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High Speed Camera Diagnostics of Dielectric Barrier Discharges with Bubble Generating Porous Graphite Electrode in Solution

バブル生成用多孔質グラファイト電極を用いた液中誘電体バリア放電の高速度カメラ計測

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Dielectric barrier discharge(DBD) plasma is produced inside water using bubble discharge method. Bubbles are produced inside water using a porous graphite electrode. A high voltage pulsed device is used for power supply. The breakdown voltage is observed at 3kV with frequency of 5 kHz. The characteristics of plasma are studied using optical emission spectra, ozone analysis and oscillographs. To understand the role of bubbles in producing discharge inside solution and in order to improve it, high speed camera is used to study their behavior in our experiment. We also used methylene blue as organic pollutant to determine the efficacy of plasma in the degradation of wastewater.

1. Introduction

So far, there have been many researches on the production of plasma discharges inside the liquid to apply them for environmental fields or synthesis of novel materials. To produce plasma inside the liquid medium, it is a common technique to introduce the micro-bubble inside the liquid between the electrodes driven by high voltages. Recently, boiling point heating of the water by high power RF and microwave is used which consumes a lot of energy [1][2].

In the present study, we propose to use the porous graphite plate as the one of DBD electrodes and as well as the bubble generator. It has an advantage that the discharge in the gas bubble can be initiated at significantly lower input power, compared to the RF and microwave plasmas.

2. Experimental setup

Figure 1 shows a schematic drawing of the experimental set-up. The parallel-plate DBD configuration consists of a punched metal plate and porous graphite plate which is mounted metal holder. A very thin mica sheet is used as dielectric material. The space between two electrodes is kept variable but the most stable discharge is observed at 5mm of gap spacing. Figure 2 shows the DBD electrode. From the graphite electrode holder, when the gas is introduced through the tube, gas opens into the solution directly forming a large number of bubbles. On applying high pulsed voltage across the electrodes, we observed discharges in gas bubbles. Typical square waves voltages applied between electrodes were 2.0 ~5.0 kV at a frequency of 1~5 kHz (Figure 3). Optical emission spectroscopy is used to study the atomic or molecular composition generated in the plasma discharges in bubbles.

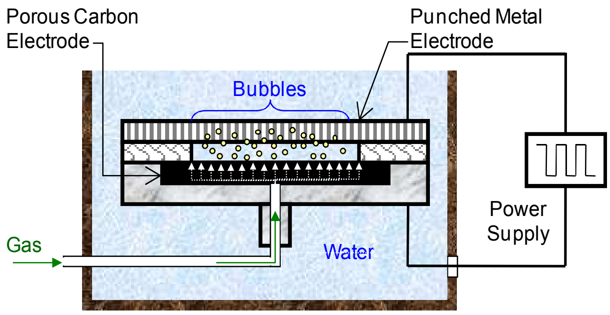


Fig. 1 Schematic drawing of the experimental setup.

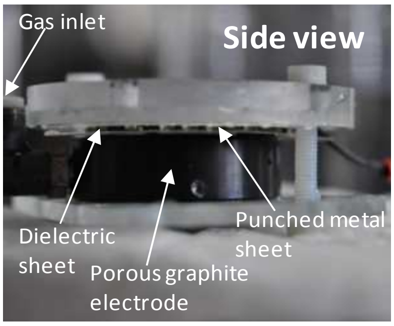


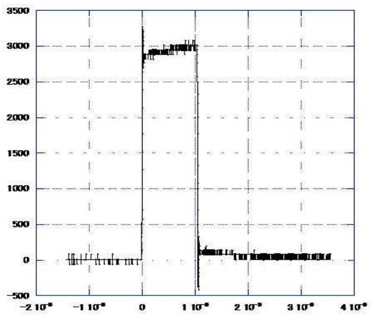
Fig. 2 DBD electrode setup

3. Results and discussion

Typical plasma with He and Ar gas inside water are shown in Fig. 4 (a) and (b) respectively. The photos are taken using camera from the top of the electrode set-up. The typical voltage is 3kV in both cases. Because of a high gas flow rate of ~ 200sccm, the plasma looks moving inside the water and plasma does not look uniform from the top.

