Section 1 - General Information

The **PVA TePla ION Series** Plasma Processing System is a batch-mode plasma system for etch, strip, clean, and surface treatment. It combines field-proven features, which minimize machine-generated particulate with the process flexibility of computer control. This combination offers ultimate performance: high throughput, low particulate generation, process versatility, precise parameter control, and fault isolation.

The **ION Series** is a production system developed with over thirty years of production experience and user-feedback from systems worldwide.

Figure 1-1. PVA TePla ION 100, ION 40 and Ion 100WB Plasma Processing System shown.

1.1 How to Use This Manual

This manual is presented in six main sections, plus a number of appendixes. See the 'Table of Contents'. Each section is independent and intended for a specific reader. For example, the System Operation section is intended for the operator, while the Maintenance and Installation Procedure sections are for the maintenance technician. The General Information section should be read by all operators and technicians, in addition to their appropriate section(s). Note: OSHA 1910.97 includes microwave radiation in radio frequency considerations. This manual shall do the same

Table 1-1. How to Use This Manual

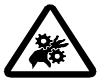
Section	Contents	Recommendation
1. General Information	This section includes the safety information and an equipment description	All Personnel
2. Site Planning Installation and Power-Up	This section steps through uncrating, set up and installation of the system. Details are provided for the proper electrical power, gas connections, gas supplies, vacuum exhaust and lines.	Maintenance Technician
3. Software Configuration	This section focuses on Hardware Configuration settings using the ***Setup*** Screen. The setup categories include: Devices, System, Lab Cards, Safety Alarms, and the optional Light Tower. Additionally, the Security settings comprising Usernames and Passwords are detailed in this section.	Maintenance Technician
4. Software Operation	This section builds on the previous one by introducing the following screens: ***Operation, Maintenance***, and ***Recipe***. The ***Operation*** Screen is used to execute a recipe in a process. The ***Maintenance*** Screen enables you to manually control items including gas flow, vacuum, and RF(including microwave) power. The ***Recipe*** Screen is used to create and edit recipe algorithms.	Operator, Process Developer, Maintenance Technician

5. Maintenance Procedures	This section provides maintenance instructions for routine testing and servicing the equipment	Process Developer and Maintenance Technician
6. Trouble shooting	This section provides guidance to resolve equipment issues that may arise.	System Administrator and Maintenance Technician

1.1.1 Safety Information

Section 1 of the technical manual incorporates all the safety information required for the operation and maintenance of the **ION Series** equipment. All users must read this section, and heed the safety warnings located throughout the book. Although **PVA TePla** has designed a system that protects human operators as much as possible, the technologies incorporated in the system create dangers that must be respected. All personnel must comply with safety procedures set forth in this manual to ensure that the system performs without personal injury or property damage.

The following safety information is found throughout this manual. You must comply with all safety instructions in the manual.



The warning sign depicts a wounded hand in mechanical gears, and indicates equipment or a situation that may result in personal injury or even death if the warning is ignored.

The caution sign depicts a broken device, and indicates equipment or a situation that may result in damage to equipment or product if the warning is ignored

The notation sign depicts an illuminated light bulb, and indicates additional information that may be useful although not directly pertinent to the manual where it appears, or may indicate emphasis.

This symbol, an exclamation point, depicts there is a risk of danger and caution is to be used. There is further information in the manual

This symbol, a lightening bolt, depicts there is a risk of electric shock and caution is to be used.

The **PVA TePla ION Series** Plasma Processing System has been designed with safety foremost. Many safety features have been incorporated to protect human operators from injury. Numerous hardware and software safety features protect the **ION Series** from equipment damage. These safety considerations have been provided in this manual.

1.2 Approved Gases

This Equipment has been designed for use with the following gases:

Aluminum and Ceramic Chambers: Argon, Oxygen, Air, Nitrogen, Nitrous oxide/CF_4/ 0_2 Mixtures, Helium, CF_4 (See Facilities section on handling of this gas)

Glass Chambers: Argon, Oxygen, Air, Nitrogen, Nitrous oxide/CF_4/ 0_2 Mixtures, Helium

WARNING: USE OF OTHER GASES MAY BE DANGEROUS. DO NOT USE OTHER PROCESS GASES WITHOUT PRIOR WRITTEN APPROVAL FROM PVA TEPLA .

