Ultra broad-band high sensitivity absorption spectroscopy of inductively-coupled plasmas in Cl_2/O_2 mixtures

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1. Introduction

Broad-band absorption spectroscopy is a powerful diagnostic for reactive plasmas, allowing measurement of the absolute densities of numerous atoms, molecules and free radicals in ground and various excited states. Many molecular absorption bands (such as Cl_2) are up to 200nm wide, and it is necessary to record the whole spectrum in order to correctly measure the baseline. Previously Xe arc lamps have been used as the continuum light source [1], but these suffer from spectral, spatiotemporal fluctuations which limit the sensitivity to about 10^{-3} in absorption. More recently UV light-emitting diodes have been used [2] offering improved stability, but these only emit over a few 10's of nm**.** Our new absorption setup uses a laser-driven plasma light source (LDLS EQ-99), achromatic optics, an aberration free spectrograph (Acton SCT 320) and a high dynamic range photodiode array detector. The light source has ideal characteristics for absorption spectroscopy (high intensity, stability and a wide spectral range (200-800nm)), overcoming previous limitations. Noise levels as low as 10^{-5} can be achieved in single-pass absorption, covering up to 250nm in a single spectrum.

2. Results and Discussion

Measurements were made in a 13.56 MHz inductively-coupled plasma reactor (described previously [3]) in O_2, Cl_2 and Cl_2/O_2 mixtures (pressure 5-100mTorr, RF power up to 500W). Fig 1 shows an example of a spectrum of a pure O_2 plasma: The series of bands observed can be attributed to highly vibrationally excited O_2 molecules (half way to dissociation) absorbing via the Schumann-Runge transition. These excited molecules (tail temperature ≈10,000K) may be created by electron impact excitation or may be the product of surface recombination. Higher resolution spectra of the (0-13) band at 322nm shows individual rotational transitions, allowing the rotational temperature T_{rot} to be determined with good precision. T_{rot} increases with gas pressure and RF power, reaching 900K at 80mTorr 500W.

In pure Cl_2 plasmas we observed the Cl_2, molecular absorption, which shows both the gas depletion by dissociation and heating, and the presence of excited vibrational states (tail temperature of 1000K, much lower than the case of O_2).

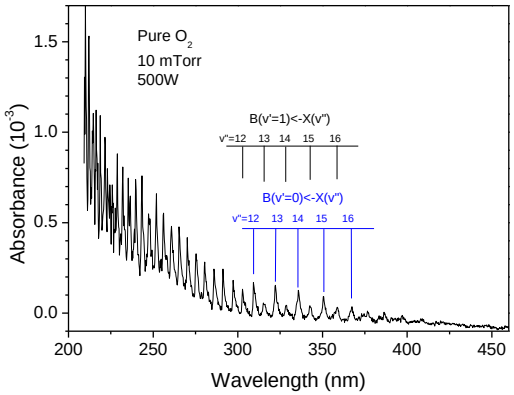

Fig 1 : Absorption of an O_2 plasma at 10 mTorr 500 W.

We also investigated Cl_2/O_2 mixtures and were able to detect the the reaction products including ClO and OClO and well as Cl_2. Combined with O and Cl atom density measurements by TALIF we can obtain a complete picture of the gas composition as a function of Cl_2/O_2 ratio in the feedstock.

The high sensitivity and wide wavelength baseline stability of this new absorption bench allows many new possibilities for plasma diagnostics.

3. Acknowledgements

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4. References

[1] Booth, J.P., G. Cunge, F. Neuilly, and N. Sadeghi, *Plasma Sources Science & Technology,* **7**, 423. (1998)

[2] Cunge, G., D. Vempaire, M. Touzeau, and N. Sadeghi, *Applied Physics Letters*, **91**, 231503. (2007)

[3] Booth, J.P., Y. Azamoum, N. Sirse, and P. Chabert, *Journal of Physics D: Applied Physics*, **45**, 195201. (2012)