Effect of Transverse Magnetic field on Atmospheric Pressure Plasma Jet: Experimental and Modeling Results

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Atmospheric pressure plasma jets (APPJ) are versatile tools for different biomedical and surface modification applications. Magnetic field can be applied on APPJ to optimize the number density (n_e) of electrons, electron temperature (T_e) according to the need of different types of applications. It can also affect the generation of reactive Oxygen and Nitrogen species (RONS). When the magnetic field is applied to APPJ, Lorentz force affects the motion of electrons and ions present in the plasma. Due to Lorentz force, the residual time of the charged particles inside the plasma increases which eventually enhances the ionization frequency in the plasma.[1] Plasma parameters n_e and T_e varies with the application of B. The change in electron density affects the generation of RONS species. Also, the magnetic field introduces Zeeman effect in APPJ. If the electron cyclotron frequency is comparable to the electron neutral collision frequency, the plasma is magnetized and magnetic effects can influence the plasma dynamics.

The plasma jet has been created inside a capillary tube employing pin to ring electrode configuration, as shown in figure 1.[2] The inner and outer diameters of the capillary are 3 mm and 5 mm, respectively. The diameter of the high voltage tungsten pin electrode is 1.6 mm. The ground ring electrode is made of copper, and its width is 5 mm. A power supply with an AC triangular waveform has been used to generate the plasma jet. The applied voltage and frequency can be varied in the range 0.2 - 4 kV and 80 -100 kHz, respectively. The gas flow and the frequency have been maintained in the range 3 - 5 lpm and at 80 kHz, respectively.

The magnetic field has been generated by permanent bar magnets (NdFeB) having dimension of 5 cm×3 cm× 2 cm. Three bar magnets have been employed on each side of the plasma jet perpendicular to the direction of plasma jet flow to create a transverse B. The magnets are encased inside thin rectangular aluminum pipes. The magnet system can be moved relative to each other to vary the B applied on the jet by a screw arrangement, as shown in the schematic diagram. The magnetic field is measured at the center of the two magnetic poles by a Hall probe Gauss meter (Lakeshore 421) at various distances.

The optical emission spectrum has been taken for H_α, H_β and Helium lines (587.6 nm, 667.8nm, 70.6.5 nm, 728.1 nm) to calculate n_e by the Stark broadening method and T_{exc} by the Boltzmann plot method. The experimental data has been compared with a fluid model data and the Zeeman simulation data. Time dependence of n_e and T_e can be calculated by fluid model equations. In the fluid model result, it has been observed that with increasing magnetic field, the saturation time of n_e and T_e decreases. It can be concluded that the plasma quickly reaches a steady state with the application of magnetic field. Moreover, with the application of the magnetic field, the shape of emission profile of H_α and H_β changes which eventually affects the full with at half maxima (FWHM) of the emission profile and subsequently changes n_e. Figure 2 shows the profile of H_α line at different magnetic fields.

Data of n_e and T_e obtained at different values of the magnetic field will be presented for experimental, fluid model and the Zeeman simulations. Additionally, the fluid model results of the variation of number density of different Nitrogen and Oxygen species with time will be presented.

References

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[2] K Barman *et al,* Plasma Research Express, **2**, 025007 (2020).

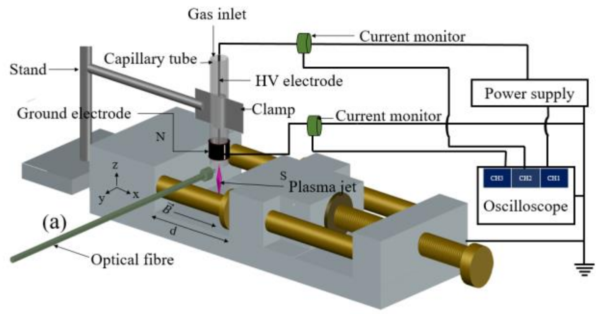

Figure1. Schematic diagram of the experimental system.

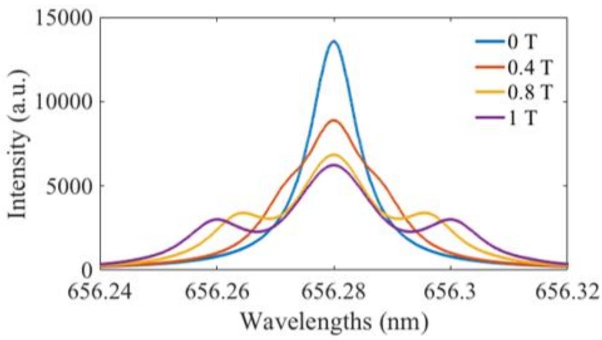

Figure 2. Optical emission profile of H_α line at different values of magnetic field B.