WARNING: DO NOT CONNECT PROCESS GASES TO THE PURGE OR COMPRESSED AIR INPUTS

The wetted materials of the **ION Series** are compatible with all the above gases. The gases themselves, however, can form a wide diversity of plasmas.

There may be ranges of pressure and power for any gas where the system cannot strike a plasma (a glow does not appear within 10 to 15 seconds after RF power switches on) or cannot tune the plasma (glow appears, but reflected power remains above two percent of forward power). If you encounter either of these conditions, try a different power or pressure, or contact **PVA TePla**.

1.3 Physical Characteristics

The **ION Series** plasma treatment system is a plasma processing system. The enclosure houses all components except the vacuum pump. The **ION Series** can be used for surface modification and cleaning of organic, metallic, and composite substrates. The following is a listing of the physical characteristics. The front and rear panels are shown in Figure 1-2.

Table 1-2. ION Series Physical Characteristics

Chamber; ION 40, 100, 100WB series, 140, 300, 330, 434	Aluminum, high-conductance KF 40 port and isolation valve and radiation-eliminating view port
Chamber; ION 100-40Q, 100WB-40Q, ION10Q	Quartz, high conductance KF 40 port and isolation valve and radiation-eliminating view port
RF Generator ION 40, 100, 100-40Q, 140, 300, 330, 434	Integral 600 (ION 100/40/ION 10Q) or up to 1250watt (ION 100/140/40Q), 13.56 MHz with impedance-matching network standard; air-cooled
Display	Graphic color touch screen for control and monitoring of PC parameters of automatic recipes or manual plasma treatments
Gases	One 500 sccm MFC standard (ION 40). 1 Alternate gas std (ION 100). (second, third and fourth MFC's optional)
Chamber Dimensions	9" by 13" by 19" (height, width, depth) ION 40 14.7 x 14.7 x 29. 4 (height, width, depth) ION 100 22" X 25" X 26" (height, width, Depth) IoN 434 12" Ø x 20" depth ION 100-40Q 9.6" Ø x 9.6" depth ION 10Q
Weight	425 lb (188.9 kg) ION 40. 295 (134 kg)
Safety and Security	Safety power interlocks; sealed chamber; over-limit circuit breaker on main power input; emergency shut-off control. Safety shut off for "No Plasma" condition

IoN 100 Series

Figure 1-2 – IoN 100 Series
(similar for IoN 220, 300, 330, 434)

