Simple Ion Beam Solutions

Ion Beam Source Selection Guide

If you are new to ion beam source processes, please take a moment to read through this guide to help you select the ideal ion source to meet your requirements. As a supplier of ion beam source equipment and services, Plasma Process Group has a comprehensive understanding of the utility of each size, style, and variation of the equipment we offer, and we are happy to apply our knowledge to find your ideal solution. Below you will find a review of each of the sizes of ion source we offer, and an overview of the various mounting and accessories that can be made to go with it. Please examine our website for standard mounting configurations. As always, do not hesitate to contact us via phone or e-mail with any questions.

Source Sizes

Ion beam sources are usually selected on the basis of 1) application for the ion beam and 2) coverage area required.

Ion beam applications are usually categorized by the ion energy required. Ion energy is typically discussed in terms of electron volts (eV) and is the same as the beam voltage. Substrate cleaning, etching and ion assisted deposition will typically use a lower ion energy range, 100 to 500 eV. Target sputtering, on the other hand, will utilize a higher energy range 1000 to 1500 eV. All of our Sources and IBEAM power supplies are capable from 100 to 1500 eV.

The coverage area will depend upon the system geometry. Each ion beam source requires a set of grids (also called ion optics) that function to extract and accelerate the ions. The beam shape and its properties will be determined by the grids. In some ways, it may be best to first read our Grid Selection Guide before selecting a source. For substrate cleaning, etching and ion assisted deposition, a wide area of coverage is preferred. For target sputtering, a focused beam will minimize beam overspray and provide a higher quality coating.

Ion sources are typically named by the ion beam size as it leaves the source. The type of ion source is defined by how the plasma is created. Our sources will create a plasma using either direct current (DC) method that uses a filament or a

radio frequency (RF) process that uses an antenna. Both types of sources work well for numerous applications. As a general rule, DC sources are used for research or small sample or batch systems. For larger production type machines, RF sources are more dependable, especially for processes that require a reactive gas such as Oxygen. The various ion beam sources that we offer are listed in Table 1.

Source Size	Type	Applications
3 cm	DC	Small target etch, substrate pre-clean
6 cm	RF	Wide area etch or assist, small target sputter
8 cm	DC	Medium target etch and substrate pre-clean
12 cm	RF	Wide area etch or assist, medium target sputter
13 cm	DC	Wide area etch or assist, medium target sputter
16 cm	RF	Large area etch, large target sputter
Linear	RF	Wide area etch, assist, and target sputter

Table 1. Various source sizes and types.

Below are in-depth descriptions of each source listed in Table 1. Each source will require a neutralizer and these are also described. Be sure to visit our website which will have typical run conditions, beam coverage diagrams and selected beam profiles for each source.

DC Ion Beam Sources

DC ion beam sources have existed for well over a half century. They are robust, reliable, and comparatively easy to understand. A filament cathode passes across the inside of a contained area inside the ion source called the discharge chamber. Surrounding this chamber is a ring of conductive material called the anode. When electrical current is passed through the filament, electrons are emitted in to the ambient gas in the discharge chamber. Due to a DC bias on the anode, the electrons are drawn through the gas, colliding and ionizing the neutral species until the electrons reach the anode. At the downstream end of the discharge chamber is a set of grids also called ion optics. The many variations of these grids will be discussed later, but the inner-most grid called the screen grid has a positive DC bias to contain the ions created in the discharge chamber. Further downstream from the screen grid is the accelerator grid, which has a negative DC bias to draw a controlled amount of the ions inside the discharge chamber down through the grids forming an ion beam.

Since only ions (positive charges) are drawn into the beam, a neutralizer must be placed downstream to inject electrons into the beam, maintaining the space-charge neutrality required by a plasma. This neutralizer can take several different forms which will be discussed below.

DC sources have the advantage of simplicity. Maintenance is minimal, with occasional inspection and cleaning of the insulators as the primary time-consuming effort. However, the filament used to create the plasma has a limited lifetime. While a simple operation, it does require regular replacement, usually between 10 and 20 hours of process time. Additionally, the filament is highly susceptible to erosion due to oxidation and reactive gases, meaning that oxide- or reactive gas-based processes will further shorten their lifetime, often to as little as one or two hours. While this effect can be somewhat mitigated, it is the most limiting factor on the use of DC ion sources. Finally, the erosion of the filament over time will inject very small amounts of Tungsten (W) into the process.

