Investigation of Discharge Parameters in Xenon filled Coaxial DBD Tube

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Abstract: *In this paper a Xenon filled coaxial dielectric barrier discharge (DBD) has been studied to understand the high pressure, non-equilibrium, nonthermal plasma discharge. A quartz coaxial DBD tube (ID: 6mm, OD: 12 mm) at 400 mbar Xenon filled pressure has been used in the experiment. Different applied voltage waveforms at 30 kHz using RF generator as well as pulse power source have been applied to the discharge electrodes for the generation of microdischarges. Visual images of discharge and electrical waveform confirm the diffused type discharges. The knowledge obtained by dynamic processes of DBDs in the discharge gap explains quantitatively the mechanism that is obtained in ignition, development and extinction of DBDs. The behaviour of different discharge parameters has also been analyzed. From the experimental results and equivalent electrical circuit, the dynamic nature of equivalent capacitance has been reported. The relative intensity analysis of the second continuum of the Xe discharge (172 nm) has been carried out for different applied voltages and it is found that the radiation power has increased with voltage.*

Keywords: Higher pressure plasma, nonequilibrium discharge, nonthermal discharge, dielectric barrier discharge, ignition and extinction of discharge, equivalent capacitance.

Introduction

The higher-pressure nonequilibrium, nonthermal discharges based on dielectric barrier discharges (DBDs) are rapidly becoming an important technological component in medical, plasma display panel and material processing applications [1-2**]**. It is established that the DBDs are the easy way to a generate non-thermal and non-equilibrium plasma at atmospheric pressure. The DBDs are also considered as promising alternatives to conventional mercury based discharge plasmas producing highly efficient vacuum ultraviolet (VUV) and ultraviolet (UV) radiations. The discharge appearance of DBDs can be either filamentary or homogeneous, depending on experimental conditions such as discharge gas, gas pressure, gas gap, dielectric surface properties and applied voltage waveform [3-4]. Efficient excimer formation in DBDs is technically very important for use in high-power ultraviolet lamps. Excimer lamps are mercury free systems and eco-friendly, and therefore they are boom for the lighting industry.

For electrical diagnostics of the discharge, a temporally dynamic model for diffuse DBDs is used [5]. From this model equations were derived which allow the calculation of internal electrical quantities in the discharge gap from measured external electrical quantities. The obtained total current (sum of the capacitive displacement current and the conduction current) and the discharge current are discussed. The voltages across the dielectric, memory voltage, gas gap voltage and charge accumulation of DBD are calculated and correlated to the current measurements. From the experimental results and equivalent electrical circuit, the dynamic nature of equivalent capacitance has been reported. Finally, the different components of the power (stored and dissipated) are calculated at different operating conditions.

Design and experimental work

Fig. 1 shows the picture of a coaxial DBD lamp consisting of two coaxial fused quartz tubes separated by gas gap where xenon is filled at 400 mbar. The outer surface of the quartz tube is wrapped by a copper wire mesh electrode and the inner electrode of Cusil foil has been inserted into the coaxial tube in close proximity to the inner wall. Different applied voltage waveforms at 30 kHz using RF generator as well as pulse power source have been applied to the discharge electrodes for the generation of microdischarges. The inner radius of the outer quartz tube is 5 mm and the thickness is 1 mm, while the inner radius of the inner quartz tube is 3 mm and the thickness is 1 mm. The gas gap is 1 mm. The total length of the DBD tube is 10 cm while the outer mesh and the inner foil electrode wrap 6 cm of the tube.

An analogous electrical circuit has been proposed for the calculation of internal electrical quantities [4-5] for Xenon filled coaxial DBD tube as shown in fig. 2. The equivalent electrical model of the DBD tube consists of three capacitors in series connection. The inner and outer quartz tube forms the dielectric barrier capacitance C_{d1} and, C_{d2} whereas the gas gap forms the capacitance C_g. Since C_{d1} and C_{d2} are in series combination, it can be represented by a single capacitance C_d. To understand the other terms clearly, the impedance of microdischarge is represented by Z_d in the equivalent circuit, which is in parallel with C_g.

