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OH radical measurement in a short-pulsed discharge plasma
短パルス放電プラズマ中におけるＯＨラジカルの計測

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Dielectric barrier discharge (DBD) is developed for application of the plasma sterilization technology. Lifetimes for OH radicals were measured with two kinds of electrode configuration, needle-plate and crossed electrode using laser-induced fluorescence method for understanding the plasma sterilization process.

1. Introduction

As one of the promising technology for biological and biomedical applications, sterilization using non-thermal plasma has recently been receiving much attention[1]. Especially, due to its ability to avoid glow-to-arc transition, dielectric barrier discharge (DBD) plasma provides an excellent alternative to conventional sterilization technique such as heat, chemical and radiation.

Although the exact mechanism for plasma sterilization is still unclear, it is widely accepted that radicals, i.e. active chemical species like OH, are playing the important role. In plasma, radicals from atoms or molecules are usually generated by high-energy electron impact and have very high reactivity. Once the radicals interact with the bacteria, chemical reaction like oxidation will occur immediately causing the death of bacteria. Understanding this process will be helpful to clarify the mechanism for plasma sterilization. However, because this reaction mechanism is still not clarified, it is necessary to observe both the generation and reaction process of radicals. Moreover, it is necessary to investigate the spatial distribution of radical in detail.

In this paper, in order to investigate the characteristic and distribution of OH radical in DBD plasma driven by nanosecond short pulses, the laser-induced fluorescence (LIF) experiments were carried out.

2. Experiment

In our experiment, two kinds of electrode configurations were prepared. One is a needle-plate electrode with the metal prate covered by a plastic film. The other consists of two crossed electrodes with both covered by ceramic pipes as shown in

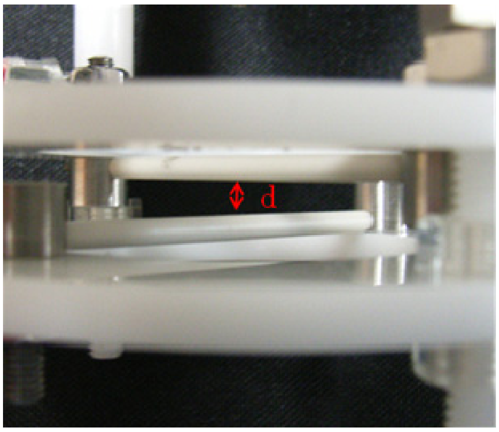


Fig. 1 Photograph of crossed electrode

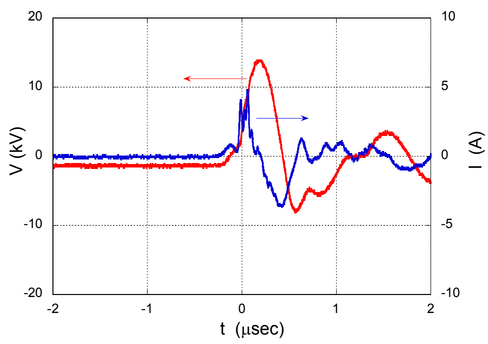


Fig. 2 Voltage and current waveform

Fig. 1. The gap distance (d) is taken from the shortest distance between two crossed ceramic pipes. The applied voltage has a duration of ~ 400 ns with a repetition rate of 1 kHz. The typical voltage and current waveforms are shown in Fig. 2. For the electric discharge at atmospheric pressure, voltage and the peak value of current were 13.0 kV and 5.5 A, respectively.

For the OH radical observation, LIF method[2][3] was employed. The experimental setup is shown in Fig. 3. The excitation wavelength of around 283 nm was generated by a dye laser (Quanta System D-100, Rhodamine 590) pumped with a frequency-doubled Nd:YAG-laser (Quanta System HY-710). Fluorescence light at around 310 nm was detected perpendicular to the laser propagation direction using a bandpass filter (Asahi Spectra, MZ0310) and a photomultiplier tube (Hamamatsu Photonics, R2256-2).

