Degradation of EDTA Complex by Underwater Dielectric Barrier Discharge

Heejae Lee[1,2] , Kangil Kim[1,3], Minwoo Kim[1] Seonkyung Jung[1], and Yong Cheol Hong[1,3,*]

[1] *Institute of Plasma Technology, Korea Institute of Fusion Energy(KFE), Korea*
[2] *Department of Applied plasma and quantum beam engineering, Jeonbujk National University, Korea*
[3] *University of Science & Technology, Daejeon, Rep. Korea*

Corresponding author: ychong@kfe.re.kr

Abstract: EDTA (Ethylenediaminetetraacetic acid) is a chelating agent that is widely used in various industrial processes, including nuclear power plants, where it is used to bind metal ions and prevent corrosion. EDTA should be released after degradation because it can risk human health and ecosystems. In this context, an underwater DBD plasma system was specially designed and optimized in terms of the gas flow rate and input power. And then, EDTA degradation experiments were carried out by measuring UV-vis spectroscopy. In the end, this study reveals the performance of an underwater DBD plasma system that could decompose the EDTA complex, meaning that the wastewaters from nuclear power plants can be purified in our plasma system.
Keywords: Dielectric Barrier Discharge(DBD), EDTA complex, Nuclear wastewater, Degradation.

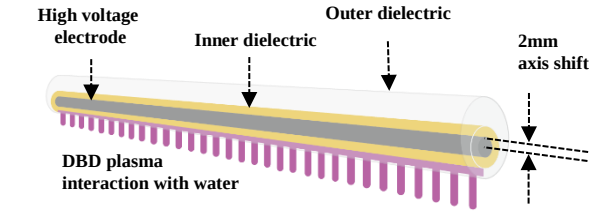
1. Introduction

The EDTA is a widely used chemical compound in various applications, including medicine, food, water treatment, and decommissioning of a nuclear power plant. EDTA is a chelating agent that can bind to metal ions and remove them from wastewater. EDTA can also bind to radioactive isotopes, which may be present in nuclear power plant wastewater streams due to the operation and maintenance of the plant. When a nuclear power plant is dismantled, various wastewater can be generated depending on the specific decommissioning process used; equipment and surfaces of the plant may be contaminated with radioactive isotopes during the decommissioning process of the nuclear power plant [1, 2]. EDTA contaminated with radioactive isotopes can be released into the environment through wastewater discharge or improper disposal. In this paper, we designed an underwater DBD plasma system and optimized it according to gas flow rate and input power. Furthermore, the degradation of EDTA and Cu-EDTA by an underwater DBD plasma system was analyzed using UV-vis spectroscopy.

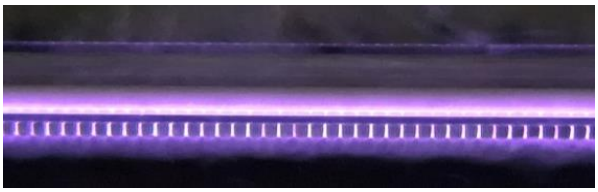
2. Experimental set-up

Fig. 1. (a) shows the schematic of the configuration of an underwater DBD plasma system. An underwater DBD plasma system consists of a high-voltage electrode, an inner dielectric, an outer dielectric, and a ground electrode. The high-voltage electrode and an inner dielectric are axis shift 2mm with an outer dielectric because the electric field can be further concentrated and discharged at a lower breakdown voltage than the coaxial configuration [3, 4].

Fig.1. (b) shows the underwater DBD plasma's close-up image while the plasma discharges into the water. When an underwater plasma is generated, the plasma interacts directly with water and generates UV, ozone, electrons, and various chemical species. The ozone and OH radicals have strong oxidizing power and react with organic compounds to break chemical bonds and finally mineralize them.



(a)

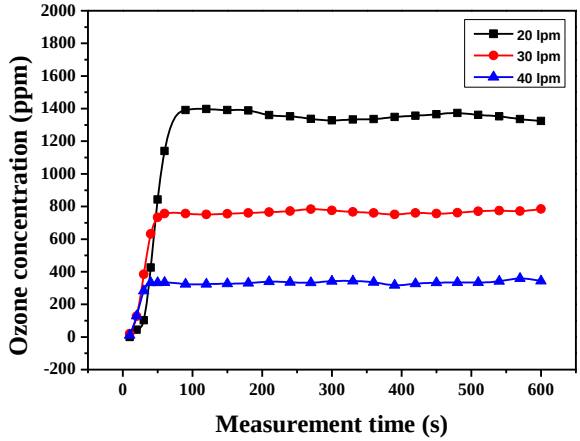


(b)

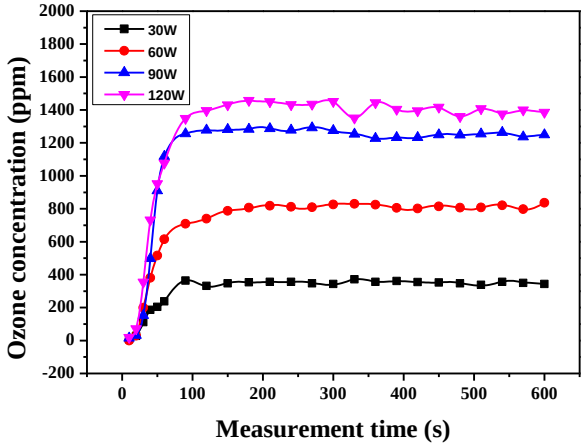
Fig. 1. (a) Schematic of underwater DBD plasma system and (b) close-up image of the plasma jets emitted into the water.

