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Influence of adsorbed charges on self-synchronization of streamers breakdown

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Dielectric barrier discharges (DBD) in air have been widely used for ozone generation and intensively studied for air treatment. The charges deposited on the dielectric surface insure against arcing and allow treating the whole reactor volume. These charges shield the applied electric field, and decrease the applied voltage required to sustain DBD in continuous regime. In spite of the great impact of adsorbed charges on the DBD behavior, many parameters related to these charges have to be determined: the nature of the species responsible for charge adsorption, the binding energy of these species, their influence on the primary avalanches required to reach the Meek criteria, influence of the dielectric geometry and its chemical nature on the charge adsorption.

Several experiments have been designed to study the kinetics of charge adsorption on the dielectric surface by Pockels effect [1]. However, these experiments were necessarily made on a devoted dielectric material and could not easily study other configurations than pin-to-plane geometry. In different DBD reactors (coaxial geometry, surface discharge or cylinder to plane), it was shown that the breakdown of one plasma filament can initiate the breakdown of several tens of others [2-4]. The photo-desorption of the charges is probably responsible for this synchronised breakdown of filaments within a few nanoseconds. To investigate further this interaction between plasma filaments, a statistical study of the synchronized breakdown was performed by iCCD fast imaging with a devoted surface DBD configuration.

Two cylindrical electrodes are connected to the same sinusoidal 10 kV power supply with a frequency from 75 to 500 Hz. The ground electrode is a salted water reservoir separated from the electrodes with a pyrex plate which allows to perform imaging of the streamers propagating onto the pyrex surface. The renewing of the gas in the chamber is obtained. An iCCD camera is used to take pictures of both electrodes simultaneously. The camera is triggered at a given applied voltage and the pictures are then collected if only one current peak occurs during the gate time of the camera, which corresponds to the breakdown of filaments synchronized with a delay shorter than 10 ns. About 100 images are collected for each condition in order to determine the probability of synchronized breakdown on both electrodes for different conditions. The gas flow, nature of the feed gas, distance between the electrodes, and frequency of the power supply are varied. A glass plate, black painted or not, could also be inserted in between the two electrodes.

The fig 1 shows for instance the probabilities P of synchronized breakdown with or without glass plate between the electrodes. About 65% of the filaments breakdown occurs simultaneously on both electrodes when no filter is inserted

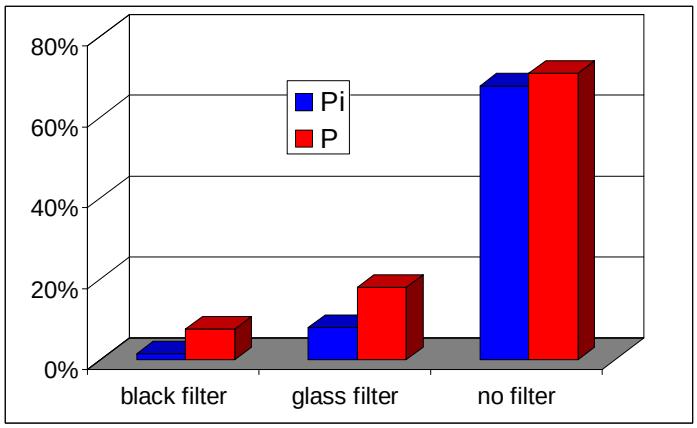

Fig. 1: proportion of synchronized breakdown on both electrodes with glass filter covered by plastic made layer (black filter), with glass filter or without any filter. Applied voltage = 10 kV, frequency = 100 Hz, dry air at 500 sccm, distance between electrodes = 25 mm

As most of the synchronisations are avoided by the glass filter, UV light emitted by a first filament seems to be responsible for the triggering of filaments breakdown on the other electrode. This is in good agreement with the measurements of Kashiwagi et al [5]. In this study the authors have reported that wavelengths shorter than 250 nm are required to trigger filaments. In their study the dielectric barrier was acrylic resin, and the spreading of filaments was observed with dust on the dielectric barrier after a single high voltage pulse of 36 kV in the ambient air. By working with single pulse, no charges could be adsorbed already on the dielectric barrier hence the energy required to trigger the filaments should be higher compared to continuous mode. However, in our case little synchronization are obtained even with glass filter so that radiation with energy about 4 eV could be sufficient for triggering filaments breakdown. This energy is too low for inducing photo-ionisation in the gas phase. The synchronized breakdown of filaments should then be due to desorption of charges from the dielectric induced by low energy radiation emitted by a first filament. For instance the second positive system of nitrogen which is the main part of light emitted by plasma filament in dry air could be energetic enough to trigger discharge.

Reference

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