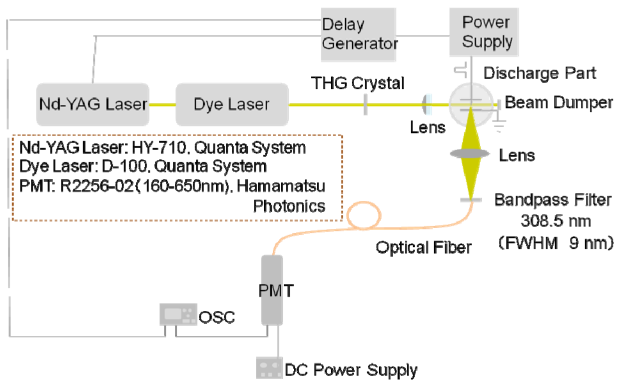


Fig. 3 Experimental setup of LIF measurement

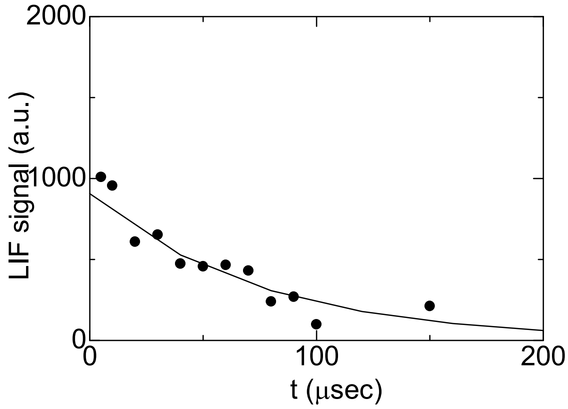
3. Results and discussion

Figures 4 show the time dependence of the OH LIF signal for both electrode configurations. Zero on the horizontal axis indicates the beginning of the light emission from the each discharge. Solid line is the curve fitted by using following equation.

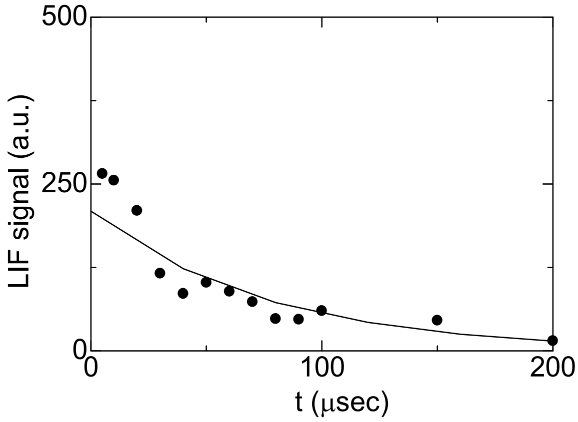
$$ln(LIF\ signal) = -1/\tau \cdot t + C$$

Here, τ is average life time and C is a constant. Moreover, in order to eliminate the influence of ozone interference[4], average value of OH LIF signal between 200 μsec and 900 μsec after discharge was subtracted from the observed value until 200 μsec.

It was observed that more OH radicals were generated by the cross electrode than by the needle-plate electrodes. The reason that OH radicals generated by cross electrodes did not diffuse since discharge plasma is having column shape, while the discharge plasma generated by needle-plate electrode spreads with cone shape. Average lifetimes of OH radicals for both electrodes were similar, that is 74 μsec for cross electrodes and is 75 μsec for needle-plate electrodes.



(a) Crossed electrode



(b) Needle-plate electrode

Fig. 4 Time dependence of OH LIF signal

4. Conclusion

Lifetimes for OH radicals were measured for DBD plasma with two kinds of electrode configuration, needle-plate and crossed electrode, by using LIF method. We will measure the temporal distribution of OH radicals for both electrodes in near future.

References

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