IoN 40, IoN 10Q

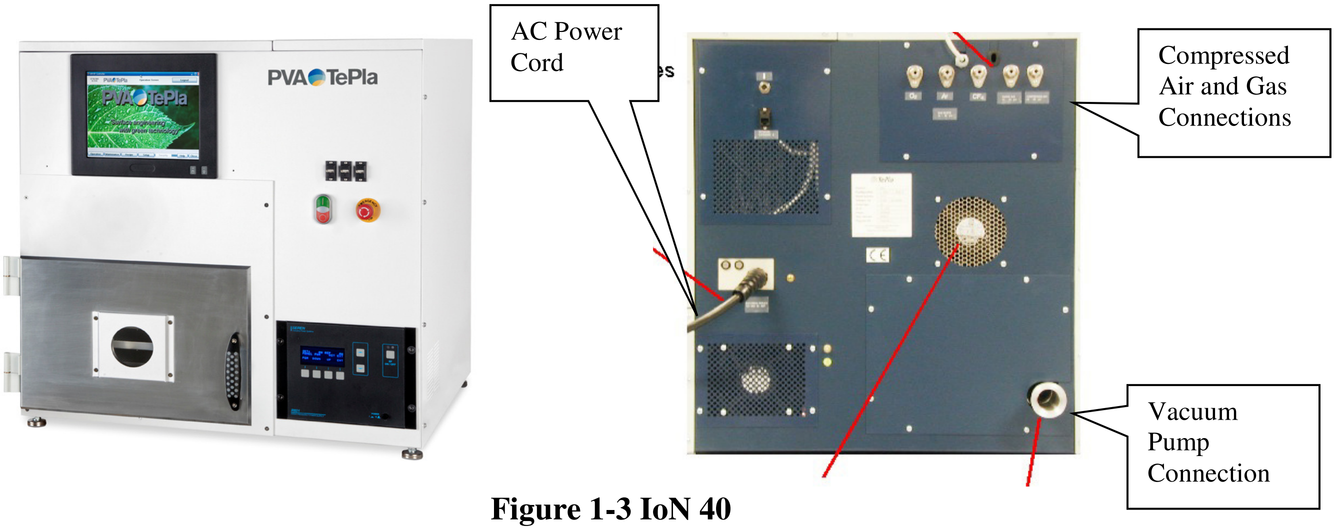


Figure 1-3 IoN 40

1.4 Equipment Overview

In this section, an overview is presented of the RF generator, Auto-Match network, system controller, and the vacuum pump.

1.4.1 Reactor Center

The reactor center contains the aluminum or quartz process chamber and the Auto-Match network for 13.56MHz and lower systems, or a quartz chamber. Plasma is generated as current passes through the gas between the energized space within the chamber. The reactive ionic, atomic, and molecular species formed by this process react with the surface of the substrate in the chamber to produce the desired results.

The 13.56 power is delivered to the reactor center through a coaxial cable from the RF power supply. A pressure switch on the rear of the process chamber will open an interlock in the RF power supply and disable application of frequency power whenever the pressure is above 272 Torr. This eliminates the possibility of electric shock to an operator from the chamber when the chamber door is open.

With chamber pressure above 272 Torr, neither the computer program nor manual operation of the RF power supply can effect application of frequency power to the chamber electrodes or antenna.

1.4.2 RF Generator- 13.56 MHz

The RF generator is the source of energy used to generate the plasma. It converts standard 50/60 Hz AC line power to 13.56 MHz. It is an all-solid-state and crystal-controlled unit. The RF generator has built-in safety features to protect the power transistors from excess reflected power, and to regulate the output power.

The RF generator contains self-limits for reflected power and heat sink temperature. The process-control program ensures that pressure in the process chamber is between acceptable limits before turning on the RF power. This prevents possible damage to the matching network.

Figure 1-4: The RF Generator Control Panel

1.4.2.1 Auto-Match™ Network

The patented Automatic Impedance-Matching Network (Auto-Match Network) is an electronic circuit that matches the impedance of the load to the internal impedance of the RF power generator. A load matched to its power source makes the most efficient transfer of power, and a perfectly matched system has no reflected (wasted) power.

The matching process minimizes the reflected power and maximizes the amount of power actually available to generate plasma. The amount of power lost because of a mismatch in impedance is generally less than two percent of total power.

1.4.3 Vacuum Pump

A major system component is the vacuum pump – which must be sized properly to handle the gas load and the process gases. Its basic function is to remove air from the chamber until the desired low pressure has been reached, then to maintain a constant low pressure as process gases enter the chamber. To do so, it must be capable of pumping out the various process gasses and resultant by-products, as well as the out-gassing vapors from processed parts.

PVA TePla can supply the most appropriate pump for your application, and supply all pump maintenance needs, including pump service.

The vacuum pump is isolated from the chamber when the chamber door is open. The vacuum valve can only be open when the chamber door is closed. This eliminates the possibility of the vacuum suddenly closing the chamber door. The pump is also protected from damage that could occur from continuous pumping at atmospheric pressure.

1.4.4 Vacuum Valve

The air-operated vacuum valve opens the system to the vacuum pump and closes off the system from the vacuum pump by commands from the computer during automatic operation or by an operator during manual operation. The valve is an air-to-open, spring-to-close valve that requires 60 to 80 psig of compressed air to operate. Any time the system is shut down or in the event of a power loss, the valve will automatically close (i.e. ‘failsafe’ operation).

