Octiv VI probe used to measure the RF characteristics of a commercial CCP reactor

INTRODUCTION:

Capacitively coupled plasma (CCP) reactors are used in a wide range of plasma processing applications. The physical processes that control the fundamental plasma properties are still not fully understood.

In this study, the authors investigate the so called α−γ mode transition – characterised by a sudden change in the plasma parameters when the threshold for secondary electron emission from the powered is exceeded. The onset of secondary electron emission, due to high rf bias power, is accompanied with an increase in ionization caused by electrons being accelerated through the rf biased sheath into the plasma bulk. The authors also investigate the electron heating mode transition as a function of discharge pressure and in the presence of negative ions in an oxygen (O_2) plasma. One of the main goals of this research was to conduct a detailed study of the electron dynamics in an O_2 RF CCP reactor due to a lack of experimental data in the published literature, under the conditions of interest to the authors.

METHOD:

The experimental setup is shown in figure 1. An industrial plasma reactor (Plasmalab 100 from Oxford Instruments) was used. This is a 200mm, CCP, reactive ion etch reactor. Gas is introduced through the grounded shower head and RF bias power at 13.56 MHz is capacitively coupled to the bottom electrode to ignite the plasma. A Langmuir probe was introduced through one of the viewports located at the axial mid-plane and used to measure the important plasma parameters. An Octiv Poly VI probe was integrated at the output of the matching unit by Impedans Ltd. to monitor the voltage and current at the RF biased electrode. A hairpin probe was also used for electron density measurement.

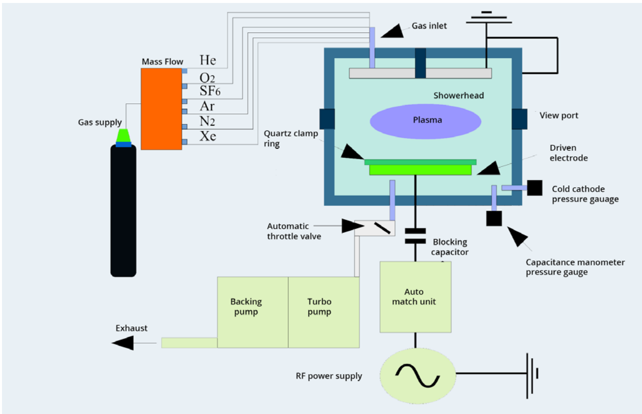

Figure 1. Schematic of plasma system.

FINDINGS:

The α–γ mode transition was investigated by measuring the electron energy probability function (EEPF) as a function of discharge power in the range of 30 W to 600 W in an O_2 plasma at discharge pressure of 100 mTorr. At a relatively low power of 75 W the EEPF changed to bi-Maxwellian shape from the Druyvesteyn shape at lower powers. This is shown in figure 2. The authors claim that the bi-Maxwellian shape is indicative of the γ mode in this case.

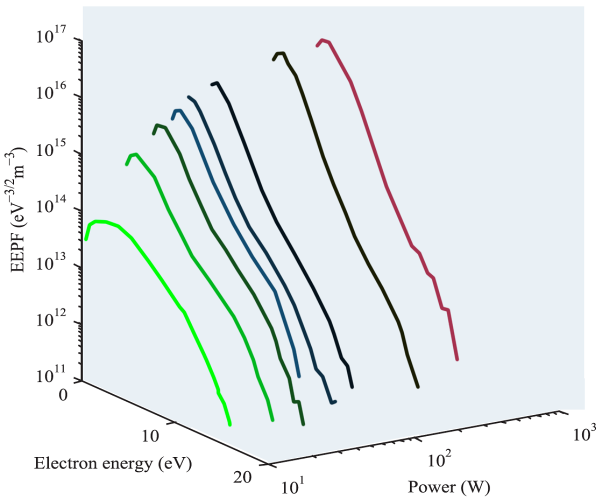

Figure 2. EEPF versus power at 100mTorr in an oxygen plasma.

The authors also point out the bi-Maxwellian shape is indicative of the well-known heating mode transition, from ohmic to stochastic heating, in low pressure CCP discharges. In general, the measurements of electron density and effective electron temperature with the Langmuir probe followed the trends expected and support the observation of the α–γ mode transition. Electron density measurements from the Langmuir probe and hairpin probe were in good agreement, further validating the experimental results.

The α–γ mode transition was also investigated by measuring the electron energy probability function (EEPF) as a function of discharge power in the range of 20 W to 600 W in an Argon (Ar) plasma at discharge pressure of 100 mTorr. A similar transition in the shape of the EEPF was found to occur at a lower power of 40 W. The EEDF in the γ mode was not as distinctly bi-Maxwellian as the O_2 case. See figure 6. No definite reason was proposed for this difference, but one hypothesis is that collisional heating is more efficient in the O2 plasma.

