Inductive Coupled Plasma source with internal coil: Performance and Stability

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An Inductively-Coupled Plasma excitation with internal antenna is characterized. The main Plasma is produced by an internal coil powered by a radiofrequency generator around 6 MHz. Experiments have been carried out for RF powers up to 200 watts and in the pressure range 1-100 mTorr. The stability of the source was investigated and the power transfer efficiency was measured in all the parameter space. Langmuir probes were used to measure the electron density and the electron energy distribution function in the discharge. Finally, magnetic confinement with permanent dipole magnets has also been studied.

1. Introduction and experimental set-up

Inductive discharges are used in many different industrial systems, from lighting to etching in microelectronics [1.2]. Many different configurations have been proposed, using either solenoids or flat coils. In this paper, we investigate a design (shown in fig. 1) in which the coil is internal, and is surrounded by the plasma. The coil is of course separated from the plasma by a dielectric window. However, in this configuration, the dielectric window thickness may be kept very small, which increases the inductor coupling to plasma, thus the power transfer efficiency.

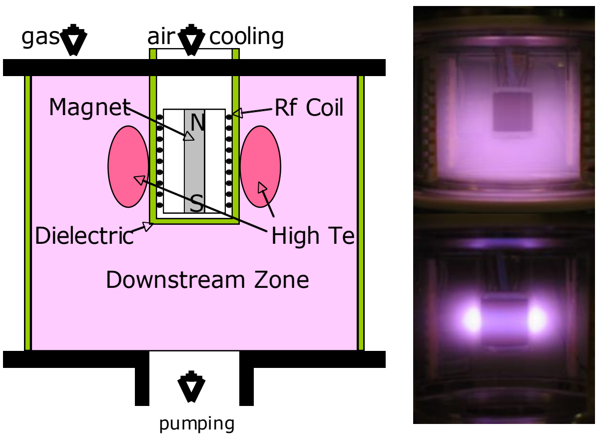

Fig. 1: Schematic of the system. A permanent magnet may be added inside the inductive coil to produce a magnetic confinement. Two pictures are taken on the side without magnet (top) and with magnet (bottom), showing the localisation of the plasma when the magnet is on.

A dipole magnet may be inserted inside the coil. In this case, the magnetic confinement localizes the plasma, as seen on the bottom picture of fig. 1.

2. Discharge stability

It was found that the discharge is unstable in most of the parameter space, as shown on fig. 2. Several types of fluctuations have been observed with a floating Langmuir probe.

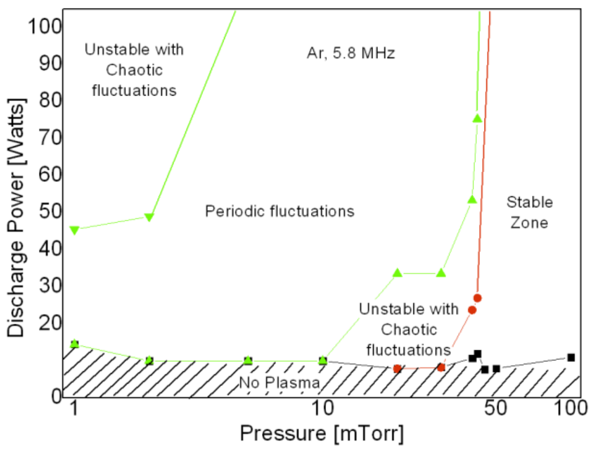

Fig. 2: Instability map in the pressure/power domain; with dipole magnet.

First note on fig. 2 that the discharge cannot be maintained at low power, which is well known for ICP discharges without significant capacitive coupling [2.3]. Then, it is seen that the discharge is stable at high pressure, but presents fluctuations in almost all powers at low pressure. The bigger area in the instability map is that corresponding to periodical fluctuations. We believe that this corresponds to a regime in which plasmaoids form and rotate azimuthally around the coil at a range frequency between 10-40 kHz. Other regimes are observed in which the fluctuations are chaotic.

3. Power transfer efficiency

The power transfer efficiency of the inductive source has been measured as a function of the input parameters. Fig. 1 shows the efficiency as a function of the discharge power for three different pressures. The efficiency increases drastically with pressure, as expected [2,3], and reaches 90% at 100 mTorr, high power.

