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

Variations in Discharge Characteristics of Bipolar Pulsed Cold Atmospheric Plasma Jets Induced by Liquid Conductivity

Abhijit Mishra[1] and Ram Prakash[1]
[1]Department of Physics, Indian Institute of Technology Jodhpur, India
e-mail (speaker): abhijit.1@iitj.ac.in

Cold atmospheric plasma (CAP) jets have emerged as a transformative technology for different biomedical and industrial applications, whose performance depends on the type of treated substrate [1], [2]. The study of plasma-liquid interactions has garnered significant interest within the scientific community due to its wide-ranging applications [3], [4]. Advancing these applications and developing mature technologies requires a deep understanding of the fundamental science behind plasma-liquid systems. This study investigates the effects of liquid conductivity on the discharge properties of bipolar pulsed CAP jets, utilizing helium and argon as working gases. The CAP jet is optimized for applied voltage, frequency, power consumption, and gas flow rate, while optical emission spectroscopy (OES) is employed to analyze key plasma properties and reactive species generation. Liquids with varying conductivity and composition –such as deionized (DI) water, tap water, wastewater, and seawater –are examined to understand their influence on plasma behavior.

Systematic analysis of electro-optical characteristics including V-I characteristics is conducted. A Collisional Radiative (CR) model, combined with the Line ratio method and deviation parameter (Δ), is used to extract electron temperature (T_e) and electron density (n_e) from the emission spectra, supported by cross-section data from Open-ADAS [5]. Additionally, plasma treated liquid properties, including nitrite, nitrate, hydrogen peroxide concentration, pH, conductivity, and OH concentration, are analyzed to evaluate the impact of CAP jet treatment.

The results demonstrate that liquid conductivity plays a significant role in discharge behavior. Specifically, higher conductivity leads to a reduction in electron temperature (T_e), an increase in electron density (n_e), and enhanced generation of reactive species. In helium plasma jets, however, the effect of liquid conductivity is less pronounced. Spectroscopic analysis reveals variations in the intensity of key species, such as OH, N_2, and O, which are crucial for different applications. These findings offer valuable insights into optimizing the parameters of CAP jets, especially in contexts where interaction with conductive liquids is unavoidable. Conductivity emerges as a critical factor across different media, and since many biomedical targets contain high water content, understanding CAP jet interactions with liquid targets is essential for comprehending complex plasma-tissue interactions. This work advances our understanding of plasma-liquid interactions and lays the groundwork for tailored plasma treatments in biomedical, environmental, and materials processing applications.

References

[1] T. Darny, J.-M. Pouvesle, V. Puech, C. Douat, S. Dozias, and E. Robert, "Analysis of conductive target influence in plasma jet experiments through helium metastable and electric field measurements," Plasma Sources Sci Technol, vol. 26, no. 4, p. 045008, Mar. 2017, doi: 10.1088/1361-6595/aa5b15.

[2] A. Mishra, S. P., P. Kumar, and R. Prakash, "Comparative analysis of disinfection effectiveness of Helium CAP jet, sodium hypochlorite and QMix in Enterococcus faecalis infected root canals," Radiation Effects and Defects in Solids, vol. 179, no. 7–8, pp. 1009–1016, Jul. 2024, doi: 10.1080/10420150.2024.2378428.

[3] F. Rezaei, P. Vanraes, A. Nikiforov, R. Morent, and N. De Geyter, "Applications of Plasma-Liquid Systems: A Review," Materials, vol. 12, no. 17, p. 2751, Aug. 2019, doi: 10.3390/ma12172751.

[4] S. Pandey, R. Mishra, A. Mishra, S. Jangra, and R. Prakash, "Plasma activated water generation in pin-to-plate gas phase DBD-based plasma source for enhanced biochemical activity," Phys Lett A, vol. 535, p. 130245, Mar. 2025, doi: 10.1016/j.physleta.2025.130245.

[5] A. Mishra, R. Mishra, Y. H. Siddiqui, S. Jangra, S. Pandey, and R. Prakash, "Analysis of discharge parameters of an argon cold atmospheric pressure plasma jet and its impact on surface characteristics of White Grapes," Phys Scr, vol. 99, no. 10, p. 105615, Oct. 2024, doi: 10.1088/1402-4896/ad7b8c.