SLAN plasma sources

Fig. 1: SLAN plasma sources

General

Plasma-based materials processing including applications in microelectronics and micro system technology often require extremely high densities of electrically charged (ions, electrons) and uncharged particles such as excited species and radicals. To induce specific reactions in chemically active plasmas and to control substrate damage one is also interested in controlling the electron temperature as well as its distribution.

Other than with ion sources the plasma ion energy is smaller, typically being in the range of a few tenth of an electron volt. Therefore all applications based on low energy large particle fluxes to substrates benefit from electrodeless microwave discharges as produced with superior efficiency by the SLAN´s.

By using either a divergent extracting magnetic field or providing a negative substrate bias charged particle energies can be increased to induce additional energy related effects. This mode where the plasma generation is locally separated from the substrate (i.e. remote mode) is being used for high rate etching and remote plasma polymerisation.

Recently is has been found that time-modulated power coupling to a plasma is extremely beneficial to variety of plasma-induced etching and deposition processes. Here the SLAN I-DS also has proved to be extremely powerful and capable to handle even very demanding plasma processes either in direct or remote processing mode.

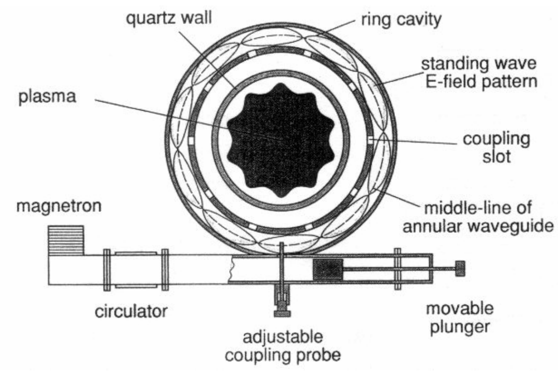
Working Principle of a Slot Antenna

The SLAN basically consists of an annular wave guide (ring resonator) with slot antennas positioned at regular intervals on the inner side (fig. 2) feeding microwave energy into the plasma. A 2.45 GHz magnetron which generates microwave power of frequency 2.45 GHz couples to the SLAN via a R26 wave guide. Between the generator and the plasma load a three port circulator directs the reflected power from the plasma into a water cooled dummy load to protect the magnetron from possible damage.

The microwaves are coupled by a movable antenna into the annular ring. Because of the highly nonlinear plasma impedance the active antenna length as well as the plunger position can be adjusted for minimum reflected power.

A three stub tuner is not necessary. By changing the antenna and plunger position virtually any plasma load in an extended power and pressure range can be handled for atomic and molecular gases.

Fig. 2: Cross sectional view of the 2.45 GHz microwave plasma source SLAN I. Indicated is also the microwave power supply including the coupling probe (antenna) and plunger.



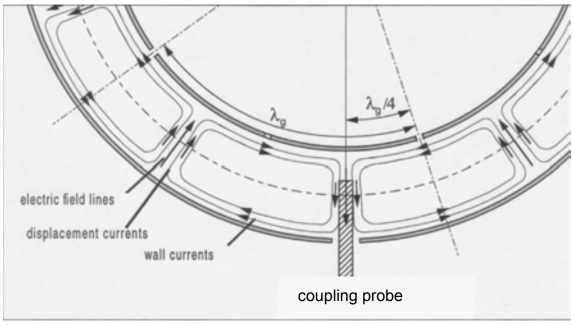


Fig. 3: Schematic representation of the electric field lines, displacement and wall currents.

The diameter of the ring-resonator is chosen such that a standing TE_{10}-wave (H_{10}-wave) develops (fig. 3). In the µ-SLAN the circumference of the annular wave guide equals two wave guide wavelengths (λ_g). On the inner side of the ring cavity there are n resonant coupling slots, half of a free-space wavelength long, equally spaced azimuthally and axially directed, i.e. perpendicular to the direction of wave propagation inside the wave guide. The distance form the coupling probe to the two nearest slots is about $\lambda_{g/4}$.

Because of the standing wave inside the annular wave guide no phase shift occurs between the electric field lines and the displacement current (as opposed to traveling waves). Thus the slots cross the lines of maximum wall current and therefore neighboring slots radiate exactly in counter phase.

Electron cyclotron resonance (ECR)

A permanent 87,5 mT SmCo-magnet assembly can be inserted into the SLAN I to increase dramatically the MW-power absorption in the lower pressure range at around 10^{-4} to 10^{-2} mbar. Ionization ratios of several percent and maximum ion concentrations of the order of 10^{+11} cm^{-3} are typical.
With decreasing pressure the electron temperature increases as well and approaches several eV.

Surface wave generation

The µ-SLAN and the SLAN I-DS generate axial surface waves at higher power levels (with argon in excess of 1 KW cw ; with molecular gases higher power levels are necessary). Prerequisite is that the plasma is overdense which is easily achieved for Ar. When operating in this mode the plasma volume increases with increasing power providing interesting options for advanced materials processing.

Plasma Consult

JE PlasmaConsult GmbH
Rainer-Gruenter-Str. 21, Geb. FN
42119 Wuppertal
Germany

Tel. ++49-202-28397-0
Fax ++49-202-28397-123

contact@plasmaconsult.de
www.plasmaconsult.com