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Influence of the dielectric on a Diffuse Dielectric Barrier Discharge in air at atmospheric pressure

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The Dielectric Barrier Discharge is an easy and robust way to obtain a cold plasma at atmospheric pressure. The discharges produced by this device are generally constituted by many microdischarges or filaments independent from each other. They have a short lifetime (1-10 ns) and are randomly distributed throughout the discharge volume. The energy is then not uniformly and optimally transferred to the discharge. This property is a significant obstacle to the use of DBD in some applications, such as plasma coating or surface treatment. Hopefully, it is possible to obtain a diffuse discharge, although it is an outstanding event only observable under restricted conditions. As a rule of thumb, diffuse discharge is always the result of a memory effect related to the previous discharges that creates seed electrons before the ignition of the discharge. Diffuse discharge can be divided into two kinds of discharges: the atmospheric pressure glow discharge (APGD) and the atmospheric pressure Townsend discharge (APTD). The APGD is obtained in noble gases with a penning mixture, while APTD was first obtained in Nitrogen.

The origin of the discharge homogeneity of the APGD and the APTD in Nitrogen is now well known and related to a memory effect in the bulk caused by long lifetime metastable [1]. For the APTD in Nitrogen, we recently pointed out the role of the $N_2(A)$ and associative ionization reaction [2]. In air, the lifetime of this $N_2(A)$ metastable is very low due to the strong quenching by the oxidizing species. It is why it was considered for a long time that it is impossible to obtain a diffuse discharge in air. However, in 2011 Osawa *et al.* presented a homogeneous discharge in air at low frequency (below 1 kHz) [3]. We observed such discharge at a higher frequency as presented in **Fig 1**. Its electrical characteristics are presented **Fig 1. a**, whereas short ICCD images taken perpendicular to the gas flow direction (position 1) are presented **Fig 1.b**. The two first images (noted + and -) are taken respectively on the positive and negative polarities with an exposure time equal to the half period. The discharge is diffuse, covering the whole electrode. The bright region is always located on the anode side, and no filament is observed. The images numbered from 1 to 6 are taken with a shorter exposure time (250 ns) to show the discharge development for each polarity. These six images are samples from a record of 2000 images. Then, it is possible to quantify the light emitted by the discharge during the whole period. When the discharge turn-on the light increases slowly with the current, moreover no light is present between the two discharges. The luminous intensity follows the evolution of the discharge current (I_d). The current shows clearly one large peak for each half period and no series of many narrow peaks distinctive to the filamentary discharge. On each half-cycle, from ignition to extinction the light is always located close to the anode, and the gas voltage of the discharge is almost constant during the discharge. In summary, we can say that: the

homogeneous discharge obtained in air is a Townsend discharge like the APTD obtained in Nitrogen.

This observation is remarkable, but the origin of this regime is not yet understood. It is not likely due to a memory effect in the gas bulk but probably to a production of seed electrons on the surface of the dielectrics. To go in this direction, we focus this work on obtaining such discharge in air and the key role of the dielectric properties on the discharge. Then, the role of the dielectric material on the discharge homogeneity will be pointed out.

To go further, we can note that the production of seed electrons is *sine qua non* but not the only requirement to obtain a diffuse discharge. It is also important to prevent the transition from electron avalanches to streamer, which can be done by limiting the discharge current. It is possible to do it by changing the capacitance of the dielectrics covering the electrodes. The influence of the dielectric capacitance on the discharge behavior is studied by varying the dielectric thickness.

Finally, the effect of the intrinsic properties of the dielectric on the power transferred to the discharge will be discussed. We will explain how to obtain a diffuse discharge in air at a frequency up to 5 kHz.

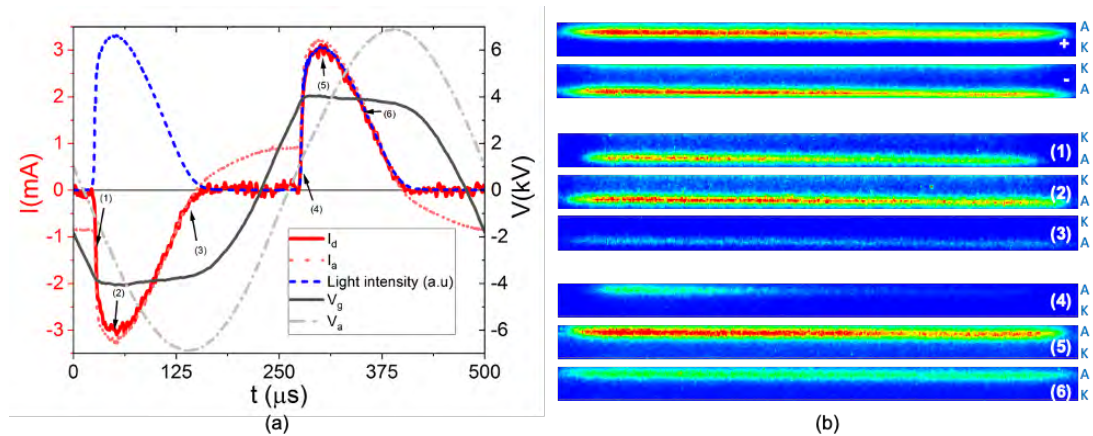


Fig 1. Homogeneous discharge in air at $f=2\text{kHz}$ and $V_{pp}=13.8\text{ kV}$. I_a and I_d are the current applied to the DBD and the discharge current. V_g and V_a are the gas voltage and the applied voltage.

References

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