1.4.5 Throttle Valve

The optional throttle valve is attached in-line, between the vacuum pump and the vacuum valve. It is used to automatically regulate the pressure in the reactor chamber independent of the gas-flow rate. For this to be possible, the entire vacuum system must function together as intended. For proper vacuum integrity and process reliability, the following is required.

a. The chamber leak-up rate should be less than 20 mTorr per minute.

b. The vacuum pump must be capable of the specified pumping speed, as measured at the rear of the system.

1.4.6 Gas Flow System

The gas control module receives signals from the system controller and converts them into actuation of gas valves. Process gas control, mixing, vacuum chamber purge, and pneumatic operation are accomplished in the gas module.

Mass-flow controllers (MFCs) regulate the flow rate of the process gases as directed by the computer. The valves direct and mix the process gases.

1.4.7 Process Controller

The process controller is the heart of the system. It is located in the electronic section, above the RF generator. All of the variables (power, pressure, gas flow rate, and process time) are controlled and monitored from it. Signals are sent through interconnecting cables to the other system components to execute the various functions. Mass-flow controllers adjust and monitor the flow of process gases. They are calibrated for the gases and flow rate indicated on the unit. The pressure in the chamber is determined by this flow rate relative to the speed at which the vacuum pump is removing the gas from the chamber. In the use of a plasma system, the operating pressure is usually the important variable, not the gas flow rate. Automatic downstream pressure control is made possible by a throttle valve. This is available as a system option for processing that requires variation of pressure independent of flow.

The pressure transducer is a thermocouple gauge that monitors chamber pressure in a calibrated range. The output is provided to the controller to initiate changes in system status, as when calling for power after the chamber pressure drops to a usable level, or to monitor and display chamber pressure during operation. The system sensors include the pressure transducer, an optional temperature probe, and a set of mass-flow controllers.

1.5 Safety Considerations

This section describes the areas of the equipment that may result in damage to equipment or injury to personnel if not understood. These features include the gas hazard, hydrocarbon-based lubricants, electrical and radiation hazards, ultraviolet hazard, and heat hazard.

1.5.1 Gas Hazard

Piping and tubing used in the oxygen delivery system should be cleaned for oxygen use according to CGA pamphlet G-4.1. Copies can be obtained by writing to the following address.

Compressed Gas Association, 1235 Jefferson Davis Highway, Arlington, VA 22202

Use of organic solvents is prohibited by the Uniform Fire Code. Engineering controls should be adequate in handling process effluent to prevent concentration of oxygen above atmospheric levels. Oxygen concentration above atmospheric levels in the presence of organic substances and hydrocarbon lubricants is potentially explosive.

For noxious gasses, a purge cycle followed by venting can be employed to clear the chamber before opening the door. See Section 3.1.2.1, Software Configuration

Pressure, valves, handling: Do not exceed the maximum process-gas pressures specified in this manual. Follow the gas manufacturer's operating instructions for connecting and disconnecting gas cylinders. The valves on the cylinder must be closed and the gas lines thoroughly purged of any hazardous gases.

Do not open any gas cylinder valves before they are properly connected to the **ION Series** equipment. Always consult the latest published safety regulations and the gas manufacturer's data sheets before handling gases.

There is a danger of explosion. Do not use hydrocarbon-based vacuum pump oils when using oxygen as a process gas. Use of these oils when combined with the use of oxygen will create the possibility of an explosive reaction. Use only vacuum pump fluids that are rated for oxygen service.

1.5.2 Lubricants and Greases

Do not use hydrocarbon-based lubricants or greases on any substrates or sealing surfaces that are exposed to vacuum. Use of these lubricants might cause undesirable results or failure of seals.

