Study of intense cavitation-assisted electric discharge

A. Gutsol[1], Y. Mirochnik[1], A. Starikovskiy[2], S. Gershman[3], S. Yatom[3]
[1]*LDS Technology Consultants, Inc., Warwick, PA, USA*
[2]*Department of Mechanical and Aerospace Engineering, Princeton University, Princeton, NJ, USA*
[3]*Princeton Plasma Physics Laboratory, Princeton, NJ, USA*

Abstract: In this contribution, we report electrical and optical measurements of the properties of the recently developed intense cavitation-assisted electric discharge (I-CAED) in water. In contrast to nanosecond CAED that develops in low-pressure two-phase cavitating flow and has rather low power density, I-CAED is a short nanosecond spark through a thin water layer that has high power density and strong emission in the UV range.

1. Introduction

An Intense Cavitation Assisted Electric Discharge (I-CAED) (Fig. 1), a recently discovered mode of a CAED, is very promising for economical water purification and disinfection by the realization of the Advanced Oxidation Process (AOP), while simple CAEDs are promising for plasma-chemical processes, e.g., effective generation of hydrogen peroxide (H_2O_2) from water or synthesis in hydrocarbon liquids. The physical properties of I-CAED are difficult to study because they change in the sequence of rather different events with a total duration of tens of nanoseconds.

Here, we use electrical measurements with nano-second resolution, high-speed imaging, and emission spectroscopy to estimate key properties of the water vapor plasma developed at different stages of I-CAED development.

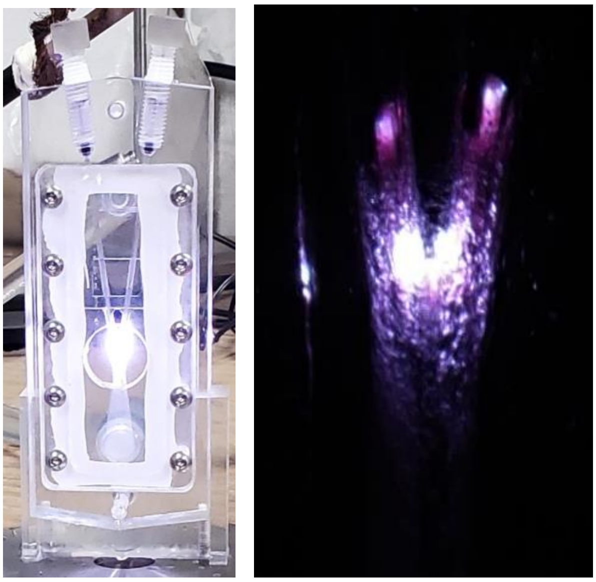

Fig. 1. I-CAED generation system and a photo of a single nanosecond discharge.

2. Methods and Results

Discharges were generated in the flow of DI water using FID pulser FPG 20-1NM that generates “rectangular” 10 ns pulses with amplitude 5-20 kV and frequency < 1 kHz. For measurements of electric parameters, a long 50-Ohm coaxial cable was used with separation of the shield and HV electrodes in the middle of the cable length. In this place, the HV signal was measured by a Tektronix HV probe, and the current through the shield electrode was measured by a current sensor with a time resolution of less than 2 ns. These measurements revealed two phases of discharge development. Thus, at the 17 kV pulser setting, the first phase, when two conductive channels grow in cavitating flows, has a duration of about 7 ns, while the current grows from 50 to 100 A, and power – from 1.3 to 2.2 MW. Then the second phase – breakdown of a thin water layer – happens during about 3 ns, current jumps to 200 A and power – to 3 MW.

To make sense of our spectroscopic results, we compare them with those presented in the paper [1], which demonstrated the time evolution of a spectrum obtained from a nanosecond micro-discharge in water. Initially, during water film breakdown, only a continuous bremsstrahlung spectrum is visible. Then, the continuous spectrum disappears while the linear spectrum appears. The total time of spectrum evolution in the paper exceeds 1 µs, and atomic spectral lines just start to appear at the end of the current pulse that has a duration of about 300 ns [2].

A time-averaged emission spectrum of I-CAED shows a combination of a continuous spectrum caused by bremsstrahlung with a linear spectrum typical for the water-vapor plasma. For 17 kV power supply voltage, the continuous background has maximal intensity at 300 nm that corresponds to the average electron energy of about 4 eV [3]. Evaluation of the electron excitation temperature and electron concentration after subtraction of the continuous background using H_α and H_β lines gave the values $T_e = 0.54$ eV and $2.5 \cdot 10^{23}$ m^{-3}, which may be attributed to the late phases of the spectrum evolution.

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References

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