# Analysis of the Chemical and Physical Processes Arising from Plasma Discharge Channels Formed at a Gas-Liquid Interface

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**Abstract:** A small, tubular (3 mm diameter), gas-liquid reactor is used to characterize chemical and physical processes occurring when a plasma discharge propagates along the interface between a flowing gas and film of flowing liquid water. The gas and liquid flows are characterized using high speed photography, the plasma properties are measured using optical emissions spectroscopy, and chemical methods are used to measure the resulting formation of hydrogen peroxide and oxidation of several organic compounds.

**Keywords:** gas-liquid interface, plasma channels, plasma properties, hydrogen peroxide, oxidation

## 1. Introduction

Electrical discharge plasma formed in and in contact with liquid water is of interest for many applications in chemical, biomedical, electrical, and materials engineering [1]. Analysis of plasma interacting with liquids provides many experimental challenges due to the complex relations among the various chemical and physical processes. In addition to the many ways to generate a plasma contacting a liquid (e.g., using AC, DC, pulsed, RF, MW power supplies) and the different geometry of electrodes used in such systems, the formation of plasma at a gas-liquid interface also depends upon the gas composition, liquid properties (e.g., conductivity), and the nature of the molecular transport processes (e.g., hydrodynamics of two-phase flow, energy transport, and mass transfer) occurring at the interface. In order to address these challenges and to focus on the specific case of filamentary plasma channels propagating along a gas-liquid interface, we have constructed a small, tubular, gas-liquid plasma reactor [2] that allows for a) control of the gas and liquid flows, b) measurement of the interfacial area and gas and liquid volumes, and c) determination of various transport and plasma properties.

## 2. Discussion

In this presentation, we will discuss how the key input conditions, including those of the gas, liquid, and power supply, ultimately affect the measured chemical products. In this work we vary the input conditions including the gas composition (e.g., argon and helium), the liquid properties (e.g. conductivity), the gas and liquid flow rates, and the input power supply characteristics (input voltage, pulse width, pulse frequency). Using hydrodynamic analysis, we determine the pressure inside the reactor chamber, and with high speed imaging, show the formation of a water film along the walls of the tubular reactor along which the plasma propagates. We also assess the geometric structure of the fluid interactions using the high speed imaging and measure the gas and liquid phase volumes as well as the interfacial areas and assess how these properties change with gas and liquid flow rate. Utilizing a highly controllable nano-pulser power supply we determine how the pulse characteristics affect the electrical properties of the discharge (current and voltage) as well as the plasma properties (plasma temperature and electron density determined by optical emissions spectroscopy). We then assess how these changes affect the formation of hydrogen peroxide, which serves as a proxy for assessing the oxidation capacity of the discharge. In addition, several approaches, including direct photography and current density/heat transfer modelling are used to determine the plasma volume and assess how it is affected by the input conditions such as gas composition, liquid conductivity, and input voltage. This small tubular reactor has previously been used in conjunction with a homemade power supply built with an automobile ignition coil where it was characterized for oxidation of hydrocarbons [3], organic dyes [4], hydrogen peroxide [5] and hydroxyl radicals (using gas and liquid phase chemical probes). We will compare selected results from the nano-pulser power supply to the those gathered with the ignition coil.

## 3. References

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