Approved lubricants: Use only lubricants or greases that are approved for use with oxygen. Perfluorinated or silicone-based lubricants are acceptable. (Perfluorinated greases are preferable for low-particulate applications.) Apply a minimal amount to O-rings and gaskets. Use only enough for a light, uniform coating.

Silicone greases may not be compatible with some processes.

Check the fluid level in the main pump and the booster pump (if equipped). Add fluid if necessary. Refer to the pump manufacturer manual for instructions on checking the nitrogen ballast or purge.

1.5.3 Electrical and Radiation Hazards

The electrical and radiation hazards described include the electrical circuits, the Auto-Match Network, Magnetron radio frequency (RF) generator(s) and power supplies.

Electrical Circuits	Hazardous voltage is present inside the components of the **ION RF** Series. Do not touch energized electrical circuits.
Auto-Match Network	Disconnect the AC power and discharge the air capacitors in the Automatch Network with an insulated screwdriver before servicing or repairing the impedance-matching network. Failure to do so can cause severe or fatal electrical shock.
Radio Frequency (RF)	RF energy can cause burns, eye damage or other serious injuries. Do not remove, modify, or alter the RF shielding. To ensure a safe operating environment, periodically monitor near the **ION RF Series** for RF radiation. The RF radiation level must not exceed the OSHA safety standard Title 29 CFR 1910.97 or CE standard EN61010.

1.5.4 Vacuum pump Exhaust gases

See chapter 2, subsections 2.4.10 for safety warning**s** regarding exhaust gases from the vacuum system. It is the responsibility of the customer to provide an adequate exhaust handling system. PVA TePla America can recommend an appropriate company that specializes in exhaust abatement.

WARNING: Operating the ION Series system with its outer covers removed will expose the operator to potentially hazardous levels of RF energy.

1.5.5 Ultraviolet Hazard

Gas plasmas produce ultraviolet (UV) rays that can cause severe skin and eye burns. The plastic wire mesh RF shield over the front view port blocks these rays. The quartz view window does not. Do not operate the system with the plastic shield removed. The radiation level must not exceed the ACGIH safety standard threshold limit values.

WARNING: Viewing the chamber via its view port, without the plastic RF shield, will potentially cause severe skin and eye burns.

1.5.6 Heat Hazard

Chamber, cage, shelves: The chamber wall, cage and shelves can become very hot during the process cycle. Always wear protective gloves and use extra caution when handling parts or working near the chamber after a process has been run. Allow an adequate amount of time for the parts to cool to a safe temperature before further handling.

1.5.7 Controller Lockup

While the system is equipped to shut off RF power if the software locks up, this is still an undesirable condition that will waste gas and time. Control is based on an industrial PC operating within Windows, and there are certain precautions that must be observed to keep system operating optimally.

While the system comes with an Ethernet connection, this is intended for a local network or temporary connection to the internet for diagnostic purposes with PVA TePla America. The software is not designed to support security programs, nor should personal or unrelated programs be loaded onto the system computer (games, videos, etc.)

1.6 Safety Features of the ION RF

To protect operators, the **ION Series** contains interlocks, low-voltage manual switches, power and heat limitations, and shields, covers, and circuitry color coding.

1.6.1 RF Power Safety Interlocks and Manual Switches

A pressure switch on the rear of the reactor chamber will prohibit RF output whenever the pressure is above 272 Torr. In addition, system software prohibits RF output when the chamber pressure is above 2000 mTorr. These interlocks eliminate the possibility of electric shock from the reactor electrodes regardless of the system conditions. Even if you bypass the computer and operate the generator from its local controls, you cannot turn RF on. There are also system alarms that will shut off the system if a plasma fails to ingite, either by a photodetector or reflected power, depending on system frequency.

1.6.2 Alarms and Warnings

Process faults trigger audible alarms and fault-diagnostic messages on the screen. All alarms put the system into a 'freeze' mode, turning off RF power but leaving the vacuum and gas valves open.

Standard warning labels on module access covers indicate dangerous voltages and temperatures.

Advice is presented throughout this manual when the user is being instructed to work around RF power, ultraviolet light, and AC power.

