Memory effect in a dielectric barrier discharge in N_2: phenomena in the gas bulk versus phenomena on the dielectric surfaces

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This work is focused on the study of the memory effect in Dielectric Barrier Discharges (DBD) at atmospheric pressure in N_2/NO and N_2/O_2 mixtures leading to a homogeneous Townsend discharge. An experimental approach with electrical measurements on a plane-to-plane DBD configuration is used. The literature suggests that the memory effect is mainly due to the collision of metastable species $N_2(A^3\Sigma_u^+)$ on the dielectric surfaces, but other phenomena in the gas bulk such as associative ionization can also contribute to the stabilization of the discharge. A comparison of the amount of seed electrons generated between two discharges for different gaseous gaps at the same power density gives a first quantification of the two phenomena, as the influence of the metastable species is assumed not to vary with the gaseous gap.

1. Introduction

The DBDs are a robust way to obtain a non-thermal plasma at atmospheric pressure, which has many applications in the surface treatment field. Atmospheric Pressure Townsend Discharges can be obtained in N_2 under specific conditions but it transits to the filamentary mode when the concentration of oxidizing gas exceeds a given threshold, which is not suitable for a homogeneous treatment of the surfaces [1].

The homogeneous regime is connected to a memory effect between two discharges which is highlighted by its electrical characteristics. The discharge current never reaches zero between two discharges. Hence, there is a current jump when the polarity reverses, due to the generation of seed electrons when the electric field is low enough to "trap" them in the gas volume. The origin of those seed electrons is thus the key phenomenon to understand the discharge physics of homogeneous DBDs.

2. Memory effect origin

The phenomena explaining the production of seed electrons under low electric field can be separated into two categories. First, in nitrogen-based mixtures, the collision of long-lived metastable species $N_2(A^3\Sigma_u^+)$ on the dielectric surfaces can enhance the secondary electron emission between two discharges. Secondly, phenomena in the gas bulk have been highlighted by the addition of small quantities of oxidizing gas in nitrogen [1]: despite the metastable species quenching by oxygen, the memory effect increases. The associative ionization of $N(^2P)$ with $O(^3P)$ could then explain the production of seed electrons under low electric field.

3. Experiments and results

The experimental set-up has already been described in a previous publication [2]. Current jump measurements have been made for two different gaseous gaps (1 and 2 mm), in nitrogen with addition of small concentrations of NO (from 0 to 40 ppm), for the same frequency and power density dissipated into the gas.

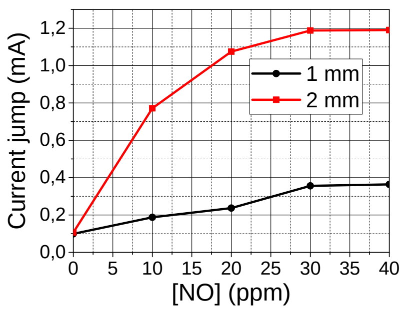

Figure 1: Current jump comparison (gap = 1-2 mm), frequency = 3 kHz, power density = 3.5 W/cm^3

Figure 1 shows that the current jump at 2 mm is twice to four times bigger than at 1 mm when NO is added to N_2. By assuming that the influence of the metastable species on the current jump does not depend on the gaseous gap, as those species do not move with the electric field, this increase would mainly be due to phenomena in the gas bulk. Thus, this comparison is a first approach which can give information on the ratio between the memory effect in the gas bulk and on the dielectric surfaces.

4. References

[1] Naudé N. *et al.*, Proc. Int. Conf. on Phenomena in Ionized Gases (2013)

[2] Massines F. *et al.*, Plasma Phys. Contr. Fusion 47 (2005) B577-B588