Analysis of Low Pressure Diglyme Plasmas by Langmuir Probe Measurements and Optical Emission Spectroscopy

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Abstract: Discharges of diethylene glycol dimethyl ether (diglyme) was analysed by optical emission spectroscopy (OES) and Langmuir probe (LP) techniques. The low pressure plasmas were generated in a capacitively coupled parallel plate reactor chamber powered by an RF-power supply. The power was ranged from 1 to 30 W and the operating pressure was held between 10 and 30 Pa. CH, CO and H emissions were evaluated by OES. Electronic temperatures between 0.2 and 1.6 eV were observed through LP measurements.

Keywords: Low pressure, plasma, diglyme, Optical Emission Spectroscopy, Langmuir probes.

1. Introduction

Thin films polymerized from diethylene glycol dimethyl ether (diglyme, $C_6H_{14}O_3$) in low-pressure discharges are very attractive for several industrial applications. Under a certain conditions they can have high biocompatibility and non-fouling properties. Though films with similar properties can be produced by conventional chemistry; the chemically produced films are soluble in acid or basic solutions, which is a great disadvantage for biomedical applications. Material properties of diglyme films were extensively studied, but due to complex nature of plasma medium the deposition process and its kinetics is still not well understood [1].

In order to understand deposition mechanisms of diglyme plasma polymers it is important to correlate plasma properties, using plasma diagnostic techniques, with the material characteristics [2].

2. Experimental

The diglyme plasmas were produced in a cylindrical stainless steel reactor with two parallel plate electrodes excited at 13.56 MHz by a Tokyo Hy-Power RF300 coupled to the electrodes through an impedance matching box. The discharge was operated from 1 to 30 W applied power with total pressure inside chamber ranged from 10 Pa to 30 Pa.

The plasmas were investigated using optical emission spectroscopy in actinometric method (A-OES), using argon as diagnostic gas, and electrostatic measurements with RF-compensated Langmuir probe technique (electronic temperature). To perform A-OES a Multichannel Avantes spectrometer (model AvaSpec-ULS2048X64) with 600 lines/mm grating and focal length of 75mm was used providing a spectral resolution up to 0.70 nm. The LP was designed with a retractable protective glass shell and a probe tip degassing system to avoid material deposition on the tip. It still has a choke system to avoid RF effects on the probe *I vs. V* signal.

The diglyme monomer was stored in an electrically heated stainless steel bottle (kept at 45°C) and carried out to chamber through a needle valve. To avoid monomer condensation the chamber walls were heated by Joule effect using a CrNi belt rounding the system. In figure 1 the system is presented with block diagrams of peripheral instruments.

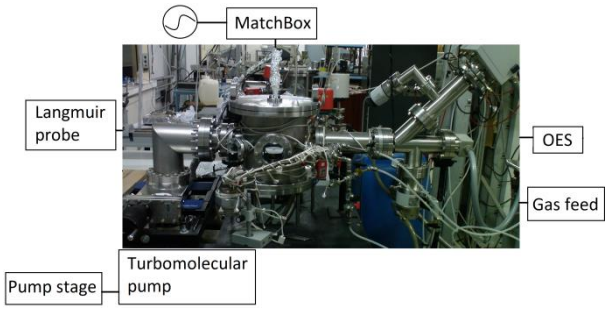

Fig.1. Picture of system with peripheral block diagrams instruments.

3. Results

The principal transitions investigated by A-OES were CH (431.2 nm), CO (519.7 nm) and H (656.5 nm). The relative intensity (spectral lines intensities divided by Ar 750.3 nm spectral line intensity) can be observed in the figures 2 and 3 as a function of applied power and operating pressure, respectively. It was observed that the relative intensities of all transition are proportional to applied power while the inverse is observed for operating pressure dependence. While the CH relative intensity has an approximately linear growth, CO emissions show a sharper increasing with the applied power changes.

