In this study, the plasma ion density, \( n_i \), and electron temperature, \( kT_e \), of Inductively Coupled Plasmas were determined by three types of Langmuir probes: a single probe with only a traditional RF choke [1], a single probe with RF choke and compensating electrode [2] and a double probe [3].

If a single probe is not well RF compensated, the I-V curve will be distorted and the values obtained for the electron temperature will be overestimated.

The simplest approach to avoid RF interference is to use a RF choke, which is essentially composed of a blocking inductor which has a very high impedance at the operating RF frequency. There exist several variations on this approach. One particularly interesting technique is the so called compensating electrode [2]. Another disadvantage of the single probe is that it may drain so much current from the discharge that it disturbs the plasma. To avoid this situation, one can use the double probe technique. The current collected by the double probe is typically 20 times less than the current collected by the single probe. As both tips of the double probe are floating with respect to the discharge circuit, the use of an RF choke is less necessary and it was not used.

The probe tips were all made of tungsten and had a 0.2 mm diameter and 4 mm length for single and 8 mm length for double probes.

The original reactor has been described as system 2 in ref.4. The wafer sits on a 6 inch diameter aluminium electrode, which we shall call the cathode from now on. Power can be applied independently to the coil and to the cathode at 13.56 MHz.

The probe collected current was measured by the resulting voltage drop over a resistor. This voltage was digitalized by a 12 bit A/D converter and collected in computer tables as a function of the probe input voltage (also digitalized by a similar A/D converter). The data in these tables were then used to calculate \( kT_e \) and \( n_i \). For the single probes, \( kT_e \) and \( n_i \) were determined using the methods of the semi-logarithmic electron current plot and of Laframboise, respectively. For the double probe, the electron temperature was determined by the logarithmic plot method [3], and the plasma density was obtained through a numerical fit of the I-V curve [5]. For each process analysis, three I-V curves were measured by the probes. Each curve was analysed and \( kT_e \) and \( n_i \) determined. From these three measurement results, the relative average standard deviations were determined: \( \sigma(kT_e/kT_e) \) and \( \sigma(n_i/n_i) \) were found to be equal to 8.8% and 6.1% for the single probe with RF choke; 9.2% and 6.0% for the single probe with RF choke and compensating electrode, and 2.0% and 3.2% for the double probe. The results obtained by the double probe offered the most reliable results for both plasma parameters, mainly for the determination of \( kT_e \); the three sigma value is only 6%, which is compatible with the reproducibility of most semiconductor processes.

The single probe with compensating electrode has a similar precision as the single probe with only an RF choke, but its accuracy is better.

For the investigated argon plasmas, \( kT_e \) increases with coil power and decreases with pressure, while the cathode power does not influence very much; \( n_i \) increases mainly with coil power, and to a lesser extent also with pressure and cathode power.

The highest plasma densities obtained in this system were of the order of 10^{12} ions/cm^3. For the evaluated pressure level of 50 mTorr, this is a really high density plasma, showing that in this system, the coil power is coupled very efficiently into the plasma. The figure below shows \( n_i \) as a function of both cathode and coil power, for a constant pressure of 50 mTorr. This figure shows that the general trends are similar for all the probes: the plasma densities increase very strongly with coil power, while the cathode power has little effect.

Plasma density as a function of coil and cathode (inset) power for 50 mTorr Ar plasmas measured with (a) single probe with RF choke, (b) single probe with RF choke and compensating electrode, (c) double probe. The error bars represent the 1 sigma value.