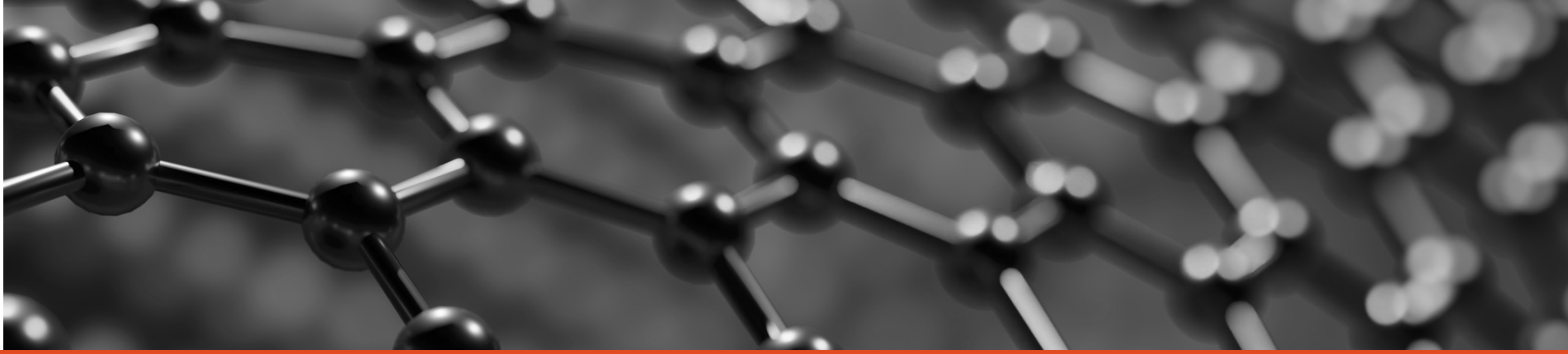

CORIAL
A Plasma-Therm Company

How to Choose a

# PLASMA ETCHING & DEPOSITION PARTNER



The plasma processing equipment segment will continue to grow as a critical part of the semiconductor industry. Nearly every aspect of device fabrication involves the essential plasma processes of etching and deposition.

Before these processes find their way into the production environment, they are used in R&D where researchers explore new capabilities in feature structures, advanced materials, nanotechnology, and surface modification. As ubiquitous as plasma processing equipment is in the production fab, they are equally crucial in the lab setting. It is in these environments where researchers rely on plasma equipment to make their discoveries.

Choosing the right equipment from the right manufacturer can be a challenging process. Plasma etching and deposition equipment is a serious investment, and each piece of equipment is designed with specific use cases in mind. Not only should you look to discover the piece of equipment that best fits your needs, products, or goals, but you also have to consider a variety of other critical factors.

**To help, we've condensed qualifying questions down into three core buckets:**

**SPECIFICATIONS**

**SERVICE**

**REPUTATION**

**Each of these categories will help you narrow down your search for a plasma etching and deposition equipment partner.**

# SPECIFICATIONS:

Plasma equipment is designed and built for specific purposes. Although there are many basic common features (e.g. chamber, pumps, gauges, valves, flow controllers, power supplies) between plasma systems, the design and construction details are carefully considered in the final piece of equipment after taking in the specific purposes and capabilities. Even the common features have many distinct and nuanced differences that give them their capabilities. To discover which specifications fit your needs, we recommend that you consider the following needs:

## What applications are of primary interest and what problem is being solved?

The first level of decision making is simply determining the application requirements. In other words, locating where plasma process fits into the fabrication process. A few questions to ask at this level might be:

- *What are the basic top-level process expectations for a new system (e.g. etch, deposition, surface modification, cleaning)? What is the specific task of the system?*
- *Is the system expected to go into production? Is it intended for industry R&D or academic R&D? Is there a plan to move the system from R&D into a production situation?*
- *Is the new system replacing an older system or are new capabilities and new processes required?*

With the answers to these questions one can determine whether a vendor has the appropriate equipment in their portfolio. Some vendors only offer R&D level equipment or only production equipment. Others serve both R&D and production. Plasma processing is used so extensively today that it is not limited to wafer format. There are plasma applications that range from removing paint from aircraft to atmosphere processing in the food industry.

