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Effect of Passive Components on the Dielectric Barrier Discharge Based on a Three-electrode Geometry

３電極バリア放電に及ぼす受動素子付加の効果

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This paper deals with a new way to change the electrical properties of a surface DBD. It consists of integrating in series passive components (*i.e.* HV resistor and coil) between the power supply and the plasma discharge. The experimental measurements of current-discharge and applied voltage show that the injected power within the plasma can be significantly modified. Moreover, results highlight a coupling between the surface DBD and the power supply (at f = 4 kHz) when an inductive component is present, resulting a drop of the electrical power consumption.

1. Introduction

Non-thermal plasmas appear as an innovative approach to solve some industrial problems [1,2]. Among these, the surface dielectric barrier discharge (surface DBD) knows an important development in many research areas: pollution control, active flow control, etc. [3,4]. The abilities of this discharge are related to the injected power into the plasma.

In this paper, we present the effect of passive components on the electrical properties of a surface DBD. To achieve this, high-voltage resistors or coils are integrated in series in the electric circuit.

2. Experimental setup

Figure 1 displays a schematic side-view of the surface DBD used in this study. It is composed by two electrodes (#1 and #2) flush mounted on each side of a dielectric plate, plus a counter-electrode (#3) placed on the top side of the insulating wall. This counter-electrode is relatively separated to the right edge of the electrode #1 by an air gap of 40 mm. Electrodes made of aluminium are 50 µm-thick, 100 mm-long (in spanwise), 20 mm-width for upper ones and 15 mm for the bottom one. The dielectric used is an alumina plate (150 mm × 150 mm) of 1.5 mm-thick. The inter-gap between electrodes #1 and #2 is 5 mm.

An adjustable power supply is applied to the electrode #1, as shown in Fig. 1. The AC high voltage is obtained with the help of a transformer supplied by a power amplifier. While electrodes #2 and #3 are grounded. In addition, passive components (HV resistor, coil) are placed in series between the power supply and the surface DBD.

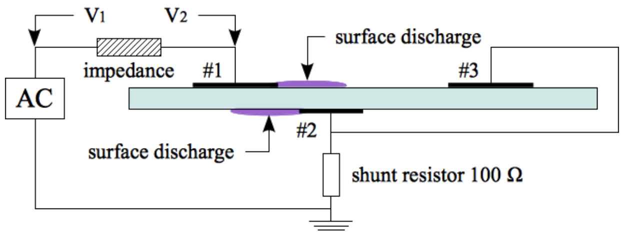

Fig. 1. Cross-view of the experimental setup.

The electric current flowing the plasma discharge was measured via a non-inductive resistor. The applied voltage V_1 and the applied voltage across terminals of the surface DBD V_2 were measured with HV probes (Tektronix, P6015A). Each electrical waveform was monitored using a digital oscilloscope (Tektronix, TDS2014B).

All experiments are conducted at atmospheric pressure, room temperature and low humidity rate (RH ≈ 20%).

3. Results

Here, we investigate the effect of the frequency of the sine waveform. The frequency ranges tested is included between 0.5 to 4.5 kHz (maximum frequency at which the transformer can operate).

3.1 *High-voltage resistor*

Fig. 2 presents the power consumption as a function of the frequency (V_1 = 12 kV) in presence and absence of HV resistors in the electric circuit. One can observe that the high-voltage resistor has no significant effect on the power consumed up to 3 kHz. In this case, its evolution is linear and is in good agreement with the results from the literature [5]. Beyond this frequency value, the power drops compared to the normal case (*i.e.* without resistor). This decline is all the more surprising because it occurs only at $f = 4$ kHz. Indeed, we see that 4.5 kHz the power consumption increases again. It means that the discharge current is reduced probably due to a coupling between the power supply and the surface DBD when the plasma operates at driving frequency 4 kHz.

