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Diagnostics and preliminary operations of a microwave discharge plasma reactor for complex molecules dissociation.

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Abstract

A microwave discharge plasma reactor for complex molecular dissociation has been designed and built at INFN-LNS in Catania. The aim of this device is the dissociation of complex molecules by means of the electron impact in plasmas. Microwaves at 2.45 GHz are used to excite the plasma in a cylindrical plasma chamber, with a magnetic field generated by permanent magnets of intensity 0.1 T inside the chamber. A complete set of measurements has been performed by means of a Langmuir probe, in order to characterize the plasma properties (electron temperature and density, ion density, ecc.) and to optimize the plasma reactor operation. A series of measurements about the dissociation fraction of complex molecules has been carried out by making use of a quadrupole mass spectrometer. The summary of the results will be given in the paper.

1 Introduction and plasma reactor description

At INFN-LNS two microwave discharge ion sources have been built in the last years: MIDAS - (MIcrowave DischArge ion Source) [1] and TRIPS (TRASCO Intense Proton Source) [2]. The know-how acquired during the study of such plasma sources has permitted to design a plasma reactor with the aim to dissociate complex molecules (in particular for environmental dangerous molecules). Microwave discharge plasmas generated in presence of an off-resonance magnetic field can be considered “weakly ionized” and strongly collisional because of low electron temperatures (T_e~1÷10 eV) and high pressures (0.1÷0.5 mbar) [3]. The high electron-neutral collision frequency determines a high rate of molecules

fragmentation, thus increasing the dissociation fractions. For safety reasons, the reactor efficiency has been tested by using non dangerous gas, in particular n-hexane (C_6H_{14}) and cyclehexane (C_6H_{12}) but the final aim of the experiment is the dissociation of dangerous complex molecules (i.e dioxine).

The plasma reactor used for our experiment consists of a cylindrical, gas filled, microwave resonating cavity, 270 mm long, with a radius of 70 mm, that is inserted in a permanent magnet. In figure 1 a drawing of the plasma chamber with the related gas inputs is shown, along with the microwave aperture and the Langmuir probe input. A plasma is generated by means of the microwaves provided by a 2.45 Ghz, 300 W Magnetron through a WR284 (76 mm x 38 mm) waveguide excited in the TE_{10} dominant mode. The vacuum inside the plasma chamber is obtained by a two-stage rotary pump and a teflon pressure window allows the microwaves to enter inside the cavity by keeping the low pressure in the plasma chamber. The magnetic system is composed by three rings of Nd-Fe-B and soft iron and it is able to produce an almost costant 100 mT magnetic field along the chamber axis. In order to characterize the plasma in terms of electron temperature T_e, electron density n_e and ion density n_i, the Langmuir probe has been inserted with a 14° angle with respect to the chamber axis. This position allowed to analize the plasma parameters even in off-axis positions. Finally, in order to analyze the dissociation fraction a quadrupole mass spectrometer has been employed.

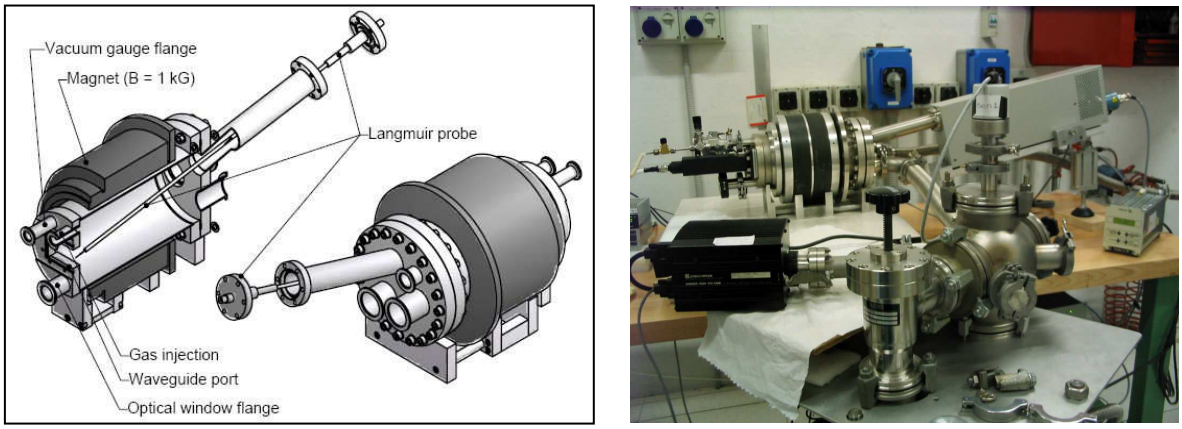

Fig. 1: The plasma reactor

2 Langmuir probe measurements

The Langmuir probe consists of a probe terminating in a tungsten tip able to determine the plasma parameters by analyzing the characteristic I-V curve [4]. A series of measurements has been carried out by varying the probe position inside the plasma chamber for different

