6th International Workshop and Summer School on Plasma Physics

at Black Sea

30 June - 6 July 2014
Kiten, Bulgaria

Programme and Abstracts

Sixth International Workshop & Summer School

on Plasma Physics

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TIME-RESOLVED OPTICAL DIAGNOSTIC OF SELF-PULSING NANOSECOND DISCHARGES FOR BIOMEDICAL APPLICATIONS

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The streamer-to-spark transition leading to the gas breakdown is a crucial issue for the generation of various atmospheric pressure electrical discharges, as well as in the design of high voltage (HV) devices. An influence of 'memory' effect (e.g. pre-heating and pre-ionization) of the gap on the streamer-to-spark transition and streamer breakdown mechanism can be investigated by using the transient spark (TS) discharge studied in our group [1-2].

The TS is a DC-driven self-pulsing streamer-to-spark transition discharge initiated by a streamer, which transforms to a short (~10-100 ns) high current (>1 A) spark pulse due to the discharging of the internal capacity C of the circuit. Charging and discharging of C is repeated with the frequency f in the kHz range. The TS generates highly reactive non-equilibrium plasma suitable for bio-medical applications [3-4].

The increase of f is achieved by increasing the generator voltage, and it is accompanied by changes of the TS characteristics, e. g. the spark current pulses are getting broader and smaller. The increase of f also changes the breakdown mechanism. The breakdown voltage decreases due to the pre-heating of the gas between the electrodes, and significant shortening of the streamer-to-spark transition time (τ) occurs with increasing the TS repetition frequency [2]. Above ~3 kHz, τ decreased from a few μs down to ~100 ns.

In order to explain these changes, we studied TS by several optical diagnostic techniques. We employed an iCCD (ANDOR Istar) camera with 2-ns gate coupled to a spectrometer to obtain time-resolved emission spectra of TS. The spectra of the N_2 2nd positive system were used to estimate time evolution of the gas temperature during the streamer-to-spark transition. Next, the emission of Hα line was used to calculate the electron density (from Stark broadening). The imaging of the TS was used to observe the frequency influence on the propagation of the streamer, and the evolution of the plasma channel diameter. Additionally, the spatiotemporal evolution of the discharges was analyzed by a photomultiplier tube (PMT). A cylindrical lens was used in the optical system to collect all the light in the plane perpendicular to the electrode's axis to avoid missing any discharge channel in case of its branching. The light collection system was set on a micrometric translation stage to enable mapping of the light emission along the electrode's axis.

The estimated average streamer propagation velocity increased with f. At ~4 kHz it was ~5×10^7 cm/s. Interestingly, the secondary streamer was only ~2 times slower than the primary one. The fast propagation of the secondary streamer could explain short streamer-to-spark transition times in TS at repetition frequencies above 3 kHz. We suppose that it is related with a memory effect induced by previous TS pulses.

Acknowledgments: Effort sponsored by the Slovak Research and Development Agency APVV-0134-12, and SK-RO-0024-12, and Slovak Grant Agency VEGA 1/0998/12.

References:
[1] M. Janda et al., *Plasma Sources Sci. Technol.* **20** (2011), Art. No 035015.
[2] M. Janda et al., *Plasma Sources Sci. Technol.* **21** (2012), Art. No 045006.
[3] Z. Machala et al., *Plasma Process. Polym.* **10** (2013), 649.

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[2] M. Janda et al., *Plasma Sources Sci. Technol.* **21** (2012), Art. No 045006.
[3] Z. Machala et al., *Plasma Process. Polym.* **10** (2013), 649.