Treatment of EDTA Contained Reactor Coolant Using Water Dielectric Barrier Discharge Plasma

Sang-Heon Song, Daniel Kwon, and Gon-Ho Kim
Department of Nuclear Engineering, Seoul National University

1. Introduction

EDTA (Ethylene Diamine Tetraacetic Acid) is used as a main absorbent for the metal ion in the secondary loop of the nuclear reactor. Dissolving the wasted EDTA with low cost, therefore, is important issue for the maintenance of the nuclear power reactor and the protection of environment. EDTA is not easily biodegradable [1], furthermore these methods could make remained another pollutant as complex chemical compounds. Compared to chemical method, the physical methods, using the energetic particles and UVs, are more favorable because they dissociate the bonds of organic compounds directly without the secondary chemical reactions during the treatment. Recently, high energy electron beam [2], the plasma torch [3], and the water breakdown by high voltage pulse [4] are applied to treatment of the waste water contained chemicals. Here consideration is narrow down to improve the interaction between the plasma and the chemical bonds of EDTA because the energetic particles; activated radicals, and UVs, are abundant in plasmas. The new method adapted of the water DBD (dielectric barrier discharge) which plasma generates directly on the top of the water contained EDTA is proposed.

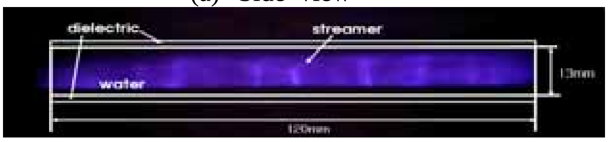
The application of DBD plasmas has been extended for cleaning the organic compounds from the contaminated surface and also for removing volatile organic chemicals (VOC) such as NO_x and SO_x from the exhausted gases [5]. Here, the water DBD reactor (SEMTECH, SD-DWG-04-1) is consisted that the one electrode is a ceramic insulator and another one is the water itself. Interestingly, the one electrode, the water, is not the solid dielectric electrode. In this study, therefore, the characteristics with driving frequency are considered and the feasibility of this new method for the DBD treatment of EDTA contained water is demonstrated.

2. Characteristics of Water-DBD

The features of DBD with water dielectric are shown in Fig. 1. Side (fig. 1a) and bottom (fig. 1b) views reveal that the streamer-type discharges generate on the water surface and plasmas covers the whole area of the water surface.

In order to consider the maximum power delivery to DBD generation, the effect of driving frequency is considered and the results are shown in Figs. 2 and 3, respectively. As shown in Fig. 2 (a), there are two regions with the applied voltage (thin line) on the

(a) Side view



(b) Bottom view

Fig. 1. The features of the DBD with water dielectric used for the decomposition of EDTA. Discharging volume is $120 \times 40.45 \times 13$ mm^3 with energy consumption 6.36×10^{-3} J.

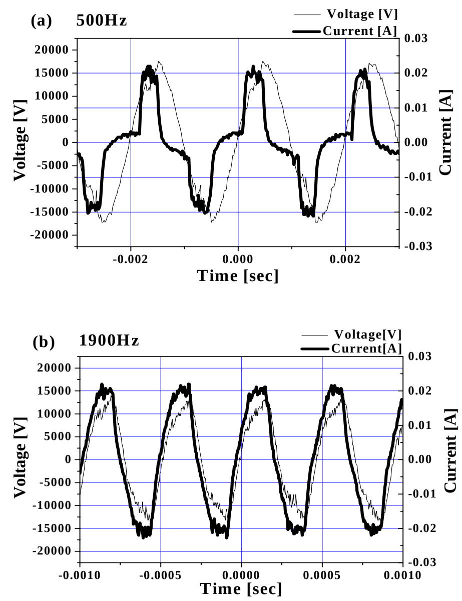


Fig. 2. The voltage (thin line) and current signal (thicker line) of DBD with water dielectric at different driving frequency.

reactor; a region whereof sustaining discharge current (thick line) and another region whereof no discharge current flowing (named of the dark discharge region). As increasing the operating frequency, the dark period is diminished as shown in Fig. 2 (b). With increasing the frequency further, the discharge cannot be fully developed due to quickly terminated voltage so that the current is reduced and the voltage and current has the same phase as shown in Fig. 2 (b). Thus, at the certain driving frequency, the applied voltage is fully grown and terminated before starting the dark period. It provides the optimum operational condition without power loss. Here it is obtained the optimum operation frequency, f_0, as 1.9kHz at 17kV.