1.6.3 Emergency Stop

There is an Emergency Stop button (EMO) on the system front panel, see Figure 1-2. As shipped, pressing this button shuts off power to the entire system. On the ION 100, an EMO is provided on the front and back to facilitate installing in a wall. The system is shipped with the front EMO controlling the pump: this can be easily configured in the field so the pump remains running. Back EMO shuts off entire system.

Operator controls of the system are powered by low-voltage (24 VAC) circuitry. The system has self-limiting DC power supplies.

The EMO is to be used as a last resort for shutting off the system, or if all power needs to be removed from the system immediately. Routinely shutting off power while the system is running can damage the electronics and possible void the warranty. If the computer locks up, it can be rebooted by pressing the "O" button on the front, eliminating a potentially harmful surge from turning off mechanical devices

1.7 How the ION RF SYSTEM Operates

The **ION RF** generates a low pressure, low temperature gaseous plasma. It does this by metering gas into the process chamber. RF energy is applied to a set of electrodes (13.56 MHz or lower) or broadcast RF power into the chamber vacuum space (2.45GHz) to separate some of the gas molecules inside the chamber into chemically reactive atoms, ions, and free radicals. These act on the surface of the material being processed to clean, etch, strip, and/or activate.

The system has a manual and an automatic mode of operation. The manual mode is used for programming the system and operating the various valves and controls, while the automatic mode is used for automated production processing.

A liquid crystal display monitors system status including gas flows, power, pressure and temperature. The process will automatically terminate if the programmed fault tolerance on any of the parameters is exceeded. A message will appear describing the fault that occurred. The user may then choose to terminate or continue the process.

The system may have a maximum of three mass-flow controllers for input of process gases. A throttling valve for precise chamber pressure control during processing is also available.

1.7.1 Front Control Panel

The Front Control Panel provides the primary control features, including the touch-screen display, power controls, disk drive, and Emergency Stop Control, see Figure 1-2. The features of the Front Control Panel are described below.

Area	Description
Display Screen	Located on the front panel, the display provides menus for interacting with the system and directing the process. It also provides on-going process status screens and message windows that keep you apprised of system functions, and parameter entry fields for entering and editing process recipe parameters Almost all interfacing with the controller can be done through the use of the touch-screen. The touch of the screen works as a mouse
Power Controls	The system ON/OFF buttons are located on the system control panel.
USB Ports	These provide the means to load the operating system and recipes, and provide storage of data and record files.
Emergency Stop	Located at the front of the system. Use this button only in a true emergency. It will remove all power to the system and shut all gas valves. Once the Emergency Stop button is pressed, turn the button to re-enable the system

1.7.2 Key Entry

The **ION Series System** is controlled through a popup 'software' touch screen keyboard and/or a conventional keyboard which may be plugged into a PS-2 jack on the front panel.

