Measuring DBD main discharge parameters using Q-V Lissajous figures

CAI Yi-xi, ZHANG Le-fu, WANG Jun, RAN Dong-li, WANG Jing
School of Automotive and Traffic Engineering, Jiangsu University
Zhenjiang, China
qc001@ujs.edu.cn

***Abstract*—Through establishing dielectric barrier discharge (DBD) experiment system, the effects of applied voltage (*V*) and its frequency (*f*) on the main parameters of DBD were studied by Q-V Lissajous figures method. some conclusions could be drawn that improving *V* and *f* effectively enhanced DBD power(*P*) and charge transfer value(*Q*); when DBD device structure parameters were certain, the effects of *V* and *f* on the total equivalent capacitance(*C*) was little, dielectric equivalent capacitance(C_d) increased with the increase of *V* and *f*, equivalent capacitance of the discharge gap(C_g) slightly decreased with the increase of *V* and *f* ; the effective electric field of the discharge gap(E_g) increased with the increase of *V*, the effects of *f* on E_g was little; the average electron energy of the DBD device was high and could be used to the equipment such as O_3 generator.**

Key words*—*dielectric barrier discharge; Q-V Lissajous figure; applied voltage; applied frequency

I. Introduction

Dielectric barrier discharge(DBD)，known as silent discharge, is a kind of non-thermal gas discharge ,at least one of the electrodes being covered with insulating dielectric layer. Loading the alternating current on the electrodes which frequency from tens to hundreds of thousands Hz, DBD formed in the discharge gap when the applied voltage exceeded the Paschen voltage. DBD could produce large mass, high energy density non-thermal plasma at or above atmospheric pressure. It was widely used in many fields such as purification of drinking water, deep treatment of waste water, bleaching, deodorization, aquiculture, medicine and so on.

The DBD electric parameters mainly included equivalent capacitance of the discharge gap (C_g); dielectric equivalent capacitance (C_d), discharge power (*P*); charge transfer value (*Q*); effective electric field of the discharge gap (E_g) and so on. Because of phase detuning of the current and voltage in the process of DBD, it is difficult to measure the parameters which characterize DBD collective effects. In this paper, Q-V Lissajous figure was used to measure electrical parameters of DBD [1-5].

II. DBD electrical parameters measurement using Q-V Lissajous figure method

A. DBD experiment system

The sketch map of DBD experiment system was shown in figure 1, one of the electrodes was covered with insulating dielectric layer.

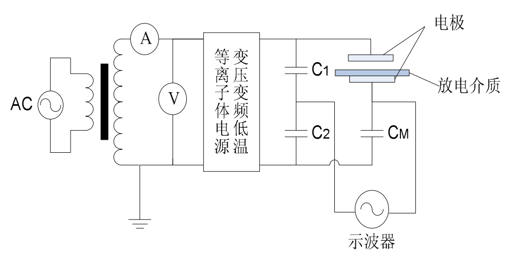


Fig.1 Sketch map of DBD experiment system

The system was composed of DBD equipment, measure circuit and high voltage-frequency power supply.

A circular quartz glass was used as a insulating dielectric layer, which thickness was 1mm and diameter was 120mm,the diameter circular coppery electrodes was 50mm, the discharge gap was 2mm. The voltage wave form was measured by the capacitance voltage divider ,which was consisted of C_1 and C_2 in series(C_1: C_2=152).. Charge transfer value was indirectly obtained from the capacitance C_M(0.1uF). The Operating range of the power supply was 0-25 kV and 8-20 kHz (adjustable). The Q-V Lissajous figure was measured by the TDS3034B Tektronix oscilloscope and Tektronix P6139A high-pressure probe. At the beginning of the experiment, the CH_1 channel of the oscilloscope should be connected at both ends of the C_M, and CH_2 channel should be connected at both ends of the C_2.

