Plasma Science and Technology
Room 201 ABCD W - Session PS2-WeA

Atmospheric Plasma

Moderators: Michael Gordon, University of California at Santa Barbara, **Kenji Ishikawa**, Nagoya University, **Scott Walton**, Naval Research Laboratory

3:00pm **PS2-WeA-4 Investigating the Thermal Behavior of Atmospheric Pressure Plasma Jets on Different Surface Types*, Vladimir Milosavljevic,*** School of Physics, Clinical & Optometric Sciences, Technological University Dublin, Ireland & Faculty of Physics, University of Belgrade, Serbia, Ireland*; James Lalor,* School of Physics, Clinical & Optometric Sciences, Technological University Dublin, Ireland

Atmospheric pressure nonthermal plasmas hold great promise for applications in environmental management, energy transformation, and material engineering. Although they operate at room temperature, nonthermal plasmas produce highly reactive species that can modify surfaces at the plasma/surface interface. This study examines the interaction of an Argon atmospheric pressure plasma jet (APPJ) with both insulating and conductive mesh surfaces. The dielectric barrier discharge APPJ functioned at 8 kV and 21 kHz.

Previous research has analyzed how an atmospheric pressure plasma jet behaves when directed perpendicularly onto both dielectric and conductive flat surfaces, revealing that the jet maintains a laminar flow, expanding radially from the impact point. The highest temperature occurs at the central impact zone, with a radial decrease outward due to jet expansion and heat dissipation along the surface.

In contrast, this study introduces a novel method by treating a mesh substrate with 0.8 mm x 0.8 mm openings, allowing partial gas plume penetration. This enables thermal mapping of the interaction between the APPJ and the substrate, offering insights into the jet plume's thermal cross-section. A series of experiments explored how different materials, such as metals and polymers, respond to the APPJ's thermal energy by analyzing temperature rise, heat distribution, and cooling rates. The distance between the APPJ nozzle and the mesh surface (standoff distance) was adjusted from 0 to 70 mm, with thermal profiles recorded to identify the optimal distance for preventing surface overheating. Additionally, treatment time was varied between 0 and 240 seconds at a fixed standoff distance to evaluate thermal effects over different exposure durations.

A FLIR i7 thermal camera with a 140 x 140-pixel resolution was employed to capture precise thermal images, enabling detailed measurement of temperature gradients across treated surfaces. Its high accuracy and sensitivity were crucial for assessing the APPJ's thermal impact on various materials, ensuring reliable data acquisition throughout the study.

This research investigates the thermal behavior of APPJ treatments on metallic and polymeric surfaces, emphasizing the effects of standoff distance and treatment duration. The results indicate that steel, with its high thermal conductivity, heats and cools rapidly, whereas polypropylene retains heat longer due to slower heating. Findings also demonstrate that reduced standoff distances increase energy transfer, with material properties playing a crucial role in temperature distribution.

3:15pm **PS2-WeA-5 Controlling Nitrogen Product Distributions in Plasma Electrolytic Reactors for Microbial Growth*, Brandon Kamiyama,*** *Diep Nguyen, Mohammadali Eslamisaray, Emily Gillmore, Angela Tomita, Ting Lu, R. Mohan Sankaran,* University of Illinois at Urbana Champaign

Fixed forms of nitrogen are essential for the growth of plants that enable global food production, and for the growth of microorganisms which power critical processes beyond agriculture such as biomanufacturing and chemical production. Currently, nitrogen fixation is predominantly carried out by industrial processes (e.g., Haber-Bosch, Ostwald processes) that have large physical and environmental footprints. The development of alternative methods that are sustainable and deployable at a small scale for point-of-use production has emerged as one of our critical technological challenges. Among the different approaches being explored, plasmas in contact with liquids have shown great promise, capable of reacting nitrogen in air with water as a source of hydrogen at atmospheric pressure and near room temperature. However, a key challenge is that these processes generate many nitrogen products, including ammonium, nitrate, and nitrite ions, in addition to other products such as hydrogen peroxide.

In this work, we studied a direct-current plasma-based electrolytic reactor and correlated process conditions such as gas feed, pH, and electrode polarity with product yields and selectivity. In particular, molecular oxygen and pH were found to be key for controlling the selectivity between the reductive and oxidative species. These results provided insight into possible reaction mechanisms and enabled us to selectively synthesize nitrogen products as substrates for microbial growth and biosynthesis.

3:30pm **PS2-WeA-6 Particle-in-Cell Modeling of the Reverse Anode Sheath in Parallel-Plate Sub-Atmospheric Pressure Hydrogen Plasmas*, Brian Jensen,*** Princeton University Plasma Physics Lab*; David Graves,* Princeton University

Parallel-plate electrode plasmas are widely used as large-area semiconductor processing tools [1-4]. In these systems, non-equilibrium electrons with non-Maxwellian electron energy distribution functions (EEDFs) drive gas-phase reactions and enable surface modification [5]. Particle-in-cell (PIC) simulations are well-suited to capture such effects, but at pressures above a few torr, 2D and 3D simulations with appropriate reactor chemistry become increasingly expensive due to disparities between plasma and chemical length and time scales. To investigate these systems, this work presents a coupled 1D PIC-fluid model for hydrogen plasma reactors and studies the effectiveness of DC parallel plate systems as tools for large-area processing, particularly for diamond substrates. We characterize the reverse anode sheath for systems with gas pressures exceeding 10 Torr and describe the range of unique processing conditions available at the anode surface under these conditions.

[1] P. Chabert and N. Braithwaite, Physics of Radio-Frequency Plasmas (Cambridge University Press, 2011).

[2] M. A. Lieberman and A. J. Lichtenberg, Principles of Plasma Discharges and Materials Processing: Lieberman/Plasma 2e (John Wiley & Sons, Inc., 2005).

[3] S. Rauf, K. Bera, and K. Collins, Plasma Sources Sci. Technol. 19, 015014 (2009).

[4] Y.-X. Liu et al., Plasma Sources Sci. Technol. 28, 075005 (2019).

[5] Y.-X. Liu et al., Chinese Phys. B 31, 085202 (2022).

Author Index

Bold page numbers indicate presenter