2.45 GHz Microwave Plasma Source SLAN I-DS by

PlasmaConsult

Features

- High plasma and radical densities
- Controlled low electron temperature
- Compatible with chemically reactive and nonreactive gases
- Low contamination
- ECR and non-ECR operation
- cw and pulse operation

Applications

- Plasma-enhanced chemical vapor deposition (PE-CVD)
- Surface modification
- Plasma cleaning
- Plasma etching
- Reactive and non-reactive ion etching
- Materials Science (in general)

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General

Plasma-based materials processing including applications in microelectronics and microsystem 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 polymerization.

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.

It is far beyond the scope of this product information to cover more aspects in detail. The reader is therefore referred to the literature or may contact Nano-Master, Inc.

Working Principle

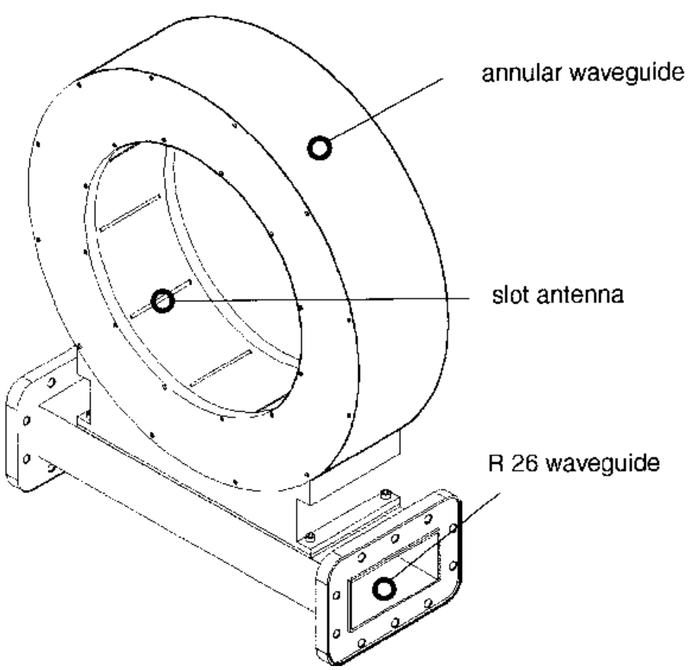

Fig. 1 Slot Antennae Ring Resonator SLAN (Principle)
Inside the annular waveguide a standing TE_{10}-wave forms. The nodes of the electron field correspond to the position of the slot antennae spaced equally around the inner waveguide periphery.

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The SLAN basically consists of an annular wave guide (ringresonator) with slot antennas positioned at regular intervals on the inner side (Fig. 1) feeding microwave energy into the plasma. A2.45 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 (Fig. 2).

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.

Electron cyclotron resonance (ECR)

A permanent 87.5 mT SmCo-magnet assembly can be inserted into the SLAN 1-DS to increase dramatically the power absorption in the lower pressure range at around 10^{-4} to 10^{-2} mbar. Ionization ratios of several percent (depending on the gas used) thereby yielding maximum ion concentrations in the order of 10^{11} cm^{-3} are typical.

At the same time the electron temperature increases with decreasing pressure approaching several eV.

Surface wave generation

The SLAN I-DS generates 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.

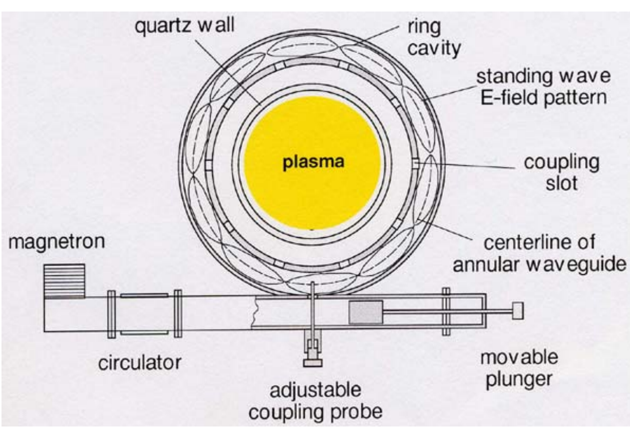

Fig. 2
Cross-section view of the 2.45 GHz microwave plasma source SLAN I.
Indicated is also the microwave power supply including the coupling probe (antenna) and plunger.

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Performance (examples)
Without electron cyclotron resonance (ECR)

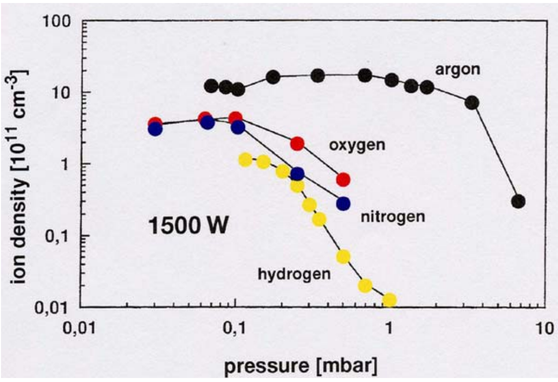

Fig. 3 Ion density for different atomic and molecular gases.
Data taken with single Langmuir-probes (PlasmaConsult L2P-System).
Center of SLAN I-DS.

