§9. The Generation Mechanism of Microwave Applied Liquid Plasma

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In physics and chemistry, plasma is a substance similar to gas in which a certain portion of the particles are ionized. Plasma is typically defined as an electrically conducting medium generally consisting of negatively charged electrons, positively charged ions, and neutral atoms or molecules or both. Plasma gas applications are readily found in various industrial fields such as, surface treatments and etching in microelectronics, among others. In environmental remediation, plasma is widely used in certain air cleaners to sterilize and to decompose various volatile organic contaminants (VOCs). By contrast, reports of plasma generated in liquids have been rather scarce compared to gas-phase plasma. In addition, research in the use of plasma in liquids has been rather limited in environmental remediation. In the study reported herein, an energy-saving and simple liquid plasma device was manufactured using a novel integrated design that coupled microwaves and an ultrasonic homogenizer.

Result and discussion: A schematic illustration and a photograph of the microwave discharge liquid plasma with the supported ultrasonic cavitation system are displayed in Fig. 1. The microwave generator was constructed using a Micro Denshi Co., Ltd. 2.45-GHz microwave generator (maximal power, 1500 W), which was coupled to an isolator (air cooling device), a power monitor, and a three-stub tuner. The microwave which occurred from the magnetron generator carried out continuation irradiation through a metallic horn of ultrasonic in the waveguide. A metallic horn fixed to the position of the electric field maximum of a microwave wave guide tube, and a metallic horn was adjusted so that it might work also as a microwave antenna. A tip of a tungsten antenna about 1 mm was immersed in the liquid, and it irradiated with 2.45-GHz microwave, irradiating with an ultrasonic wave on the frequency of 19.5 kHz. The pink colored light water plasma was continuously produced by microwave irradiation alone at a power level of ca. 1000W (power consumption) for the ignition in water under normal atmospheric conditions. However, under simultaneous microwave irradiation and ultrasonic cavitation at a power level of ca. 90 W, the pink colored water plasma could be generated at a microwave power level of 500W (see Fig. 2b), i.e. at 50% power by simultaneous ultrasonic cavitation. The microwave power was decreased to 700W when microwave irradiation alone was used and to 220W for microwave irradiation/ultrasonic cavitation while maintaining the plasma. Thus, the microwave power could be decreased by 69% for continued plasma generation. Consequently, the decrease in microwave power can lower the temperature around the tip of the titanium/tungsten antenna. The plasma generated in water produced such active species as the •OH, •H, HO_2• and •O^1(D) radicals.

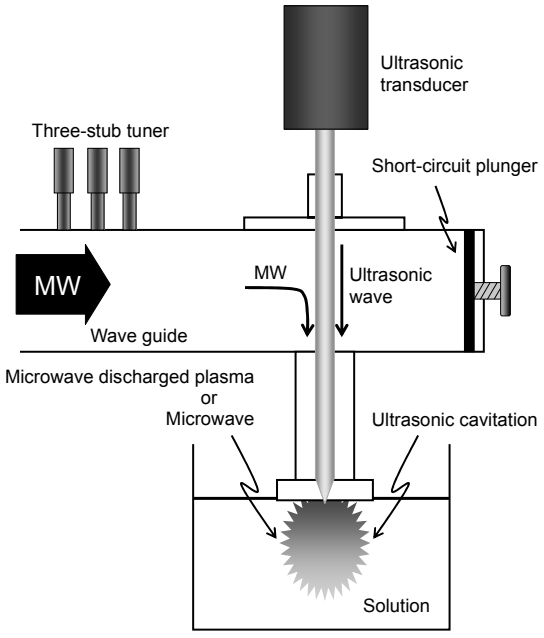

Fig. 1 – Schematic illustration of the microwave discharge plasma and ultrasonic cavitations system