Standard Operating Procedures - Corial 210IL

INDUCTIVELY COUPLED PLASMA SYSTEM - Corial 210IL S/N: 156 CONTENT

1 PRINCIPLE OF PROCESS PROGRAMMING

General description of process programming is given in CORTEX user manual (accessible via Help/Cortex Corial Help/Recipes & Process Settings).

The first steps of any process are needed to get plasma ignition (RIE plasma) and to ensure

highly repeatable processes. CORIAL matching boxes perform automatic matching using the

LOAD capacitor by default. The TUNE capacitor is either set at the matching position or the

RampTo function can also be used for the best tuning.

Note. Selection of regulation of LOAD or TUNE is done in Tool settings: System/PM1/RF/MB1

To ensure plasma ignition, the preset positions of LOAD and TUNE capacitors in the step prior to plasma ignition are not at the matching point. The LOAD and TUNE positions allowing minimum reflected RF power are determined and set in the recipe for each process step by using the "Interactive" mode and setting 'PM1 RF AMN Control Mode' to Manual.

The matching position is found by either increasing the LOAD capacitor and decreasing the

TUNE capacitor or vice versa after ignition of plasma.

The RF reflected power cannot be > 50 W for more than 3 s during ignition steps

1.1 RIE Recipes

The recipe has a minimum of 7 steps to establish smoothly the process conditions:

Step 1 - Initial

Pump Down the chamber pumps to the set base pressure and to set the temperature of the process.

Step 2 - Stabilization

Set the machine parameters (gas flow rates, working pressure) prior to starting next process steps. To facilitate the plasma ignition (13.56 MHz), the working pressure is set according to the process (minimum value for plasma ignition = 10 mT), the RF LOAD is set 10% below the RF LOAD matching position and the RF TUNE is set 10 % above the RF Tune position in this step. The AMN mode of RF matchbox is in Manual.

Step 3 - RF ON

3 sec to ignite the RIE plasma, the RF power is set at 100 W for 3 s. The ramping setting, in the windows Details, is selected to get the LOAD and TUNE capacitors ramping to the matching position. The RF reflected power cannot be > 50 W during more than 3 s for the ignition step.

Step 4 - Go To Etching

(OPTIONAL)

5 to 10 s may be needed to go smoothly to etching conditions,

particularly, when high RF power is used. In such a case, the

ramping setting is selected for RF power, LOAD and TUNE to

ensure minimum reflected RF power during this step.

Step 5 - Etching

Duration is selected according to the application. Endpoint can be used also for process duration control (ref to EndpointWorks III). This step uses auto-match function (AMN mode in Automatic or Man->Auto) to continuously minimize the reflected RF power.

Step 6 - Purge

10 sec are set to purge process gases with O2, N2 or Ar.

Step 7 - End

10 sec to pump the reactor without any gas.

1.2 ICP Recipes

The recipe has a minimum of 8 steps to establish smoothly the process conditions:

Step 1 - Initial

Same as RIE process

Step 2 - Stabilization

Set the machine parameters (gas flow rates, working pressure) prior starting next process steps. To facilitate the plasma ignition (13.56 MHz), the working pressure is set according to the process (minimum value for plasma ignition = 10 mT), the RF LOAD is set 10% below the RF LOAD matching position and the RF TUNE is set 10 % above the RF Tune position in this step 2. The AMN mode of RF matchbox is in Manual. To facilitate the ICP plasma ignition (2 MHz), the ICP LOAD position is set at 10% below the ICP LOAD matching position and the ICP TUNE is set at the ICP TUNE matching position. The AMN mode of ICP matchbox is in Manual.

Step 3 - RF ON

Same than RIE process

Step 4 - ICP ON

To ignite the ICP plasma the RF plasma must be established first, the ICP power is set at 500 W (Corial 200 series) or 1000 W (Corial 300 series) for 2 s. The ramping setting is selected to get the LOAD capacitor ramping to the ICP matching position. The ramping setting is selected to get the LOAD and TUNE capacitors ramping to the RF matching position. The ICP and RF reflected power cannot be > 50 W during more than 3 s for the ignition step.

