

Research on the Characteristics of Dielectric Barrier Discharge and Dielectric Barrier Corona Discharge

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INTRODUCTION

The low temperature plasma and its application produced by glow discharge under normal atmospheric pressure (here, the “glow discharge under normal atmospheric pressure” is referred simply to as “APGD”) are research hotspots attended extensively by the scholars both abroad and at home. It overcomes the shortcoming of the vacuum chamber. And the non-equilibrium homogeneous plasma produced by APGD has broad application prospects on material surface modification, thin film deposition, etching, medical appliance sterilization, fiber modified, etc[1]. Research on the dielectric barrier discharge(referred simply to as “DBD”) adopted different electrode configurations is a quite effective method to realize APGD, which devises specific powers and mediums with different frequencies to construct APGD environment in some specific gases and gas mixtures. This method gets a long general persistent research on a global scale[2-4]. Therefore, if corona discharge and dielectric barrier discharge can be combined with a suitable ways, we should gain a better glow discharge under normal atmospheric pressure. Here, we call this kind of discharge as dielectric barrier and corona discharge (referred simply to as “DBCD”)

TYPICAL CONFIGURATIONS OF DBD AND DBCD

Fig 1 a is common configuration of flat - flat electrode configuration in DBD, which adds a layer of insulating medium between the two electrodes. Fig 1 b is a typical electrode configuration of DBCD adopted line - tube configuration electrode, which fine lines electrode is a high voltage electrode of diameter 0.2-1mm and fixed in the center of barrier medium glass tube. The outside diameter of the tube is 30 ~ 40mm. The thickness of medium is 1 ~ 5mm. Barrier medium can adopt tube of glass, resin, polytetrafluoroethylene, etc.

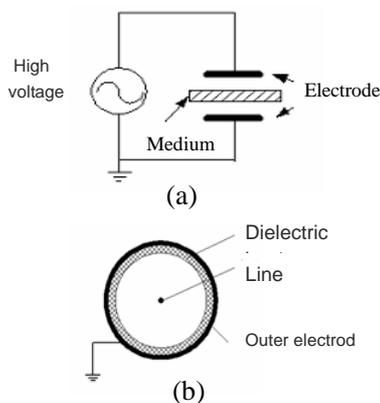


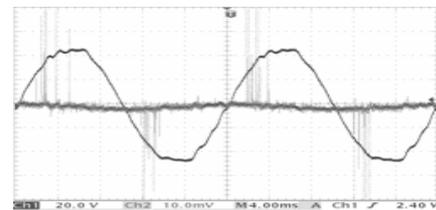
Fig.1 Typical electrode configuration of dielectric barrier discharge and barrier corona discharge

CHARACTERISTICS AND MECHANISM OF DISCHARGE

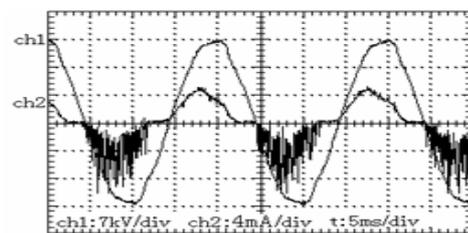
Fig.2 a is the variation waveform curve of current and voltage of flat-flat electrode DBD and Fig.2-b is the waveform curve of line-tube electrode DBCD. From Fig.2 a, it shows that many micro-electrical discharge pulses compose the current in every half cycle of voltage. The phenomenon of u-EDM begins initial discharge voltage and ends up with the maximum voltage. And the current waveform almost distributes symmetrically in voltage positive and negative half cycle separately.

From Fig.2 b, the line-tube electrode DBCD current waveform appears as distinct polarity effect. In the positive half cycle of voltage, it appears as continuous discharge current mode. But in negative half cycle of voltage, it appears as Trichel pulse mode.

This kind of phenomenon can be explained as follows. The diameter of outer barrel discharge cathode is larger than the inner line cathode's, and this factor leads to the volume of outer cathode's ionization region of cathode sheath layer is larger than the inner line cathode's. so in whole voltage cycle, the current of upper half cycle appears larger than the current of under half cycle, even though the electric field of the inner line cathode is more power than the outer.



