Corona inducing dielectric barrier discharge

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Abstract: Dielectric barrier discharge (DBD) is a typical non-equilibrium gas discharge at atmospheric pressure. In generally, DBD with large gap requires high applied voltage and has sparse discharge channels。DBD induced by corona is developed to produce large volume, dense discharge channels with lower applied voltage at atmosphere pressure. Graphite granules(30-70 mesh) are introduced and well-distributed in the discharge gap，the granules distort the local electric field and enhance the non-equilibrium of electric field about graphite granules. Corona discharge occurs nearby graphite granules and propagates to entire discharge gap. Such device has a low breakdown voltage cut down by approximately 40% , and more dense discharge channels are achieved.

Keyword: dielectric barrier discharge, corona, breakdown voltage

1. Introduction

A plasma source of large volume is useful in industrial applications. Atmospheric pressure non-equilibrium plasma extensively used in chemistry processes, surface modification and pollution control etc.. Several types of discharges, such as glow discharge, corona discharge and DBD, have been applied to generate atmospheric plasma of large volume [1-12]. Among them, corona discharge and DBD are conventional simple discharge form.

Corona discharge has very low inception voltage, while the discharge gap is relatively large[4,5]. Nonetheless, the distribution of plasma depends on the corona electrodes, and the plasma density is inequable in the entire discharge zone.

DBD device can gain dense plasma between small discharge gap in large area at atmospheric pressure. The DBD shows a large number of separate current filaments referred to as micro-discharges in most gases, thus appearing to the eye as bright filamentary mode plasma formation[6,7]. The existence of dielectric medium (such as quartz glass) can not only restraint rapidly increasing of current in micro-discharge channels, but also equably separate current filamentary on entire electrodes area[8,9]. Nonetheless, dense and well-distributed DBD plasma can not be obtained between a large discharge gap[10].

In view of the advantages of corona and DBD, dielectric barrier corona discharge(DBCD), consisted of multineedle-to-plane discharge form, was carried out to realize relatively dense plasma between large gap[11,12]. However, the plasma density extraordinary depends on the distribution and numbers of needles. So, DBCD can not generate genuine well-distributed plasma between large gap at atmospheric pressure.

In this paper, a new discharge form called corona inducing dielectric barrier discharge (CIDBD), with advantages of both corona and DBD, was carried out to generate dense atmospheric plasma between large gap under lower applied voltage. Graphite granules, acting as vary small curvature radius of conductor, was introduced in discharge gap in a cocurrent downward circulating fluidized bed. Graphite granules, distorts local electric field and enhances the non-equilibrium of electric field nearby the powders, corona discharge occurs relatively easily on the surface of powders. Therefore，the corona plasma, nearby graphite granules, induces to generate dielectric barrier discharge plasma under low applied voltage.

CIDBD has extensively application fields in chemistry processes, surface modification and pollution control, while the graphite granules is replaced by catalyst or relevant material granules.

2. Experimental methodology

The experimental setup is shown in Fig.1. The reactor consists of an outer quartz tube(OD 73mm) and an inner tube (OD 48mm), with wall

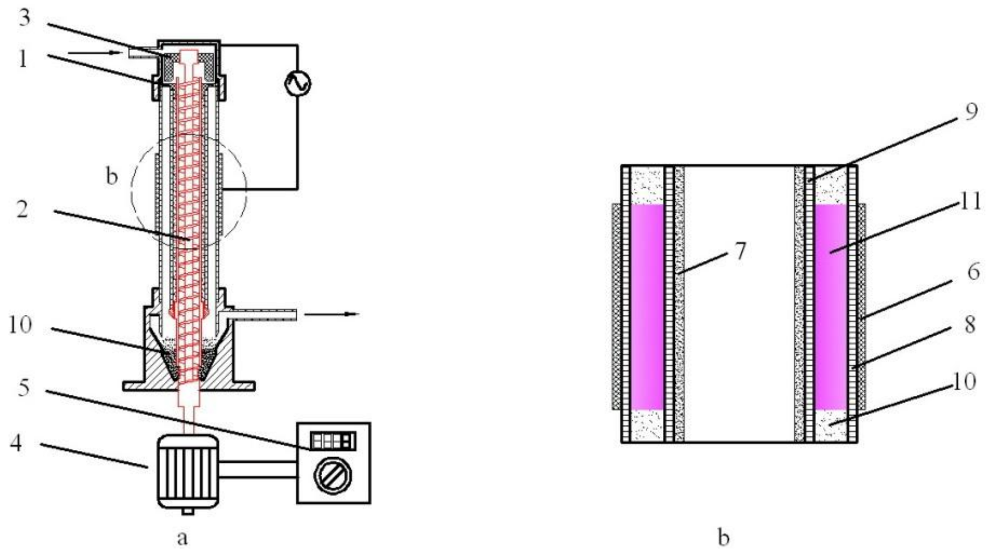

Fig1. *Schematic diagram of experimental set: 1. Distribution plate, 2. Screw feeder, 3. Leaf blade, 4. Motor, 5. Speed governor, 6. Outer electrode, 7. Inner electrode, 8. Outer quartz tube, 9. Inner quartz tube,, 10. Graphite granules, 11. Discharge zone.*