conditions in terms of gas pressure and microwave power. At first, a plasma composed by air has been created. The trend of the electron density and electron temperature in the whole

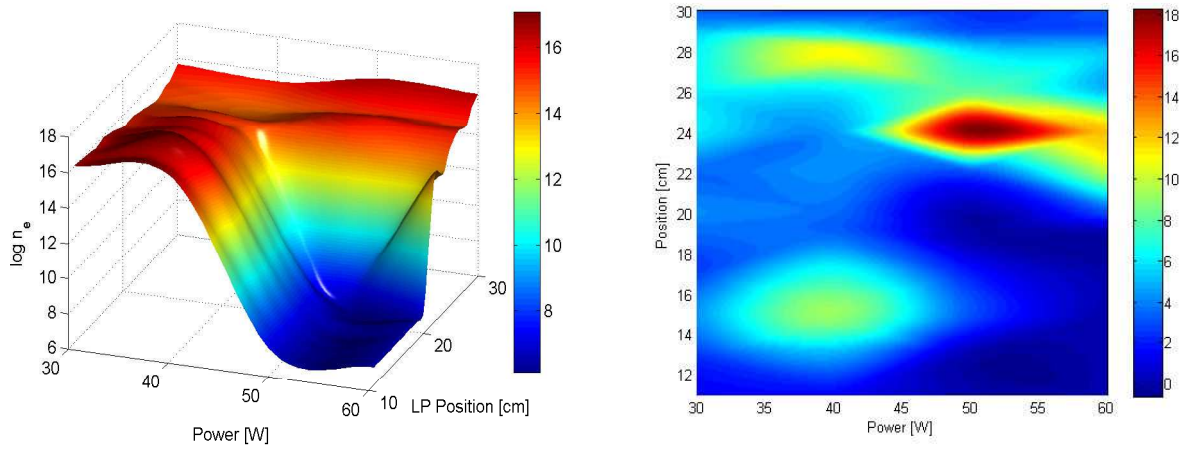

Fig2: (a) Surface plot of electron density n_e vs. position and microwave power; (b) Plot of electron temperature T_e vs. position and microwave power.

volume of the plasma chamber has been analyzed in order to determine the better experimental set-up parameters in terms of gas pressure and microwave power. The microwave power range used for the experiment was 30÷60 W and the gas pressure varies from 0.1 to 0.6 mbar. In particular for low pressures and high RF power the plasma creation occurs only in the first part of the cavity (in proximity of microwave window – see fig. 1), as shown in fig. 2; for lower powers (up to 40 Watts) or for higher pressures the plasma is distributed along the entire plasma chamber. In the case of larger volume plasmas $n_e \sim 10^{14} \div 10^{17}$ m^{-3}, $T_e \sim 1 \div 11$ eV; these values permit the molecular dissociation as the dissociation energies for n-hexane and cyclehexane are 3÷5 eV.

3 Complex molecules dissociation

A quadrupole spectrum analyzer has been used to obtain the dissociation fraction of n-hexane (C_6H_{14}) and cyclehexane (C_6H_{12}) by means of the formula:

$$D = \frac{S_{off} - S_{on}}{S_{off}}$$

where S_{on} is the spectrometer current when the discharge is switched on and S_{off} is the spectrometer current before the application of the discharge (without plasma). High dissociation fractions (up to 95% of n-hexane, 80% of cyclehexane) have been obtained and the results are reported in figure 3. Although the dissociation fraction generally increases for

higher power and decreases by increasing the gas pressure, there are values of power and pressure for wich D does not follow this trend. It has been measured that D increases as $<n_e>$ increases. The increase of $<n_e>$ is not strictly related to the power increase as in many cases for higher powers the plasma is created in a larger region of the chamber but with a lower $<n_e>$, as shown in figure 4. For ideal conditions of pressure and powers the great part of complex molecules are completely destroyed thus obtaining at the end of the plasma processing only H_2 and CO_2.

