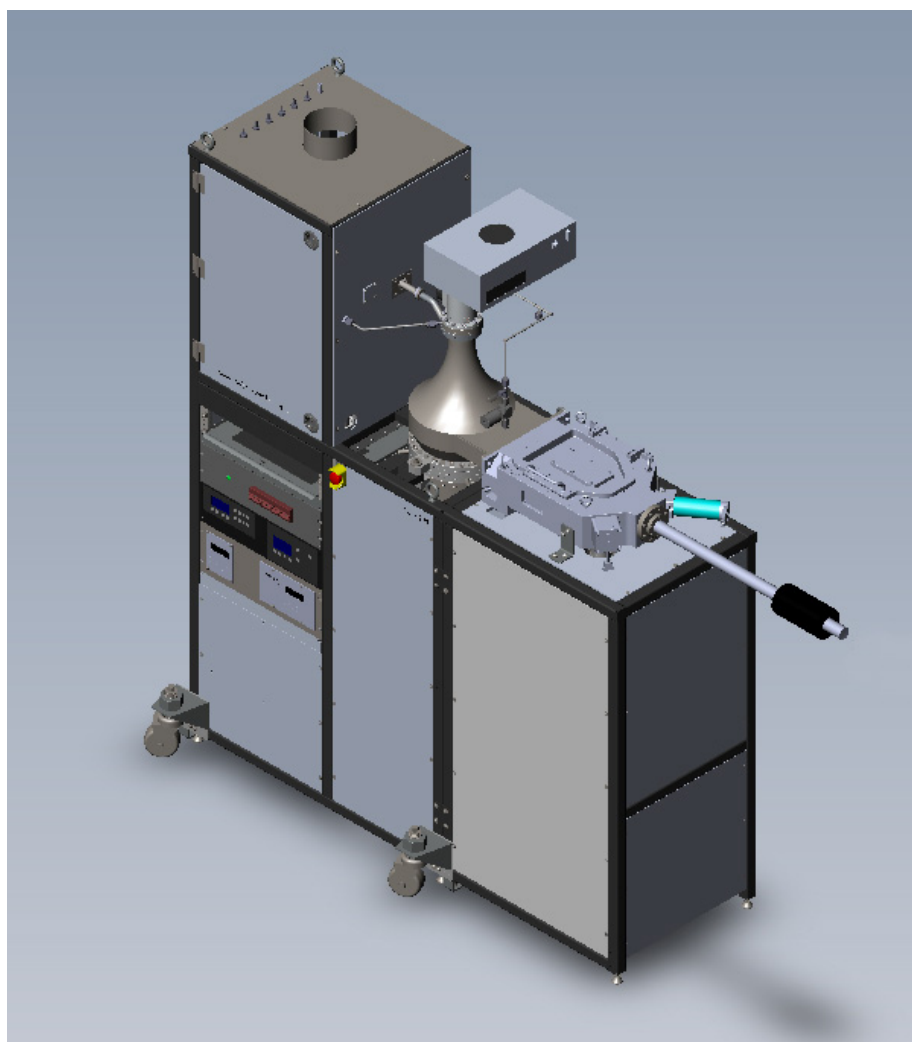


Fiji F200

Atomic Layer Deposition System

Installation and Use Manual V2 - July 25, 2009



Cambridge NanoTech Inc. welcomes requests for information, comments and inquiries about its products.

Address all correspondence to:

Cambridge NanoTech Inc.
68 Rogers Street
Cambridge, MA 02142
USA

This manual is also available in other languages upon written request.

Notice

This is a Cambridge NanoTech Inc. publication which is protected by copyright. Original copyright date 2004. No part of this document may be photocopied, reproduced, translated to another language, or published on-line without the prior written consent of Cambridge NanoTech Inc. The information contained in this publication is subject to change without notice.

Trademarks

Cambridge NanoTech Inc. and Fiji, are trademarks of Cambridge NanoTech Inc.

Kalrez and Viton are registered trademarks of E.I. DuPont de Nemours & Co.

VCR is a registered trademark of Swagelok Company.

©2009 Cambridge NanoTech, Inc. All rights reserved.

Table of Contents

Section 1	System Overview	7
	System Description	7
Section 2	Theory	10
	Atomic Layer Deposition: Principle of Al₂O₃ formation	10
	Modes of Operation	12
	Pyrophoric Precursors	12
Section 3	Installation	13
	Introduction	13
	Facility Requirements Checklist.....	13
	Unpacking.....	15
	Required Equipment and Supplies	15
	Installation Procedure	15
	Step 1: Move the System into Position.....	15
	Step 2: Level the System.....	15
	Step 3: Connect Vacuum Fittings.....	16
	Step 4: Connect Cabinet Exhaust	17
	Step 5: Connect Plasma Source and Lines	17
	Step 6: Install the substrate carrier arm	19
	Step 7: Connect Input Power to the System	20
	Step 8: Fill and Install the H₂O Cylinder	21
	Step 9: Install the Precursor Cylinders.....	21
	Step 10: Connect Facility Gases	22

