*35th EPS Conference on Plasma Phys. Hersonissos, 9 - 13 June 2008 ECA Vol.**32D**, O-2.016 (2008)*

Discharge Diagnostics During Particle Growth in a Complex Plasma

B.W. James[1], L. Couëdel[1,2] , A.A. Samarian[1], L. Boufendi[2]

[1]*School of Physics, The University of Sydney, NSW 2006, Australia*

[2] *GREMI (Groupe de Recherches sur l'Énergétique des Milieux Ionisés), CNRS/Université d'Orléans, 14 rue d'Issoudun, 45067 Orléans Cedex 2, France*

Introduction

The effect on the positive column plasma of a capacitively-coupled radiofrequency discharge as a result of the growth of particles that were introduced by sputtering from the powered electrode has been investigated. Although the growth of particles in reactive plasmas has received considerable attention [1,2], there has been less study of the growth of particles in non-reactive plasmas [3].

The Experiment

The measurements were carried out in a capacitively-coupled discharge operating in argon at a pressure of 1.75 Torr. The powered electrode had a diameter of 100 mm, and there was a grounded electrode of diameter 115 at a distance of 30 mm (see Figure 1). The chamber was also grounded. A 13.56 MHz radiofrequency power supply was capacitively-coupled to the powered electrode. The discharge was slightly asymmetric, producing a dc self-bias of the powered electrode of ~ 17 V, for an rf waveform of amplitude 280 V.

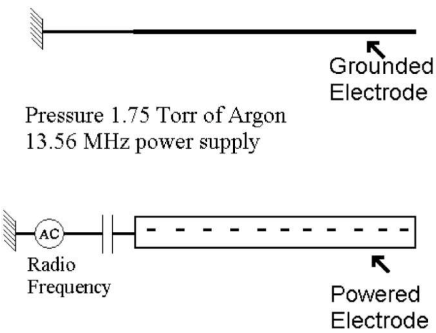

Figure 1: Electrode configuration

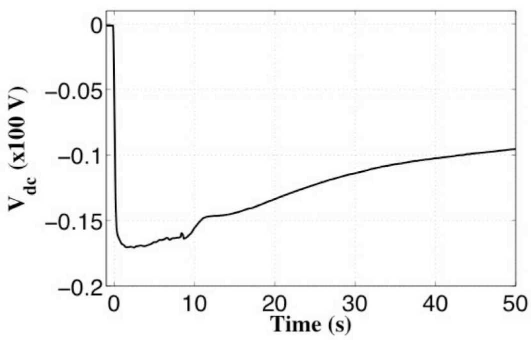

Figure 2: Powered electrode self-bias voltage

An rf compensated Langmuir probe was inserted via a side port into the region between the electrodes. Light from this region was also collected for spectroscopic measurements. Nanoparticles produced by sputtering of melamine dust placed on the powered electrode entered the discharge and filled the positive column of the discharge. During the growth of particles over several tens of seconds the self-bias was monitored and plasma measurements made using the Langmuir probe and argon emission spectroscopy.

Results and Discussion

The variation of the powered electrode self-bias V_{dc} as a function of time from the initiation of a discharge is shown in Figure 2. After an initial period of little change a steady increase in self-bias voltage (a decrease in $|V_{dc}|$) was observed with an asymptotic approach to an apparent plateau value. As the plasma changes, the self-bias achieves a value that ensures there in no average current to the powered electrode [4,5]. For most of the rf cycle the powered electrode is negative with respect to the plasma and there is an ion flux to the electrode. For a small fraction of the cycle the electrode is positive with respect to the plasma, allowing sufficient electrons to flow so that there is no net charge to the electrode over the cycle. It has been reported that the self-bias voltage changes as a result of the effect of particle growth on the discharge, and that this variation correlates with particle growth [3]. Qualitatively, the effect of particle growth on the self-bias can be seen as a consequence of the reduction in electron density due to negative charge accumulating on the particles: a reduced self-bias will reduce the ion flux and allow a longer period of electron flow so that a new equilibrium is established.

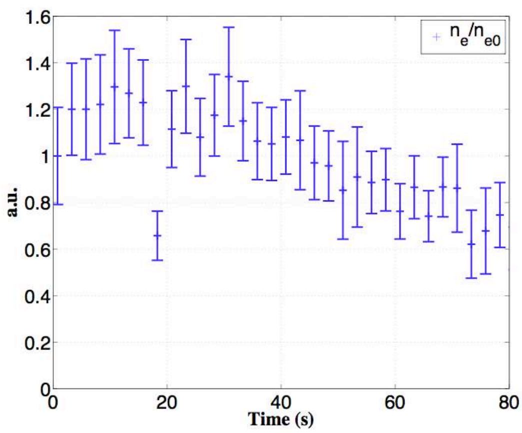

Figure 3: Reltive change in electron density n_e/n_{e0} ($n_{e0} \sim 4x10^9$ cm^{-3})

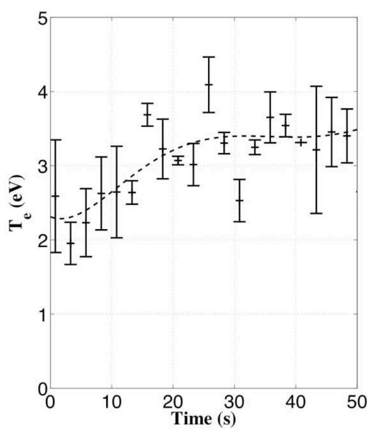

Figure 4: Electron temperature

Figures 3 and 4 show respectively the variation in electron density and electron temperature obtained from the Langmuir probe using the standard Langmuir analysis procedure. The decrease in n_e is consistent with the expectation that electrons are lost due to charging of the growing particles. The rise in T_e is qualitatively in agreement with similar observations during particle growth in reactive plasmas [6].

