Imaging of self-pulsing nanosecond transient spark discharge

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1. Introduction

The transient spark (TS) is a periodic streamer-to-spark transition discharge with controlled spark phase operating at the repetition frequency *f* in the range of 1-10 kHz [1]. Due to the short spark current pulse duration (~10–100 ns), the TS generates highly reactive non-equilibrium plasma, suitable for example for the bio-decontamination of water [2].

The transfer of reactive species from the plasma to the liquid water is crucial for the efficiency of the bio-decontamination. We obtained good results when the contaminated water was electro-sprayed through the active zone of the TS discharge [2]. However, the bio-decontamination efficiency strongly depends also on *f*. Above ~3 kHz, the TS characteristics change (smaller and broader spark pulses) and its biocidal efficiency declines. We therefore performed extensive study of the TS dependence on *f*. However, we decided to discuss only one issue in this abstract – changes of the breakdown mechanism in the TS with increasing *f*.

2. Methodology

Besides electrical measurements, we performed time resolved emission spectroscopy and imaging of the TS using a fast iCCD camera (2 ns minimum gate width). Additionally, a streak camera like images were obtained using spatiotemporal reconstruction of the discharge emission detected by a photomultiplier tube with light collection system placed on a micrometric translation stage.

The positive polarity TS was generated in the ambient air between metal electrodes in point-to-plane configuration with distance d = 4-7 mm.

3. Results and Discussion

The TS is initiated by a primary streamer creating a relatively conductive plasma bridge between the electrodes. It enables partial discharging of the internal capacity C of the electric circuit, and a local gas heating inside the plasma channel. When the gas temperature T inside the plasma channel reaches ~1000 K, a very short (~10-100 ns) high current (>1 A) spark current pulse appears [3].

Since the appearance of the spark in the TS is governed by the increase of T to ~1000 K [3], the breakdown can be explained by the hydrodynamic expansion mechanism [4].

However, the increase of *f* influences the breakdown mechanism in the TS, since the significant shortening of the streamer-to-spark transition time (τ) was observed above ~3 kHz [3]. Above ~3 kHz, the breakdown in the TS is probably significantly influenced by the attachment control processes [5] initiating the so called secondary streamer.

The imaging of TS revealed the presence of the secondary steamer following the primary steamer. We observed the increase of the propagation velocity of both the primary and the secondary streamer with increasing *f*. Accelerating propagation of the secondary streamer crossing the entire gap could explain short streamer-to-spark transition times τ (~100 ns) at *f* above ~3 kHz. The secondary streamer was observed below 3 kHz as well, but it did not cross the whole gap and it probably disappeared long before the spark current pulse.

Acceleration of the primary and secondary streamers and shortening of τ with increasing *f* was attributed to the memory effect composed of pre-heating, pre-ionization, or gas composition changes induced by the previous TS pulses. Further research is required, including kinetic modeling, to verify this hypothesis and distinguish the respective contributors to the memory effect.

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