Once you have narrowed down the type of basic top level plasma process needed, there is then the need to refine the requirement. Simply knowing that one requires an etch process is insufficient as there are many types of plasma etch and deposition system configurations. Deposition systems range from PECVD to HDPCVD while etching systems range from RIE to IBE.

## What materials are to be etched?

Engineers and researchers are asked to etch an ever expanding list of materials. Understanding what materials are to be etched will help determine some of the features that are desirable in the system. For example, if materials that require corrosive chlorine chemistry are going to be etched in a production setting, it would be useful to have corrosion-resistant internal components. It would also be very important to isolate the cleanroom from corrosive chemistry through the use of a loadlock. Another example would be if the system is used for sputter etching nonvolatile materials such as Pt and Au. In that case, it may benefit from hardware components to address re-deposition on the chamber walls. The list below is only meant as an example or rough guide in answering this question. Even within these sets of similar materials there are very significant differences that need to be addressed.

- ***Group IV (Silicon and silicon-based compounds):*** *e.g. Si , $SiO_2$ , $SiN_x$, quartz*
- ***Group IV (other):*** *e.g. diamond, Ge, Sn, graphene*
- ***Group III-V compounds:*** *e.g. GaAs, GaN, InP, InSb, AlN, BN*
- ***Group II-VI compounds:*** *e.g. ZnSe, CdTe, HgCdTe*
- ***Polymers:*** *e.g. PMMA, SU-8, BCB, polyimide, photoresist*
- ***Metals:*** *e.g. Pt, Al, Ni, Nb, Au, Ta, Ti, Cu, Mo, PZT*
- ***Metal oxides:*** *e.g. sapphire ($Al_2O_3$), ZnO, $HfO_2$, $Ta_2O_5$, $Ti_2O_3$, $LiTaO_3$, $LiNbO_3$*

## What materials are to be deposited?

The demand for higher performing materials has led the field of material science to become even more integrated with semiconductor electronics. Similar to the list of potential materials to be etched, understanding the materials to be deposited also helps shape the plasma deposition equipment configuration. There are many materials that are suitable for one configuration but not another. For instance metals are rarely, if ever, deposited in PECVD but can be easily deposited by ion beam deposition. Another case where the desired results affect the hardware selection is when highly toxic gases are required for doping. Highly toxic doping gases should utilize a load lock to protect the users. Fire and building codes may affect the allowed concentration of some highly reactive precursor gases (e.g. $<5\%$ silane vs. 100% silane) and how they are used. Some systems require 100% silane while some do not.

