Application Note

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Plasma Modes: Primary and Secondary Plasmas

There are two basic types of cold gas plasma: 'primary' (or 'direct') plasma and 'secondary' (or 'indirect') plasma. Secondary plasma is also commonly referred to as 'downstream' or 'remote' plasma. The strengths and limitations of each type are addressed below.

Primary Plasma

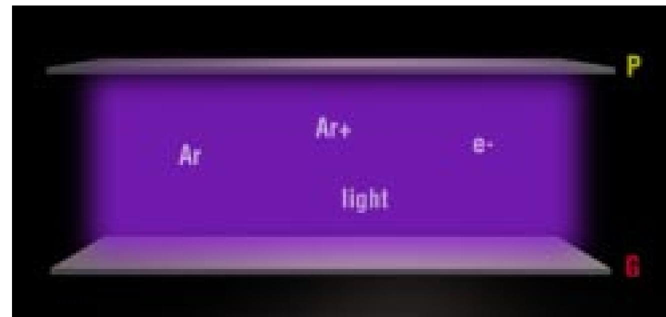
Primary plasma is one in which a radio-frequency, electromagnetic field is used to generate a glow discharge, usually between a set of electrodes. Samples or substrates to be treated by the plasma are placed directly in the electromagnetic field between the electrode plates. The active species that perform the work within the plasma field are the ions and free radicals. These active species have a relatively short lifetime and must be constantly replenished due to their consumption from recombination and reaction processes. This replenishment through the continuous application of the electromagnetic field ensures that highly uniform surface activation, etching and contamination removal occur.

Primary plasma is capable of generating a negative direct-current (DC) bias on the electrode plates. The negative DC bias is a result of negative charge buildup on the capacitively coupled powered electrode. DC bias is extremely useful when aggressive or anisotrophic (i.e., perpendicular to the electrode surface) etching is required due to the enhanced ion bombardment at the sample surface. The DC bias created in March Plasma System's process tools is harmlessly dissipated to ground during the plasma process. Therefore, electrostatic discharge (ESD) due to the charge buildup is not of concern.

There are two variations of primary plasma:

Directional Direct Plasma

Directional Direct Plasma allows for the sample to be positioned either on the powered electrode, ground electrode, or floating in the discharge. Location of the sample within the direct plasma is determined by the process required, the chemical and physical properties of the sample, and the required throughput. The powered electrode is normally more aggressive than the grounded electrode. It cleans, surface activates, and etches faster than the ground electrode, but consideration must be given to the possible effects of heat buildup and high ion bombardment.



Directional Direct Plasma

Alternatively, the grounded electrode is somewhat less aggressive and typically cleans and surface activates more uniformly with limited heat buildup. Placing the sample between the two electrodes, or floating the sample, will provide plasma conditions intermediate between the powered and ground electrode conditions. Applications experience is the key to understanding which electrode (or direction) is more useful for a given cleaning or etching operation.

Reactive Ion Etch (RIE)

RIE plasma is typically used in failure analysis applications or when features must be etched in surfaces. It is an extreme form of direct plasma that uses small surface-area electrodes spaced closely together. A high RF-electric field is used to ignite the plasma. The combination of closely spaced electrodes and the high RF-electric field result in increased DC bias levels – making RIE plasma highly anisotropic and aggressive.

Reactive Ion Etch (RIE)

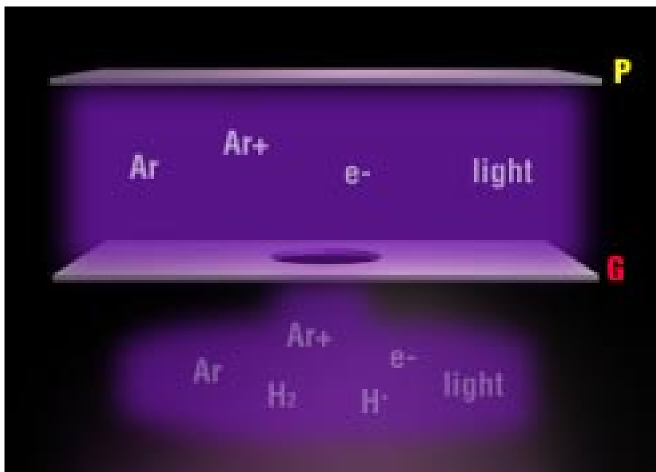
Secondary Plasma

Secondary plasma is used for materials that may be sensitive to some or all of the components in the primary plasma. Cycle times are typically longer for secondary plasmas due to the reduced concentration and energy of the active species.

There are two variations of secondary plasma:

Secondary Downstream Plasma

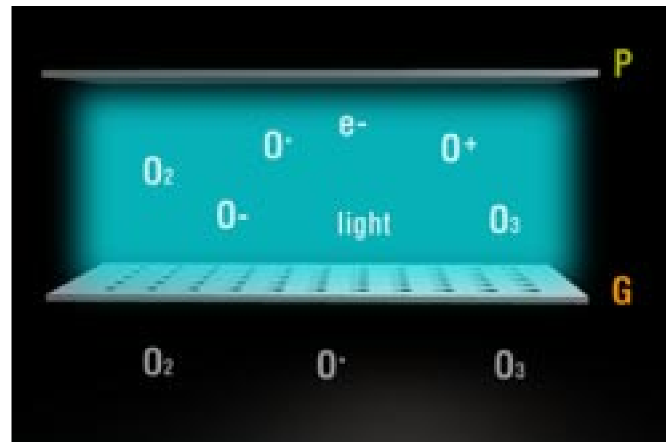
Secondary downstream plasma is generated downstream of a primary discharge. Secondary downstream plasma contains the same types of active species as the primary plasma but with lower energy. The ions and electrons from the primary discharge are pumped into the secondary plasma chamber. The secondary downstream plasma is initiated by these ions and electrons, and sustained with additional process gas in the secondary chamber. The use of this plasma mode is limited as it has similar attributes of the primary plasma but with poor uniformity and throughput.



Secondary Downstream Plasma

Ion-Free Plasma

In an ion-free plasma the samples are only exposed to the plasma-generated radicals and not the ions or photons. A primary plasma is generated upstream of the sample zone; the primary plasma-active species diffuse through a barrier whereby the ions are removed. This type of plasma is purely a chemically active plasma and is employed when processing parts that are extremely sensitive to ion bombardment or ultraviolet light exposure.



Ion-Free Plasma

Summary

Both primary and secondary plasmas are practical methods for surface modification of many types of substrates and materials. Selection of an appropriate plasma mode is determined by the surface modification process required, the sample's chemical, physical, and electrical properties, and the throughput required.

Contact March Plasma System's Applications Engineering group at apps@marchplasma.com to determine which mode is best suited for your specific product and desired outcome.

Our Applications and Customer Service departments bring to you more than 20 years of experience in RF plasma technology.

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