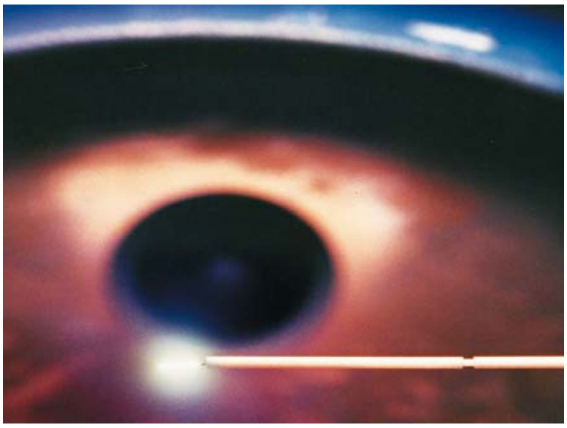
Plasma Consult

TECHNICAL NOTE

Langmuir Probe System L2P



Working Principle

Measurement of the density and mean kinetic energy of charged particles in a plasma is crucial for the control of industrial plasma processes.
For this purpose several techniques are known:

- *Thomson scattering*
  measurement of electron density and temperature by laser scattering
- *Microwave interferometry*
  measurement of electron density by phase shift of a microwave beam
- *Plasma Oscillation Probe (POP)*
  measurement of electron density by measuring the electron plasma frequency
- *Emission Spectroscopy*
  measurement of electron temperature by measuring emission intensity of different spectral lines
- *Langmuir Probe*
  measurement of electron/ ion density and EEPF (Electron Energy Probability Function) by measuring the current-voltage characteristic of an electrical probe immersed to the plasma

Among these techniques the Langmuir Probe combines good spatial resolution of the measurement with easy handling of the equipment. Two types of Langmuir Probes are well established:

- *Double Langmuir Probe*
  Double Probes consist of two probe tips, which are electrical floating . By applying a voltage between the two probe tips a current results, which depends on the ion density and electron temperature (Fig. 1).
- *Single Langmuir Probe*
  This type of probe uses only one probe tip, which is polarized relative to a reference potential, often the potential of the plasma chamber. Using this probe one is able to determine the EEPF, which is related to the second derivative of the I-V characteristic of the probe.

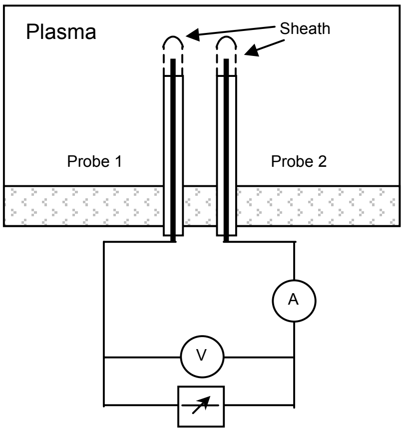


Fig. 1a: *Double Langmuir Probe*
Principle set up
The double probe is electrically floating.

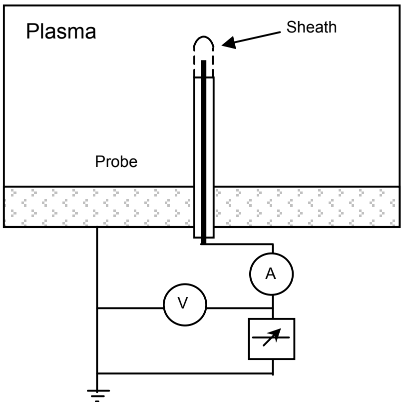


Fig. 1b: *Single Langmuir Probe*
Principle set up
The probe tip is referenced to ground potential.

L2P

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Fig. 2 shows a measured I-V characteristic for a Double Probe of the L2P System in a capacitively coupled RF-plasma. The ion density is 3.8×10^{10} cm^{-3} and the electron temperature is 2.3 eV. In RF-plasmas the sheath is oscillating with the RF frequency thus changing the capacity of the sheath. This has an unwanted effect on the measurement of the I-V characteristic of electrical probes. Fortunately, the Double Probe is operating in the ion branch of the characteristic, so the effect on the measurement is negligible. The Single Probe on the other hand is very sensitive to RF-effects since it is operating in the electron branch of the characteristic.

Many industrial plasma sources use an electrodeless coupling scheme. In that case it is often impossible to define a reference potential which is necessary for Single Probe operation.

If the characteristic in Fig. 2 is used to calculate the electron temperature one has to make the assumption of a Maxwellian EEPF. Especially in low pressure discharges this assumption often not holds. In that case one should, if possible, use a Single Langmuir Probe to determine the EEPF. An example for the I-V characteristic of a Single Probe can be seen in Fig. 3 for a microwave plasma of 5×10^{10} cm^{-3} electron density and 2.35 eV electron temperature.

Besides the different capabilities of these two types of Langmuir Probes, there are some negative effects on probe measurements, which have to be taken into account:

- *Magnetic fields*
  Langmuir probe measurements in magnetic fields are effected by a change of the trajectory of charged particles in magneto static fields.
- *High pressure*
  In high pressure plasmas the sheath is no longer collisionless, therefore known theories to calculate plasma parameters from I-V characteristics become invalid.
- *Flowing plasmas*
  In directed flows of plasma the flow motion leads to a decrease of the measured current, therefore the results of the L2P System have to be corrected.
- *Deposition plasmas*
  If the tips of the probe are coated by an insulating film, the probe current is significantly reduced. If the deposition rate is quite low it might be possible to clean the probe at the beginning of each measurement by heating up the tips.

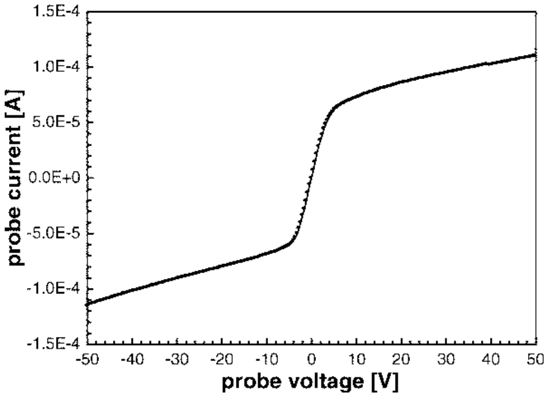

Fig. 2 I-V charcteristic of a Double Probe in an argon plasma generated by VP-HCD RF plasma source

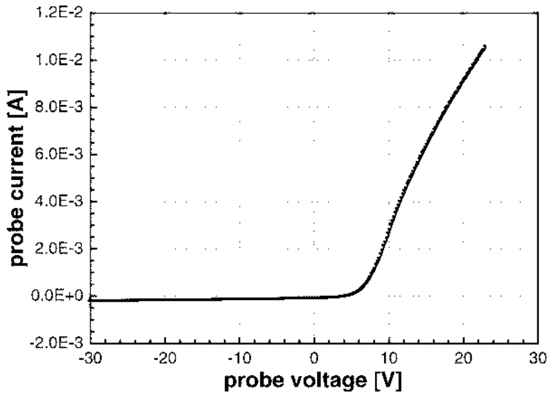

Fig. 3 I-V charactersitic of Single Probe in an argon plasma generated by a SLAN I microwave plasma source

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