Time Resolved Plasma Characterization by Optical Emissions in a Nanosecond Pulsed Plasma Gas-Liquid Discharge using Burst Mode

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Abstract: The effect of burst-mode pulsing on plasma properties and PFOA mineralization in a continuous gas-liquid flowing film reactor was studied. Optical emission spectroscopy was used to measure electron density and temperature varying in a burst. These findings provide insights into optimizing burst parameters to improve plasma-based chemical processes.

1. Introduction

This study focuses on "burst" mode of pulse delivery, where a series of high-frequency pulses is followed by a relaxation period before the next set of pulses. Burst mode provides the inter-pulse time-period which allows for relaxation of reactive species such that the backreactions that suppresses the efficiency of desired chemical reactions are reduced. In our previous study [1], when using uniform pulsing, the highest peak electron density was correlated to highest mineralization of perfluorooctanoic acid (PFOA) to fluoride (F^-) at 20kHz when pulse frequency was varied between 5-100kHz. In this study, we investigate the effect of burst mode on the peak electron density and electron temperature on each pulse in a burst which influences the mineralization of PFOA to F^-.

2. Methods

2.1 Experimental set-up

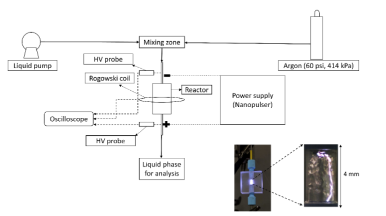

Fig. 1. Experimental set-up

The continuous gas-liquid flowing film reactor used in this study, shown in Fig. 1, is like that used in previous work [2]. Argon was used as the carrier gas and DI water was used as the liquid phase. DI water was supplied to the system with high-pressure reciprocating pump at 2mL/min.

2.2 Burst parameters

The nanosecond pulser used in this study was custom-made by Airity Technologies, LLC (Palo Alto, CA). The pulser was connected to a function generator (Rigol 1022Z, Portland, OR). The pulse width of the nanosecond pulse was 96 ns. The input voltage used in the study was 10 kV. In this work, the burst mode of the function generator was utilized to trigger the Airity pulser to send a high-frequency train of pulses. The burst parameters used in this study were reported in Table 1.

Table 1: Burst parameters used in this study

	Burst Period (ms)	Internal Frequency (kHz)	N-cycles
Case 1	0.1 – 1	1000	10
Case 2	1	100 – 1000	10
Case 3	1	1000	1 – 20

2.3 Electron density and electron temperature

Optical emission spectroscopy was used to determine the electron density and electron temperature within a single burst. The reactor was placed across the slit of the imaging spectrometer (HRX Spectra Pro 750). An iCCD camera (PI max 4 by Princeton Instruments, NJ) was attached to the spectrometer. The electron density was determined using the stark broadening of H_α and the electron temperature was determined using line intensity ratio of H_α and H_β. Fig 2. shows the stark FWHM of H_α varying with time in a burst. The peak electron density was observed to decrease with increase in N-cycles and levels off.

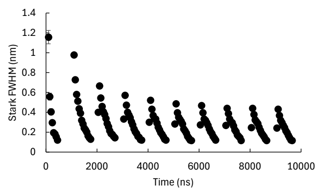

Fig. 2. Stark FWHM varying with time at 1MHz (internal frequency) – 10 (N-cycles) – 0.1ms (Burst Period)

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References

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[2] R. K. M. Bulusu et al., *Plasma Chem. Plasma Process*, **43**, 1549-1565 (2023)