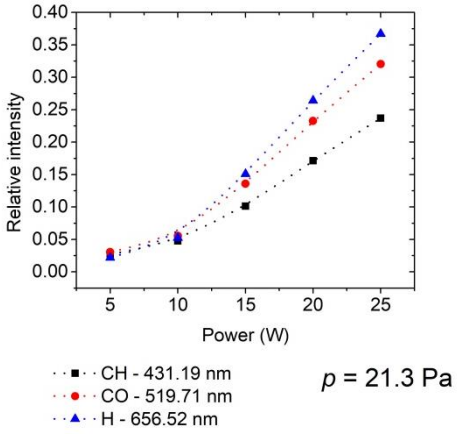

Fig.2. Relative intensity of CO, CH and H emissions as a function of applied power for 21.3 Pa.

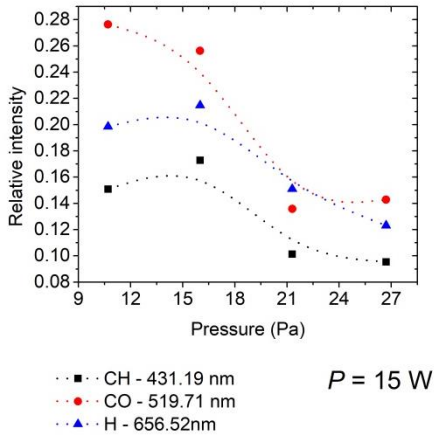

Fig.3. Relative intensity of CO, CH and H emissions as a function of operating pressure for 15 W.

The electronic temperatures were calculated for various conditions of applied power in the range between 1 and 30 W for two pressure conditions, 21.3 and 26.7 Pa. The evaluated electron temperature is represented in figure 4 as a function of the applied power.

It was observed that the electronic temperature varied from 0.20 eV to 1.60 eV. The value of electronic energy was increasing together with applied power for both pressure conditions and shows lower values for higher operating pressure.

This results for LP measurements show the strong dependence of electron temperature when parameters as applied power and operating pressure are changed. At higher applied power conditions, the electric field between parallel plate electrodes becomes stronger performing more energetic electron population. This is according with the relative intensity growth observed in A-OES once with higher electronic temperature, the probability of excitation of CH, CO and H increases.

At higher operating pressures, the mean-free-path decreases and the effective time for electrons acquire energy between inelastic collisions decreases, thus this conditions will promote less energetic electronic population. The A-OES results for pressure dependence (Fig.3) support these lasts assumptions.

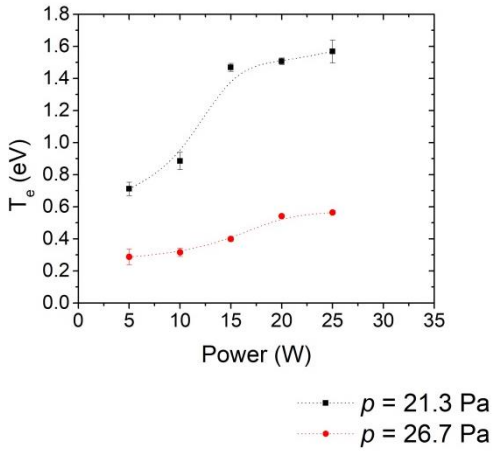

Fig.4. Electron temperature as a function of applied power for 21.3 and 26.7 Pa.

4. Conclusions

Plasmas of diethylene glycol dimethyl-ether were studied by Optical Emission Spectroscopy together with Langmuir probe measurements. Since diglyme is a pure hydrocarbon molecule, the main products observed by OES were CH, CO and H. The behaviour of these species was evaluated, presenting a good agreement with LP measurements. This work shows the importance to perform these two techniques together to diagnose this kind of plasmas and provides key information to be compared with plasma polymers properties and explain a few deposition mechanisms.

Acknowledgements

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5. References

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