Step 5 - Go To Etching

(OPTIONAL)

5 to 10 s may be needed to go smoothly to etching conditions, particularly, when high RF power is used. In such a case, the ramping setting is selected for RF power, LOAD and TUNE to ensure minimum reflected RF power during this step.

Step 6 - Etching

Duration is selected according to the application. Endpoint can be used also for process duration control (ref to EndpointWorks III). This step uses auto-match function (AMN mode in Automatic or Man->Auto) to continuously minimize the reflected RF power.

Step 7 - Purge

10 sec are set to purge process gases with O2, N2 or Ar.

Step 8 - End

10 sec to pump the reactor without any gas.

1.3 RF and ICP Power Matching

Here are basic rules allowing to simplify searching for RF and ICP matching points:

ICP MATCHING		
Action on process parameter	**Required action on matching**	
	ICP Tune	**ICP Load**
ICP Fwd Power ↑	↑	↑
Working pressure ↑	↓	↓
Type of gas: electropositive gas (e.g., Ar) ➔ electronegative gas (e.g., O_2, SF_6, Cl_2)	↓	↓
RF MATCHING		
Action on process parameter	**Required action on matching**	
	RF Tune	**RF Load**
RF Fwd Power ↑	↑	↑
Working pressure ↑	↓	↓
Type of gas: electropositive gas (e.g., Ar) ➔ electronegative gas (e.g., O_2, SF_6, Cl_2)	↑	↓
Note: in ICP processes ICP matching must be implemented first, and then RF matching has to be done.		

2 LASER ENDPOINT DETECTOR

Laser endpoint detector (laser interferometer) allows real-time control over deposition/etching rate, thickness/etched depth, and process end pointing.

In the "Step Termination" window of the etching step, select 'Endpoint Detector' and the recipe that you have created in the software EndpointWorks III. It is needed to determine also maximum and minimum time and appearance of an alarm if endpoint detector is unable to process the signal. The refractive index of the material must be programmed also.

Refractive index versus wavelength is reported in Table 1, the exact value for given films can be determined by ellipsometry. Typical wavelength of the laser diode of the system is 675 nm, exact value can be read on the endpoint detector case.

Wavelength (nm)	**254**	**405**	**436**	**546**	**675**	**905**
Photoresist	/	/	/	/	**1.64**	1.62
Si	1.608	5.42	4.831	4.106	**3.815**	3.67
SiO_2	1.5	1.469	1.466	1.46	**1.455**	1.451
Si_3N_4	2.27	2.07	2.06	2.03	**2.02**	2.005
SiO	2.01	2.12	2.09	2.01	**1.948**	1.913
TiO_2	2.37	3.2	3.0	2.8	**2.6**	2.7
SiC	/	/	/	/	**2.621**	2.592
GaAs	2.89	4.44	5.06	4.07	**3.79**	3.57
GaN	/	/	/	/	**2.36**	2.34
AlN	/	/	/	/	**2.145**	2.131
Sapphire	/	/	/	/	**1.764**	/
Perylene-C	/	/	/	/	**1.64**	/
InP	/	/	/	/	**3.504**	3.047
$Al_{0.2}Ga_{0.8}As$	/	/	/	/	**3.676**	3.455
$Al_{0.4}Ga_{0.6}As$	/	/	/	/	**3.522**	3.301
$Al_{0.6}Ga_{0.4}As$	/	/	/	/	**3.361**	3.177
$Al_{0.8}Ga_{0.2}As$	/	/	/	/	**3.215**	3.097
AlAs	/	/	/	/	**3.213**	3.096

Deposition/etching rate, thickness/etched depth during recipe adjustment can be estimated 'on the fly' using the relation between the thickness per interferogram period and optical parameters of the film:

$Period = \lambda/2n$

where λ: lager wavelength (nm), n: film refractive index.

