Comparison Study of Sliding and Water Electrode Discharges for Organic Pollutant Degradation

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Abstract: This study evaluates the degradation efficiency of a nanosecond pulsed, sliding discharge and a water electrode discharge for removing organic pollutants such as Rhodamine-B (Rh-B) from water. Findings show that the water electrode discharge achieved comparable Rh-B degradation (>90%) but with >75 times higher energy efficiency compared with the sliding discharge.

1. Introduction

Non-thermal plasma technology, considered one of the advanced oxidation methods, is anticipated to break down harmful pollutants in the environmental matrix. The characteristics of plasma are influenced by various factors including electrode geometry, the applied electric field, the gases utilized, and the working environment.

This study assesses the degradation efficacy of two different plasma-based treatment approaches - nanosecond pulsed sliding discharge and water electrode discharge -for removing Rhodamine-B (Rh-B), an organic pollutant, from water. To examine the influence of electrode designs on the discharge initiation, two-dimensional electrostatic modeling was performed by determining the electric field distribution at the gas-water interface prior to discharge breakdown for both systems.

2. Methods

Both discharges were generated using rectangular plastic containers where aluminium strip lines were arranged at opposite locations to serve as the anode and cathode. Similar electrode configurations for sliding discharges were described previously [1], where the anode and cathode were placed approximately on the same plane that is above the liquid surface. The electrode configuration for the water electrode discharge has the similar arrangement except that the cathode strip line is at the bottom of the liquid and has vertical offset from the anode strip line. For the treatment, a peristaltic pump circulated the solution at 1 mL/s, while ambient air or nitrogen was introduced through a mass flow controller (MFC) at 990 sccm. Sliding discharges were produced at the gas-water interface in ambient air or nitrogen by applying 300-ns, 15–20 kV pulses at a frequency of 500 Hz. Similarly, direct discharge was generated with the water electrode configuration applying 300 ns, 15 kV pulses at 500 Hz.

3. Results and Discussion

The sliding discharge system achieved 30% (air) and 19% (nitrogen) reduction per cycle, while the water electrode discharge system showed 22% (air) and 13% (nitrogen) reduction. After nine treatment cycles, over 90% Rh-B degradation was achieved in both systems, with the sliding discharge operating at 0.12 J per pulse (60 W) in air, while the water electrode discharge reached >90% degradation at 0.0015 J per pulse (0.8 W), making it 75 times more energy-efficient.

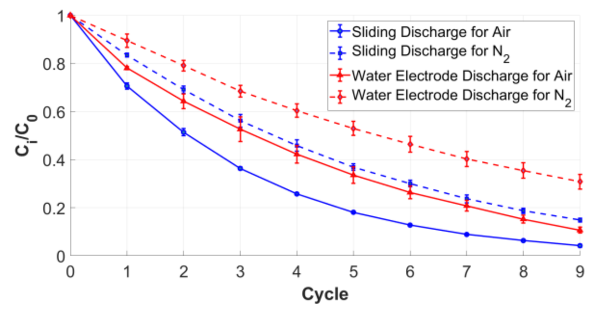

Fig. 1.: Relative concentration of Rh-B over multiple treatment cycles for sliding discharge and water electrode discharge using air and N_2 as the working gas

4. Conclusion

This study evaluates nanosecond sliding discharge and water electrode discharge plasma reactors for organic pollutant degradation. Both systems achieved over 90% removal, with the water electrode discharge system being 75 times more energy efficient. The results highlight the impact of electrode configurations on plasma behavior and pollutant removal.

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