6th Asia-Pacific Conference on Plasma Physics, 9-14 Oct, 2022, Remote e-conference

# Interaction of an atmospheric pressure micro plasma jet with various substrates : copper, silicon, Teflon, quartz, and biological skin

Deepika Behmani and Sudeep Bhattacharjee
Department of Physics, Indian Institute of Technology, Kanpur, Uttar Pradesh: 208016, India
e-mail (speaker): deepika@iitk.ac.in

Atmospheric pressure micro-plasma jets have gained considerable attention due to their wide applicability in various applications. The distinctive properties such as low gas temperature, micro size, and non-equilibrium nature make them suitable for the treatment of sensitive biological samples such as wounds, tissues, and cancer cells [1,2]. Apart from this, these plasmas are also used in industry for cleaning, removal of metal oxide, and changing the wettability of various substrates such as metal, polymer, and glass [3]. Reactive species concentration (especially for biological samples) and electric field impinging on a treated sample are two key parameters that may affect the treatment of the sample's surface. The plasma-substrate interaction affects not only the treated surface morphology but also the plasma plume properties (electrical and optical) depending upon the behavior of treated sample. As a result of this, the electric field fluctuation and modification of electron energy distribution function (EEDF) that links with the rate coefficient of reactive species, hence their production, may vary from sample to sample. Thus, fluctuation and non-uniformity of the electric field can harm the wound, treated cells, and the intended surfaces. Therefore, it is important to study the spatial asymmetry and fluctuation in electric fields of plasma jets.

A ring-to-ring electrode configuration has been used in this experiment to create a plasma jet [4,5]. Helium plasma has been created inside the capillary tube by applying a sinusoidal waveform (peak to peak amplitude: 15 kV and frequency: 10 kHz). The plasma emerges out from the orifice of the capillary tube as a fine jet into ambient air, as shown in Fig.1.

In the present work, the plasma jet is made to impinge on five different types of substrates (in grounded conditions): copper, silicon, Teflon (polytetrafluoroethylene (PTFE)), quartz, and a biological sample which is chosen as goat skin. The distance between the sample and the orifice of the capillary has been fixed at 8 mm. The substrate current, electric field fluctuations, and plasma parameters are investigated inside the plasma plume under the influence of these samples. The plasma parameters are measured by optical emission spectroscopy (OES) method and electric field fluctuations are characterized by Fast Fourier transform (FFT). A double pin probe collects the plasma floating potential at two local points $V_{f1}$ and $V_{f2}$ in plasma, and a known distance (d = 0.260 mm) between two pins makes the electric field measurements possible. An axial and poloidal mapping of electric field fluctuations is done by using a rotating frame arrangement, which can be seen in Fig 1. Fluctuation in $E_z$ and $E_\varphi$ components has been measured depending upon the orientation with respect to plasma plume. The fluctuations (both in $E_z$ and $E_\varphi$ components) are observed until about a frequency of 10 kHz and are higher in the case of quartz and goat skin as compared to other samples. Fig. 2 shows the axial variation of $E_z$ fluctuations along the plasma plume. It tends to increase axially in the case of silicon, copper, and goat skin samples; however, decreases for dielectric samples i.e., quartz and Teflon. To know the behavior of plasma after interacting with the substrate, a time correlation analysis between the signals which are captured at different axial locations will be performed. Thus, this work provides an insight of the impact of different materials on plasma plumes which are crucial from the application point of view.

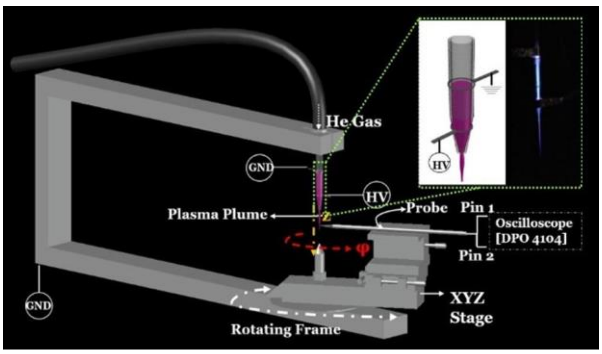


Fig. 1. Schematic diagram of experimental set-up of plasma jet with rotating frame designed to measure the electric field in axial and poloidal direction of jet

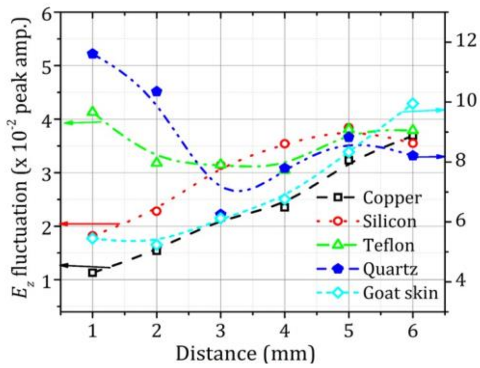


Fig.2 Variation of peak amplitude of fluctuating frequencies in electric field ($E_z$) with axial distance of plasma jet

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