B. Q-V Lissajous figure

A typical Q-V Lissajous figure of DBD is shown in figure 2. As could be seen in the figure: in one discharge cycle, A→B, C→D are micro-discharge stages, A, C points are the discharge points, B, D points are the termination of the discharge; B→C, D→A are the charging stages to the total capacitance C after discharge quenching.

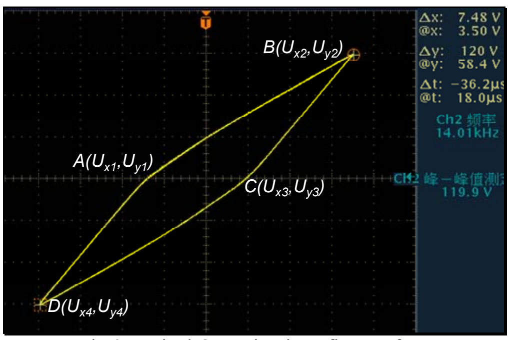


Fig.2 Typical Q-V Lissajous figure of DBD

Through calculating the parallelogram area S of a Q-V Lissajous figure and recording its peak voltage coordinates, electrical parameters of DBD ,such as P ,C, Q, E_g ,could be measured indirectly [6-7].

III. Experiment results

A. Discharge power

DBD power had close relationship with the applied voltage and frequency, which was shown in figure 3.

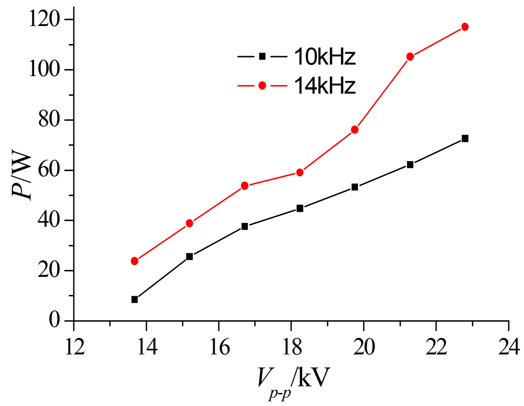
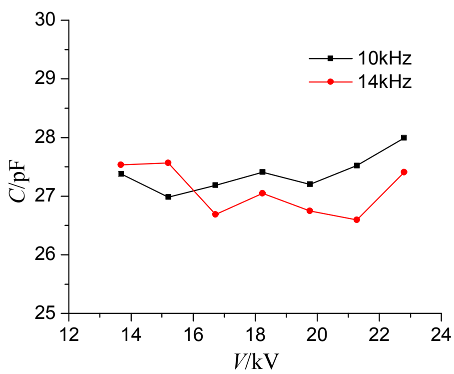


Fig.3 Discharge power as a function of applied voltage

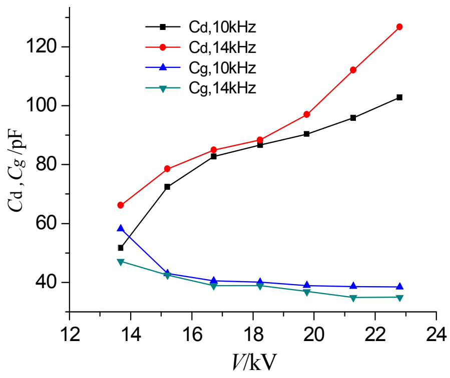
As could be seen from Fig.3，at the same frequency, power almost linearly increased with the increase of the applied voltage, power increased when frequency increased at the same applied voltage. When structure parameters of DBD device were certain, improving the power could effectively increase the amount of current filament in discharge gap, so could effectively increase the amount of the high-energy electron.

B. Equivalent capacitance

The variation of C, C_d and C_g with applied voltage was shown in figure 4.



(a)



(b)

Fig.4 Equivalent capacitance as a function of applied voltage

Some results could be drawn that:(1) when DBD device structure parameters were certain, the effects of applied voltage and frequency on the C were little, its value was about 26.5-27.5 pF; (2) C_d increased with the increase of applied voltage and frequency; C_g slightly decreased with the increase of applied voltage and frequency; (3) the micro-discharge in the discharge gap gradually developed from part to the whole region with the increase of applied voltage and frequency and the discharge became gradually steady in the experiment.