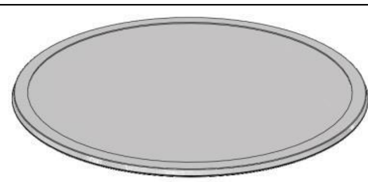
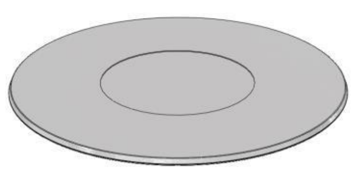
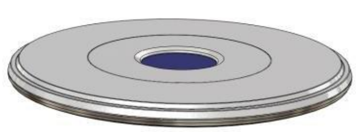
Material	RI	Wavelength (nm)	Thickness per period (nm)
Photoresist	1.64	675	205.8
Si	3.815	675	88.5
SiO2	1.455	675	232
Si3N4	2.02	675	167.1
SiO	1.948	675	173.3
TiO2	2.6	675	129.8
SiC	2.621	675	128.8
GaAs	3.79	675	89.1
GaN	2.36	675	143
AlN	2.145	675	157.3
Sapphire	1.764	675	191.3
Perylene-C	1.64	675	205.8
InP	3.504	675	96.3
Al0.2Ga0.8As	3.676	675	91.8
Al0.4Ga0.6As	3.522	675	95.8
Al0.6Ga0.4As	3.361	675	100.4
Al0.8Ga0.2As	3.215	675	105
AlAs	3.213	675	105

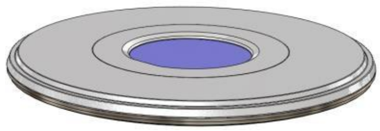
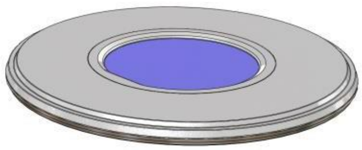
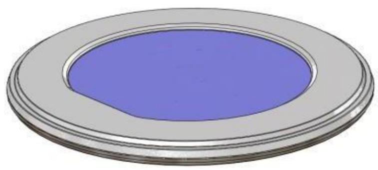
3 SHUTTLES FOR ETCHING

Shuttles are selected according to the material to etch. Generally speaking, the quartz shuttle is used for chlorinated chemistry and the graphite shuttle for the fluorinated one.

It is not allowed to use graphite shuttle components during Chlorinated processes due to desorption of Chlorine species from graphite after shuttle is out the reactor.

The table below gives the range of use for each type of shuttle.

Shuttle	Picture	Acceptable wafer thickness	Helium Clamp. Pressure	Acceptable temperature
NG20 **1 x 200 mm**		**100 µm to 900 µm**	Clamping pressure with or without substrate P_{He} > 3 Torr P_{He} < 10 Torr	The shuttle must be used within the temperature range **-20°C to 150°C**
NG20-100 **1 x 100 mm**		**100 µm to 900 µm**	Clamping pressure with or without substrate P_{He} > 3 Torr P_{He} < 10 Torr	The shuttle must be used within the temperature range **-20°C to 150°C**
NQ200 **1 x 200 mm**		**100 µm to 900 µm**	Clamping pressure with or without substrate P_{He} > 3 Torr P_{He} < 10 Torr	The shuttle must be used within the temperature range **-20°C to 150°C**
NQ200-100 **1 x 100 mm**		**100 µm to 900 µm**	Clamping pressure with or without substrate P_{He} > 3 Torr P_{He} < 10 Torr	The shuttle must be used within the temperature range **-20°C to 150°C**
WF50 **1 x 2"**		**250 µm to 450 µm**	Clamping pressure with standard 2" Si wafer PHe > 2 Torr PHe < 10 Torr	The shuttle must be used within the temperature range **-20°C to 150°C**