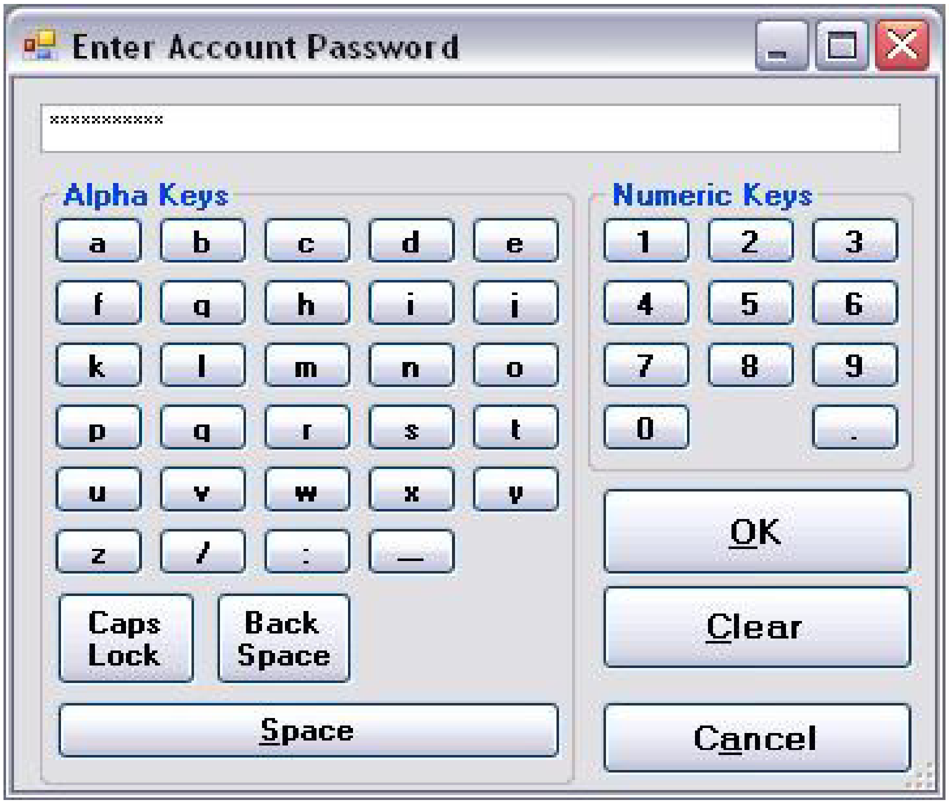


Figure 1.5 – Software Keyboard

1.8 Passwords

Separate passwords for the maintenance supervisor, process engineer, and operator are available to limit access to the various sections of the **ION RF** system. Please refer to section ***4.2.7 "Command Panel – Security Button"*** of this manual additional information regarding the login procedure.

The password should be stored in a safe place for reference. Should you loose your password, contact PVA TePla America, Inc. for assistance.

1.9 Typical Process Run

A typical automatic processing cycle begins when the parts are loaded into the chamber and the door is closed. Pushing the "Run" button will start the process recipe that has been previously selected. A typical recipe will perform the following steps. See Figure 1.6 below.

The vacuum valve mounted on the back of the reactor center opens. Vacuum will hold the door closed.

1. The vacuum pump extracts most of the air from the chamber. The air pressure is reduced to a few mTorr. At a preset pressure, gases start flowing into the chamber through the mass-flow controllers. The vacuum pump continues to evacuate the chamber, balancing the inlet flow rate of gas with the gas removal rate of the vacuum system, so a stable pressure is reached.

2. The pressure in the chamber is determined by the MFC flow rate relative to the speed at which the vacuum pump is removing the gas from the chamber. With a plasma system, the operating pressure is the most important variable, more so than the gas flow rate. Therefore, proper sizing of the vacuum pump is critical. An optional automatic throttle valve allows precise pressure control independent of gas flow rate.

3. The RF power then turns on. This excites the molecules of the gas and plasma is formed. This can be seen as a glow inside the chamber. The exact color of the glow depends on the reactant gases being used. (Oxygen plasma gives almost no visible light.)

4. Once the parts have been treated with the plasma for the preset time, the RF power and gas flows shut off. The chamber begins a purging and venting sequence to return to atmospheric pressure.

5. Once the pressure inside the chamber equalizes to atmospheric pressure, the door can be opened. An independent pressure switch senses a raise in pressure and opens an interlock inside the generator which prevents application of RF power. This prevents the user from being exposed to electric shock from the electrodes when removing parts from the chamber.

The chamber wall, door plate, electrode components, and parts become hot during processing. Always wear protective gloves and long sleeves to prevent burns to your hands and arms.

1.9.1 Processing Guidelines for 13.56MHz:

As stated in 1.5.5., heat will build up in the chamber and electrodes. How much is dependant on the settings: power, gas, pressure and length of process. See the table below for typical temperature characteristics for a 13.56 MHz system using dry air for 1 hour.

