Diagnostics of atmospheric pressure plasmas: recent progress and challenges

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Low temperature atmospheric pressure plasmas (APPs) interfacing with solid and liquid substrates have been extensively investigated in the context of material processing and synthesis, pollution control, decontamination, new medical treatment procedures and sustainable energy processes. These applications are enabled by the ability of APPs to deliver highly reactive plasma species to surfaces at near ambient temperatures. The plasma-produced reactive species and resulting fluxes to the interfacing substrate can in principle be controlled by voltage waveforms and feed gas composition. However, plasmas are self-organizing systems and the strong non-linear coupling between the plasma and substrate leads to complex plasma-surface interactions which remain not well understood to date and have a major, and sometimes unknown, impact on the plasma properties and species fluxes impinging on the substrate.

To gain a better understanding of the underlying plasma processes in complex APPs, a requirement to fully exploit the advantages of plasmas for many applications, there is a strong need for improved diagnostics or extension of the current boundaries of available diagnostics. The properties and species density distributions of APPs can have spatial gradients at micrometer length scales and exhibit transient behavior down to nanosecond timescales. This transient nature of APPs is further enhanced due to ubiquitous plasma instabilities at atmospheric pressure posing enormous challenges on diagnostics and their interpretation.

In this presentation, we will discuss these unique diagnostic challenges in probing plasma kinetics and chemistry, species flux measurements to substrates including boundary layer effects, and the measurement of highly dynamic plasma instabilities. This will include time and spatially resolved Thomson scattering measurements performed during the development of plasma instabilities in pulsed discharges which allowed us to describe the underpinning mechanisms that can trigger or prevent the formation of such plasma instabilities in the presence of a liquid electrode. We will also report on microscopic laser induced fluorescence measurements and how such measurements allow us to deduce sticking coefficients of radicals on substrates under realistic plasma conditions, critical input data for plasma models, and deduce species fluxes to solutions that allow us to quantitatively explain plasma-induced redox reactions with probe molecules in the liquid phase.

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References

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