SPECTROSCOPIC CHARACTERISATION OF AN ATMOSPHERIC PRESSURE GLOW DISCHARGE*

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1 Introduction

Recently there has been considerable interest in atmospheric discharges operating in a glow discharge mode i.e. with a spatial and sheath structure similar to that of low pressure glow discharges [1,2,3]. Here spectroscopy has been used to characterise an atmospheric pressure glow discharge (APGD), operating with either dry air, argon or helium gas flowing through the inter-electrode space and with the interelectrode gap either free or with woven polypropylene or polyester samples present. Emission spectroscopy is used to determine the rotational and vibrational temperature of the nitrogen gas, while electron temperatures are determined from the relative intensities of Ar emission lines. Ozone production is monitored by a simple absorption technique to evaluate its potential in process control.

2 Experimental Details

The experimental set up is shown schematically in Figure 1. The discharge is created between two parallel glass plates separated by typically 5 mm and sitting in air. Electrodes are formed by two discs of copper foil 220mm in diameter which are glued to the outer surfaces of each of the plates. The outputs of a variable frequency voltage supply are attached to each electrode through a step up transformer. The power supply and transformer provide peak to peak voltages of up to 6kV at frequencies from 10kHz to 500kHz. The flow rate of gas forced through the gap between the glass plates from pressured cylinders is continually monitored.

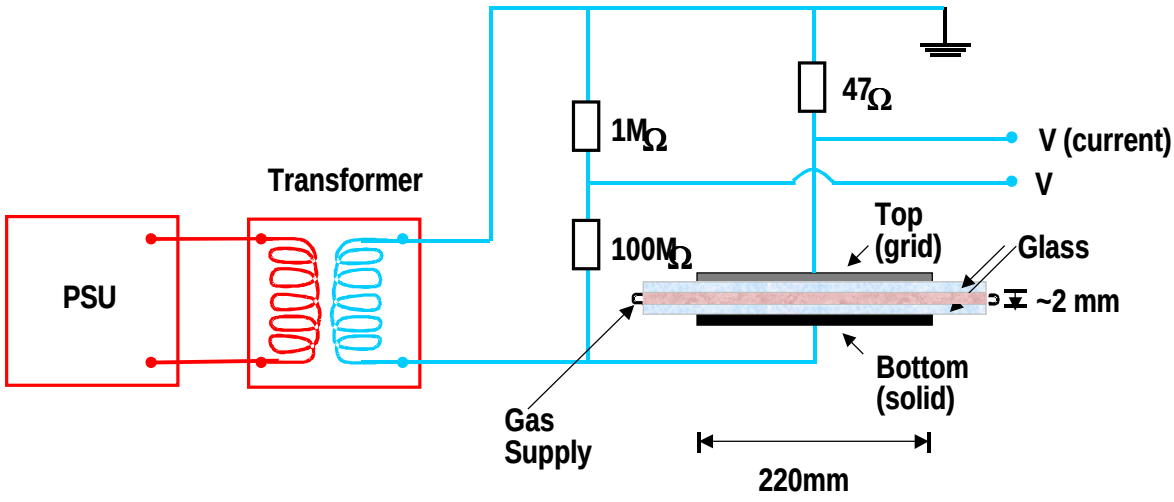

Figure 1. A schematic diagram of the atmospheric plasma system.

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The discharges can operate in two modes. In one mode, known as the filamentary discharge (FD mode), the discharge is seen to consist of a number of small, random microdischarges. In another mode, the glow discharge (GD) mode, the discharge appears to be spatially uniform The operating mode was found to

be sensitive to the gas used, gas flow rate, voltage magnitude, frequency and electrode gap size. Here the different operating modes were identified in two ways. A simple approach is to observe the discharge and assume GD mode when no filaments were observed. An alternative is to study the electrical characteristics. It has been shown [3] that in pure GD mode the current drawn from the power supply will exhibit a distinct peak twice during each period of the driving voltage. In FD mode there will be a random distribution of shorter, smaller magnitude peaks. The system used in [3] had been initially evacuated and then filled with He to atmospheric pressure. In the present system, operating in air, when observation indicated GD mode then the measured current draw showed a pronounced peak at one phase of the driving voltage, although this was not as distinct as that found in [3].

The light emission was analysed by imaging the electrode gap onto the entrance slit of a an Oriel MS257 imaging spectrometer. The spectrometer is capable of a wavelength coverage from 180 nm to 1600 nm with a spectral resolution of 0.8 nm. The detector at the exit slit was an InstaSpec V gated intensified CCD system. For the absorption measurements a Hg lamp was positioned at the opposite side of the discharge from the spectrometer input. The spectrometer selected the 253 nm line which is strongly absorbed by ozone. The concentration of ozone was calculated using Beer's law and an absorption cross section of 1.13 x 10^{-17} cm^2.

