Electron dynamics and plasma jet formation in atmospheric pressure plasmas

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Non-thermal atmospheric pressure plasma jets are of particular technological interest. They have the capability of delivering a unique reactive dry chemistry at room temperature and pressure to delicate surfaces. With improved understanding of these devices there is potential to control defined compositions of reactive species for surface modifications and bio-medical applications, such as in plasma medicine [1]. In this presentation we examine the electron dynamics to identify the plasma sustainment mechanisms within the main plasma production region and energy transport through the interface to the plasma jet itself. The excitation dynamics in a kHz atmospheric pressure dielectric barrier discharge (DBD) jet and a rf microplasma (< 1mm) will be presented. Plasma breakdown and sustainment in both these devices is investigated.

A plasma jet T-tube configuration is designed such that the kHz DBD plasma jets and their origin at both the powered and grounded electrode side can be simultaneously investigated. Helium gas of 4 slm flows through the main arm of the tube so that it symmetrically enters the dielectric barrier discharge with 2 slm of gas flowing through each end. Relatively long plasma plumes are emitted from the plasma source, at both the powered and electrode ends, and propagate into free space in the helium gas channel. These plumes, while continuous to the naked eye, are in fact transient and consist of a series of plasma pulses when imaged on a nanosecond time scale. The plasma pulses are often referred to as 'plasma bullets'. Optical emission with temporal, spatial and spectral resolution is measured during one phase of the 20 kHz cycle; optical emission is observed for a duration of approx. 2 microseconds. Within the dielectric tube the plasma ignites as a streamer-type discharge. Plasma jets are emitted from both the powered and grounded electrode end; their dynamics are compared and contrasted. Ignition of these jets are quite different; the jet emitted from the powered electrode ignites with a slight time lag to plasma ignition inside the dielectric tube, while breakdown of the jet at the grounded electrode end is from charging of the dielectric and is therefore dependent on plasma production and transport within the dielectric tube. Present streamer theories can explain these dynamics. Interactions between multiple atmospheric pressure plasma jets reveal interesting fundamental insights into the formation and propagation mechanisms of individual jets. This new interaction zone also offers a promising operation regime with improved control for emerging applications in plasma medicine.

Microplasmas can have dimensions on the order of living cells and this offers immense promise for precise application in plasma medicine. Plasmas approaching these dimensions are investigated for the purpose of identifying efficient regimes for stable homogeneous plasma operation. The interaction of atmospheric pressure plasma jets with different bio-materials is investigated and will also be presented.

[1] O'Connell D, Cox L.J., Hyland W.B., McMahon S.J., Reuter S., Graham WG, Gans T, Currell FJ, *Cold atmospheric pressure plasma jet interactions with plasmid DNA*, Applied Physics Letters, **98** **(4)**, 043701 (2011)