Characterization of a Large Volume Reduced Pressure Plasma Ignited by a Guided Ionization Wave

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Abstract: In this paper measurements of the various parameters of low pressure diffuse plasma remotely generated by an external guided ionization wave are presented. Diagnostics techniques that include spectroscopy, fast imaging, and Langmuir probe are employed to obtain discharge parameters such as the magnitude of the electric field, the plasma electron number density and temperature, and discharge propagation speed.

Keywords: ionization wave, diffuse plasma, low temperature plasma, plasma jet

1. Introduction

A transient discharge plasma can be generated remotely in a nonconductive chamber at reduced pressure by applying an external guided ionization wave (GIW). An atmospheric-pressure low temperature plasma jet was used as an external source of GIW to transfer the enhanced electric field at the wave front to an electrodeless Pyrex glass chamber and with no direct physical or electrical connection to the jet source [1]. Figure 1 shows a photograph of the diffuse large volume plasma inside the chamber.

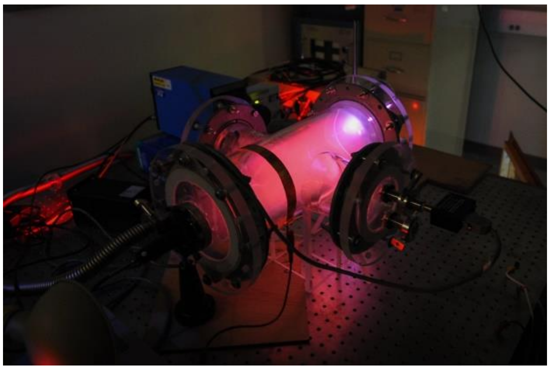

Fig. 1 Large volume diffuse plasma ignited inside a reduced pressure Pyrex chamber by an external guided ionization wave

Here, the characteristics of the plasma generated inside the chamber are reported using various diagnostics techniques.

2. Experimental Methods

Various diagnostics tools are used to measure the important parameters of the reduced pressure diffuse plasma. These include emission spectroscopy, fast imaging and a Langmuir probe. Figures 2 & 3 show schematics of the experimental set ups.

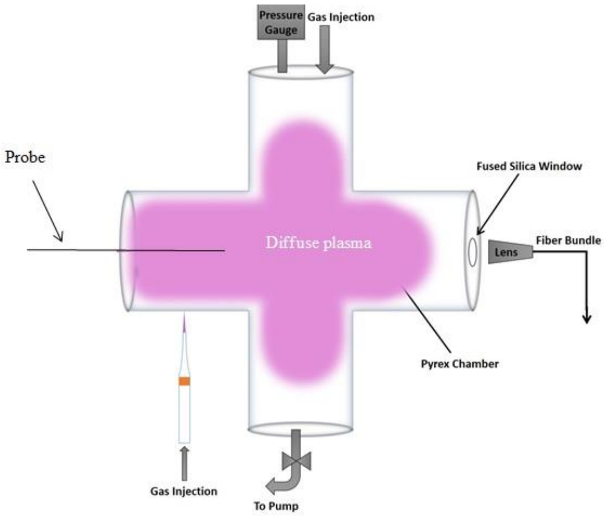

Fig. 2 Schematic of the experimental setup showing probe and light collection

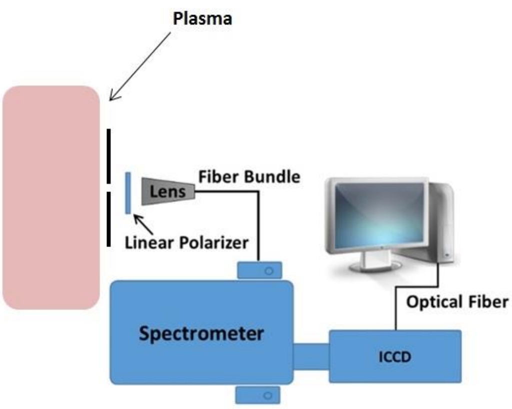

Fig. 3 Schematic of the experimental setup showing the spectroscopic technique used to identify excited species and also to measure the magnitude of the electric field

3. Results and Discussion

Plasma jets emitted in ambient conditions are in fact enabled and sustained by fast ionization waves that are guided by the gas flow, hence the term guided ionization wave [2]. There is a relatively large electric field at the head of the ionization front. The magnitude of this field was measured by various investigators and was found to be in 10 – 20 kV/cm range [3] – [5]. This electric field can be transmitted through a dielectric target/wall and under proper conditions can ignite a plasma behind the dielectric wall. This is the mechanism whereby the reduced pressure plasma is generated inside the Pyrex chamber. The characteristics of the plasma inside the chamber can be revealed by conducting measurements of the electric field inside the chamber, of the speed by which the ionization front travels, and of the plasma electron density and temperature.

Optical emission spectroscopy showed that the reduced pressure diffuse plasma produced second and third ionized nitrogen and oxygen atoms (OII, NII, and NIII). Fast images taken by an intensified CCD (to study the launching and propagation phases of the transient reduced pressure discharge plasma) showed that the ionization front entered the chamber at the point of contact of the tip of the jet with the wall of the chamber and then propagated at a velocity of several hundreds of km/s until the entire volume of the chamber was filled. Using a Langmuir probe the electron number density and temperature were found to be in the 10^{10} cm^{-3} and 2 eV ranges, respectively. This measurements were taken at air pressures in the 0.3 - 0.5 Torr range.

Using the Stark splitting and shifting of the helium visible lines and their forbidden lines the electric field strength can be measured. The displacement of the Stark sublevels of He I 447.1 nm and its forbidden component was calculate. The wavelength separation ($\Delta\lambda_{Allowed-Forbidden}$) of π components of allowed and forbidden lines ($m_{upper} = 0 \rightarrow m_{lower} = 0$) was measured and its relationship with the electric field strength was used to calculate E using a polynomial relation [6]. Electric field strength up to 19 kV/cm was found. Figure 4 shows an example of such measurement.

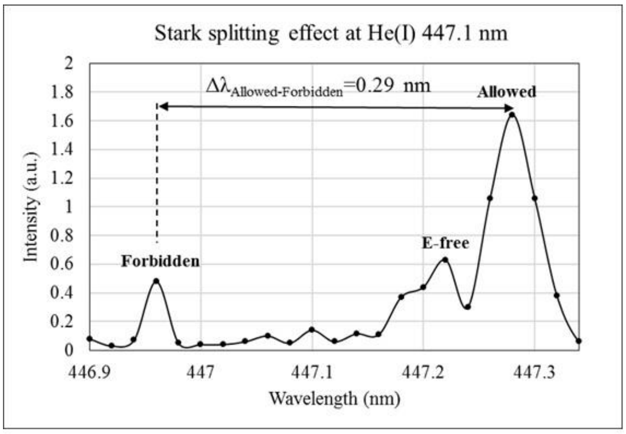

Fig. 4 Wavelength separation of the allowed and forbidden lines of He (I)

4. References

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