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OPTICAL EMISSION SPECTROSCOPY OF A GLIDING ARC TORNADO DEVICE

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Abstract. Optical emission spectroscopy was used to characterize the gas-phase in a gliding arc tornado reactor used for plasma applications. Results concerning the transition between spark and fully developed arc regimes are presented.

1. INTRODUCTION

The Gliding Arc Tornado (GAT) was proposed long ago to improve properties of gliding arcs reactors, in particular a better insulation of the device walls from the discharge, with a higher level of non-equilibrium and much larger residence times (see Kalra et al. 2005). These devices were mostly used for industrial applications including fuel conversion, carbon dioxide conversion and waste treatment (see Liu et al. 2016, Bublievsky et al. 2015). Their name refers to the formation of a reverse vortex flow configuration, a tornado, usually achieved by tangential gas injection near the walls in a cylindrical chamber. We have developed and used a kind of these devices for the treatment of lignin by plasmas (see Zanini et al. 2008). Milled lignin can be easily in a sustained gas fluxes and advected in the hydrodynamical flow. So optimal interaction with the discharge gas phase could be achieved. Here we will present some results concerning the characterization of the process and its optimization, based on optical diagnostics. Optical Emission Spectroscopy (OES) is a suitable technique to investigate the plasma gas-phase, since it is passive and non-perturbing, and takes advantage of the rich emission pattern in/near visible range of such systems. Besides gathering information about the discharge, it is possible to get insight on the interactions of lignin particles with plasma and the mechanism of the treatment.

2. EXPERIMENTAL SETUP

The discharge was ignited and supplied by means of a high-voltage dc generator (SHV9000 by Alintel). Its performances cannot exceed 5 kV and 2 A at most. It also provided integrated measurements of the total charge effectively delivered and the mean applied high voltage, which could be used to estimate the actual power absorbed by the device. Besides the HV setting, the generator was controlled with a tunable mean current regulation. It also provided integrated measurements such as the total charge effectively delivered before being switched off and the mean applied high voltage. The actual electrical characteristics of the discharge are controlled by the supply, by setting a fixed mean current intensity value. The supply was connected to the anode electrode through an electrical circuit (a set of 16 high voltage, high power resistances, with a global resistance of 4 kΩ), which helps to control the electrical characteristics of the discharges. HV sensors were inserted in the circuit also to measure the instantaneous values of the voltages on a digital scope. Due to the limitation in the output current provided by the generator and the external circuit impedance, the discharge assumed an intermittent spark character at low current settings (see Barni et al. 2008). It develops to a full arcing above a certain threshold of the current set, slightly depending on the inlet flow pressure and gas mixture composition. A three turns molybdenum electrode acts as the arc anode, figure 1. HV sensors measure the instantaneous voltage at the ends of the resistors set and thus of the discharge current, as it is shown in Figure 2. It could be grasped as the system shows intense current bursts with a limited duration, separated by dead times, corresponding to a sequence of spark discharges. Although not exactly constant, the shape, the amplitude, the duration, and the repetition rate of bursts were comparable and fairly cyclic. These parameters were measured and averaged using long time series (10 MSamples) with a digital scope and their statistical properties were studied.

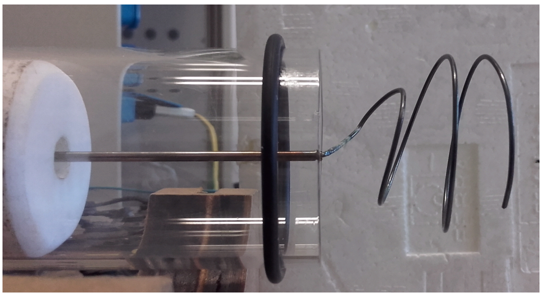

Figure 1: Experimental layout of the GAT device.

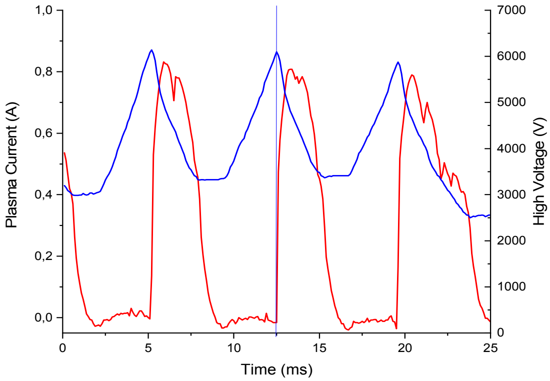

Figure 2: Electrical characteristics of the GAT device in sparking mode.

