UNIVERSITY OF MINNESOTA

ISPC26

26th International Symposium on Plasma Chemistry

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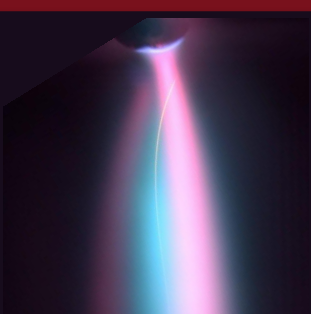

Welcome

Dear Colleagues and Friends,

We are pleased to welcome you to the 26th International Symposium on Plasma Chemistry (ISPC26), on the campus of the University of Minnesota in Minneapolis, USA.

The symposium aims to bring together leading experts, academics, engineers, practitioners, and students working in the field of plasma chemistry and to establish an informal forum for discussing plasma chemistry, the exchange of new ideas, and to foster new connections and collaborations. We hope that the symposium will offer you a unique opportunity to gain comprehensive first-hand information on the latest developments in the field of plasma chemistry.

ISPC was held for the first time in 1973 and is sponsored by the International Plasma Chemistry Society (IPCS), the largest international not-for-profit professional society specializing in plasma chemistry. The IPCS was established in 1999 as the successor of the association named 'the International Union of Pure and Applied Chemistry (IUPAC) Subcommittee on Plasma Chemistry.' As some of you might remember, ISPC 12 took place here in Minneapolis thirty years ago (1995) chaired by Professor Joachim Heberlein.

This year, the IPCS Summer School is collocated with the US Low-Temperature Plasma Summer School and the ASPIRE Summer School, and took place over the weekend prior to ISPC26. The school had as goal to provide an opportunity for graduate students and early-career researchers and engineers to be immersed in the fundamentals and applications of low-temperature plasmas and to learn from leading researchers in their field. There was a special session on Plasma Materials Processing for Microelectronics Fabrication. We also offer a special invited session on Monday morning on the topic of plasma chemistry for microelectronics fabrication.

The campus of the University of Minnesota Twin Cities is located in the metropolitan area of the cities of Minneapolis and Saint Paul and is connected by light rail to the downtown areas and also to the airport. We hope you also have the opportunity to explore the Twin Cities area and enjoy the natural beauty of the Mississippi River and parks, along with the region's rich industrial history, vibrant culture, and growing craft beer scene.

Peter J. Bruggeman
University of Minnesota, USA
Chair ISPC 26

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Tuning the plasma-activated water by controlling the transport of reactive species from cold plasma into water bulk and aerosols

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Abstract: In this contribution, we experimentally studied the transport of typical air plasma long-lived reactive oxygen and nitrogen species (RONS): HNO_2, NO_2, NO, H_2O_2, and O_3 into water bulk water or electrosprayed or nebulized aerosols. Using direct or indirect interaction of the plasma discharge with electrosprayed aerosol, plasma-activated water with selected RONS composition were generated.

1. Introduction

Reactive species generated by cold atmospheric plasma of electrical discharges can be transported into liquids, particularly water, to produce a chemically active plasma-activated water (PAW). PAW represents a great potential for disinfection and wastewater treatment, especially to inactivate pathogenic microorganisms, and also acts as a source of nitrogen to promote the plant growth.

PAW can be prepared by a variety of plasma-liquid interacting systems. Typically, cold plasmas get in direct contact with bulk water in batch or flow systems. However, systems where plasma interacts with liquid aerosols bring multiple advantages, exhibiting high chemical reactivity within small liquid microdroplet volumes [1].

We experimentally studied the transport of typical air plasma long-lived reactive oxygen and nitrogen species (RONS): HNO_2, NO_2, NO, H_2O_2, and O_3 into water. To better understand the transport mechanisms, RONS were generated either one by one by external sources, or in mixture by a hybrid streamer-transient spark plasma discharge, in contact with bulk water or aerosol of charged electrospray (ES) or non-charged nebulized microdroplets with a large gas/plasma-water interface. [2]

We found that NO's contribution to nitrite (NO_2^-) ion formation in PAW was negligible, NO_2 contributed to about 10%, while the dominant contributor to NO_2^- was gaseous HNO_2. A higher transport efficiency of O_3, and a much higher formation efficiency of NO_2^- from gaseous NO_2 or HNO_2 than those predicted by Henry's law was observed, compared to the transport efficiency of H_2O_2 (Fig. 1). The improvement of the transport/formation efficiencies by aerosol microdroplets, with their surface area significantly enhanced compared to the bulk water, is most evident for the solvation enhancement of the weakly soluble O_3. NO_2^- formation efficiency was strongly improved in ES microdroplets with respect to bulk water and even to nebulized microdroplets, which is likely due to charge effects enhancing the formation of aqueous NO_2^-.

We also studied the generation of PAW by transient spark discharge in various gases (N_2, O_2, and dry or humidified synthetic air) with either direct or indirect contact of the discharge with electrosprayed water microdroplets. In direct contact, ES microdroplets were generated within the discharge zone. In the indirect treatment, the gas was first treated by the discharge to generate the active species, and then sprayed by the ES water aerosol. Using direct or indirect treatment, and

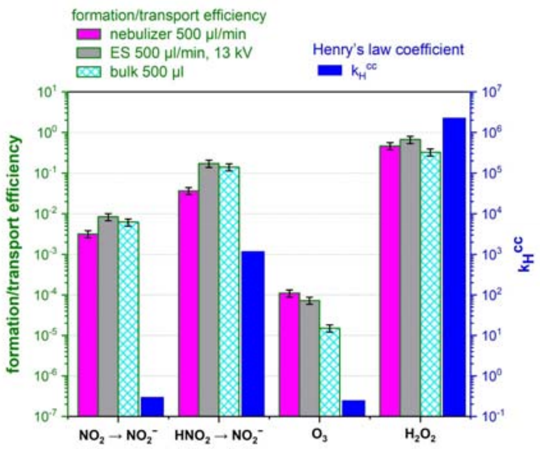

Fig. 1. Comparison of the formation efficiency of NO_2^- from NO_2 and HNO_2, and the transport efficiency of O_3 and H_2O_2 in the nebulized and electrosprayed microdroplets, and bulk water, with the dimensionless Henry's law coefficients of NO_2, HNO_2, O_3, and H_2O_2.#

different inlet gases and input energy densities, PAWs with different compositions were generated [3].

Finally, by combining two distinct plasma sources - a transient spark generating NO_x and nitrous/nitric acids, and an ozone generator based on dielectric barrier discharge - we generated two distinct types of PAW. The first type, rich in NO_2^- and H_2O_2 exhibits strong antimicrobial properties. The second type of PAW rich in nitrate ions (NO_3^-), shows promise as a "green" fertilizer for plant growth, with a lower impact on global climate than Haber-Bosch ammonia based synthetic nitrogen-based fertilizers.

This study contributes to a deeper understanding of the transport mechanism of gaseous plasma RONS into water that can optimize the design of plasma–liquid interaction systems to efficiently produce selected RONS in water.

Acknowledgement

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References

[1] M. Janda et al., Plasma Process. Polym. 22: e2400275 (2025).

[2] M. Hassan et al., Plasma Chem. Plasma. Process. 45, 161–189 (2025).

[3] P. Pareek et al., Chem. Eng. J. 493, 152583 (2024).