Analysis of microplasma discharge process in sea water

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1. Introduction

Recently plasma processes in liquids are gaining a lot of attention due to their possible applications in the nanoparticles and materials production, water cleaning, elemental analysis and plasma medicine. Due to a wide range of possible applications there is a need in operating plasmas under various conditions. Plasmas in a dielectric and low-conductivity liquids are studied extensively and as result the breakdown phenomena, discharge process and plasma parameters are already well known. However, plasmas and microplasmas in highly-conductive liquids are poorly investigated and mostly only used in application oriented studies, for that reason more detailed analysis of the microplasma discharge process in highly-conductive is required. This work proposes a micro-gap plasma discharge in a highly-conducive sea water under various conditions and reports on discharge characteristics and results of the discharge process modeling.

2. Experimental

For the experiments, artificial sea water consisting of ten typical components (10ASW, electrical conductivity 45.1 mS/cm at 20.3°C) was used. A needle(Pd)-to-plane(Pt) electrode system was sunk into liquid in a quartz cuvette. The needle was 50 µm in tip radius. The gap between electrodes was ranged from 10 to 40 µm.

An impulse generator circuit consisting of a MOSFET switch, capacitor (C), inductor (L) and resistance of water between the electrodes (R) was used to supply the discharge. Inductance and capacitance were ranged in 10-150 µH and 7-220 nF, respectively. The capacitor was charged to 500-1000 V.

3. Mathematical model

For modeling following approximations were applied:

- No effect of pressure on process
- No chemical reactions
- No electrolysis processes
- At the start of discharge all water presented in modeling has same conductivity and temperature.

Model was solved in two blocks. First block is RLC oscillation model with defined steps in time and second block is a local process in the discharge gap for each step of the first block.

In the second block calculation of electric field strength distribution in the discharge gap was performed, based on voltage calculated in the current step of the fist block.

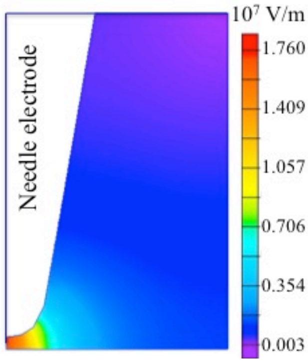

Fig. 1 – Electric field strength profile

Using electric field profile current density distribution in the gap was computed and amount of energy delivered to the liquid due to joule heating was estimated. As result, temperature and electric conductivity values of the liquid for each mesh point were calculated and used for calculation of the next step in the first block.

4. Results and discussion

Mathematical model shows good agreement with experimentally measured current and voltage waveforms until the moment of breakdown, however estimation of breakdown moment time is complicated, due to not complete at this stage model of bubble formation process.

For modeling of breakdown and microplasma discharge stages, breakdown moment and conductivity of medium at the time of the discharge were estimated from a fitting of the experimental current and voltage waveforms.

With mentioned before approximations, it is possible to compute current and voltage waveforms of entire process with good agreement to experimental results.

Conclusions

Modeling of microplasma discharge process in sea water was performed using and showed good agreement with experimental measurements. Fitting of experimental data was used to estimate breakdown moment.

For the further analysis it is necessary to introduce complete bubble formation and dynamics block to the model, to make computation of process independently to the experimental data.