The Uniformity of Radio Frequency Dielectric Barrier Glow Discharge in Atmospheric Helium Plasma

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The radio frequency dielectric barrier glow discharge (RF-DBGD) is obtained in atmospheric helium by using a dielectric barrier discharge system, which consists of a powered brass electrode covered by fused-silica as a dielectric layer and a grounded liquid electrode. The discharge images taken in radial direction by ICCD camera reveal that RF-DBGD do not appear the radial evolution but a high uniformity. The reason is that space charges play more dominant role in RF-DBGD. The discharge images taken in axial direction by ICCD camera also evidence the high uniformity of RF-DBGD in axial direction. Due to the high uniformity of RF-DBGD in radial and axial directions, this plasma source is perspective to be used in industrial applications.

1. Introduction

Dielectric barrier discharge (DBD) working at atmospheric pressure as one of very popular plasma sources is widely employed for industrious applications because a large area discharge can be facilely obtained, especially the plasma is generated in middle frequency (20 KHz) power supply [1]. However, the plasma generated at atmospheric pressure by radio frequency (RF, 13.56 MHz) power source demonstrates a low breakdown voltage, a sound homogenization and a high stability. Unfortunately few works of the discharge uniformity were reported in radio frequency plasma, especially in RF-DBD. Besides, it is generally known that there are two kinds of discharge modes, Townsend discharge and streamer-like discharge, in low (1~5KHz) or middle frequency power source sustained DBD plasma [2], which depend on conditions such as the *pd* value (the product of gas pressure multiplying gas gap) and the gas sort. How about it influenced of discharge mode on RF-DBD is still veiled.

The large-current operation of atmospheric glow discharges results under RF-DBD in both a greater risk of non-uniformity and instability, such as the glow-to-arc transition [3]. Then the discharge stability and plasma uniformity become mutually exclusive, the mode transition in RF-DBD shall be explored immediately.

From the point of RF-DBD application, furthermore, the plasma uniformity is critical to application reliability, whereas the plasma reactivity is related to application efficiency. It is therefore desirable to achieve greater plasma reactivity without compromising the plasma non-uniformity. In here we present the recent results on discharge uniformity based on RF-DBD plasma. We compare the results with that in middle frequency DBD plasma.

2. Results and Discussion

The RF-DBD setup consists of two parallel panel electrodes, a powered (13.56 MHz) copper electrode covered by a quartz sheet (1mm in thickness) and a water electrode. The water electrode composes of a quartz box (3 mm in thickness) filled with tap water and a grounded circle sheet copper. So it actually works as a double-layer RF-DBD. The electrode area is 8.9 mm×10 mm. Of all experiments are carried out at atmospheric pressure. During the experiments, the gas gap is fixed at 3.3 mm and the gas flow rate of argon is fixed at 2 slm. Only one parameter, the applied power is varied during the study of the discharge uniformity.

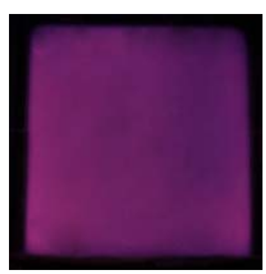

Fig. 1 The photo of RF-DBD along the radial direction (flow rate 2 slm, gap 3.3 mm, applied power 300 W and exposure time 1/100 s)

In Fig. 1 the photo shows the uniform glow covering the whole electrode surface. The intensity of glow decaying from the left to the right is caused from the discharge gas flow direction. When the applied power 1s increased, the intensity is identical and the whole surface is covered by the glow light. From *I-V* curve we know the discharge mode has changed from α mode to the γ mode. It means in the radial direction either the discharge mode in α mode or in γ mode the glow is uniform under 300 W.

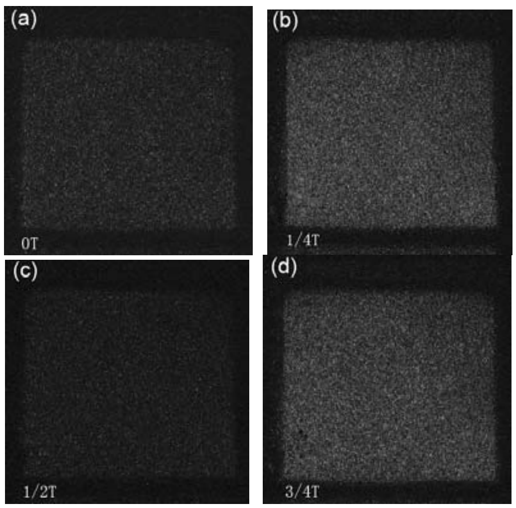

Fig. 2 The light emission images in radial direction during one cycle of RF taken at different periods with 2 ns exposure time and 200 cycles of accumulation by ICCD at t= (a) 0 T, (b) 1/4 T, (c) 1/2 T, (d) 3/4 T, respectively, where T is RF period

In order to resolve the dynamics of uniformity in RF period (73.74ns), the fast intensified camera PI-MAX2 (Princeton Instruments Co.) that allows an exposure time down to 2 ns with frame rates up to 2000 a frame per second (fps) is used. With this camera we can apply samples of images and add up the frames, i.e. increase the signal/noise ratio of the resulting picture and reveal uniformity in the dynamics of the glow formation in the whole RF cycle.

In Fig. 2, the four plasma images with an exposure time of 2 ns are shown when the applied power is 300W. The visually observed glow occupies the entire discharge area as shown in Fig. 2(b) and (d). Actually, theses photos show a time accumulated image spatiotemporal structure, which unveil the uniformity.

One can see that the glows are periodic at the driving frequency with the brighter images at $T/4$ and $3T/4$ taken at the discharge current peaks. Their spatial profile is in uniform glow mode, spreading over the whole electrode indicates an uniform discharge. This suggests that the excited plasma is uniform in radial direction, no evolution is appeared, which is different from that in middle frequency DBD plasma.

We then check the images in the cross-section of the gap. The photos taken in the axial direction, the gap between the two dielectrics, also show the uniformity in RF-DBD.

3. Conclusions

With a copper electrode cover a dielectric and water electrode we explore the He discharge under atmospheric pressure DBD. With ICCD we find that in RF-DBD the discharge is uniform in the radial direction, no diffusion is occurred, which is different from that in middle frequency DBD plasma. We think the uniform glow discharge in RF DBD is benefit to the spatial charges, which dominate the uniformity, whereas in middle frequency the surface charges aggregating on the dielectric surface intense the electrical field, which pattern the discharge image on the surface and evolve the glow along the radial direction of electrode.

References

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