Memory effect of a diffuse dielectric barrier discharge obtained in air: surface and volume mechanisms

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There are generally two discharge regimes observed in Dielectric Barrier Discharge at atmospheric pressure: filamentary and diffuse regimes [1]. The discharge regime depends on factors such as the nature of the gas, the electrical parameters, and the electrode configuration. The filamentary regime is characterized by small and fast microdischarges randomly distributed on the electrode surface. As for the diffuse regime, it is characterized by only one discharge canal covering the whole electrode surface. In addition, it exhibits a more uniform distribution of the the energy provided to the electrode surface, making it more appropriate for various surface engineering applications, including thin-film deposition [2]. To obtain a diffuse discharge, a pre-ionization of the gas is needed. Recent studies have shown the potential to achieve a diffuse DBD in air [3–6]. The discharge is a Townsend one. As observed in other gases, the first discharge is always filamentary before a transition to a diffuse discharge (Fig. 1). Hence, the previous discharge influences the following one; this effect is called the memory effect. In N_2 discharges, this effect is related to $N_2(A)$ metastables, which are not present in air due to their efficient quenching by oxygen species. It is interesting to notice that a memory effect also exists in air. Currently, the mechanisms related to this memory effect and the production of seed electrons are not understood. It could be related to the features involved at the surface of the dielectrics and/or to processes occurring in the the gas volume. In this work, we examine these two potential mechanisms. Firstly, we assess any surface mechanisms by comparing two dielectric materials. Secondly, we investigate the volume effect by using a segmented electrode.

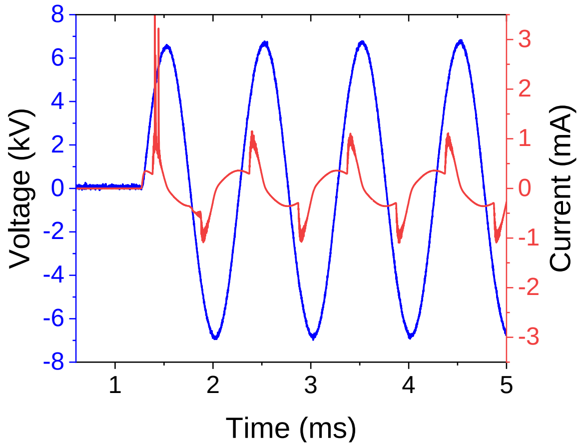

Fig. 1: Evolution of the applied voltage and the measured current during the first discharges for a DBD obtained in air (14 kV_{pp} and 1 kHz)

Fig. 2 (a) and (b) present the electrical measurements obtained with two different alumina. It is important to note that they have exactly the same dielectric properties (permittivity, thickness, percentage of purity); only the manufacturer and the surface morphology are different. Moreover, the same power supply conditions are applied in both cases. However, the discharge behavior is entirely different. With alumina 1, the discharge is diffuse, whereas with alumina 2, the discharge is filamentary. Hence, the surface has an enormous influence on the discharge regime. Hence, the alumina in contact with the discharge affects the memory effect. More details concerning the impact of the surface on the production of seed electrons will be discussed.

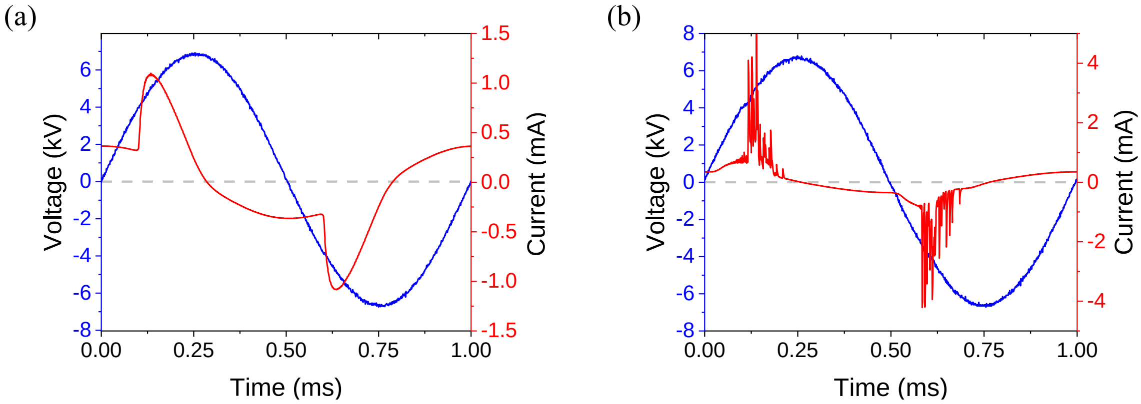

Fig. 2: Electrical measurements for a DBD obtained with alumina coming from two manufacturer with (a) alumina from manufacturer 1 and (b) alumina from manufacturer 2

To study the effect of the gas volume mechanism(s), we used a segmented ground electrode to obtain a spatial resolution of the current discharge and the gas voltage as a function of the gas residence time. The setup has been previously described [7]. As shown in Fig. 3, the breakdown voltage increases with the gas residence time until a saturation appears for a time longer than 200 ms. Consequently, the memory effect decreases with the gas residence time, which is counterintuitive and the opposite of what is generally observed in N_2 discharges. This evolution will be discussed to differentiate the influence of the different processes.

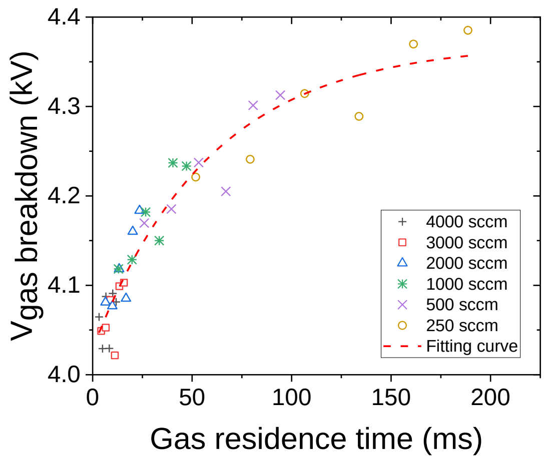

Fig. 3: Evolution of the breakdown voltage as a function of the gas residence time

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