DC sources are most often operated with graphite grids. DC sources can be provided with “Flange Mount”, “Extension Mount”, and “Internal Mount” configurations. See below for further information.

3cm DC Ion Beam Source

The 3cm DC source manufactured by Plasma Process Group is small, fitting easily into R&D and small process chambers. The source is 72.5mm in diameter by 120mm in length, cylindrical, and has a maximum output ion beam current of 75mA. The source is can output ion energies between 50 and 1200eV, making it capable of both deposition and etch operations. It is most typically used in an ion assist role in evaporative processes, or in R&D process chambers. In Flange Mount setup, the 3cm DC ion source requires a 4.625-inch CF as a minimum flange size. In Internal Mount setup, the source requires two 1-inch feedthroughs or larger, or one 4.5-inch feedthrough or larger, and provides 18 inches of lead length for flexible placement inside your vacuum chamber. In addition to seven DC connections, the ion source provides one $^{1}/_{8}$-inch VCR connection for the processes gas. For custom feedthrough requirements, please contact us. The 3cm DC source is currently ***only*** available with graphite grids.

8cm DC Ion Beam Source

The 8cm DC source manufactured by Plasma Process Group is ideal for etch applications. With an overall diameter of 19.4cm and a length of 20cm, its larger size provides extra output beam current for larger substrates and faster processing, while still fitting into smaller chambers. The source has a maximum output of 250mA, and can handle a range of ion energies from 50 to 1500eV. The most common uses for 8cm ion sources are in etching and R&D chambers. In Flange Mount or Extension Mount setups, the source requires a 10-inch CF as a minimum flange size, though larger flanges are recommended. In addition to seven DC connections, the source provides

one ¼-inch VCR connection for process gas. In Internal Mount setup, the 8cm source requires at least two 1-inch or larger flanges, or one 4.5-inch flange or larger. In this configuration, the source also provides one $^{1}/_{8}$-inch VCR connection for process gas. The standard grid type for the 8cm source is graphite. For custom feedthrough or grid requirements, please contact us.

13cm DC Ion Beam Source

The 13cm DC source manufactured by Plasma Process Group is designed for full deposition systems doing metallic processes or large area etching. With a maximum output of 450mA and a range of 100 to 1500eV, our 13cm ion source can provide deposition rates and uniformity nearly equal to larger RF ion sources on the market such as our 16cm RF source. The 13cm ion source is 27cm in diameter by 14cm tall, and does have a water-cooled shroud. The most common uses for this ion source include deposition in non-oxide production processes and large-area etching processes. In Flange Mount or Extension Mount setups, the source requires a 14-inch CF as a minimum flange size, and features two ¼" Swagelok water connections and one ¼-inch VCR connection in addition to seven DC connections. In Internal Mount setups, the 13cm ion source requires at least three 1-inch or larger flanges, or at least two 2.75-inch flanges or larger, or at least one 6-inch flange or larger. In this configuration, the source provides two ¼-inch Swagelok connections for cooling water and one $^{1}/_{8}$-inch VCR connection for process gas in addition to the seven DC connections. The 13cm source is available with Molybdenum or Graphite grids. Many of our 12cm grid styles will work for the 13cm source. For custom flange or grid requirements, please contact us.

DC Neutralizer Options

Most DC sources utilize a single filament passing across the ion beam to generate the electrons that maintain the plasma at roughly neutral potential in the chamber. A filament neutralizer is very simple and very inexpensive and this setup is standard with every DC ion source manufactured by Plasma Process Group. The filament is susceptible to the same degrading effects of oxygen and reactive gases as the cathode filament, and must be regularly changed.