thickness of 2.5mm. Acopper mesh (width=10cm), wrapped around the outside of outer tube, is used to be high voltage electrode. Conductor powders, filled in the gap between inner tube and screw lifting device, acts as low voltage electrode. Therefore, the radial discharge gap width is 10 mm and discharge volume is approximately 166 cm^3. The screw lifting device, driven by adjustable speed motor (maximum speed 3r/s) inside of inner tube, was used to carry graphite granules (30-70mesh) from the bottom of reactor to the top. To describe the density of graphite granules in discharge zone, the granules volume fraction is defined :

$$\lambda = \frac{V_{granules}}{V_{plasma}}$$

$V_{granules}$ is the total volume of graphite granules in plasma zone, V_{plasma} is the volume of plasma zone. The density of graphite granules in plasma zone was controled by regulation rotate speed of screw. To drive the discharge, AC power source(1-30kV, 10-30kHz) is used (CTP—2000K). In this paper, a frequency of 18.66kHz is selected. The discharge power is calculated from Lissajous figure using oscilloscopes (TDS2014B). Air under room temperature was introduced in reactor.

3. Result and discussion

3.1 Discharge waveform and photos

The discharge waveforms of *U-t*, *I-t* and discharge photos with different graphite granules density are shown in Fig.2. The current pulses of discharge, with high density of graphite granules, are extremley dense; in the oppsite side, there are much fewer current pulses with a little granules; all together, the pulse current amplitude of former is much smaller and well-distributed than the latter. As shown in Fig.2.(d), some similarly spark appeared in discharge zone, this phenomenon displays that DBD is not stable and dense between large gap with low density of granules. The reason is as follows: much higher applied voltage is needed to sustain discharge between larger discharge gap(10mm),. The cross section of discharge channel becomes larger under higher applied voltage, and more charge are transported through a single discharge channel, that leads to spark discharge easily. When graphite granules are located uniformly between plasma zone, the distribution of electric field is distorted by graphite granules, the partial electric field nearby the granules is enhanced to ignite plasma faintly, and then, the number of discharge channels obviously increases, and the charge transported through single discharge channel comparatively decreases.

As shown in Fig.2.(c), the spatial distribution of discharge channels is comparative uniform, the photo shows a typical DBD form without arc and spark discharge appearing. Together these reasults show that well-distributed and dense DBD plasma has been realized via the device investigated in this paper.