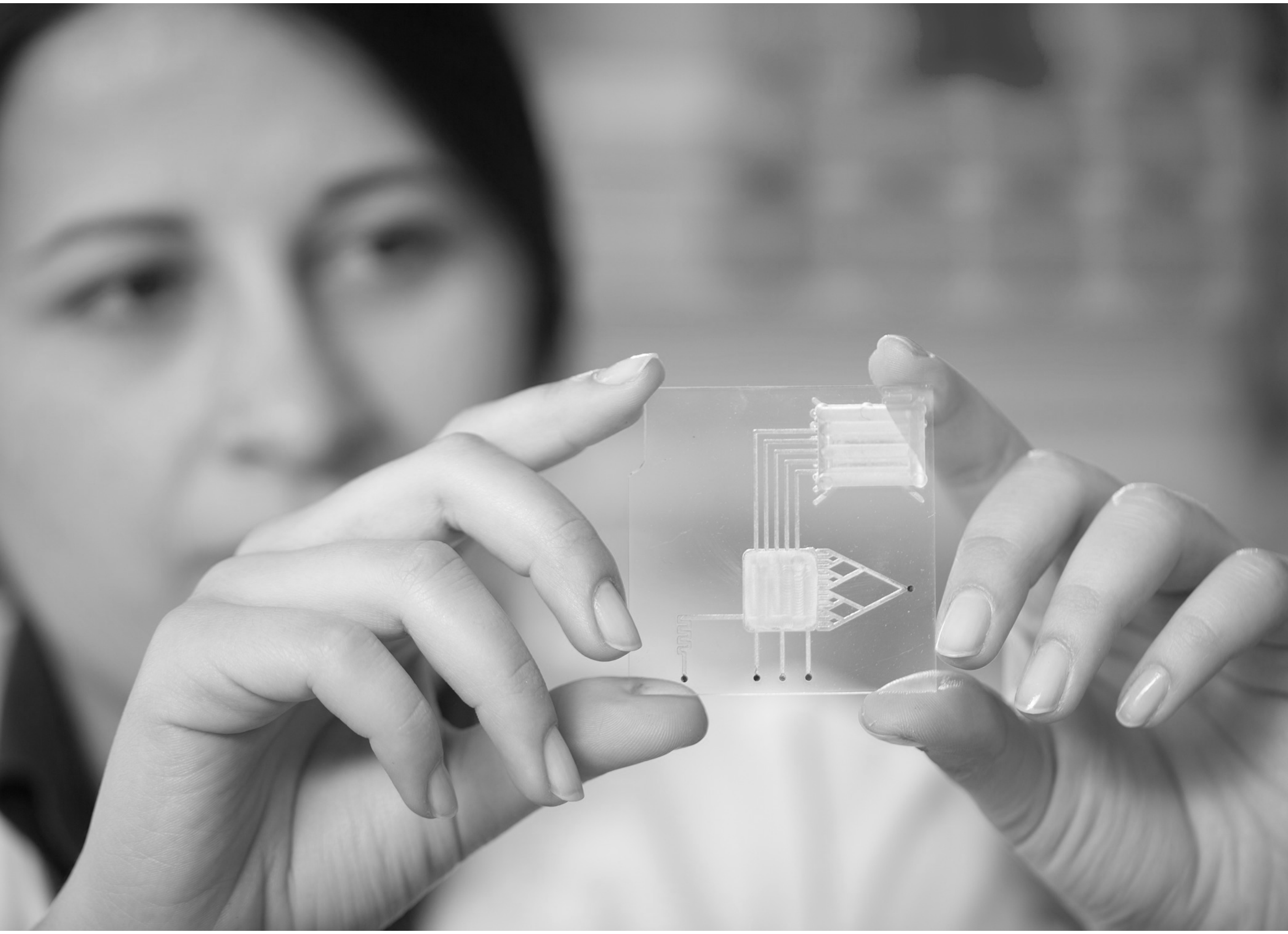
- ***Group IV (Silicon and silicon-based compounds):*** *e.g. a-Si, $SiO_2$, $SiN_x$, $SiO_xN_y$*
- ***Group IV (other):*** *e.g. DLC*
- ***Polymers:*** *e.g. fluoropolymers*
- ***Metals:*** *e.g. Pt, Al, Ni, Nb, Au, Ta, Ti, Cu, Mo, PZT*
- ***Metal oxides:*** *e.g. sapphire ($Al_2O_3$), ZnO, $HfO_2$, $Ta_2O_5$, $Ti_2O_3$,*
- ***Metal nitrides:*** *e.g. TiN, TaN, WN, AlN*

Before you choose your equipment partner, think about all the materials in the device you're interested in fabricating. You may be interested in

# SPECIFICATIONS:

R&D across a variety of substrates and projects. In that case, it may be preferable to choose a piece of equipment that's versatile enough to handle different materials. Wafer size also factors into this equation. If you are looking to fabricate on larger wafers, you need to choose a machine that delivers uniform, etch and deposition rates up to the size you need.

There are other equipment needs to consider. For example, including a load lock not only helps protect users from hazardous exposures, it also helps facilitate repeatable fabricating conditions by avoiding exposing the process chamber to the atmosphere between runs. Heated walls and chamber liners in the reactor can decrease cleaning time and reduce maintenance frequency and effort.



# SPECIFICATIONS:

## What capacity or throughput do you need?

Startup companies and R&D departments in university or industrial laboratories are going to have significantly different capacity needs than those operating a high volume production facility. In the former group, often an operator manually loads a wafer, runs the process, and unloads the wafer. In production mode, an operator loads a cassette of wafers that will usually run long enough to free the operator to do many other activities before the cassette needs unloading. These two models of operation require different automation, come with a different footprint, and have very different throughputs. Typically the higher the capacity needs, the more automation is required. Amongst these handling approaches there can be requirements for batch loading to be able to run several wafers at one time. A mistake that is often made is either under or over estimating the required capacity. This leads to either buying too much or too little automation. Handling options are usually divided into four categories.