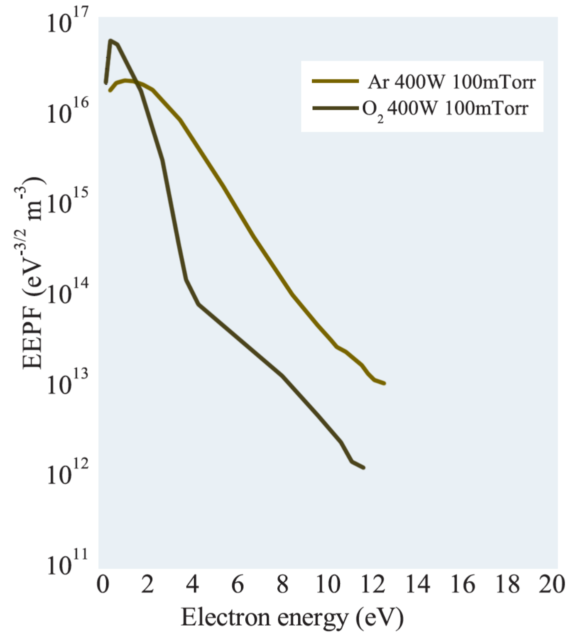

Figure 3. EEPF comparison for a 400W plasma at 100 mTorr in oxygen and argon discharges.

The variation of the electron density, measured with the Langmuir probe, as a function of RF power for O_2 and Ar discharges is shown in figure 4. The curves are qualitatively similar and appear to follow a roughly square root dependency on the discharge power.

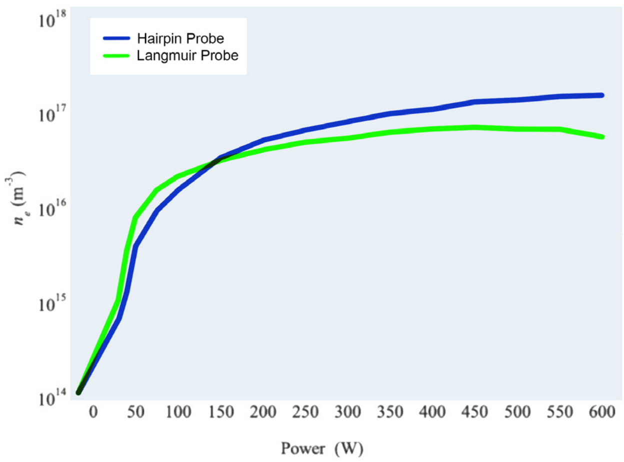

Figure 4. n_e measured as a function of RF power in O_2 plasma operated at 100 mTorr.

The Octiv VI probe voltage and current measurements are shown in figure 5. The bias voltage, and more importantly the discharge current, follow a square root dependency on the bias power. It is expected that the electron density variation is proportional to the discharge current, in good qualitative agreement with the observations.

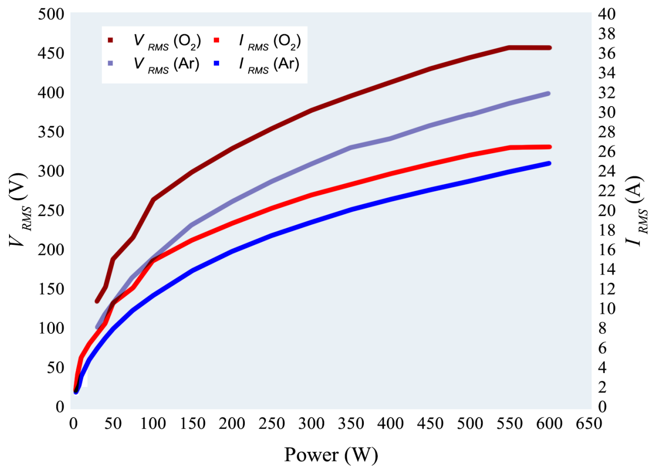

Figure 5. RF voltage (V_{rms}) and RF current (I_{rms}) comparison as a function of power in Ar and O_2 at 100mTorr.

CONCLUSION:

The electron dynamics of Ar and O_2 discharges were investigated in the α−γ mode transition region. The differences between the Ar and O2 discharges were highlighted and explained. The Impedans Octiv probe was used to measure the RF bias voltage and discharge current in an industrial plasma reactor. The profile of the electron density measured with a Langmuir probe and hairpin probe, as a function of RF bias power, qualitatively match the discharge current profile measured with the Octiv probe. These observations help to further validate the experimental data. RF probes installed in the output of matching networks provide critical data for the electrical characterization of plasma processes.

REFERENCES:

* Kechkar S., Kelly S., Daniels S., Turner M.
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