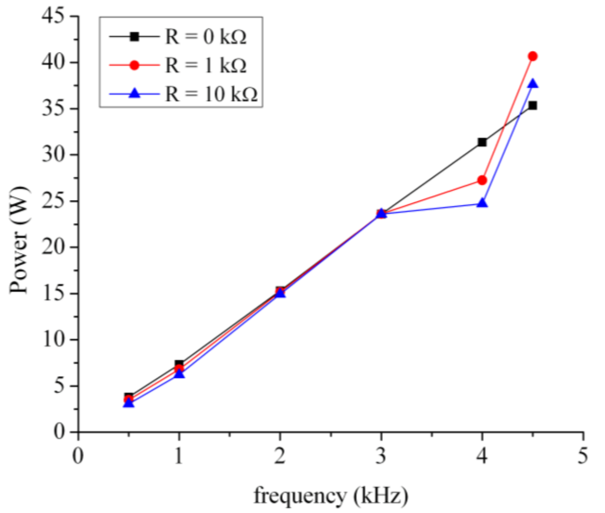

Fig. 2. Power consumed versus frequency without and with HV resistor ($0 \leq R \leq 10$ kΩ).

3.2 *Coil*

Fig. 3. shows the electric power variation with the frequency (V_1 = 11 kV) in presence and absence of coil. In this figure, we see that coils significantly affect the power consumed by the plasma discharge. Here, the effect occurs for frequencies above 2 kHz.

Beyond 2kHz, an electric power gap is obtained whatever the value of coil. It appears that the power gain depends on the inductance value. For example, at 4.5 kHz, the power reaches about 40, 75 and 120 W with an inductance of 1, 2 and 3 H, respectively. It means the discharge current is increased probably due to an impedance matching of electrical circuit of the surface DBD, which results an increase of the injected energy into the plasma. Moreover, Chen [6] has highlighted, by numerical modeling, a similar result (*i.e.* increase of plasma power) for a parallel plate OAUGDP reactor by using an impedance matching network, composed by inductance and capacitance.

However, the discharge presents a particular operating point when the signal frequency is 4 kHz. Indeed, we notice that the power consumed drops and this decrease seems to depend on the value of inductance. The power decline highlights a coupling between the power supply and the surface DBD. This coupling appears to be related to a specific value of frequency (4 kHz), suggesting a tuning frequency of the transformer. Furthermore, it is remarkable that this particular point occurs at the same frequency whatever the inductor used. This is probably due to the frequency range tested which is rather narrow, *i.e.* $0.5 \leq f \leq 4.5$ kHz.

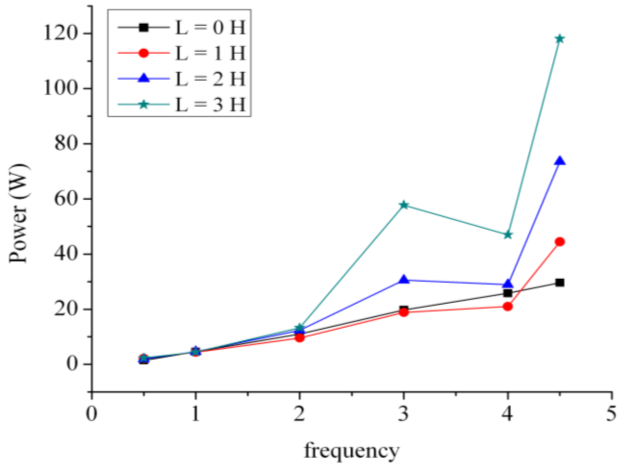

Fig. 3. Power consumed versus frequency without and with coil ($0 \leq L \leq 3$ H).

4. Conclusion

In this paper, we have investigated the effect of passive components on the electrical properties of a surface DBD.

The main results are as follows:

(1) With the HV resistor, the electric power is modified for frequencies above 3 kHz, probably due to the fact that the resistor is wire-wound.

(2) The coils significantly affect the discharge current, which results an increase of the injected energy into the plasma.

(3) A coupling between the power supply and the surface DBD as a function of frequency (here, $f = 4$ kHz) is observed. So, a drop of power consumed occurs.

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