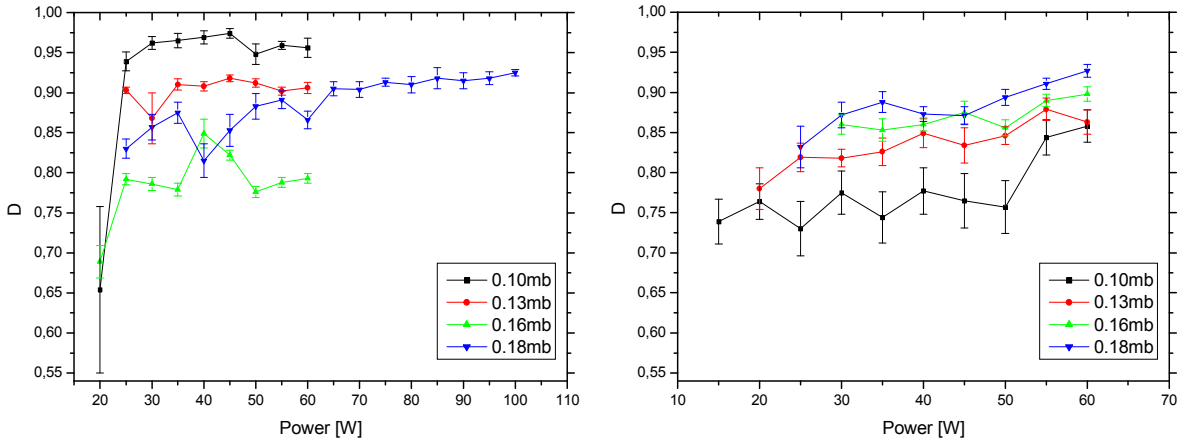

Fig 3: Dissociation fractions for the n-hexane (left) and for the cyclehexane (right) vs. power at different gas pressures

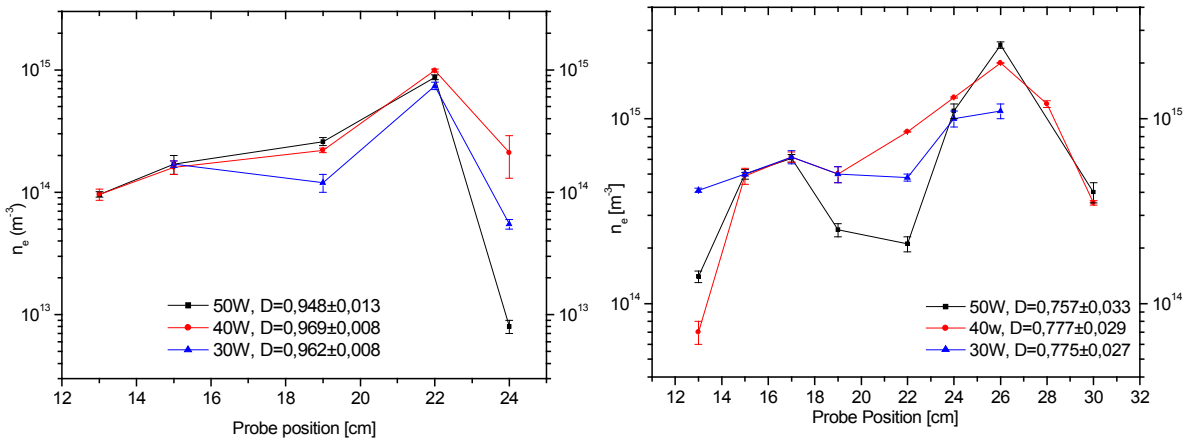

Fig. 4 Electron density n_e for n-exane plasma (left) and for the cyclehexane plasma (right) at different positions along the plasma chamber and for different microwave powers.

References

[1] G. Ciavola *et al*. Rev. Sci. Instrum. 69, (1998), p. 747.

[2] G .Ciavola *et al*. Rev. Sci. Instrum. 73, (2002), p. 1030.

[3] R. Geller, *Electron Cyclotron Resonance Ion Sources and ECR Plasmas*, Bristol Publisher, second edition 1996.

[4] J.E. Allen *Probe Theory - Physica Scripta*, Vol. 45, 1992.