**TABLE I:**

| | KEY FEATURE | ADVANTAGES | DISADVANTAGES |
|---|---|---|---|
| **OPEN LOAD** | • No automation | • Lower cost<br>• Simple operation<br>• Potential for batch loading<br>• Wafer size flexible<br>• Smallest footprint | • Process module exposed to atmosphere each loading<br>• Limited by process gas hazards |
| **MANUAL LOAD WITH LOAD LOCK** | • Limited automation | • Moderate cost<br>• No atmospheric exposure to the chamber between runs<br>• Often can be upgraded to cassette-to-cassette | • Lower throughput<br>• Some considerations to run batch |
| **CASSETTE-TO-CASSETTE POINT SYSTEMS** | • Cassette loading<br>• High automation | • Production configuration with highest throughput | • Higher cost<br>• Larger footprint |
| **CLUSTER SYSTEM** | • Highest automation<br>• Multiple chambers on one handler | • Redundant or sequential processes<br>• Stepwise capacity increases to high volume production | • Multiple chambers dependent on one handler<br>• Largest footprint |

There is a wide variety of unique features that can increase capacity. Of course, you may need less capacity and want to focus more on process flexibility for unique project goals. In this case, material versatility is an important consideration.

# SPECIFICATIONS:

## What etch or deposition characteristics are most important to your application?

There is no perfect equipment or perfect process. The characteristics of your equipment require tradeoffs. For example, high selectivity is often at **the cost of etch rate**. Similarly, a high etch rate often involves greater demands on substrate temperature control. You need to consider both the results that are most important to the application and the equipment needs to achieve those goals.

Neither production nor R&D are static in that the “hot” topic of research and funding this year may not be the “hot” topic in two or three years. Choosing equipment that has the flexibility to accommodate the changes in research directions is important.

Keeping in mind the concept of tradeoffs, one must realize that perfect performance in all aspects of a process cannot be achieved simultaneously. For example, if the product is discrete, small devices where there may be 10k die per wafer, it may not hurt yield terribly to have a 100 small particles. However, if the product consists of large die such that there are only 200 die per wafer, then the same 100 small particles can be devastating. Thus, for the small discrete die case, particles may not be a high priority.

Another example is damage. Large silicon mechanical structures often found in MEMS are typically not susceptible to plasma damage (ion bombardment or UV radiation). However, there are many electronic and photonic devices where damage is a very important parameter. These are only meant to highlight the concept of picking a specification carefully. Table II provides a list of considerations for etch and deposition specifications.

**TABLE II:**

| CONSIDERATION | “SPECIFICATION” | COMMENT |
|---|---|---|
| ETCH PERFORMANCE | Etching rate | High rate vs. low and controllable control |
| | Uniformity | Etch depth, profile and CD with in wafer and run-to-run |
| | Flexibility | What materials can be etched |
| | Profile | Vertical vs. sloped |
| | Selectivity | To mask and/or underlayer(s) |
| | Substrate Temperature | Etching conditions, thermal budget |
| | Morphology | Smoothness |
| | Cleanliness/ Particles | Yield |
| | Damage | Radiation, ion induced, contamination |
| DEPOSITION PERFORMANCE | Deposition Rate | High rate vs. low and controllable control |
| | Uniformity | Thickness, refractive index within wafer and run-to-run |
| | Flexibility | What materials can be deposited |

# SPECIFICATIONS:

**TABLE II (CONT'D):**

| CONSIDERATION | "SPECIFICATION" | COMMENT |
|---|---|---|
| DEPOSITION PERFORMANCE | Profile | Step coverage, fill |
| | Film Properties | Stress, wet etch rate, pinholes, adhesion, density, H-concentration, breakdown |
| | Substrate Temperature | Deposition conditions, thermal budget |
| | Morphology | Smoothness |
| | Cleanliness/ Particles | Yield discussion |
| | Damage | Radiation, ion induced, contamination |

While Table II provides the process performance aspect of a specification, Table III provides general guidance on the hardware aspects of an etch or deposition system.

