Imaging, shadowgraphy and emission of plasma in liquids

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1. Introduction

It is generally admitted that the breakdown of dielectric fluid can be divided in 4 stages of different time scales: i) initiation (nanoseconds), ii) propagation of the discharge (tens or hundreds of nanoseconds), iii) bridging of discharge gap (microseconds) and iv) post-discharge evolution (microseconds to milliseconds) [1-3].

We investigate the generation and the propagation of a microplasma generated in water by nanosecond voltage pulser.

2. Methods and results

The voltage pulse has 5 ns rise time, 30 ns duration (FWHM) and 10 kV amplitude (FID GmBH). We work in single shot mode, each shot providing series of six voltage pulses of alternative polarities delayed by few hundreds of nanoseconds. Plasma is characterized by fast iCCD (ANDOR iStar 734) shadowgraphic imaging and time-resolved spectroscopic study (Shamrock SR-303i).

At lower voltage a slow mode propagates at a velocity of few km/s; this mode is often called “bush like” with a typical size of several tens of micrometers. At higher voltage, a fast mode propagates at a velocity of few tens of km/s; this latter, called tree-like mode, generates filamentary discharge pattern as long as 1 mm [2].

Two different methods were used to estimate the gas pressure inside the tree-like discharge: i) one based on shock pressure measurements and ii) the other describing the expansion of a long cylindrical cavity. Some key results may be summarized as following:

These two different models could be simultaneously applied at 6 kV. They give consistent values of maximal pressure of 0.3 – 0.4 GPa. At 15 kV, the maximal shock velocity is 4.2 km/s which corresponds to 5.8 GPa of initial pressure. Our results demonstrate strong pressure dependence in tree-like discharge on applied voltage [4]. The pressure evolution during HV pulse and in the post-discharge phase demonstrated rapid relaxation down to 100 MPa already at 200 ns.

Optical emission spectroscopy was performed to study evolution of plasma parameters, i.e. Ne, during applied HV pulse and under successive pulses [4]. It was shown that:

Emission spectra of the first positive pulse consists of intense continuum between 300 nm and 800 nm and strongly broadened lines of hydrogen Balmer series and atomic oxygen triplet bands IO. Baseline of spectrum could be fitted with black body emission curve at T = 7000 K. However, this continuum emission could also be due to molecular emission.

During the first (positive) HV pulse Hα line has asymmetric red wing and can be approximated by the sum two shifted Lorentzian profiles. These two Lorentzian functions were ascribed to direct and back discharge inside the discharge channels during the HV rise and decay front respectively. Each profile was assumed to be a sum of combined action of Stark and Van der Waals broadening. Based on this assumption we obtained electron density of $1.3*10^{26}$ m^{-3} for the direct discharge and $2*10^{25}$ m^{-3} for the back discharge.

The total width of hydrogen alpha line observed during second (negative) pulse demonstrated a more than three times decrease which is consistent with pressure relaxation demonstrated in section

During the third (positive) HV pulse observed Hα profile consisted of two strongly (30 nm FWHM) and weakly (1 nm FWHM) components that could be attributed to spatially distinct denser high pressure plasma in newly created channels and emission from expanded discharge. No continuum emission was observed.

Weakly broadened (0.6 nm) Hα profile detected under the fourth (positive) pulse was consistent with pressure relaxation inside the discharge channel.

References

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