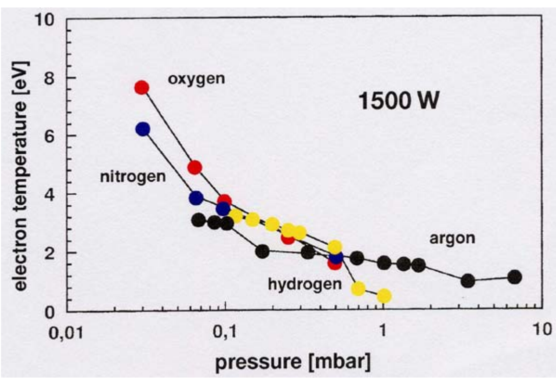

Fig. 4 Electron temperatures for different atomic and molecular gases.
Data taken with single Langmuir-probes (PlasmaConsult L2P-System).
Center of SLAN I-DS.

With electron cyclotron resonance (ECR)

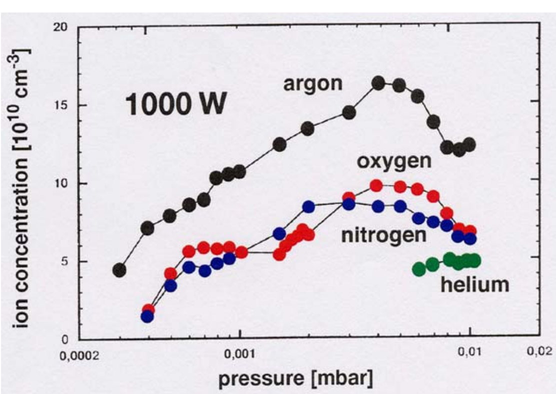

Fig. 5 Ion density for different atomic and mlecular gases.
ECR-plasma, toroidal symmetry. Data were taken 7 cm downstream the source DN 250 ISO-flange. (Plasma Consult L2P Langmuir probe System)

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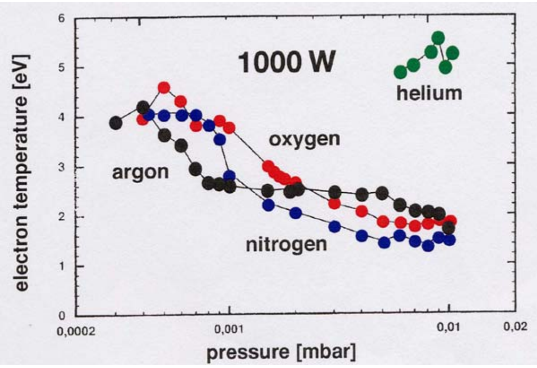

Fig. 6 Electron temperature for different atomic and molecular gases
Parameter as in Fig. 5.

Technical Data

• Plasma diameter	16 cm	
• Max. microwave power	2 kW (cw), with pulsed power operation higher peak power possible	
• Pressure range	10^{-2} to > several mbar	maximum pressure depends on the gas used, no ECR
	10^{-4} to 10^{-2} mbar	with ECR
• Electron cyclotron resonance (ECR)	SmCo permanent magnets, toroidal symmetry	
• gas flow rates	May vary with the specific plasma-process. Examples are: Argon 10…. 200 sccm Oxygen 10….500 sccm	
• Air-cooled		

SLAN I-DS Dimensions

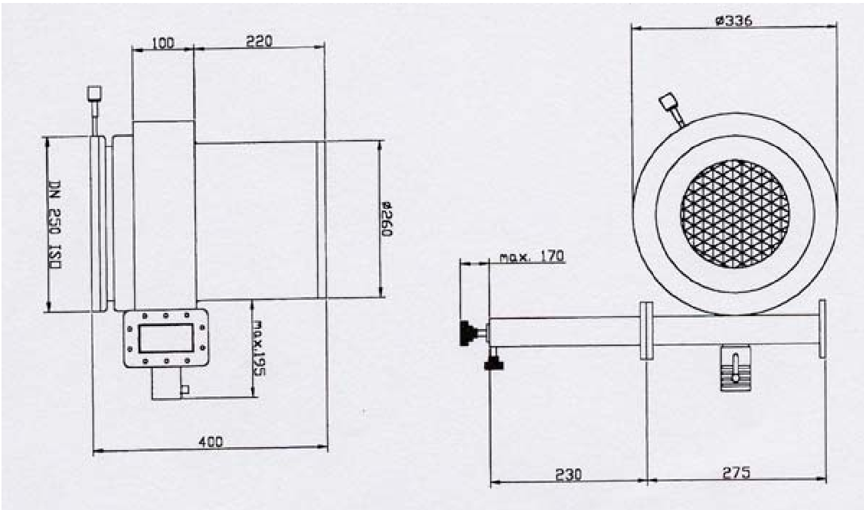

Fig. 7 SLAN I-DS dimensions in mm.
The source is mounted on a standard DN 250 ISO-flange.

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