The intensity of three isolated ArI spectral lines (416 nm, 519 nm and 750 nm) are shown as a function of time in Figure 5(a). The ratios of the intensities of each of the first two lines to that of the third line are shown in Figure 5(b).

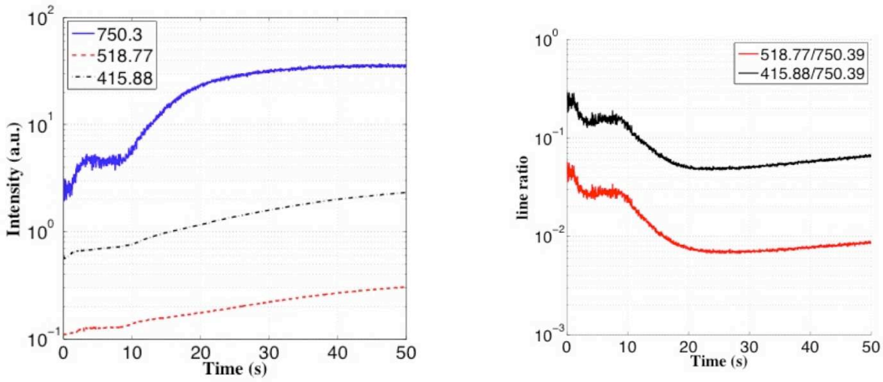

Figure 5: Intensities of three isolated argon lines (left) and the intensity ratios (right) of two lines (416 nm, 519 nm) with respect to the third (750 nm)

The interpretation of spectral measurements in terms of plasma parameters presents some difficulties. The most general approach is to use a collisional-radiative model which takes account of the all collisional and radiative processes that influence the populations of excited states, and hence the intensities of spectral emission lines (as a function of the pressure, electron density and electron temperature). In order to simply the problem the electron distribution is invariably assumed to be Maxwellian [7,8]. Low pressure discharges such as the one used in this work allow a simplified version of the model to be used: the corona approximation where the dominant processes are collisional excitation from the ground state and radiative de-excitation. Again, for simplicity, a Maxwellian electron distribution is usually assumed [9,10].

The rising spectral line intensities during particle growth (when electron density is falling) implies an increase in electron temperature. In the latter circumstances the corona model predicts that the intensity ratios of Figure 5(b) should rise rather than fall. The resolution of this discrepancy may be due to the well known fact that such discharges have non-Maxwellian distributions: at sufficiently low pressures the distribution is bi-Maxwellian, becoming Druyvesteyn-like at higher pressures [11]. The present experiment falls within the latter regime. The effect of large dust concentrations on the electron distribution is however problematic. A recent kinetic model [12] suggests that the Druyvesteyn-like distribution is modified in such a way that it becomes nearly Maxwellian. The slow increase in the intensity ratios after 20 s could be interpreted as providing support for this prediction.

As the tail of the electron distribution is responsible for the excitation of spectral lines, emission spectroscopy has the potential to provide information about changes in the tail of the distribution. This would, however, require a more detailed spectroscopic investigation.

Acknowledgements

The authors are grateful for assistance with measurements from Blake Churton. This work has been supported by the Australian Research Council, the University of Sydney and the Science Foundation for Physics within the School of Physics.

References

1. M. Cavarroc, M.C. Jouanny, K. Radouane, M. Mikikian and L. Boufendi, *J Appl Phys* **99** 064301 (2006)
2. C. Szopa, G. Cernogora, L. Boufendi, J.J. Correa and P. Coll, *Planetary and Space Science* 54 394 (2006)
3. C. Dominique and C. Amas, *J Appl Phys* **101** 123304 (2007)
4. M.A. Lieberman and A.J. Lichtenberg, *Principles of Plasma Discharges and Materials Processing*, John Wiley & Sons, New York (1994)
5. Y.P. Raizer, M.N. Shneider and N.A. Yatsenko, *Radio-Frequency Capacitive Discharges*, CRC Press, Florida (1995)
6. A Bouchoule and L. Boufendi, , *Plasma Sources Sci Technol* **3** 292 (1994)

7 J. Vlcek, *J Phys D: Appl Phys* **22** 623 (1989); J. Vlcek and V. Pelikan, *J Phys D: Appl Phys* **22** 632 (1989)

8 A. Bogaerts and R. Gijbels, *J Appl Phys* **84** 121 (1998)

9 F.J. Gordillo-Váárquez, M. Camero and C. Gómez-Aleixandre, *Plasma Sources Sci Technol* **15** 42 (2006)

10 X-M Zhu and Y-K Pu , *J Phys D: Appl Phys* **40** 2533 (2007)

11 V.A. Godyak, *IEEE Trans Plasma Sci* **34** 755 (2006)

12. I. Denysenko, M.Y. Yu, K. Ostrikov, N.A. Azarenkov, and L. Stenflo, *Phys Plasmas* **11** 4959 (2004)