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Characterization of fluctuations in atmospheric pressure micro-plasma jets

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Atmospheric pressure micro-plasmas are non-equilibrium plasma with widely different ion (~0.026 eV) and electron temperature (~0.5 eV) [1]. These plasmas are popularly known as "cold" plasmas and used in several varieties of applications in fields such as surface functionalization and modifications, biology, medicine, environmental, and cell or tumor treatments [2]. The strength of potential (or electric field) penetrating onto the target is one of the most important parameters that can affect these applications. A minor fluctuation in the potential and electric field can affect these processes drastically due to transport and heating of active species. Therefore, it is important to investigate the fluctuations of these parameters in the plasma jet.

In our laboratory, a plasma jet has been created by dielectric barrier discharge inside a tapered glass capillary tube having inlet outer and inner diameter of 4.14 mm and 2.5 mm respectively, and outlet outer and inner diameters of 2.06 mm and 0.8 mm respectively [3]. Helium is used as a primary working gas. The plasma is ignited by applying a sine wave of maximum amplitude of 15 kV pp and of frequency 10 kHz. A ring to ring electrode configuration having a gap of 10 mm between the electrodes, has been used in this experiment. The charged particles emerge from the capillary tube into the ambient air as a fine plasma jet of length ~10 mm and diameter ~ 0.8 mm as shown in Fig. 1. A double pin probe having a diameter of 0.18 mm and length of 2 mm each, and 0.267 mm distance between them, has been employed to measure the floating plasma potential at spatial points in the jet at a downstream distance of 5 mm from the orifice of the capillary. The probe is kept inside a metallic aluminum box to shield it from the high voltage signal. The floating potential (amplitude-time series) has been captured by a digital oscilloscope through a double pin probe inside the jet, and their frequency characteristics have been investigated by employing classical tools such as fast Fourier transform (FFT) and time-frequency analysis (TFA) [4].

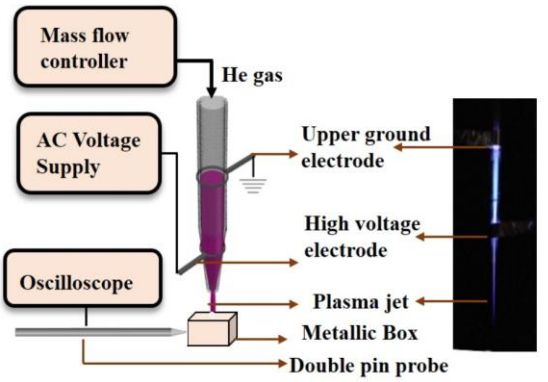

Fig.1. Schematic diagram of experimental set-up with the digital picture of plasma jet (at an applied voltage 10 kV and flowrate 2 lpm)

In the present work, the dependence of floating potential fluctuations on the operating parameters (applied voltage, gas flow rate, and mixing of other gas (Ar) with the main He gas) has been studied. It has been found that at a fixed flow rate (1 l/min), fluctuation increases with applied voltage (from 7 kV to 11 kV), then attains a maximum value at 11 kV because of high discharge current at this particular voltage and thereafter decreases. For a fixed applied voltage 14 kV, the plasma jet becomes turbulent after a flow rate of 3 l/min. The fluctuation analysis confirms that the turbulent jet is less stable than the laminar one. In the case of mixing argon, different general properties of argon gas e.g. low thermal conductivity and ionization potential as compared to helium gas, make argon jet highly unstable than helium jet. Time-frequency analysis further helps in understanding the stability of plasma jet during different operating conditions. TFA plot (Fig.2) shows that narrow frequency band (~6 kHz) almost disappears in case of argon but frequencies in another wide band (~2 to 4 kHz) increases that depicts the instability of argon jet. Hence, this research is helpful to choose suitable operating parameters and gas as per the requirement of the application.

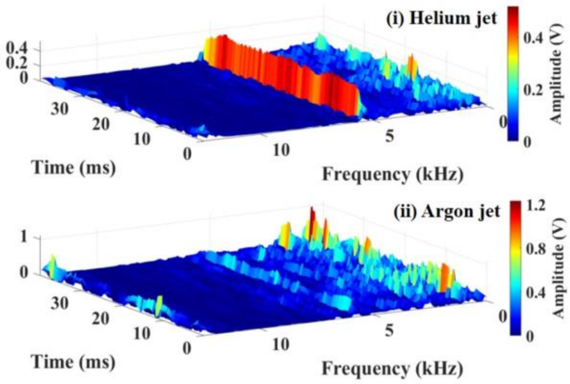

Fig.2. Time frequency analysis results at a fixed voltage of 14 kV and flow rate of 1 l/min for (i) helium plasma jet and (ii) argon plasma jet

References

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