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Breakdown in mm-sized discharges: Modifying the electric field

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Due to the small size of the gas gap in micro- and millimeter sized discharges, the presence of a metallic structure in its vicinity profoundly influences the breakdown process. This is a drawback because it makes electrical probing impossible, but can also be an advantage because it allows control over the electric field in the discharge reactor. Optical and electrical measurements were performed in an argon atmosphere at 0.3 or 0.7 bar. A pin-pin geometry was used, with 4 or 7mm between the electrode tips. We found that both active and passive structures influence breakdown, and we demonstrated the differences between the two types and their effects on the breakdown process.

1. Introduction

Micro- and millimeter-sized discharges are used in many places and are studied in many configurations. Surface treatment and biomedical applications are one of the many industrially important usages, and a few years ago jets became focus points of research for their potential in production of chemically active non-thermal plasmas.

The non-equilibrium ignition process (breakdown) in many of these applications where small-scale gas gaps are used is hard to qualify because of its erratic nature, the associated jitter, fast speed of growth and low amount of emitted light. Particularly interesting for this paper is probing for electrical properties, which is a method that often requires conductive bodies to be present in the vicinity of the growing discharge. Consequently, in many of the applications listed above, metallic structures can be found close or in contact with the plasma reactor, and not only as electrodes. If placed near a discharge reactor, metallic structures influence the growing discharge by changing the electric field in its vicinity. Any metallic structure, regardless of its potential, has an influence. This is a drawback because of the inability to use probes for electrical measurements, but can also be an advantage because by strategically placing the metallic structures we can influence the breakdown process in a more controlled way.

The lighting industry has significant experience with metallic structures that influence a growing discharge. There they are called 'antennas' and are used to deliberately influence the electric field

in lamps during the start-up phase. Antennas proved to be a robust addition to lamps that helps lower ignition voltage irrespective of the conditions lamps are operated in or for the most part their complex and delicately balanced chemistry.

The aim of this paper is to examine, compare and analyze the influence of three antenna arrangements that differ only in their respective potentials. The setup used for this features a set of standard 70-W HID (High Intensity Discharge) lamps filled only with argon. Even though the experiment was done on a lamp geometry, the results apply to all similar gas gaps.

2. Setup

The experimental setup is fully described in [1, 2]. We used a pin-pin electrode system enclosed in a dielectric casing. The electrodes were tungsten, rod-shaped and had the diameter of 0.6 mm. The distance between the electrode tips was 4 or 7 mm. The dielectric casing was that of a 70-W HID lamp burner, made of YAG (Yttrium Aluminium Garnet). The burners were filled with 0.3 or 0.7 bar argon.

Three antenna arrangements were tested in this research, shown in figure 1. All the antenna arrangements have the same basic shape, but differ in the potential. One of the antennas is at fixed potential (grounded), while the other two are floating. One floating antenna was designed symmetrically, while the other one was asymmetric, where we attempted to design the capacitances such that the initial potential distribution in the burner would be similar to the one provided

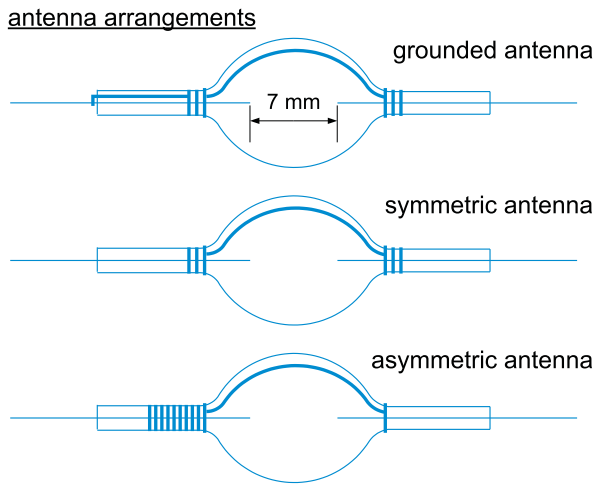


Fig. 1: The three arrangements of antennas (metallic structures on the outer side of the discharge reactor) used in the experiment. See text for more details.

by the grounded antenna.

We used sine voltage of high frequency, between 500 kHz and 1 MHz. To obtain the signal and desired amplification, we used three function generators, a HF amplifier and a passive amplifier. Electrical measurements were conducted by using a high-voltage probe for voltage and a Rogowski coil for current measurements. Optical measurements were done by using a Princeton Instruments UNIGEN II filmless GEN III iCCD camera with a 1024×1024 pixel CCD array. We used gate widths of 100 ns for detailed view of the discharge development, as this is sufficiently short in the domain of HF AC-discharges [1,2].

3. Results and discussion

This was an extensive research project, where we had several objectives. First was to measure the influence of the three antenna arrangements on the minimum breakdown voltage in the given frequency range. Second was to image the process and compare it to the unperturbed arrangement [1]. Third was to attempt to qualify the effect of the antennas on the breakdown process in our geometry, with special emphasis on floating (also called passive at times) arrangement. We will now shortly describe the results in each of these aspects.

The appearance of the discharge differed somewhat from the non-aided breakdown [1]. In the non-aided case the discharge was diffuse, formed in the gas volume and took up to 100 voltage cycles to form (around 100 μ s). When aided by

antennas, it formed in 3 cycles or less, over the surface and appeared to be streamer-like.

All three antenna arrangements were proven to have a measurable effect on the minimum breakdown voltage - the breakdown voltage was lower when an antenna was present. The biggest influence was made by the grounded antenna, which was followed by the two floating antennas. We argue that the observed effects on the appearance and the minimum breakdown voltage can be explained by the amplification of the electric field in the discharge reactor, caused by the presence of antennas.

The reason why the grounded antenna has the biggest influence is because it is on constant potential, unaffected by the discharge, and as such can constantly provide high potential gradient at the tip of the streamer featured in the breakdown process. On the other hand, the floating antennas are on potential that is a function of the size and position of the discharge. When the symmetric floating antenna was used, its initial potential was the arithmetic average of the potentials at the electrodes, and as such could not replicate the amplification of the electric field that was present when the grounded antenna was used. This is why measurements were made with an asymmetric floating antenna, designed to replicate the conditions provided by the grounded antenna. Even though the initial conditions were as expected, because of big changes in capacitance during the discharge growth, the conditions in the burner during the streamer growth changed drastically and reduced the electric field amplification at the streamer tip.

This research was done on a very specific geometry, which was closed and featured two pin electrodes. The analysis of the results, however, is as general as we could have made it and as such can be used in other geometries as well. For details on the experiment and the analysis, we would like to refer you to [2].

References

- [1] A Sobota, J H M Kanters, F Manders, M F Gendre, J Hendriks, E M van Veldhuizen and M Haverlag, *J. Phys. D: Appl. Phys.* 44 (2011) 224002
- [2] A Sobota, M F Gendre, F Manders, E M van Veldhuizen and M Haverlag, *J. Phys. D: Appl. Phys.* 44 (2011) 155205