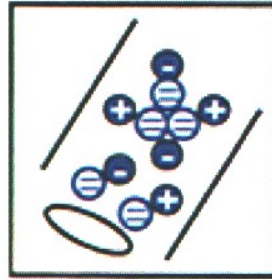


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The memory effect on the breakdown of atmospheric pressure air studied on transient spark discharge using fast iCCD camera.

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1. Introduction

Transient spark (TS) is a streamer-to-spark transition type discharge initiated by a streamer followed by the gas breakdown and a short (~ 10 ns) spark current pulse (~ 1 A) [1-3]. We studied this discharge of positive polarity in atmospheric pressure air in point-to-plane geometry. Despite using DC high voltage (HV) power, TS has a repetitively pulsed character: and the streamer-to-spark transition repeats in the kHz frequency range. It is due to periodical charging and discharging of the internal capacity C of the used electric circuit. Thanks to the small value of C (~ 10 -40 pF), the plasma formed during the short spark pulse of TS cannot reach LTE conditions and so differs from a classical spark. TS generates highly reactive non-equilibrium plasma, as indicated by optical emission spectroscopy (OES). Several excited species, such as $N_2(C)$, $N_2(B)$, O^* , N^* or $N_2^+(B)$ were observed [1].

Transition to an arc and generation of thermal plasma is also prevented by a large external resistor R (5-10 M Ω) placed between the HV power supply and the needle HV electrode. The product of R and C determines the repetition frequency f that can be controlled by the onset voltage U_{oo} [2]:

$$f = 1 / RC \ln \left(\frac{U_{oo}}{U_{oo} - U_{TS}} \right).$$

Here, U_{TS} represents breakdown voltage at which streamer initiating the transient spark appears.

The U_{TS} was found to decrease with the growing f . It was attributed to the influence of a ‘memory’ effect [2]. We performed time resolved OES study using a fast photomultiplier tube and a fast intensified CCD camera coupled with high resolution spectrometer in order to find more about the role of the increasing f and the induced ‘memory’ effect on TS and the breakdown processes.

2. Results and Discussion

Time resolved emission spectra of the N_2 2nd positive system were used to estimate time evolution of the gas temperature T during the streamer-to-spark transition [3]. The value of T at the beginning of the streamer $T^{streamer}$ was used to estimate the pre-heating effect of increasing f . Next, the emission spectra of H_α line were used to calculate the electron

density during the spark phase of TS (Stark broadening). Finally, the imaging of TS was used to observe the influence of f on the propagation of the streamer, and the evolution of the plasma channel diameter.

Both electrical and optical data showed differences between TS at ‘low’ f (below ~ 3 kHz) and at ‘high’ f (~ 6 kHz). There was almost no delay between the streamer and the spark at ~ 6 kHz. The OES and imaging showed disappearance of atomic lines and no constriction of plasma channel during the spark phase at ~ 6 kHz.

The increase of $T^{streamer}$ with growing f explains the observed decrease of the breakdown voltage, while the reduced electric field E/N , at which streamer initiating TS starts, does not change with f . We suppose that for TS below ~ 3 kHz, the breakdown mechanism suggested by Marode [4] is crucial, i.e. heating of the channel \rightarrow increase of the pressure \rightarrow hydrodynamic expansion \rightarrow decrease of N in the core of the channel \rightarrow increase of E/N \rightarrow acceleration of ionization processes. The ‘memory’ effect on U_{TS} can be thus reduced on the influence of pre-heating. However, we assume that pre-ionization or accumulation of reactive species can play important role on TS characteristics and breakdown processes at higher f (~ 6 kHz). Under these conditions, the chemical and stepwise ionization [5] or accumulation of metastable species influence the breakdown significantly.

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