Plasma Consult

TECHNICAL NOTE

13.56 MHz Hollow Cathode Plasma Source HCD-P 100

General Principle

Hollow Cathode Discharges (HCD) represent a very effective and yet comparatively simple, low cost effective means of high density, low temperature plasma generation.

The Hollow Cathode Effect

Consider two parallel metallic plates in a vacuum chamber filled with a low-pressure gas. For a given plate separation ***d*** and pressure ***p*** there exists an optimum product ***d*** x ***p*** such that the plasma ignition voltage (or power) becomes minimum (so-called ***Paschen - Law***). This voltage is applied to the two plates one of which is usually grounded (often being the vacuum chamber wall). A plasma excited in such a way has a comparatively low density being insufficient for advanced plasma processing.

If the negatively biased electrode is formed as a cavity or cylindrical cathode structure the conservation of particles and photons leads to a drastically increased ionisation and/or emission.

To understand the working principle it is in order to look a little closer to the underlying physics. Usually the so-called plasma potential is the most positive of the whole set-up including the vacuum chamber walls.

As a consequence the negatively charged electrons tend to be confined to the plasma. To be more precise, this holds only for the lower energy electron population representing a substantial fraction of all electrons.

In the hollow cathode a negatively biased cavity or cylindrical tube encloses the plasma (Fig.1). Electrons within this plasma are constantly being repelled when approaching the hollow cathode walls: An oscillatory motion of the electrons results yielding greatly improved ionisation rates and thereby higher plasma densities.

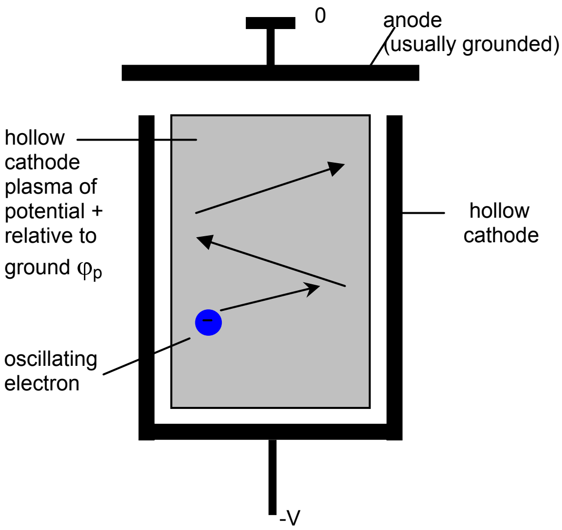

Fig. 1: Principle of a dc-hollow cathode discharge
The discharge is driven by direct current (dc). In the remote plasma processing mode the hollow cathode plasma shown is often referred to as the "primary plasma".

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HCD: hollow cathode discharge

Fig.1 relates to a dc-hollow cathode discharge. The dc-power coupling works very well when using only chemically non reactive gases such as argon (Ar) or helium (He). However, the addition of film forming monomers possibly blocks the dc-current flow after a thin, electrically non-conducting polymer film forms on one of the source electrodes. As a consequence, the dc discharge may be extinct. RF excited discharges are much more insensitive to these unwanted contaminations. Furthermore, due to the specific capacitive coupling used a well balanced and symmetric power flow is guaranteed for each individual plasma jet.

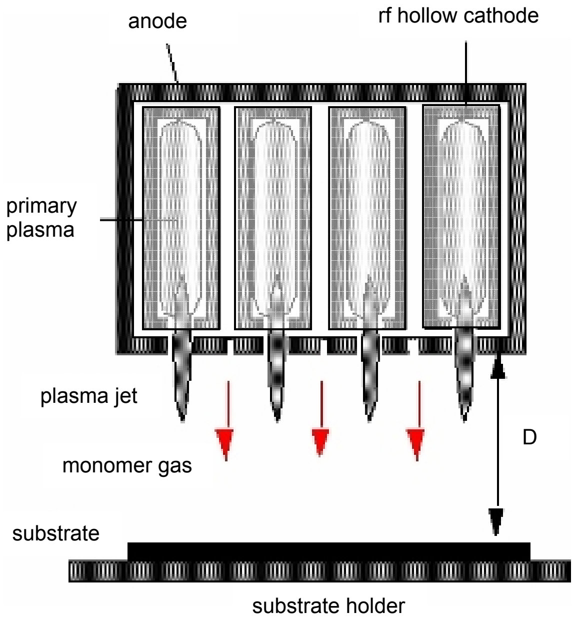

Fig.2: Functional principle of the plasma polymerization with the HCD P
The plasma jets (consisting of electrons, ions and excited neutrals/radicals) interact with the monomer fed into the system by another matrix of 48 orifices, located between the plasma jet outlets. At a distance D downstream the plasma combination with the jet-particles initiate the polymerization process - taking place at the substrate surface.

Concept of the HCD-P

Fig. 2 shows four plasma jets of the hexagonal matrix of 48 jets. The inner tubes are rf-powered enclosing the primary plasma; the outer part of the source is electrically grounded. 48 hollow cathode cylinders are arranged in a hexagonal matrix forming the high intensity primary plasma jets. The hollow cylinders are electrically isolated from the housing. They are connected to the rf-power generator; the housing is grounded. A hexagonal array of orifices is drilled into the housing and the hollow cylinders allowing plasma jets to be extracted after the primary plasma has been excited in the hollow cathode. A proprietary compact gas distribution system (primary gas monomer) featuring fractal geometry gas channels plus a proprietary internal cathode structure guaranties a homogeneous jet formation over extended source dimensions. The material used is all-aluminum, important for a good thermal conductivity and reduced surface loss rates when working with radicals and excited species. Depending on the technological needs the whole system can be operated isothermally by adjusting the cooling/heating water-temperature.

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