3 Results

All the measurements reported below were obtained when the discharge was operating in a predominantly GD mode as defined above. The emission spectra from 250nm to 800nm were dominated by emission from short lived N_2 states. In addition emission lines from either He and Ar were seen that gas was flowing and when the polypropylene or polyester samples were present OH emission at around 310nm was also observed.

3. 3.1 Vibrational temperatures

The relative intensities of the emission from different vibrational states of nitrogen allows the vibrational energy distribution to be evaluated. This was done with different gases flowing through the electrode gap. The temperature was calculated from the relative intensities of the lines from N_2 (C $\rightarrow$B) $\Delta\nu$ = 1,2,3,4 sequences, corrected with the appropriate Frank-Condon factors. (Figure 2). Only in the case of nitrogen gas flow did all the sequences yield a consistent temperature of 2000 K. Evaluation of rotational data is currently underway.

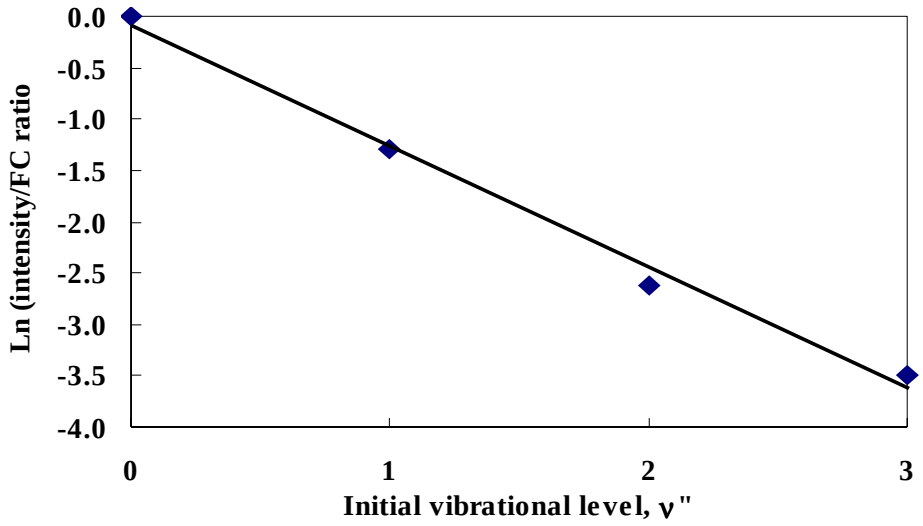

Figure 2. A typical vibration line intensity plot, in this case for N_2 (C$\rightarrow$B) $\Delta\nu$ = 2 sequences.

3.2 Electron temperatures

If the electron energy distribution is assumed to be Maxwellian then the relative Ar line intensities can be used to estimate the electron temperature. The electron temperatures, determined from the ratios of the 750, 751 and 763 nm , are shown in Table 1.

Table 1 Electron temperature calculated from the relative ratio of Ar emission lines.

Sample	Flowing gas	Forward power (Watts)	Electron Temperature (eV)
Stainless Steel	O_2 and Ar	1430	0.4
Stainless Steel	Ar	770	0.5
Polypropylene	Ar	1440	0.6
Polyester	Ar	770	0.3

3.3 Absorption measurements

Figure 3 shows how the absorption and so the ozone density changes as the discharge is turned on at 4 seconds and off at 60 seconds. The ozone density reaches maximum values of about 10^{16} cm^{-3}. This simple absorption measured allowed real time optimisation of the ozone production.

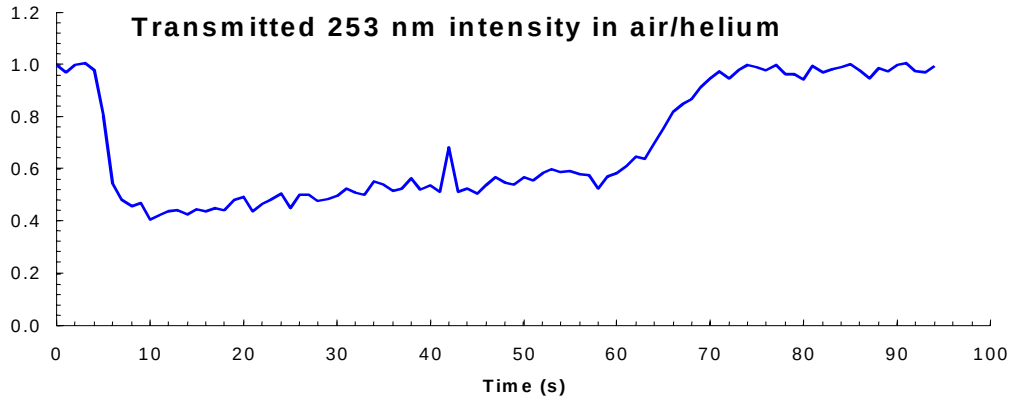

Figure 3. Time evolution of the absorption of 253 nm radiation.

4 References

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