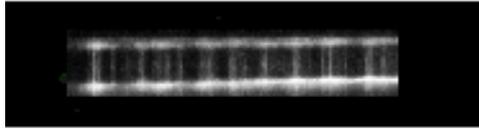
(a) Voltage-current oscillogram of DBD



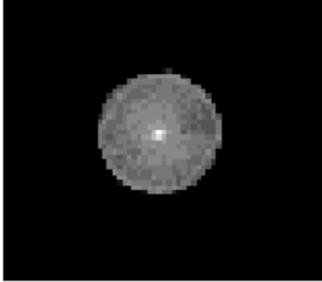
(b) Voltage-current oscillogram of DBCD

Fig.2 Voltage-current oscillogram

Fig.3 is illuminated diagrams of two different electrode configurations shoot by camera. Fig.3 a is illuminated diagram of flat-flat electrode DBD. It shows that many filamentous luminances homogeneously distribute in the discharge space. Fig.3 b is illuminated diagram of line-tube electrode DBCD. It shows the air gap of the tube appears stable glow when the 14kV~20kV of voltage is brought on the electrode.



(a) Discharge of flat-flat electrode DBD



(b) Discharge of line-tube electrode DBCD

Fig.3 Discharge of different electrodes

The DBD of flat-flat electrode can be explained by Stream Theory as follows. Because its discharge space is approximately homogeneous electronic space, and when the ionization coefficient α of stronger area of discharge electronic space is up to an enough value, the α of most of area in the gap will also up to a corresponding value. Then the initial electron avalanche will develop rapidly in high electric area, and will soon form streams in the gap. Moreover, the space charges are accumulated on dielectric because of existence of barrier dielectric. The accumulated charges form an additional electric field in opposition to the applied electric field, and it neutralizes a part of effect of the applied electric field. With the accumulation of charges on the dielectric, the effect of the additional electric field is escalating and the decrease in whole electrical field strength is increasing in gas gap. When field strength in gas gap decreases to less than the gas gap breaking down field strength of gas, the discharge will interrupt. And because DBD adopts ac power, the discharge still appears in current of under half cycle though the discharge is interrupted[5]. Therefore, the DBD of flat-flat electrode is approximate match the discharge of DBD in homogeneous electric field. And its current waveforms approximately express many pulse modes in voltage positive and negative half cycle symmetrically and alternately.

It is necessary to limit electron avalanches increase if want to get a stable diffused mode discharge in DBD. In a high atmospheric pressure, electronic collisions are inevitable. To limit ionization coefficient α of collision is a feasible measure to limit the development of electron avalanches. And because α increases with field strength of air gap, it is necessary to bring down the breaking down field strength of gas, that is those electrons must be gain

only in low AC electric field[6]. Normally, the breaking down field strength of air under normal atmospheric pressure is very high, and the average strength is about 30kV/cm. So it is very difficult to limit the development of electron avalanche in this environment. So some other measures should be taken to gain secondary electrons or form preionization, and gain a homogeneous diffused mode discharge. The line-tube electrode configuration of DBCD adopts the preionization of line electrode, and realizes the diffused mode discharge preferably. The electric fields of line-tube electrode configuration are very inhomogeneous, especially those electric fields around the line electrode. Therefore, when voltage gets to a certain extent and before gas gap being broken down, a corona luminous layer will appear nearby the center of these line electrodes. With the increase of voltage, the homogeneous corona layer expands unceasingly, and forms a comparatively stable diffusion mode discharge eventually.

SUMMARY

Both of DBD and DBCD are available to realize APGD. the current of flat-flat electrode DBD is composed by many micro-electrical discharge pulses in every half cycle of voltage. The current waveform of flat-flat electrode DBD almost distributes symmetrically in voltage positive and negative half cycle separately. Comparatively, The current waveform of line-tube electrode DBCD shows polarity effect distinctly. In the positive half cycle of voltage, it appears as continuous discharge current mode. And in negative half cycle of voltage, it appears as Trichel pulse mode. Through comparing, the discharge of configuration of DBCD is more stable than DBD'.

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