The alternative to a Filament Neutralizer is a Plasma Bridge Neutralizer (PBN). A PBN is a small, cylindrical electron source that can be placed anywhere in the chamber. Typically it is placed downstream of the grids, and often points toward the ion beam. The PBN is capable of emitting enough neutralization to mitigate charge build-up on the target or substrate, preventing any unexpected variations in the process due to these effects. A PBN does still use a filament to generate electrons

rendering it vulnerable to reactive gases, but as a contained cylinder it can resist these effects far better than the filament neutralizer. A PBN adds one additional feedthrough to the source requirements. This feedthrough can be 1-inch or larger.

RF Ion Beam Sources

RF ion beam sources are the most flexible type of gridded ion source. Capable of handling processes including almost any gas, and providing exceptionally long maintenance intervals, RF ion sources are the most common choice for production systems. A quartz bowl serves as the discharge chamber, containing the plasma. An adjacent RF coil produces the plasma-sustaining RF field. A positive DC bias on the screen (inner-most) grid in conjunction with a negative bias on the accelerator grid focuses the ions into a beam. Most RF ion sources use 3-grid assemblies, with the outer-most decelerator grid acting to shield the accelerator grid from process material.

RF sources have a significant advantage in maintenance compared to DC sources. Typical source shroud and RF circuit maintenance intervals are on the order of several thousands of process hours. A source can run months or even years of process without needing any adjustments to those items. The source grids may require maintenance or cleaning every 200 hours depending upon the process.

For metallic coating or etching processes, the quartz discharge chamber may become coated, creating a “Faraday Cage effect” in which the RF power can no longer reach the plasma inside the discharge chamber. New technology developed by Plasma Process Group has mitigated this, but cleaning the discharge chamber may still be required every 200 hours.

RF ion sources can be installed with “Flange Mount”, “Extension Mount”, and “Internal Mount” setups. RF ion sources are most frequently operated with RF neutralizers and Molybdenum grids. Multiple grid shapes allow for the beam to be diverged or converged as needed. Please see our “Grid Selection Guide” for more information about grids.

6cm RF Ion Beam Source

The 6cm RF source is our smallest RF source and designed for ion assisted deposition (IAD) processes. It can be utilized in evaporative coating systems. Providing up to 200mA of ion current, and with an energy range from 100 to 1500eV, our 6cm ion source can be equipped with grids to create a convergent or a divergent ion beam. Most commonly used as an assist ion source, our 6cm is quite capable of deposition or etching in smaller production chambers as well.

The 6cm source is 19cm in diameter by 14cm deep. In Flange Mount setup this source requires a 10-inch CF flange or larger. A shielded atmosphere-side interface includes the RF Matching Network, and will require two ¼-inch Swagelok water connections for the cooling circuit input and output and one ¼-inch VCR connection for the process gas along with the standard DC bias connections. Due to the RF Matching Network, the atmosphere side of the source flange requires at least 20 inches of clearance outward from the flange, and an additional 1 inch of clearance in the diameter. For Internal Mount setups, the 6cm source will require two 2.75-inch conflat flanges and requires two ¼-inch Swagelok water connections for the antenna cooling input and output and one ¼-inch VCR connection for the process gas. Finally, due to RF tuning concerns, the maximum length and flexibility of the RF lines is limited to about 18 inches. The 6cm RF sources are most commonly run with dished Molybdenum grids.

12cm RF Ion Beam Source

The 12cm RF source manufactured by Plasma Process Group is designed for ion assisted deposition (IAD) processes. It can be utilized in either evaporative chambers or in ion beam deposition chambers. Providing up to 400mA of ion current, and with a range from 100 to 1500eV, our 12cm ion source can be equipped with grids to create a convergent or divergent ion beam. Most commonly used as an assist ion source, our 12cm is quite capable of deposition or etching in smaller production chambers as well.

The 12cm source is 27cm in diameter by 14cm deep, and has a water-cooled shroud. In Flange Mount or Extension Mount setups, this source requires a 14-inch CF flange or larger. A shielded atmosphere-side interface includes the RF Matching Network, and will require two ¼-inch Swagelok water connections for the cooling circuit input and output and one ¼-inch VCR connection for the process gas along with the standard DC bias connections. Due to the RF Matching Network, the atmosphere side of the source flange requires at least 14 inches of clearance outward from the flange, and an additional 3 inches of clearance in the diameter. In Internal Mount setups, the 12cm source will require four 1-inch or larger flanges, or three 2.75-inch or larger flanges, or one 8-inch or larger flange, and requires two ¼-inch Swagelok water connections for the cooling input and output and one ¼-inch VCR connection for the process gas. Additionally, the water output from the RF lines must be connected to the input for the cooling shroud. Finally, due to RF tuning concerns, the maximum length and flexibility of the RF lines is limited to about 18 inches. The 12cm RF sources are most commonly run with shaped Molybdenum grids, but can be run with Graphite as well.