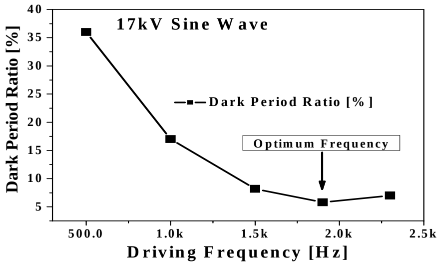


Fig. 3. The dark period ratio as the driving frequency.

The oscillation frequency of the current signals shown in Fig. 2 as the character of water DBDs is analyzed with FFT (Fast Fourier Transform) and the results are shown in Fig. 4. The current signal has an odd number of harmonics to the driving frequency. It implies that the driving force affects on the water surface oscillation and the discharge properties.

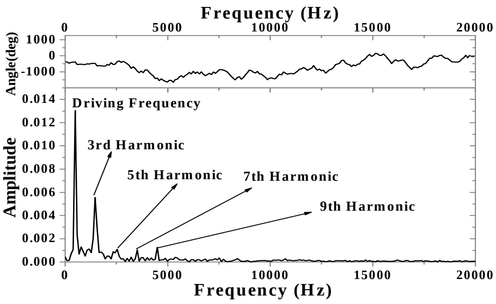


Fig. 4. FFT (Fast Fourier Transform) result for the current signal at the frequency of 500Hz.

Plasma enforces on the surface of water and the inertia of water will be resonant with the odd number harmonics of driving frequency because the power is supplied only on the top electrode. When the level of dielectric (water) is increased and the gap distance between two electrodes reduces, resulting that the induced electric field is stronger and the discharge current is increased.

3. Preliminary Results of Treatment EDTA Contained Water

For the decomposition of EDTA using DBD with water dielectric, EDTA was dissolved in the water 2*l* used as dielectric for discharge and was circulated by circulation pump as 4 *lpm*. EDTA becomes known to be soluble in water at room temperature up to 8mM about pH 3.0 to 3.5. HPLC (High Pressure Liquid Chromatography) was used as the analysis method [6]. The preliminary data of treatment with time is shown in Fig. 5. As shown the dotted line in figure, the reduction is experimentally proportional to the time as $y = 5.4\exp(-t/3.7) + 6$, where y is the peak of EDTA signal from the HPLC spectrum. Assuming that the EDTA in the water is dissociated through the simple reaction with the DBD plasmas, the variation is $dn(t)/dt = -n_0 \nu$, where $n(t)$ and n_0 are the density of EDTA and the initial value, and ν is the reaction rate, which is related to the interaction rate of energetic particles, radicals, and UVs with EDTA, respectively. From the preliminary results, e-folding time is 3.7 min, and the corresponding reaction rate is 0.27 (min-1), implying that the treatment is carried quite efficiently.

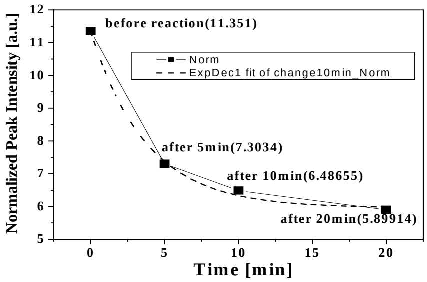


Fig. 5. The preliminary result about the reduced quantities of EDTA as the plasma treatment time.

4. Summary

Streamer mode plasma is generated in the water DBD. Driving frequency is an important parameter for improving the discharge efficiency. With the optimum frequency, the decomposition of EDTA in the water is effectively preceded in the water-DBD plasma.

Acknowledgement

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