WF75 **1 x 3”**		**325 µm to 525 µm**	Clamping pressure with standard 3’’ Si wafer PHe > 2 Torr PHe < 10 Torr	The shuttle must be used within the temperature range **-20°C to 150°C**
WF100 **1 x 100mm**		**425 µm to 625 µm**	Clamping pressure with standard 4’’ Si wafer PHe > 2 Torr PHe < 10 Torr	The shuttle must be used within the temperature range **-20°C to 150°C**
WF150 **1 x 150 mm**		**550 µm to 750 µm**	Clamping pressure with standard 150 mm Si wafer PHe > 2 Torr PHe < 10 Torr	The shuttle must be used within the temperature range **-20°C to 150°C**
WF200 **1 x 200 mm**		**650 µm to 850 µm**	Clamping pressure with standard 200 mm Si wafer PHe > 2 Torr PHe < 10 Torr	The shuttle must be used within the temperature range **-20°C to 150°C**

For the shuttle WF50, WF75 and WF100 the central clamping ring can be in graphite or quartz.

Graphite clamping ring is recommended for conductive wafers, large PR surface and with fluorine chemistry.

Wafer sizes must be within the dimension acceptable to avoid any shuttle breakage, or He leak

4 HELIUM BACK SIDE COOLING

A helium flow is applied at the backside of the shuttle when a process is running.

The helium pressure applied at the backside of shuttle allows thermal exchange between the cathode and the plate or shuttle. The helium pressure leads to cool or heat the shuttle. A helium clamping pressure is > to 3 Torr to allow efficient exchange.

It is mandatory to use helium backside cooling when ICP recipes are used to ensure sufficient thermal exchange between the wafer and the shuttle.

He backside cooling is not mandatory for RIE processes.

The table below describes the adapted He clamping pressure and the He flow associated.

Shuttle	Steps in the recipe	He Clamp. Pressure (Torr)	He flow (sccm)	Process Interlock Stop of process
WF 50 **WF 75** **WF 100** **WF150** **WF200**	All steps	Set to 5 Torr	Reg To 15 sccm	He Clamp. Pressure > 25 Torr
NQ200 **NQ100** **NG20** **NG20-100**	All steps	Set To 5 Torr	Reg To 10 sccm	He Clamp. Pressure > 25 Torr

Please note that Helium clamping pressure is defined as:

He clamping Pressure = He Pressure measured with substrate – He Pressure measured without shuttle.

The figure below gives the He pressure for the shuttles with no wafer for He flow rate within the range from 0 to 50 sccm.