3. RESULTS AND DISCUSSION

While the pattern of the single discharge is somewhat fuzzy, it appears that most of the flow cross section is affected by the discharge and emits light. OES of the discharge is used to gain insight in the excited species produced. Measurements of the emission spectra are obtained with a wide band, low resolution spectrometer. The spectrometer (PS2000 by Ocean Optics) has a resolution of about 0.4 nm and a spectral band extending from 180 to 860 nm. It is equipped with a 10 µm slit, a holographic grating (600 lines/mm, blazed at 400 nm), and a coated quartz lens to increase sensitivity in UV (see Barni et al. 2008). Emission line intensity was measured and atoms and molecules have been identified (see Pearse et al. 1976). The light emitted from the plasma sheet was collected by means of a UV enhanced optical fibre placed just in front of the exit 10 cm apart, to not perturb the outflowing gas jet. The view-field of the optical fibre was large enough to cover the whole light-emitting region and to smear possible discharge disuniformities. A typical spectrum is shown in Figure 3.

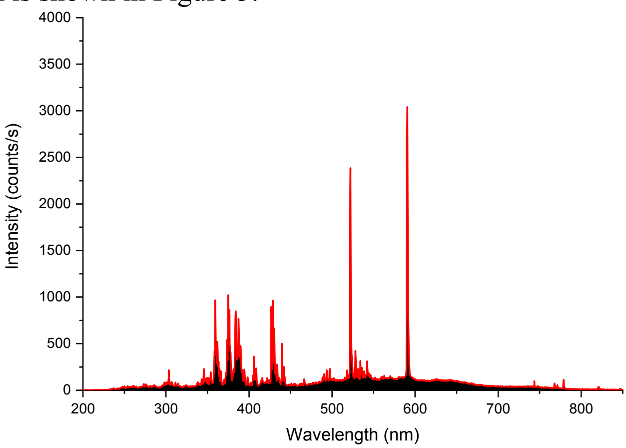

Figure 3: A typical emission spectra of the plasma in an air GAT.

Spectra of the light emitted from the discharge show a broad continuum peaking at about 500-550 nm, with superimposed a rich structure of lines, some quite narrow, comparable to the spectrometer resolution and other that appears larger, clearly emitted by molecular states and appearing together due to their unresolved rotational substructure. As the mean current setting is increased the continuum contribution increases at expenses of the lines, until transition to arcing is achieved and the spectra approaches a structureless shape. The reported trend is displayed in Figure 4, where the transition could be clearly appreciated.

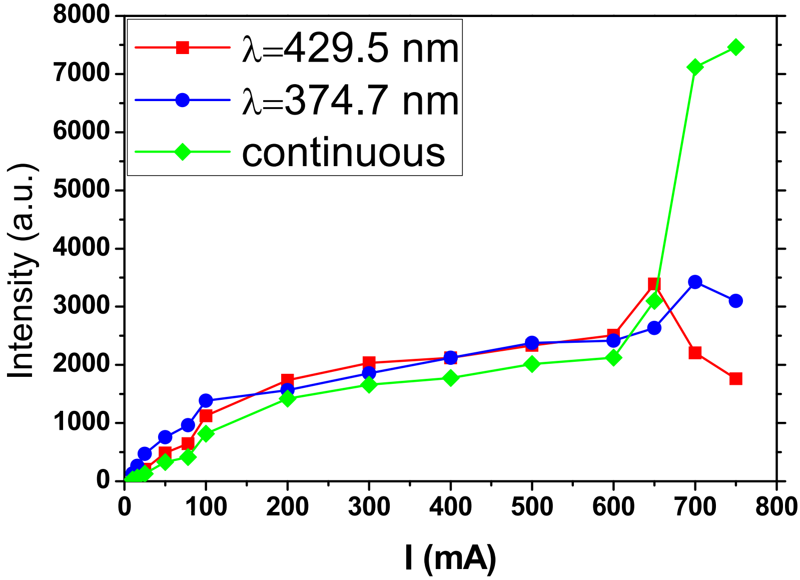

Figure 4: Intensity of a few emission lines and of the continuous as a function of the total current drawn by the GAT.

Acknowledgements

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