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Time-resolved emission spectroscopy and imaging of transient spark discharge in atmospheric air

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Transient spark (TS) is a DC-driven streamer-to-spark transition discharge operating at atmospheric pressure, which has been successfully applied for flue gas cleaning or bio-decontamination and has a potential in plasma shielding, combustion, flow control, and other microplasma applications. It can also be run with water sprayed through the plasma, thus enabling efficient decontamination.
Since various applications have different demands on TS with respect to the optimal frequency, energy per pulse and other parameters, a better ability to control TS by changing its electric circuit parameters requires further research.
Despite DC applied voltage, TS has a repetitively pulsed character. It is 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 of the reactor. A typical frequency *f* is from around 1 to 15 kHz.
The increase of *f*, achieved by increasing the onset voltage, is accompanied by change of emission characteristics. At 'low' frequencies (<3 kHz), the emission of O, N and N^+ atomic lines and N_2 2^{nd} positive system dominates in the spectra, but at higher frequencies the atomic lines almost disappear. In order to understand this phenomenon, we employed a photomultiplier tube with 2.2 ns rise time and appropriate narrow band optical filters, as well as a fast iCCD camera with 2 ns gate coupled with a 2-m monochromator covering UV and VIS and providing spectral resolution of 0.05 nm.
Estimation of the temporal evolution of electron density using the discharge diameter measured by time-resolved iCCD imaging and supported by preliminary spectroscopic measurements from Hα line broadening show that electron densities around 10^{16}-10^{17} cm^{-3} at maximum and ~10^{11} cm^{-3} in average are reached using a relatively low power delivered to the plasma (0.2-3 W). Thanks to the high repetition frequency, electron density between two current pulses does not fall below a critical value and therefore the plasma exists during the whole time.
Spectrometer coupled with the fast iCCD camera enables us studying the streamer-to-spark transition process, e.g. by measuring time-resolved spectra of N_2 2^{nd} positive system. By fitting these measured spectra by simulated ones, we obtain the gas temperature. We found that the streamer-to-spark transition is governed by the increase of the gas temperature in the plasma channel. The initial gas temperature at the beginning of the streamer is ~300 K, and increases with frequency up to ~450 K at 10 kHz. The transition to spark occurs at ~1000 K. This heating accelerates with increasing *f*, leading to a shorter average streamer-to-spark transition time from a few μs to less than 100 ns.
The imaging by iCCD camera was also used to estimate the diameter of discharge channel. We obtained radial profiles of emission intensity of a single TS discharge channel for several different phases of TS evolution. Typical diameter of the plasma column generated by the streamer which initiates the transient spark is ~200 μm. This number represents the full width at half maximum of the radial profile of the emission intensity. We observed the contraction of this plasma column, the FWHM of its emission profile compressed to less than 100 μm during the spark phase.

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