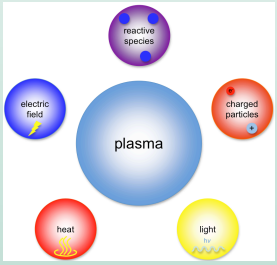
Max-Planck-Institut für extraterrestrische Physik

Analysis of Plasma Flow at Gas-Liquid Interface for Biological Interaction

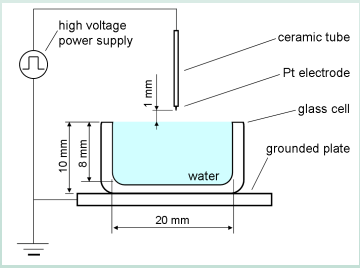
Tetsuji Shimizu [1], Yutaka Iwafuchi [2], Takehiko Sato [2], and Gregor Morfill [1]

[1]Max-Planck Institute for Extraterrestrial Physics, Giessenbachstraße, D-85748 Garching, Germany.

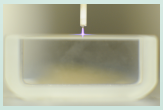
[2]Institute of Fluid Science, Tohoku University, 980-8577 Sendai, Japan.



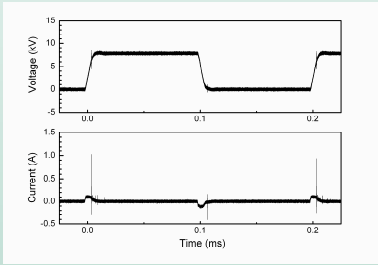
Components of plasma.



Experimental setup.

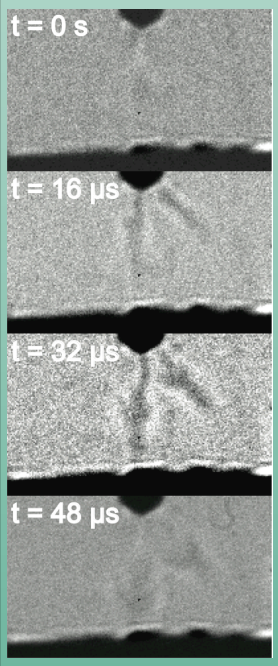


voltage: 7.5 kV_{0p}
frequency: 5 kHz
waveform: square wave
electrode distance: 1 mm

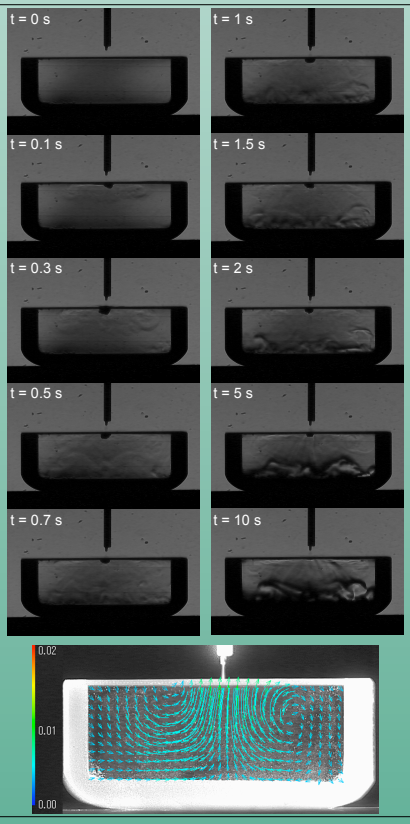


Waveforms of voltage and current.

Plasma consists of charged particles and neutrals. Because of its physical properties plasma has a bactericidal/fungicidal property due to reactive oxygen and nitrogen species (ROS and RNS), charged particles, UV radiation, electric fields, and heat. Cold atmospheric plasmas operate at almost room temperature and allow us *in vivo* applications. In order to understand the mechanism of biocidal property, it is important to know a physical property of plasma. In this study, a dielectric barrier discharge was produced between a tip of Pt electrode and water surface by applying high voltage (5 kHz, square wave, 7.5 kV_{0p}) and we studied a flow formation in the air as well as liquid by the Schlieren method. The discharge produces a flow in the air above the water surface and this air flow drives a flow in the water. This phenomena is important to understand the transport of chemically reactive species produced by the discharge to living tissues often submerged in liquid.



The Schlieren visualization gives us the density variation in the plasma as shown in the figure. Because the signal is very faint, a difference between an image and the previous image was calculated for all the frames in order to emphasize the signal. At t = 0 s, the plasma discharge was ignited and every 16 μs the images are shown. In these images a temperature field is shown since the pressure is constant at atmosphere in this experiment. Note that this plasma was produced in an open air at atmosphere. Firstly a hot region in a rod shape between the electrode and water surface was created. Neutral gas in the plasma discharge was heated locally. Following that a hot region in a crescent shape was produced and transported toward the water surface. We suppose that this transport was driven by accelerated ions in the electric field, producing a flow. This flow is quite important because it can induce a flow in the water and affect a mixing of chemically active agents in the water.



The thermal flow field in the water was analyzed by the Schlieren visualization technique. Figures show a time series of images in the water. The gas flow to the water surface at the discharge was created. We suppose that this drives a flow along the water surface and at the water surface the water is driven to follow the gas flow above the surface. As shown in figures from t = 0 to 0.3 s, a temperature profile was built up along the water surface. Afterwards, the thermal field develops a profile downward when this thermal field reaches the wall of the cell (t = 0.3 s). At t = 1.5 s, the direction of thermal field goes up and we think a convectional flow is produced. Figure at the bottom shows a result of the analysis using PIV method. The flow pattern looks a convectional flow and the flow speed in the vicinity of the surface is faster than that at the bottom. The shape of this result looks quite similar to that of the thermal field measured using the Schlieren method. We believe that the thermal field pattern also represents the flow. The maximum velocity of this flow is ~1-2 cm/s.

Summary and outlook

The flow produced by the plasma discharge was measured in the air and water. The flow in the air drives the flow in the water and a convectional flow pattern was observed. this phenomena is very important to understand the transport of chemically reactive species in liquid. In the next step, profiles of reactive species are measured in the air and water we compare the profiles with the measured flow patterns.