Result and discussion

Fig. 3 shows the total current trace together with the applied voltage, where the discharge current waveform having a number of current pulses with nanosecond order, which are superimposed on the total current, confirms filamentary discharges [5]. Fig. 3 also shows the average image of discharges taken with a digital camera (SONY DSC-P100, exposure time: 25 ms). The image indicates that the diffuse discharge covers the entire surface of the electrodes.

The dynamic behaviour of different voltages for the DBD cell is shown in fig. 4. The discharge occurs when the applied voltage reaches the breakdown voltage which results in significant electron production. Fig. 5 shows Lissajous diagram~~s~~ for different applied voltages at 30 kHz frequency. The total amount of power consumed by the DBD tube must be known in order to estimate both the total efficiency of the system and the required power of the HV supply. The energy consumed by the plasma for one cycle is calculated from the area of parallelograms for different applied voltage. It found to be 25.29 µJ, 8.76 µJ and 6.14 µJ for voltages -5.8, -5.4 and -4.1 kV respectively which infers the reduction in consumed energy as the applied voltage is reduced.

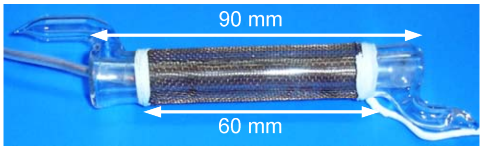

Figure 1. Photo of fabricated coaxial DBD tube.

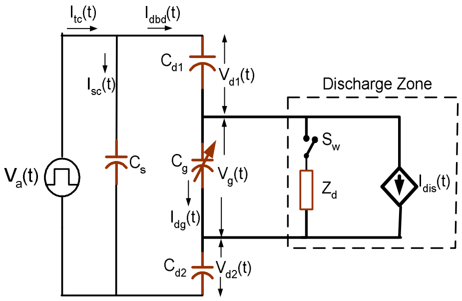

Figure 2. Equivalent electrical circuit of Xenon filled coaxial DBD tube.

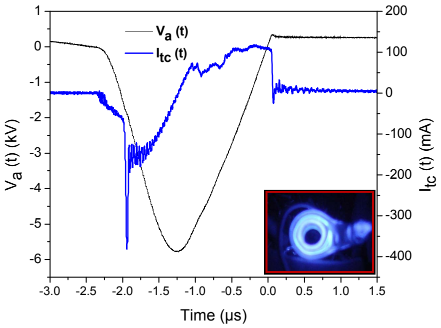

Figure 3. Applied voltage V_a *(t)* and total current I_{tc} *(t)* vs time.

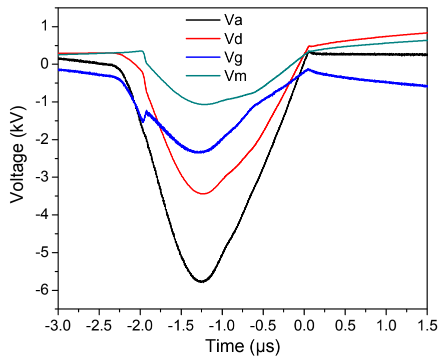

Figure 4. Experimental values of different voltages.

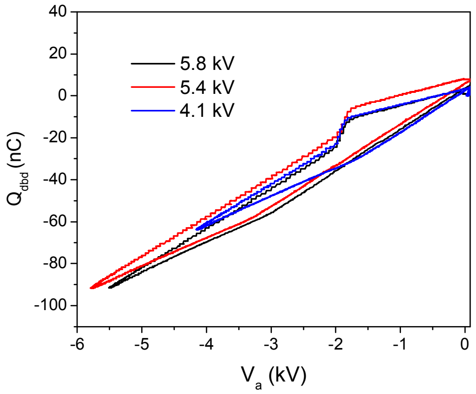

Figure 5. Lissajous V –Q diagram of the DBD in case of three different amplitude of applied voltage waveform at 30 kHz.

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