RECENT ADVANCES IN THE UNDERSTANDING OF HOMOGENEOUS DIELECTRIC BARRIER DISCHARGES

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Abstract. This paper is a state of the art of the understanding of the physics of homogeneous dielectric barrier discharge at atmospheric pressure. It is based on the analysis of present and previous work about the behavior of these discharges and the conditions to get them. Mechanisms controlling the homogeneity during gas breakdown and discharge development are successively discussed. The breakdown has to be a Townsend one, the ionization has to be slow enough to avoid a large avalanche development. During the breakdown, the discharge homogeneity is related to the ratio of the secondary emission at the cathode (γ coefficient) on the ionization in the gas bulk (α coefficient). Higher is this ratio, higher is the pressure $\times$ gas gap product (P.d.) value for which a Townsend breakdown is obtained. Among the phenomena enhancing the secondary emission there is the negative charge of the dielectric on the cathode surface, the trapping of ions in the gas and the existence of excited state having a long lifetime compared to the time between two consecutive discharges. The first phenomenon is always present when the electrodes are covered by a solid dielectric, the second one is related to the formation of a positive column and the third one is specific of the gas. During the discharge development, the homogeneity is mainly controlled by the voltage or the current imposed by the electrical circuit applicators and to the gas ability to be slowly ionized. Larger is the contribution of a multiple step ionization process like Penning ionization, higher will be the working domain of the discharge. A decrease of the gas voltage during the discharge development is a solution to enhance the contribution of this process. After 20 years of research a lot of mechanisms have been understood however there is still open questions like the nature of the Inhibited homogeneous DBD, surface energy transfers, role of attachment and detachment…

1. INTRODUCTION

Dielectric barrier discharge (DBD) is an easy and robust solution to generate low temperature plasma at atmospheric pressure [1]. This discharge has a lot of applications since more than one century [2]. Its configuration uses dielectric barriers to maintain current densities below the threshold for glow-to-arc transition. The dielectrics trap charges on the surfaces during a pulse which in turn generates a self-induced field in the gas gap that inhibits the discharge before the current densities exceed the threshold.

It was long thought that for gas gap in the millimetric range or larger, DBD only occurs in a “filamentary” mode, comprising many short (<100 ns), narrow (<200 µm) current filaments, in general randomly distributed in time and space over the dielectric surface. Even if several authors [3,4] reported that ac discharges in helium can also manifest a pulseless “glow”, in which the atmospheric-pressure discharge assumes a diffuse, non-filamentary appearance, it is the work of Okazaki and their collaborators since 1987 [5] which has been at the origin of a real investigation of homogeneous DBD. Okazaki, Kogoma et al. studied a lot of different reactor configurations [5,6,7,8] to extend the gases panel leading to homogeneous DBD which at first was limited to helium. They also have shown the interest of these discharges for gas and surface chemistry. In parallel, since 1992 in France, Massines, Ségur and their collaborators [9] have focused on the understanding of these discharges physics mainly in He [10,11,12] and N_2 [13,14,15] and their application to polymer surface treatments [16,17] and thin film coatings [18,19,20]. At the same time in United States, Roth and collaborators have worked on all the possible applications [21,22,23,24] including sterilisation [25,26] and gas flow control [27,28].

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