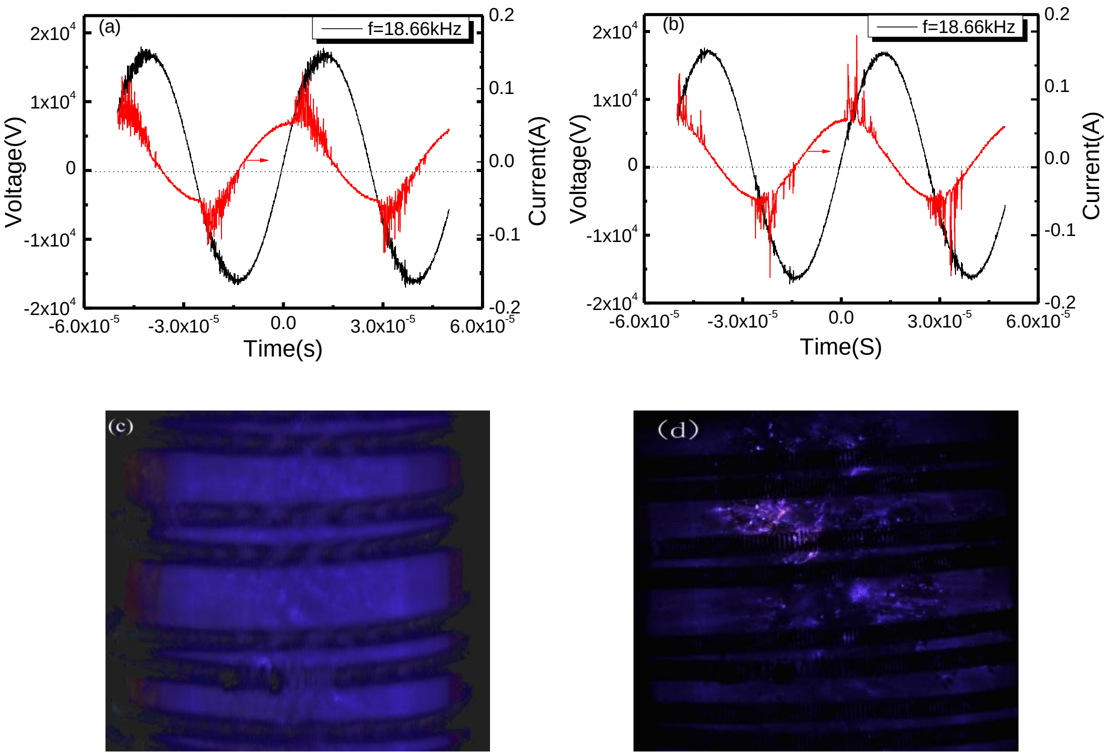

Fig2. *Discharge waveforms of current, voltage and photos (U_P=16.8 kV): (a, c) λ=1.5%; (b, d) λ=0.2%.(U_P: peak voltage).*

3.2 Effect of granules volume fraction on breakdown voltage

As shown in Fig.3, both of the positive and negative breakdown voltage evidently decrease, while the granules volume fraction increases from 0 to 1.5%. When granules volume fraction equals to 1.5%, positive and negative breakdown voltage are approximately 18.3kV and 17.6kV, separately. The breakdown voltage of DBD at atmospheric pressure without graphite granules is 3.0kV/mm[5], therefore, the existence of granules decreases breakdown voltage approximately 40%. Such mechanism is described as follows: the existence of graphite granules distorts electric field to generate extraordinary high partial electric field around granules; increasing the density of granules causes high twisting of electric field, corona discharge occurs around granules under adequate applied voltage, and then it develops to be DBD with increasing voltage.

Positive breakdown voltage is higher than negative breakdown voltage. Positive and negative breakdown voltage is equivalent in plate to plate DBD form[8,9]. This phenomenon results from the different radius of curvature of anode and cathode[10]. The difference between positive and negative half period becomes small, while the granules volume fraction increases, it indicates that existence of granules, to some extent, can bate the uneven distribution caused by different radius of curvature of electrodes. The gradient of curves in Fig.3 becomes greatly low when the granules volume fraction increases, especially, the gradient nearly equals to zero(λ=1.5%). Together these results show that the existence of graphite granules in discharge zone can evidently reduce breakdown voltage between large discharge gap under low applied voltage.

3.3 Effect of granules volume fraction on input power

The discharge power, shown in Fig.4, increases with applied voltage. The growth speed of discharge power is different under low and high applied voltage. The turning points of gradient appear at points of A, B, C and D, while the voltage at these points reaches the breakdown voltage, and DBD occurs. The applied voltage at turning points reduces when the density of graphite granules increases, all together,,applied voltage has a ripidly reduction to gain the same discharge power. Especially, the power density can reach 1W/cm^3 when the particle volume fraction equals to 1.5% (applied voltage=17kV, discharge distance=10mm). However, in this expriement, plasma nearly can not be obtained when the quartz tube is very clean and no granules exists in discharge gap.

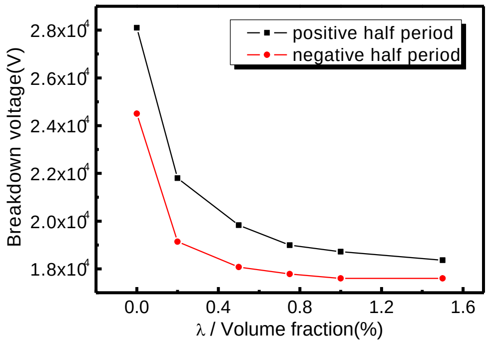

Fig.3 *Effect of granules volume fraction on breakdown voltage.*

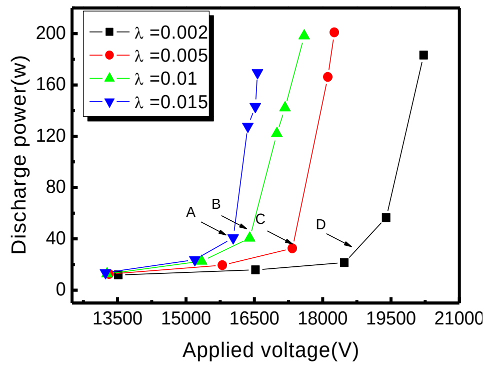

Fig.4 *Effect of input power and granules volume fraction on discharge power.*

4. Conclusion

We demonstrated a new method to generate large volume, dense plasma between large discharge gap in atmospheric air under low applied voltage. Corona discharge was observed when the graphite granules passed through dielectric barrier discharge zone. These results illustrate that CIDBD was realized by the device in this paper. CIDBD has lower breakdown voltage and much higher discharge power than DBD alone. It is expected that CIDBD will be a new concept to design reactor used in chemistry processes, surface modification and pollution control etc..

5. Acknowledgement

The authors gratefully acknowledge the asistant by NSFC50876101, NSFC10675122 and “863” ST Program 2007AA05Z105.

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