We determine the efficiency of our plasma for environmental applications by using it for the degradation of 10mg/l methylene blue solution. In order to check its applications for commercial purposes, all experiments are with 2 liters of solution. Figure 5 shows the degradation of MB with time. It takes 6 hours for the 96% reduction of the MB.

(a)



(b)

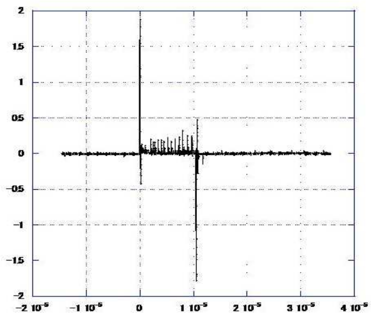
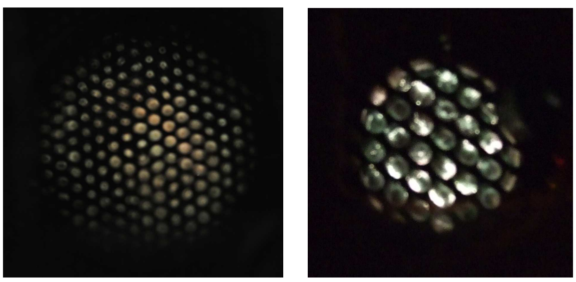


Fig. 3 Typical waveforms of (a) voltage and (b) current.



(a) (b)

Fig. 4 Typical pictures of plasma discharges produced between two electrodes in the water; (a) Gas: He and (b) Ar.

Since, time is an important parameter; our motive is to increase the efficiency of our plasma without input of more energy. So, one of the ways is to increase the number of bubbles in which discharge occurs.

Different gases with various gas flow rate is used in the experiment in order to understand the bubbles discharge. The number and size of the bubbles are of prime concern in our experiment as discharge inside the gas bubble produces a large amount of oxidizing species which is expected to be the reason behind wastewater treatment. So, It is obvious that more the number of bubbles discharge, more is the efficiency of plasma for applications. The number and size of the bubbles are partially dependent on the pore size of graphite bed of the graphite electrode but the physical nature of the bubbles are remarkably affected by the neighbor bubbles as the bubbles are continuously moving inside the water at high rate in the small space between two electrodes. In order to improve the discharge occurring in the bubbles, we need to understand the critical size and exact location of the bubbles between the electrodes. To understand behavior of the bubbles, we use high speed camera and we will show our results at the conference.

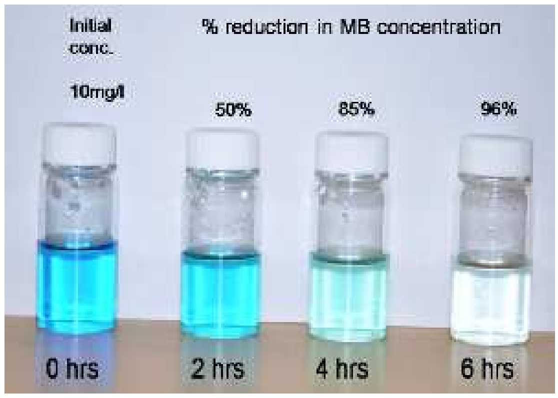


Fig. 5 Degradation of MB using Ar discharge

4. Conclusion

In this study, we presented the preliminary results on DBD plasma produced inside water using bubble discharge method. The DBD plasma was successfully produced inside the water. In order to determine the efficacy of plasma in the degradation of wastewater, we demonstrated the decomposition of methylene blue as organic pollutant. To understand the role of bubbles in producing discharge inside solution, we carried out measurement using a high speed camera. These results will be presented and discussed at the conference.

References

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