9th Asia-Pacific Conference on Plasma Physics, 21-26 Sep, 2025 at Fukuoka

Cold plasma within a stable supercavitation bubble - a breakthrough technology for efficient inactivation of viruses in water

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Alternative methods for the inactivation of viruses in water have recently attracted the scientific community's attention. The methods should enable rapid inactivation at room temperature and should be free from chemicals. The application of gaseous plasma fulfills these regulations but may be impractical because plasma sustained at atmospheric pressure is limited to the volume of the large electric field.

A useful method for sustaining plasma at low pressure despite the water being at atmospheric pressure is the application of hydrodynamic cavitation. The saturated water vapor pressure at the water room temperature is established in a stable supercavitation bubble of volume several cm^3, and the electrodes are immersed in a bubble and powered with a suitable voltage supply to sustain the non-equilibrium gaseous plasma in a glow discharge mode. A preferred embodiment is illustrated in Figure 1. Plasma sustained in water vapor at the pressure of a few 10 mbar is a rich source of OH radicals, which are dissolved in liquid. The high speed of liquid water passing the cavitation nozzle enables optimal mixing, so a few passages of water enable the inactivation of viruses for 5 decades by an irreversible interaction of OH radicals with organic matter. The water pH does not change significantly, and the concentration of hydrogen peroxide remains below 1 mg/L, so the effect of H_2O_2 on virus inactivation is marginal. The preferred discharge power is between 10 and 100 W.

An alternative to hydrodynamic cavitation is the irradiation of water at atmospheric pressure with vacuum ultraviolet (VUV) radiation. An extensive source of VUV radiation is inductively coupled radiofrequency (RF) hydrogen plasma sustained in the H mode. As much as about 10% of discharge power is converted to VUV radiation in the preferred range of discharge parameters. A VUV transparent window separates low-pressure plasma from the liquid water, and the concentration of active viruses drops by 5 orders of magnitude within a minute of treatment. The rapid inactivation in this configuration is also attributed to the irreversible interaction of viruses with OH radicals, as well as some other effects.

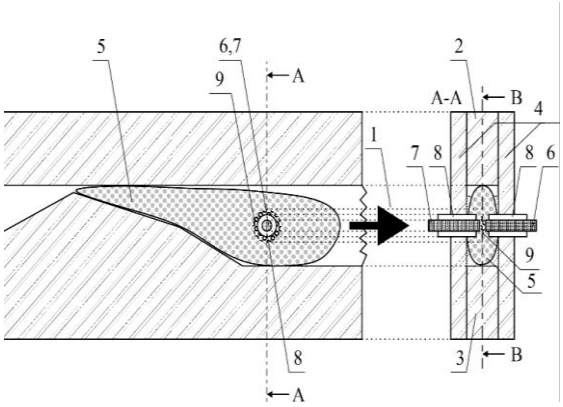

Figure 1: Figure illustrating the formation of a bubble of water vapor (5) inside liquid water at atmospheric or higher pressure. Electrodes (6, 7) are immersed into the bubble and sustain stable plasma in the bubble. The arrow (1) indicates the direction of the water flow.

References

[1] A. Filipić *et al*, Cold plasma, a new hope in the field of virus in-activation, Trends in biotechnology, **38**, 1278-1291 (2020)

[2] M. Zver, *et al,* Non-thermal plasma inactivation of viruses in water solutions, J. Water Process Eng. **53**, 103839-1-103839-12 (2023)

[3] G. Primc *et al* Method and device for disinfection of liquid, US 11,807,555 B2 (2023)

[4] A. Filipić *et al* Cold plasma within a stable supercavitation bubble - a breakthrough technology for efficient inactivation of viruses in water, Environment International **182,** 108285-1-108285-10 (2023)

[5] M. Zver *et al,* Characterization of low-pressure plasma radiation and its usage for inactivation of waterborne viruses, Separation and Purification Technology **254**, 128691 (2025)