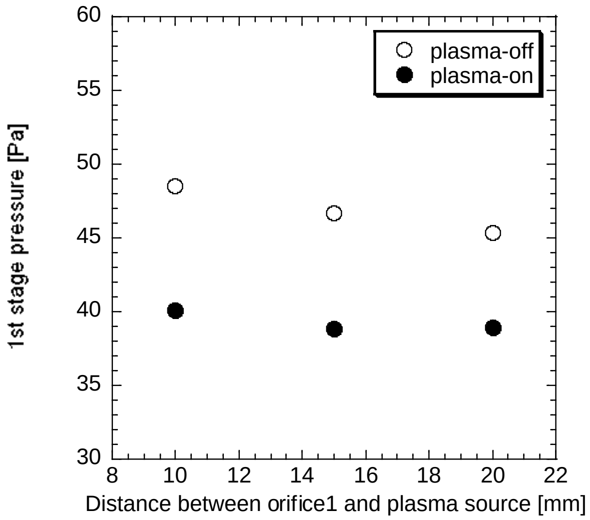

Fig.5. Dependency of 1st stage pressure on the distance between the nozzle of plasma device and orifice1 with or without helium plasma jet.

References

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