Seminar

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Institute for Plasma Research

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Title: Spectroscopic Diagnostics and Machine Learning for Optimizing Nonthermal Atmospheric Pressure Plasma Jets

Speaker: Dr. P S Naga Sai Raghavendra Srikar
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Date: 02nd May 2025 (Friday)

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Venue: Online link: https://meet.google.com/aor-ytkn-udp

Abstract

Atmospheric pressure low-temperature plasmas (APLTPs) have attracted significant attention for applications in water purification, agriculture, food processing, and materials synthesis due to their rich composition of electrons, ions, excited states, and reactive chemical species (RCS). Operating at atmospheric pressure allows for continuous processing without the need for external chemical inputs. To investigate and address many challenges in operating and optimizing APLTPs, a dielectric barrier discharge-based argon plasma jet (Ar-NTAPPJ) was developed and operated across a range of flow rates, applied voltages, and electrode gaps. Non-invasive optical emission spectroscopy (OES) was employed for plasma diagnostics, with T_e estimated using a collisional-radiative (CR) model and electron density (n_e) determined from Stark broadening of the Ar 696.5 nm line. These diagnostics were coupled with chemical probe-based quantification of key RCS such as hydroxyl radicals (•OH) and hydrogen peroxide (H_2O_2). The impact of varying operating conditions on plasma characteristics and RCS production was systematically analyzed, and a strong correlation with the energy efficiency of atrazine degradation a model pollutant was established, demonstrating the potential for optimized plasma-driven chemical processing [1].

To further enhance diagnostic speed and enable real-time analysis, machine learning (ML) techniques were integrated with the OES-CR framework. Random Forest and Deep Neural Network models were trained on synthetic data generated from the CR model to predict T_e with high accuracy (R^2=0.996 for RF and R^2 = 0.996 for DNN [2]. A multi-jet plasma configuration was also developed to explore scalability. Emissions from key species such as Ar I, OH, N_2, and O I were monitored, and dimensionality reduction using principal component analysis (PCA) was performed. The ML models successfully captured the relationship between operating parameters and spectral features, enabling effective optimization of plasma conditions. This work demonstrates how the integration of advanced diagnostics, machine learning, and plasma chemistry can lead to deeper insights and improved control of nonthermal plasmas, paving the way for their wider adoption in industrial and environmental applications. The detailed results will be discussed in the talk.

References

[1] P. S. N. S. R. Srikar, S. M. Allabakshi, S. M. Maliyekkal, and R. K. Gangwar, "Development of efficient nonthermal atmospheric-pressure Ar-plasma jet through simultaneous spectroscopic characterization and radical quantification," *Journal of Physics D: Applied Physics*, vol. 57, p. 395204, 2024. Link to article.

[2] P. S. N. S. R. Srikar, I. Suresh, and R. K. Gangwar, "Accelerated real-time plasma diagnostics: Integrating argon collisional-radiative models with machine learning methods," *Spectrochimica Acta Part B: Atomic Spectroscopy*, vol. 215, p. 106909, 2024. Link to article.