5th Asia-Pacific Conference on Plasma Physics, 26 Sept-1Oct, 2021, Remote e-conference

Characteristics of radio frequency discharge assisted by kilohertz pulsed plasma bullet at atmospheric pressure

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The cascade process of pulse discharge assisted radio frequency (rf) discharge is studied. By studying the spatio-temporal distribution of discharge, the effect of the pulsed plasma bullet on the rf plume is explained. Experiments have found that adjusting the pulse width can control the distance of plasma bullets to form different cascade modes. After the plasma bullet reaches the rf discharge area, the length and intensity of the rf plume begin to increase. The plasma bullet passes through the rf plume, and the intensity of the rf plume reaches its maximum. Through the spatio-temporal distribution of the discharge image and the intensity of the image, it can be proved that the length of the rf plume is increased from 2 mm to 6 mm, and the discharge intensity is increased by four times. This effect can be maintained for tens of microseconds.

The atmospheric pressure glow discharge plasma jet driven by a rf power supply has become one of the hot topics in non-thermal plasmas due to their low and controllable gas temperature, high stability, and high concentrations of chemically reactive species. These advantages make rf discharge widely employed in medicine, agriculture and surface modifications (e.g. on polymer fibres). The short length of the rf plasma plume is often an important factor affecting the application of rf discharge. In order to increase the length of the rf plasma plume, a method of injecting a pulsed plasma bullet into the rf discharge region was proposed.

As shown in Fig. 1, The combined discharge device consists of three 5mm wide copper sheets and a quartz tube. The inner diameter and outer diameter of the quartz tube are 2 mm and 4 mm, respectively. Helium gas (99.999%) is introduced into the quartz tube at a rate of 2 SLM.

The cascade discharge images with pulse widths of 0.6 µs, 1.4 µs and 2.4 µs taken by the digital camera are shown in Fig. 2(a1), (b1) and (c1) respectively. The spatio-temporal evolution of pulse discharge and rf discharge within the time from 0 to 4 µs is given in Fig. 2(a2), 2(b2), and 2(c2). In Fig. 2(a2), a plasma bullet is generated by the pulse discharge at 0.2 µs. The discharge intensity of the rf area and the nozzle area did not change, and the length of the rf plume was about 2 mm. In Fig. 2(b1), the plasma bullet generated by the pulse discharge reaches the rf discharge area, and the length of the rf plume increases to 4 mm. In the normalized Fig. 2(b2), It can be found that the plasma bullet enters the rf discharge area at 1.2 µs and leaves the rf electrode at 1.7 µs. After the pulsed plasma reaches the rf discharge area, the intensity of the rf discharge increases. This was mentioned in our previous report.[1] The increase in rf plume length in this combined mode is due to the increase in the intensity of the rf discharge. In Fig. 2(c1), it can be found by color discrimination that the pulsed plasma bullet has passed through the rf plume, and the length of the rf plume reaches 8 mm. The pulsed plasma bullet can reach 16 mm outside the tube. In normalized Fig. 2(c2), the pulsed plasma bullet not only enhances the intensity of the rf discharge, but also increases the ionization rate outside the tube, further increasing the length of the rf plume.

References

1.Y. Guo, Q. H. Han, X. D. Wang, and J. J. Shi, Phys. Plasmas 24 (7), 4 (2017).

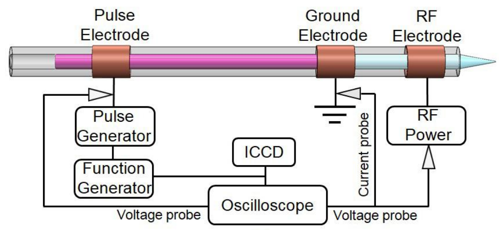

Figure 1 Combined discharge experimental device

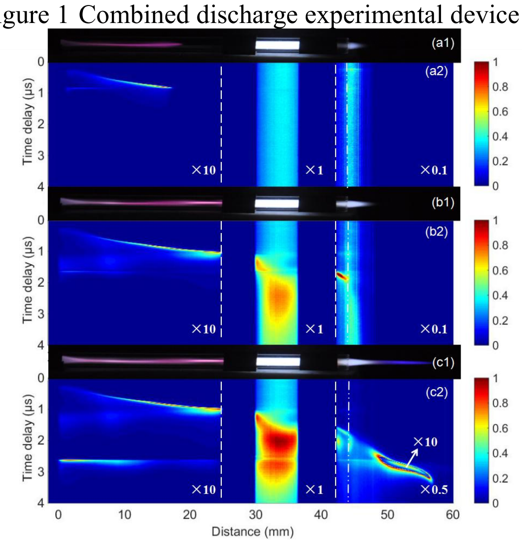

Figure 2 The camera photo of cascade discharge with pulse width of (a1) 0.6 µs, (b1) 1.4 µs, and (c1) 2.4 µs; the spatio-temporal evolution of cascade discharge with pulse width of (a2) 0.6 µs, (b2) 1.4 µs, and (c2) 2.4 µs.