1st Asia-Pacific Conference on Plasma Physics, 18-22, 09.2017, Chengdu, China

Injection of plasma plume into radio frequency atmospheric pressure glow discharge

Ying Guo[1,2], Qianhan Han[1], Xiaodong Wang[1], Jing Zhang[1,2], Jianjun Shi[1,2]

[1] College of Science, Donghua University, China,[2]Magnetic Confinement Fusion Research Center, Ministry of Education of the People's Republic of China

Atmospheric pressure glow discharges (APGDs) have been generated in a number of different ways with various voltage waveforms and frequencies ranging from ac (60 Hz) to microwave. They, e.g., generate plasmas for biomedical applications, or act with the surface of the material to improve adhesion, or make it possible to use them for the fast ignition of chemically reactive gas mixtures. Rf APGD has higher plasma density and lower breakdown and maintains voltage than that in the atmospheric dielectric barrier discharge (DBD) excited by kilo hertz rang power. However, the high gas temperature and power consumption in rf APGD restrict its application scope. Therefore, it is proposed that rf APGDs with reduced gas temperature and power consumption can be obtained by using pulse modulated rf excitation [1]. The important role of residual electrons on ignition of each rf discharge burst can be studied with pulse modulation[2]. Thus, the reduction of the power density and gas temperature were achieved by decreasing the duty cycle. However, the results of this modulation are limited and it is not clear whether the residual electrons may alter generation mechanisms of rf APGDs. Here, the combined electrode system is employed in the experiments by introducing sub-microsecond high voltage pulse power electrode in front of the radio frequency power electrode. And the plasma jet was injected into the rf discharge region in the form of plasma bullets. The interaction between plasma bullets and rf discharge is studied experimentally by means of current voltage characteristics and spatio-temporal evolution of discharge.

Figure 1 presents the ICCD images of the plasma bullet propagating from the pulse electrode (left) to the rf electrode (right) with 10 ns exposure time. Fig.3 (a)-(b) is a continuous rf discharge stage, the rf discharge is stable but the discharge intensity is relatively low, as shown in Fig.4 in the 0-0.8us time period. Fig.3 (b)-(d) is the process of generating the plasma bullet by pulsed discharge in the dielectric tube. The plasma bullets move at about 50km/s from the pulse electrode to the ground electrode.

Figure 2 gives the image intensity of discharge during the interaction of plasma bullet and rf discharge. The value of the rf discharge intensity (0.83 a.u.) is shown at point (a). Figure 2 (b)-(f) is the transport process of plasma bullets in the rf discharge region. Considering the velocity of the plasma bullet, approximately at point (f) in Figure 2, the plasma bullet moves away from the rf discharge region. Compared to the plasma bullet in the pulse voltage rising phase, the plasma bullet in fall phase was shorter and started to die off in middle of the discharge gap well before reaching the ground electrode. So the enhancement of rf discharge at point (h) in Figure 2, we note that the flash does not occur during the pulse.

It is demonstrated that with introducing the pulsed discharge, the intensity of rf discharge and the number of energetic electrons are enhanced, which is explained by the residual plasma species generated in the pulsed discharge assists the neutral gas ionization of the rf discharge region. It provides a way to achieve a stable atmospheric rf discharge with energetic electrons.

References

[1] Li XC, Wang H, Ding ZF, Wang YN. Effect of Duty Cycle on the Characteristics of Pulse-Modulated Radio-Frequency Atmospheric Pressure Dielectric Barrier Discharge. Plasma Science & Technology. 2012;14(12):1069-72.

[2] Shi JJ, Zhang J, Qiu G, Walsh JL, Kong MG. Modes in a pulse-modulated radio-frequency dielectric-barrier glow discharge. Applied Physics Letters. 2008;93(4).

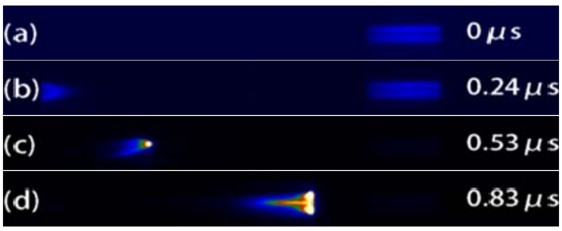

Figure 1 the plasma images of Jet with 10 ns exposure time of the plasma jet at different delay times from the rising phase of the ICCD gate signal

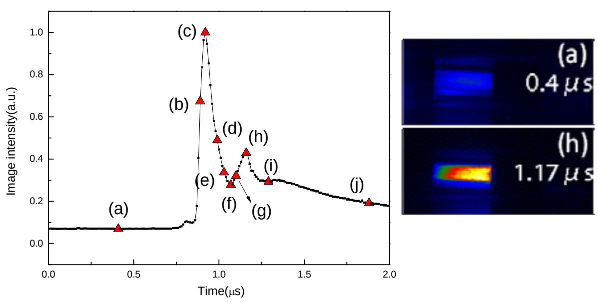

Figure 2 Image intensity of rf APGD as a function of time delay and the (a) and (h) points corresponding to the ICCD discharge images