Finite Impedance of Voltage Sources Driving Atmospheric Pressure Plasma Jets

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Abstract: Although well-known experimentally, the finite impedance of the power source driving atmospheric pressure plasma jets (APPJs) is not often addressed in models. We report on a computational investigation of an APPJ delivering electron fluence to a thin water layer for which the voltage source has a finite impedance. The magnitude and extent of electron fluences onto the water generally scale inversely with the impedance of the circuit.

1. Introduction

Impedance matching of power supplies to pulsed atmospheric pressure plasma jets (APPJs) is problematic. Breakdown requires matching with a high impedance source while sustaining the plasma requires matching with low impedance source [1]. With a finite impedance, the circuit powering the APPJ has a limited ability to deliver current with voltage across the discharge experiencing droop. Experimentally, current limits and voltage droop are natural outcomes of the driving circuitry. However models of APPJs rarely account for the finite impedance of the power supply. We discuss results from a computational investigation of APPJs sustained in Ar/H_2O mixtures incident onto thin water layers. A ballast resistor is included in series between the voltage source and APPJ to demonstrate the consequences of finite impedance in the source circuit.

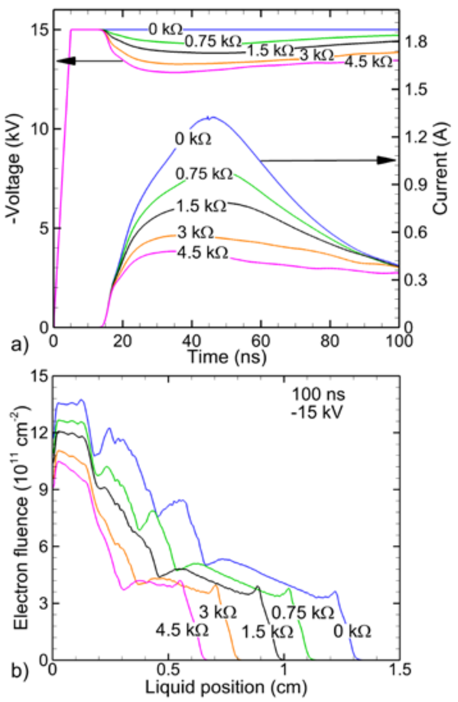

Fig. 1. APPJ properties for different series ballast resistors. a) Current through and voltage across the discharge. b) Electron fluences to the water layer.

2. Description of the Model

The model used in this investigation is *nonPDPSIM*, a 2-dimensional plasma hydrodynamics model executed on an unstructured mesh [2]. Charged particle transport is implicitly solved coincident with Poisson's equation for the electric potential. For the results discussed here, the APPJ is sustained in an Ar/H_2O = 98/2 gas mixture flowing through a tube 2 mm wide. The APPJ is incident onto a 2.4 mm thick water layer over a flat grounded electrode. A -15 kV pulse of 100 ns duration (5 ns rise time) is applied to the powered electrode through a ballast resistor.

3. Finite Impedance Circuits and APPJs

Following breakdown, the APPJ strikes the water layer, and transitions into a surface ionization wave (SIW) that propagates along the surface at 10^7 cm/s. The voltage across the APPJ (powered electrode to ground under the water) and current through the discharge are shown in Fig. 1a for ballast resistors of 0 to 4.5 kΩ. Beginning at the onset of current at breakdown, the finite impedance of the circuit is less able to deliver current and consumes an increasing portion of the applied voltage. This is, to first order, voltage division between the finite impedances of the voltage source, discharge and water layer. From 0 to 4.5 kΩ, the peak current through the discharge decreases from 1.3 A to 0.4 A and occurs earlier. The voltage across the discharge droops from -15 kV to -13 kV due to voltage drop across the series impedance. At the end of the voltage pulse, currents for all impedances are similar as the total impedance is limited by the water layer.

With increasing impedance, the speed of the SIW decreases by a factor of 2, as shown by the electron fluences (time integral of flux) to the water in Fig. 1b. The magnitudes of the fluence are similar beyond 0.5 cm where the discharge is a SIW as these fluences are determined, in part, by the current required to charge the capacitance of the water layer. However the general trend is that lower impedances increase electron fluence onto the water over a larger area.

4. Concluding Remarks

The consequences of impedance in the driving circuitry of APPJs was computational investigated. Tailoring the series impedance provides a degree of control over electron fluences (magnitude and extent) delivered to surfaces.

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References

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