**TABLE III:**

| | | |
|---|---|---|
| EQUIPMENT | Automation (Handling) | Manual, load lock, cassette, cluster |
| | Capacity | Ability to stepwise increase |
| | Substrate Dimensions | Sizes, thickness, weight |
| | Layout / Footprint / Installation | Cleanroom space, distance to pump |
| | Endpoint | Optical emission spectroscopy, Optical emission interferometry, laser reflectance, laser interferometry, ellipsometry |
| | Operational Range | Pressure, RF power, gas flow, temperature |
| | Gas Lines | How many and gas compatibilities |
| | Hardware Features | Heated components, spacers, liners |
| | Other Operational Features | Isolation valves, gas purges, venting |

# Finding the right company to fulfill these specifications

Once you understand your specification needs, your list of potential suppliers is going to be relatively short. There may be 2 to 5 companies that can produce the type of equipment you need. That is when it becomes essential to check out other criteria such as service guarantees.

## Important:

Because of the tradeoffs in plasma processes you can't have a system with the optimum performance in all the specification categories. That means for etching one cannot simply choose the highest etch, best uniformity, and best selectivity. For deposition one cannot choose the highest deposition rate, best stress, and best uniformity. You have to make a conscious decision about which specific properties benefit your goals most. Don't set yourself up for disappointment, and certainly don't trust any vendor that promises the sun-and-moon. Your vendor should be able to communicate flaws effectively and inform you of tradeoffs and sacrifices that need to be made to fabricate plasma etching equipment that makes sense for your use cases.

# SERVICE:

There's a reason that 96% of people in the United States say that customer service is a core component of how loyal they are to a brand. Having good service when you need it is invaluable. When it comes to highly complex, specialized, and expensive machines, service has to be factored into costs. If your equipment goes down, you lose time and money — regardless of your production or R&D environment.

**There are a few things you should look out for when it comes to service:**

1. ***Service availability:*** You need 24/7 global availability. Outages or issues can stall operations and happen at any time. You need someone to answer the call, field the question, and provide the solution regardless of the day or time.
2. ***Technical support group:*** Ideally, you want a partner that provides a full technical support group — not just a single technician. The highly complex nature of plasma processing equipment may require the expertise of a mechanical engineer, parts engineer, software engineer, or repair technician. This group should be agile, collaborative, and willing to engage any part of your organization. As part of global responsiveness, it is important that the vendor has a sensitivity to the cultures around the world so as to enhance communication effectiveness and efficiency.
3. ***On-site availability:*** Some equipment manufacturers offer contracts that oblige them to deploy engineers to your site within a few days. This could be crucial, depending on how deeply ingrained the plasma processing equipment is in your organization.
4. ***Capabilities:*** Support should be capable of handling hardware, software, or process issues — not just parts problems.
5. ***Escalation Plan:*** Service can absolutely critical in some situations. It is important that the vendor understand the customer's perspective and have a culture of service. This can be highlighted when the vendor has a clear escalation path that leads to a general manager or CEO.

Generally, service is built into contracts. For example, best-in-class partners provide multiple layers of support. One such layer is hardware support for the first year of equipment life. They should also offer a variety of services or annual maintenance contracts, warranties, and acceptance testing. Always communicate your support needs with your vendor.

# REPUTATION:

Reputation is earned. In fact, reputation is about the only brand quality that can't be bought. So, the first thing you should do when comparing a few different partners is to compare their history, awards, and reputation in the industry. Occasionally, equipment vendors have parent companies and it is important to check the credentials of the parent company. The culture of the parent company is often the imprinted on their partner companies.

Make sure that your equipment partner has a similar reputation. Reviews can be bought. Quality can be reduced to decrease prices. Reputation is based on years of consistency and quality. Always check each potential partner's reputation.

# Ready to Find a Plasma Equipment Partner?

Finally, you are not just purchasing a system, you are purchasing a solution to a problem. That means you are choosing more than an equipment manufacturer, you are also choosing a partner to help you manage the challenges that come with solving any problem.

At CORIAL, we take this ideal to heart. By combining our EU-based capabilities with Plasma-Therm's world-class service team, we can offer not just great equipment but a full solution to your plasma processing problems no matter where you are in the world.

**To learn more about how our partnership can help you with your most difficult issues, please contact us.**

***ACRONYMS:***

*HDPCVD- High density plasma chemical vapor deposition*

*ICP-RIE – Inductively Coupled Plasma Reactive Ion Etching*

*IBE – Ion Beam Etching*

*MEMS – Microelectromechanical system*

*PECVD – Plasma-enhanced chemical vapor deposition*

*R&D – Research and Development*

*RIE – Reactive Ion Etching*