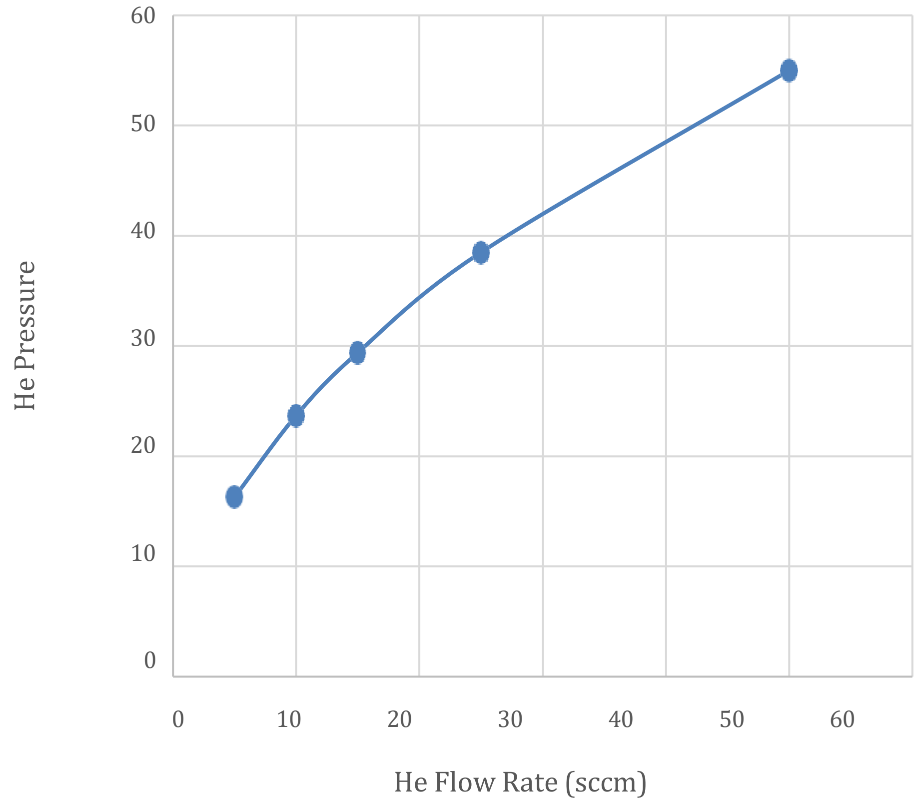


Figure 5 He pressure as function of He flow rate without substrate

5 SWITCHING OF PROCESS CHEMISTRIES – F/Cl

Switching between Fluorinated and Chlorinated process chemistries is possible, certain precautions must be taken to assure reproducibility of processes.

The overall principle is to do plasma cleaning followed by a conditioning of the reactor with respective process (SiO2 etching for example if transition to fluorinated gas).

Plasma cleaning is based on an O2/CHF3 plasma in ICP-RIE mode of sufficiently long duration (say, 45 minutes). The conditioning process depends on the customer and its application.

Transitioning from chlorinated to fluorinated chemistry recommended steps:

1. Plasma cleaning.

2. Reactor venting for manual cleaning with DI water then IPA may be necessary if the reactor was heavily contaminated. If quartz liner is used in the vacuum vessel, it is recommended to swap the quartz liner and clean the enclosure before putting back the vessel under vacuum.

3. Return to vacuum.

4. Implement plasma cleaning.

5. Implement reactor conditioning.

Conditioning plasma: plasma with the same recipe used for the etching process and the same shuttle. We advise running a conditioning plasma for 5-10 minutes for an etching of few minutes after few hours to condition the reactor walls.

In some cases (e.g., after running PSS processes) the recovery of etching performances can be achieved after 2 or 3 conditioning processes.

6 COOLING PERFORMANCE OF THE CHILLER JULABO

Typically, it takes less than 10 min to reach 50°C from a coolant temperature of 20°C (and vice versa). The efficiency of the thermal isolation of cooling pipes and the cooling power of our chiller enables to start quickly a production run even if the coolant was at room temperature. Typically, it takes less than 60 min to reach 80°C from temperature of 20°C

7 CONDITIONS TO BE FULFILLED TO RUN A PROCESS

7.1 Temperature, N2 and Exhaust settings For Dry Roughing Pump

Settings must be done according to the User's Manual provided by the pump manufacturer.

Settings for PFEIFFER A124H Dry Pump	
Dry Pump Temperature	100°C
N2 Purge Flow	> 50 slm

Settings for PFEIFFER A1600MT TMP	
TMP Temperature	75°C
N2 Purge Flow	50 sccm

7.2 MP Pumping Capacity

TMP is operating at > 80% of its full capacity. The pumping performance is given in the

Quality Control Sheet. As soon as the working pressure is 20% above the value measured

for a given flow rate of gas, the TMP maintenance must be performed.

7.3 Reactor and Load-lock Leak Rates

Operation actions must be stopped if either the reactor leak rate is > 10 mT/min or the load-lock leak rate is > 20 mT/min. In such a case, the reactor maintenance must be performed to get the system ready for operation.

8 PROCESSES WITH WAFER PREHEATING BY PLASMA

Wafers can be plasma-preheated to sustain processes requiring wafer temperatures that exceed maximum cathode chiller temperature. Examples of such processes are: ICPRIE of In-based III-V compounds, ICPCVD of dielectrics and aSiH, etc.

In order to increase wafer temperature, a heating step needs to be applied prior to the etching (deposition) step. A wafer is preferably placed on the NQ200 quartz plate shuttle. The temperature of the cathode is set at 20°C to allow shuttle cooling after the process is completed. The following recipe can be used as an example.

9 PLASMA ETCHING RECIPES

To have a reproducible process, a conditioning process before etching is mandatory.

The conditioning process is a plasma with the same recipe used for the etching process and the same shuttle. We advise running a conditioning plasma for 5-10 min for an etching of few minutes every few hours to condition the reactor walls.