C. Charge transfer value in a discharge cycle

The relationships between Q in a discharge cycle and applied voltage and frequency were shown in figure 5. When frequency was certain, Q almost linearly with the increase of applied voltage, P increased when frequency increased. The increase of Q mainly attributed to P increase which was caused by the increase of applied voltage and frequency. When applied voltage and frequency increased, the more current filaments formed in the discharge gap, so Q in a discharge cycle increased.

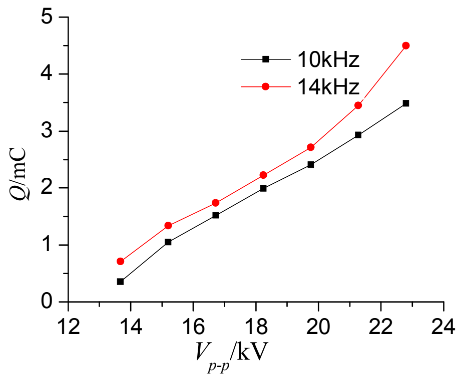


Fig.5 Charge transfer value per one cycle as a function of applied voltage

D. Effective electric field of the discharge gap

The relationships between E_g and applied were shown in figure 6. E_g linearly increased with the increase of applied voltage and the effect of frequency on E_g was little. In addition, E_g could be enhanced through using larger C_d and thinner insulating dielectric layer.

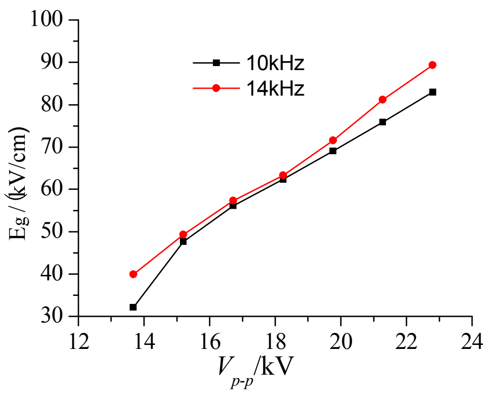


Fig.6 Effective electric field of the discharge gap as a function of applied voltage

E. Converted electric field of the discharge gap

Converted electric field of the discharge gap (E/N) was generally used to indicate the average energy that electrons obtained from the electric field, its formula was:

$$E/n = \frac{E_g}{6.02\times10^{23}/22.4\times1000}$$
$$= 3.721E_g\times10^{-17}(\mathrm{V\times cm^2}) = 3.721E_g(\mathrm{T_d})$$

In standard atmospheric condition, E/n was linear relationship with E_g, E/n could be indirectly estimated from E_g. When frequency was 14kHz, the *E/n* range was about 148.6-332.4T_d,accordingly, the average electric energy was about 5～9eV, which could decompose the general gas molecules and meet the requirements for non-thermal plasma chemical reactions. Now, the DBD technology was widely used in ozonizer.

IV. Conclusions

Q-V Lissajous figures method could display the DBD process, through calculating its area and recording its peak voltage coordinates, the effects of applied voltage and frequency on electrical parameters of DBD ,such as *P* ,*C*, *Q,* E_g, could be observed. Some conclusions could be drawn:

1) When the applied voltage and frequency increased, the power and charge transfer value in a discharge cycle enhanced, moreover, more current filament produced in discharge region.

2) When DBD device structure parameters were certain, total equivalent capacitance was almost unchanged, dielectric equivalent capacitance increased with the increase of applied voltage and frequency, however, equivalent capacitance of the discharge gap slightly decreased with the increase of applied voltage and frequency.

3) When DBD device structure parameters were certain, the effective electric field of the discharge gap increased with the increase of applied voltage, the effect of frequency on E_g was little.

Acknowledgments

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