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Plasma–ozone combination process for decomposition of persistent organic compounds with efficient generation of hydrogen peroxide

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Accompanied by population growth and development of industry and agriculture, water pollution has become a global issue of significant concern. Conventional water treatment technologies include coagulation, sedimentation, filtration, ozonation, and disinfection using chlorine [1]. However, persistent organic compounds that are soluble in water cannot be treated with some of these conventional technologies. One of promising options for the treatment of persistent organic compounds is advanced oxidation processes (AOPs) which utilize OH radicals (·OH) for the decomposition of persistent organic compounds.

The use of plasma in contact with water is an AOP that has been studied as a promising technology for water treatment for several decades [2,3]. When plasma is generated in contact with water, ·OH is generated from water molecules. A portion of the gas-phase ·OH diffuses into the water and decomposes organic compounds. However, most of ·OH is lost by the self-quenching reaction that generates H_2O_2 and reactions with H_2O_2 and HO_2·, which causes a tradeoff between the decomposition rate and efficiency. To overcome this tradeoff issue, we have developed plasma–ozone combination processes in which ·OH is regenerated from H_2O_2 by reacting with O_3 as shown in Fig. 1 [3]. An O_3 generation technology using a dielectric barrier discharge has already been in practical use and commercial ozone generators are available. Therefore, the key for an effective treatment of persistent organic compounds by plasma–ozone combination processes is to achieve high H_2O_2 generation rate and efficiency by plasmas.

We have selected a diaphragm discharge plasma as the H_2O_2 source because relatively high H_2O_2 generation rate and efficiency were achieved. Fig. 2 shows a schematic diagram of a diaphragm discharge plasma reactor [4]. There is a 1 mm thick ceramic plate with ten microholes of 0.3 mm in diameter, which separates an acrylic container. A treatment solution is introduced into the reactor so that the microholes on the ceramic plate are submerged in the treatment solution, and high voltage is applied between the electrodes. Current concentration occurs in the microholes, generating bubbles due to Joule heating, and discharges occur inside the bubbles to generate plasma.

Due to the large input power to the plasma, the solution temperature easily increased. Thus, the effects of solution temperature on the plasma generation and H_2O_2 generation were investigated. The discharge current decreased significantly as the solution temperature increased, resulting in low power consumption. When we use a solution cooling system to keep the temperature, the H_2O_2 generation rate was constant. However, the H_2O_2 generation rate without cooling decreased when the solution temperature exceeded approximately 70°C. We have also investigated the effect of the waveform of applied voltage on the H_2O_2 generation to improve the H_2O_2 generation efficiency [4].

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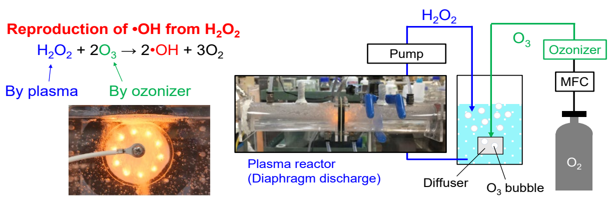

Figure 1. Plasma/ozone combination process.

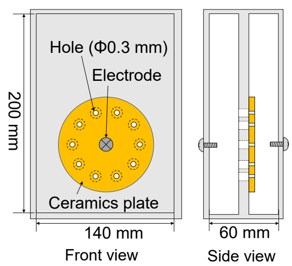

Figure 2. Diaphragm discharge plasma reactor.