A comparision of discharge-averaged electrical diagnostics to local spectroscopic measurements in the gliding discharge

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Abstract: Non-thermal plasmas have long been diagnosed through electrical methods. This work investigates a gliding argon discharge with electrical diagnostics, high-speed imaging, and optical emission spectroscopy, revealing a plasma in a non-equilibrium regime despite what electrical measurements may indicate. While electrical diagnostics offer some insights, they fail to capture local behavior that defines a plasma's dynamics.

1. Introduction

Electrical diagnostics are often the most accessible tool in a plasma physics laboratory. They offer relatively easy ways to determine basic parameters – voltage, current – in a plasma, necessary for linking power consumption to outputs such as gas conversion efficiency. However, as they are discharge-averaged diagnostics, they are unable to capture the localized behavior of plasmas, and thus the exact usage of the delivered power cannot be tracked.

Upon their discovery, gliding discharges (GDs) have found applications in plasma chemistry, with initial success in combustion control, chemical reformation, and surface treatment [1]. Their simplicity and perceived capablities generated excitement, and they propelled into applications, remaining largely physically unexplored. Electrical diagnostics and power delivery studies have been central to understanding these discharges [2] [3].

In this study, a low-current (< 0.5 A), low-flow rate (300 sccm), pulsed DC argon gliding discharge in an open-to-air configuration is investigated with nonlocalized, electrical and localized, spectroscopic diagnostics. While electrical diagnostics can provide some insight, their use as a diagnostic tool to uncover the operating plasma regime should be approached with caution.

2. Methodology

A high-voltage, pulsed-power (9 kV, 15 μs) supply is used to ignite flowing Ar gas in the shortest electrode gap of the GD. At the same time, a DC current follower supplies a constant voltage to the copper electrodes. A 3D-printed optical fiber holder allows for observation at multiple points along the discharge and electrodes. Two optical emission spectrometers are used: a high-resolution (1.8 pm) spectrometer to obtain neutral gas temperature measurements through broadening of selected Ar lines, and a broadband spectrometer for obtaining multiple-line intensity measurements of Ar >5p transitions (to extract the Ar excitation temperature) and Ar 2p-to-1s transitions to gather the electron temperature. These tools are also used to record excitation, rotational, and vibrational temperatures of other species (Cu, and N_2 and OH from air). Along with this, high-speed optical images are taken, from which GD length can be found, as triggered by the pulsed-power supply, and voltage and current signals are acquired via an oscilloscope.

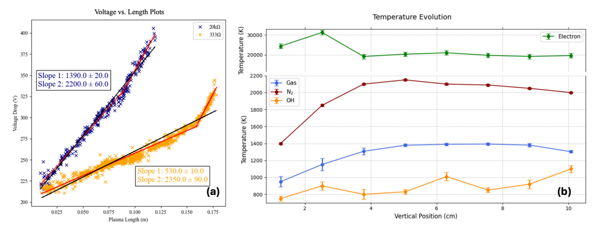

Fig. 1. (a) Two-slope method indicates that the slope increases as a function of time, indicating a rise in the electric field, and thus a supposed indicator of entering a more non-thermal regime. (b) Spectroscopic measurements show that the plasma is non-thermal throughout the discharge, with no apparent further departure from equilibrium with time.

3. Results and Discussion

Figure 1 illustrates an example of where electrical methods can be misleading. By measuring the electric field through the slope of a voltage-length plot [2], an increase in slope suggests a transition to a more non-thermal regime with higher electric fields. However, spectroscopic measurements show no such deviation or further non-equilibrium behavior, indicating a plasma that remains strongly non-equilibrium throughout its lifetime. This discrepancy highlights the limitations of electrical diagnostics in capturing local behavior.

4. Conclusion

We stress the importance of the cautious use of bulk, electrical diagnostics to inform GD studies. Though they can provide insights into plasma behaviour, they are not able to inform energy injection, plasma regime or, crucially, localized efficiency in a plasma chemical process.

References

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