This plasma will heat the wall of the reactor. Moreover, the wall will see the same chemistry during the etching. So, from the first few minutes the plasma will see a hot wall and the same chemistry meaning that the plasma parameters and process will be stable.

Moreover, this conditioning process can play an important role in uniformity.

When you run one process after one another of the same recipe, you only need to do a conditioning plasma before the first etching.

9.1 ICPRIE of SiN: “A_SiN_WF200” Recipe

This recipe is used for SiN etching. The process is based on CHF3 chemistry and cathode

Process description:

- Make sure that a shuttle WF200 with a wafer is loaded in the machine.
- Extended Stabilization step of the recipe is needed for stabilization of the gas flows and shuttle temperature. Increased pressure during this step is needed to improve discharge ignition on the RF_ON step.
- The first steps are needed to establish plasma.
- Etching of SiN takes place during step Etching.
- Prolonged Purge step is required for shuttle cooling after long etching process.

The following table details the recipe:

Electrode (°C)	Current

	1	2	3	4
	< Initial >	< Stabilization >	RF_ON	ICP_ON
Duration	0:10.0	Stabilized	0:03.0	0:02.0
Pressure (mTorr)	1	10	10	10
Throttle Position (%)				
Helium Pressure (mTo		5000		
Helium Flow (sccm)		5		
CHF3 (sccm)		30	30	30
O2 (sccm)		3	3	3
Bias (W)		0	150	150
AMN Mode		Manual	Manual	Manual
AMN Load (%)		33	0ms → 3000ms ↕ 43.0	43
AMN Tune (%)		25	0ms → 3000ms ↕ 15.0	15
ICP (W)		0	0	870
AMN Mode		Manual	Manual	Manual
AMN Load (%)		25	25	0ms → 2000ms ↕ 35.0
AMN Tune (%)		72	72	72

	5	6	7
	Go to Etch	Etch SiNx	< End >
Duration	0:05.0	1:00.0	0:10.0
Pressure (mTorr)	2.8	2.8	1
Throttle Position (%)			
Helium Pressure (mTo			
Helium Flow (sccm)			
CHF3 (sccm)	30	30	
O2 (sccm)	3	3	
Bias (W)	150	150	
AMN Mode	Manual	Man→Auto	
AMN Load (%)	14	15	
AMN Tune (%)	2.6	1.8	
ICP (W)	870	870	
AMN Mode	Man→Auto	Man→Auto	
AMN Load (%)	36.4	35.1	
AMN Tune (%)	80.8	82.2	

Process performances:

- Etch rate: 203 nm/min
- Uniformity WIW at 10 mm: 3.9%
- Uniformity WTW : 1.6%

9.2 ICPRIE of SiO2: "A_SiO2_WF200" Recipe

This recipe is used for SiO2 etching. The process is based on CHF3 chemistry and cathode temperature 20°C.

Process description:

- Make sure that a shuttle WF200 with a wafer is loaded in the machine.
- Extended Stabilization step of the recipe is needed for stabilization of the gas flows and shuttle temperature. Increased pressure during this step is needed to improve discharge ignition on the RF_ON step.
- The first steps are needed to establish a plasma.
- Etching of SiN takes place during step Etching.
- Prolonged Purge step is required for shuttle cooling after long etching process.

The following table details the recipe:

Electrode (°C)	20 C

	1	2	3	4
	< Initial >	< Stabilization >	RF_ON	ICP_ON
Duration	0:10.0	Stabilized	0:03.0	0:02.0
Pressure (mTorr)	1	10	10	10
Throttle Position (%)				
Helium Pressure (mTo		5000		
Helium Flow (sccm)		5		
CHF3 (sccm)		30	30	30
O2 (sccm)		3	3	3
Bias (W)		0	200	200
AMN Mode		Manual	Manual	Manual
AMN Load (%)		33	0ms ¬ 3000ms ↕ 43.0	43
AMN Tune (%)		25	0ms ¬ 3000ms ↕ 15.0	15
ICP (W)		0	0	900
AMN Mode		Manual	Manual	Manual
AMN Load (%)		25	25	0ms ¬ 2000ms ↕ 35.0
AMN Tune (%)		72	72	72