Electrode	Pressure	MFC air flow	RF wattage	Final temperature
1 shelf pos	270 mTorr	154 SCCM	600	147 C
3 shelf pos	270 mTorr	154 SCCM	600	140 C
1 shelf pos	1000 mTorr	486 SCCM	600	115 C

Table 1-3

Each system comes with the alarm configurator set so the system will not turn on RF below 200 mTorr or above 2200 mTorr pressure. PVA TePla America recommends running the system for up to one hour at full wattage above 250 mTorr pressure.

For systems using the 13.56 MHz generator and a shelf electrode, using the chamber as a negative reference, the electrode must always have at least one positive shelf installed. For every positive shelf, there must be a negative shelf or negative chamber surface reference to establish a primary plasma between trays or the negative surface and tray (Ref Figure 1-6).

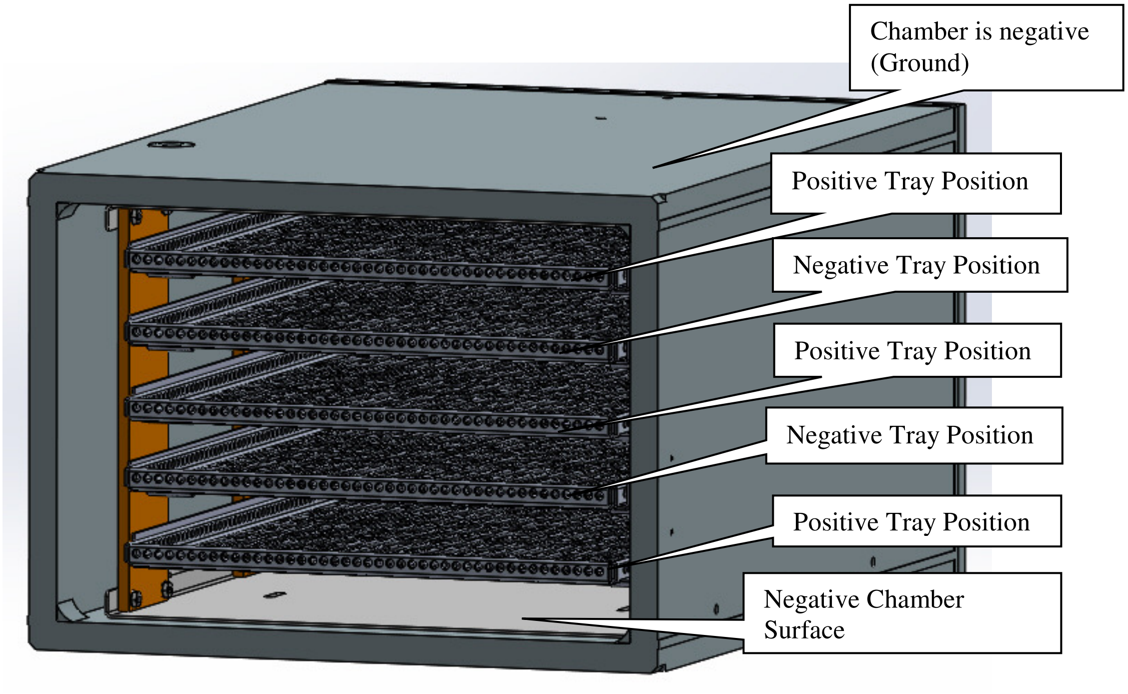


Figure 1-6 The 5 Shelf Electrode in an ION 40 Chamber

The Ion 40 electrode shown has plugs so trays can only go in one way. Other electrode designs allow flexibility in tray location, but user must understand how to load trays to get the resultant plasma treatment

Running trays of the same potential (both positive or both negative) will result in a weak or no plasma between the surfaces, commonly referred as "secondary plasma". This gentler secondary plasma will produce a slower process.

The more positive shelves, the cooler the system will run. Similar process runs with argon, instead of air, will run cooler at lower pressures.

The Ion systems are set up so they will tune the RF power between 200- 2200 mTorr. In some instances, processes may want to be run below 200 mTorr. To do that, the minimum pressure setpoint must be reduced in the "Setup" page. A sample plasma strike will shall be performed to determine if automatch can tune to the lower pressure.