3. Results and discussion

Fig. 2. (a) show the graph of ozone concentration measurement according to the gas flow rate at 100 W. When the gas flow rate increased, that ozone concentration decreased. Because when the gas flow rate increases at the constant cross-sectional area, the time for gas to stay in the strong electric field is shorted, the amount of gas to be plasma is reduced. Fig. 2. (b) shows the graph of ozone concentration measurement according to input power at the gas flow rate 20 slm. In Fig. 2. (b) the ozone concentration is the highest at 120 W so, we had experimented with the gas flow rate and input power at 20 slm and 120 W, respectively.



(a)

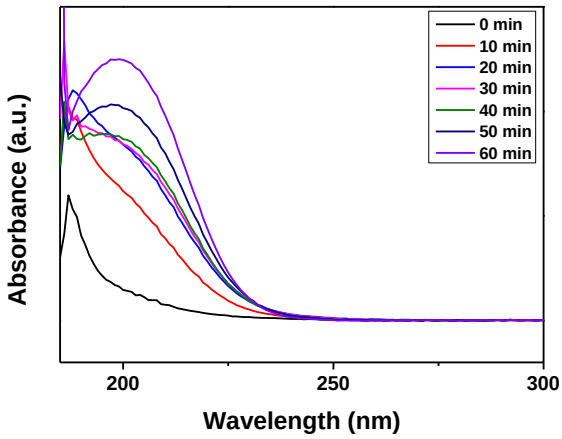


(b)

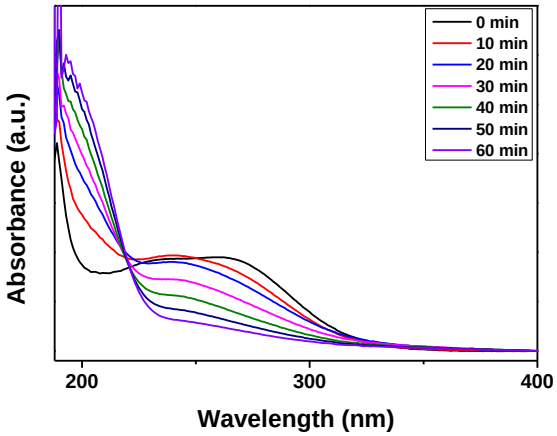
Fig.2. (a) Ozone concentration according to the gas flow rate at 100 W and (b) Ozone concentration according to input power at the gas flow rate 20 slm.

Fig. 3. show the UV-vis spectra of (a) EDTA and (b) Cu-EDTA, respectively. Fig. 3. (a) shows that the EDTA with a concentration of 40 ppm was detected at 187nm. When treated with underwater DBD plasma, the peak of 187 nm decreases, and the peak increases in approximately 200nm region.

Fig.3. (b) shows the UV-vis spectra of Cu-EDTA during plasma treatment. The main peak of Cu-EDTA decreases after the shift, and the peak increases at approximately 200 nm, as in Fig. 3. (a). UV-vis results show EDTA and Cu-EDTA are considered to be mineralized as they are decomposed by ozone and OH radicals, which are strong oxidants generated by an underwater DBD plasma system. According to Wang et al., when EDTA and Cu-EDTA were treated by plasma, they mineralized to CO_2, H_2O, and NO_3. Therefore, we considered the newly generated peak after underwater DBD plasma treatment as the NO_3 peak [2, 5].



(a)



(b)

Fig. 3. UV-vis spectra (a) EDTA and (b) Cu-EDTA according to the underwater DBD plasma treatment time

4. Conclusion

In conclusion, we designed and experimented with an underwater DBD plasma system to degrade EDTA and Cu-EDTA. An underwater DBD plasma system was optimized by the gas flow rate and input power, and the degradation with plasma treatment time was measured using UV-vis spectroscopy. The UV-vis spectra showed a decrease in peak with plasma treatment time, and it was confirmed that a new peak was detected. It is considered to be generated by NO_3 molecule peaks by combining nitrogen atoms in EDTA and Cu-EDTA as they are degraded by ozone and OH radicals generated during underwater DBD plasma discharge. Based on the results, an underwater DBD plasma system is expected to be a technology to degrade EDTA wastewater generated from nuclear power plants.

Acknowledgments

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