	5	6	7
	Go to Etch	Etch SiO2	< End >
Duration	0:05.0	1:00.0	0:10.0
Pressure (mTorr)	2.6	2.6	1
Throttle Position (%)			
Helium Pressure (mTo			
Helium Flow (sccm)			
CHF3 (sccm)	30	30	
O2 (sccm)	3	3	
Bias (W)	200	200	
AMN Mode	Manual	Man→Auto	
AMN Load (%)	14	15	
AMN Tune (%)	2.4	1.9	
ICP (W)	900	900	
AMN Mode	Man→Auto	Man→Auto	
AMN Load (%)	36.4	34.8	
AMN Tune (%)	82	83	

Process performances:

- Etch rate: 160 nm/min
- Uniformity WIW at mm: 4.3%
- Uniformity WTW: 1%

10 PLASMA CLEANING RECIPES

The overall principle is to do plasma cleaning followed by a conditioning of the reactor with respective process (SiO_2 etching for example if transition to fluorinated gas).

Plasma cleaning is based on an O_2/CHF_3 plasma in ICP-RIE mode of sufficiently long duration (say, 45 minutes).

This recipe is used for reactor and shuttle cleaning from deposited polymer layers and to heat up the reactor before ICPRIE if the reactor was not used for prolonged time (>45 min).

The process is based on O_2/CHF_3 chemistry. The reactor is clean when the throttle valve position is stable.

The process is run at the current temperature, so there is no need to change the temperature between your process and the cleaning recipe.

We strongly recommend running a cleaning process after etching, to keep the reactor clean for the next use. It is not needed to run a cleaning process between all your runs if you use the same chemistry for a low etching time.

Few examples of when to run a plasma cleaning:

- After a long total time etching process. It can be 1 etching with long time or several etchings. You will need to run a conditioning plasma after the cleaning process.
- After ventilation of the reactor.
- When the status of the reactor is unknown.
- When the reactor will not be used for long time. To keep the reactor clean during the standby time.

Process description:

- Make sure that the shuttle is loaded in the reactor.
- The first steps are needed to establish a plasma.

10.1 Plasma Cleaning: "B_CLEAN_WF200" Recipe

Electrode (°C)	20 C

	1	2	3	4	5
	< Initial >	< Stabilization >	RF_ON	ICP_ON	GoTo Clean
Duration	0:10.0	Stabilized	0:03.0	0:02.0	0:05.0
Pressure (mTorr)	1	10	10	10	10
Throttle Position (%)					
Helium Pressure (mTo		5000			
Helium Flow (sccm)		5			
CHF3 (sccm)		15	15	15	15
O2 (sccm)		100	100	100	100
Bias (W)		0	200	200	0
AMN Mode		Manual	Manual	Manual	Manual
AMN Load (%)		45	0ms → 3000ms ↕ 43.0	43	43
AMN Tune (%)		12	0ms → 3000ms ↕ 15.0	15	12
ICP (W)		0	0	800	800
AMN Mode		Manual	Manual	Manual	Manual
AMN Load (%)		31	39	0ms → 2000ms ↕ 39.0	38
AMN Tune (%)		64	64	64	65

	6	7	8	9
	Clean phase1	Clean phase 2	Purge	< End >
Duration	5:00.0	5:00.0	0:10.0	0:10.0
Pressure (mTorr)	10	10		1
Throttle Position (%)			100	
Helium Pressure (mTo				
Helium Flow (sccm)				
CHF3 (sccm)	15	15	0	
O2 (sccm)	100	100	100	
Bias (W)	0	0	0	
AMN Mode	Manual	Manual	Manual	
AMN Load (%)	34	34	34	
AMN Tune (%)	20	20	20	
ICP (W)	800	800	0	
AMN Mode	Man→Auto	Man→Auto	Manual	
AMN Load (%)	38.5	38.5	40.1	
AMN Tune (%)	65.2	65.5	65.6	