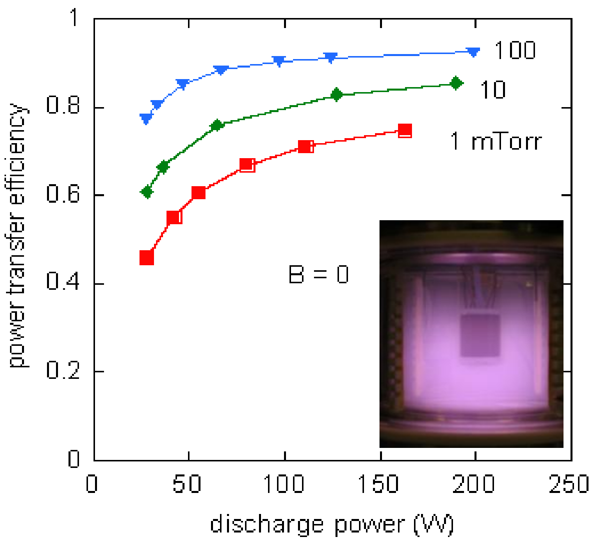

Fig. 3: Power transfer efficiency as a function of discharge power without central magnet.

When the central magnet is added, the power transfer efficiency is increased.

4. Electron density and electron energy probability function

Finally, the electron density and the electron energy probability functions EEPF were also measured. Fig. 4 shows the electron energy probability function measured on the axis, below the coil, without the permanent magnet. The distributions are similar to distributions measured in argon ICP of pancake configuration [4].

Fig. 5 shows the electron energy probability functions measured on the axis, below the coil, with the dipole magnet. A strong electron cooling is observed at the low pressure. Thus the electron temperatures found from measured EEPF at 1 mTorr are 5.8 eV and 0.83 eV, without and with dipole magnet respectively. The electron cooling is result of trapping of high energy electrons by a magnetic filter formed by magnetic field of the dipole magnet.

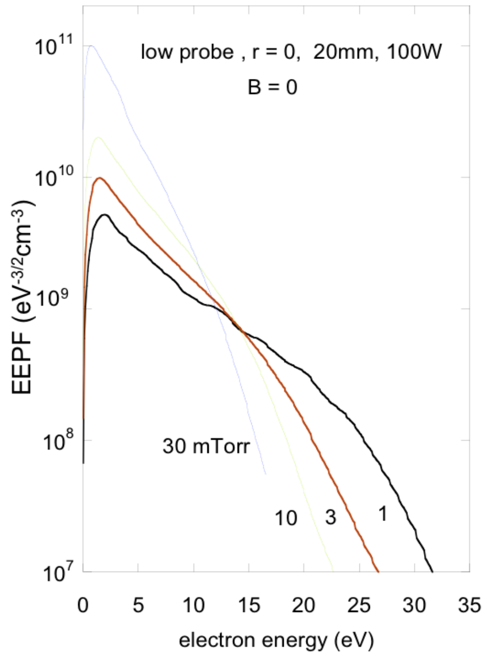

Fig.4: Electron energy probability function on the axis, below the coil, without magnet.

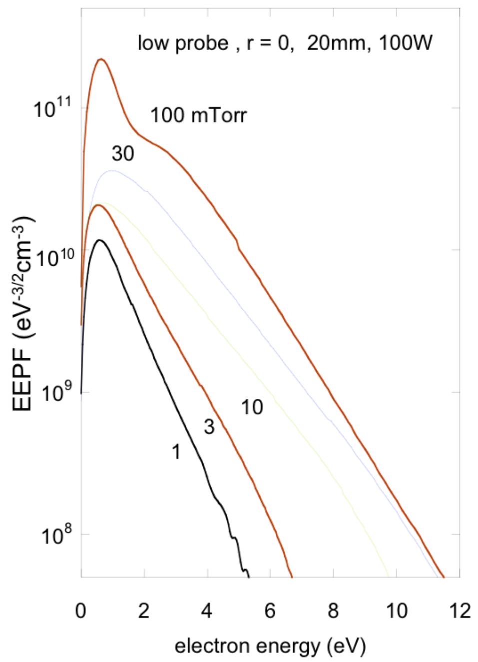

Fig.5: Electron energy probability function on the axis, below the coil, with magnet on.

5. References

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