16cm RF Ion Beam Source

The 16cm RF source from Plasma Process Group is the workhorse unit for ion beam deposition. Designed for maximum beam current and beam voltage, this unit provides the industry standard deposition rates with a wide variety of grid options for shaping the output. Capable of producing up to 1000mA of beam current with an energy range from 100 to 1500eV, the 16cm ion source is the top choice for deposition processes. These capabilities also make it an excellent choice for a large-area assist application using a divergent grid set.

The 16cm ion source measures 30cm in diameter by 14cm deep. In Flange Mount or Extension Mount setups, this ion source requires a 16.5-inch CF flange or larger, and needs two ¼-inch Swagelok water connections and one ¼-inch VCR process gas connection in addition to the standard DC bias connections. In Internal Mount setups, the 16cm source will require four 1-inch or larger flanges, or three 2.75-inch or larger flanges, or one 8-inch or larger flange, and requires two ¼-inch Swagelok water connections for the cooling input and output and one ¼-inch VCR connection for the process gas. Additionally, the water output from the RF lines must be connected to the input for the cooling shroud. Finally, due to RF tuning concerns, the maximum length and flexibility of the RF lines is limited to about 18 inches. 16cm RF sources are most commonly run with 3-focal point Molybdenum grids to maximize target utilization in deposition processes. However, a wide range of grid shapes are available for other applications, as well as Graphite and Titanium grids.

RF Linear Ion Beam Sources

We offer two choices for RF linear ion beam sources. These are the 6x22cm and 6x30cm, ideal for in-line coating systems. Either source can produce ion energies from 100 to 1500eV. The 6x22cm will produce a maximum beam current of 400 mA while the 6x30cm will produce nearly 600 mA. These capabilities also make the linear source an excellent choice for a large-area assist or pre-clean.

The 6x22cm source measures 21cm wide by 35cm long by 13cm tall while the 6x30cm measures 21cm wide by 44cm long by 13cm tall. Either source is typically installed with an Internal Mount setup requiring two 2.75-inch conflate flanges. They also require two ¼-inch Swagelok water connections for the antenna cooling input and output and one ¼-inch VCR connection for the process gas. Finally, due to RF tuning concerns, the maximum length and flexibility of the RF lines is limited to about 18 inches.

The Linear RF sources are most commonly run with either 6x22 cm dished Molybdenum grids or 6x30 cm Graphite grids. For increased process flexibility, the 6x30cm can be equipped with 6x22cm grids.

RF Neutralizer Options

For RF ion beam sources situated in production environments, a small RF electron source, or RF neutralizer (RFN) is preferred. In addition to providing space-charge neutralization downstream from the source, the RFN is also used to ignite the plasma during the startup sequence. Once the RFN has ignited, the ion source voltage is pulsed to draw electrons from the RFN into the discharge chamber and ignite the plasma in the source.

RF neutralizers offer higher emission than DC neutralizers and have the ability to function in a heavy oxide or reactive environment. They also have a much longer life than their DC counterparts. The normal maintenance cycle for an RFN is over 2000 hours of process, however careful use of the RFN is strongly recommended to obtain the maximum cycle length. In particular, RFNs require a cool-down before being exposed to atmospheric water vapor. Their complexity makes maintaining them quite difficult and most users opt to send the RFN to the vendor for maintenance, which incurs added cost.

RFNs are cylindrical with three shielded leads connecting them to their feedthrough flange. The minimum flange size is 2.75-inches. Additionally, the atmosphere side of the flange has an RF matching network exclusively for the RFN which requires 8 inches of clearance out from the flange. Connections are one ¼-inch VCR connection for Argon gas used in the RFN plus RF and DC connections from the power supply.