Section 4	Operation	23
	Initial Startup	23
	Step 1: Verify Installation	23
	Step 2: Power-up the System	23
	Step 3: Start the Control Software	23
	Step 4: Turn on the Heaters	24
	Step 5: Degas the System	25
	Degas the System Procedure	25
	Step 6: Load a Substrate into the Load/Lock Chamber	26
	Step 7: Move the Substrate into the Process Chamber	27
	Step 8: Perform a Growth Run	29
	Step 10: Remove the Substrate Carrier from the Process Chamber	29
Section 5	Software Reference	31
	Process Screen	31
	Control buttons:	32
	Input and display boxes:	32
	Process Chamber Pressure Plot Area:	33
	Recipe Table	34
	Help Button:	36
	Heater Control Area:	36
	Notes & Items Page:	37
	Advanced Page:	37
	Vacuum page:	38

Appendix A	Troubleshooting, Process Questions	40
	Frequently Asked Questions	40
	Process Questions	40
Appendix B	Manual General Information	44
	General Notes	44
	Using this Manual	44
	Recommended Training for Operation Personnel	44
Appendix C	Safety	45
	Introduction	45
	Qualified Personnel	45
	Intended Use	45
	Regulations and Approvals	45
	Client Modifications	45
	Definitions for Signal Words	46
	Safety Symbols	46
	Personal Safety	47
	Equipment Safety Labels Locations	48
	EMO, Safety Switches	48
	Fire Safety	48
	Electrical Safety	49
	Mechanical Hazards	49
	Mechanical Hazard Locations	49
	Electrical Hazards	50
	Chemical Hazards	50
	Precursors Fire Hazards	50
	Location of Chemical Supplies	50

- Material Safety Data Sheets 50**
- Recommended Practices 51**
 - Operational Notes 51**
 - Best Practices 51**
 - Help 51**
- Evacuations 51**
- Action in the Event of a Malfunction 51**
- Disposal 51**

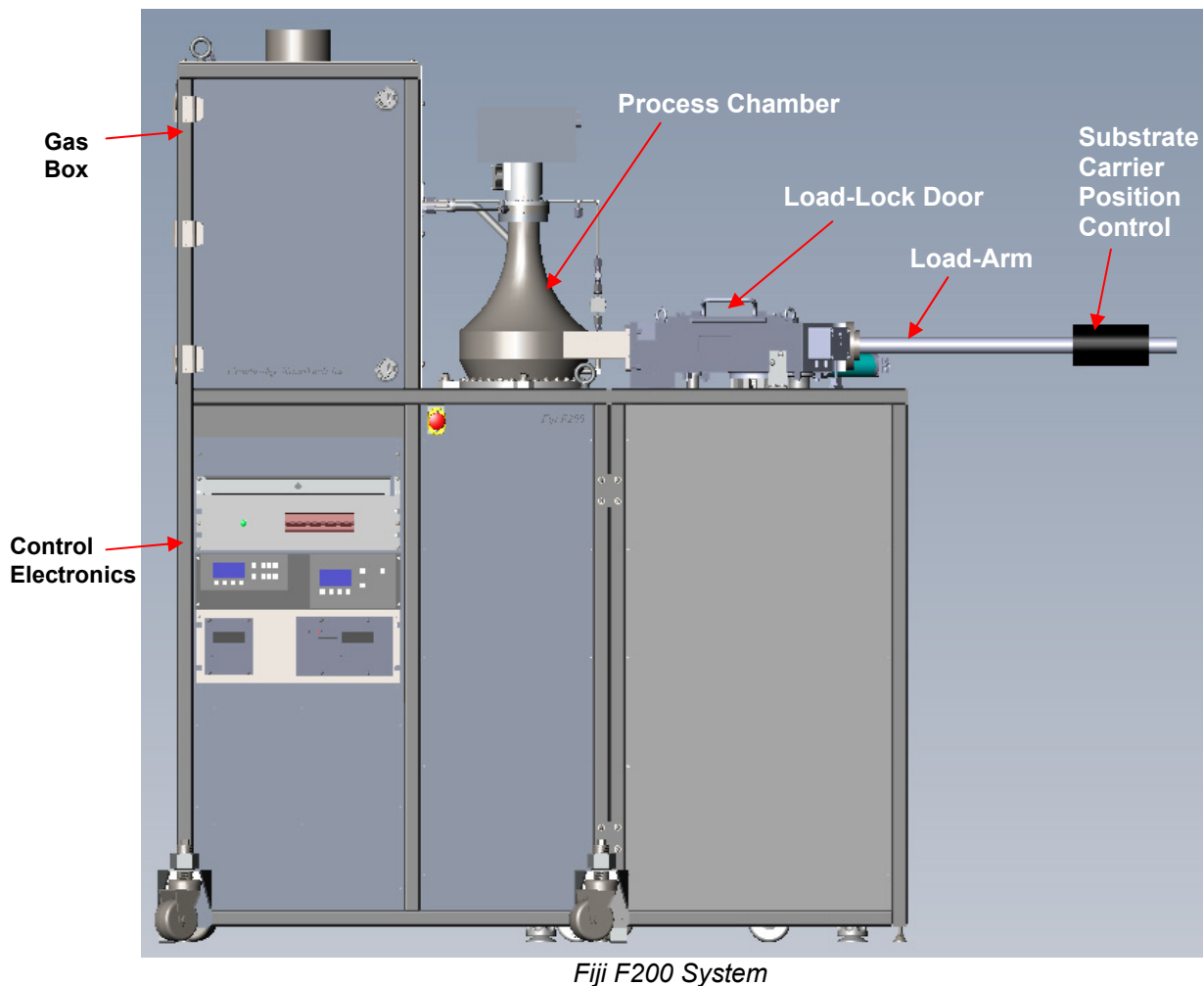
Section 1 System Overview

System Description

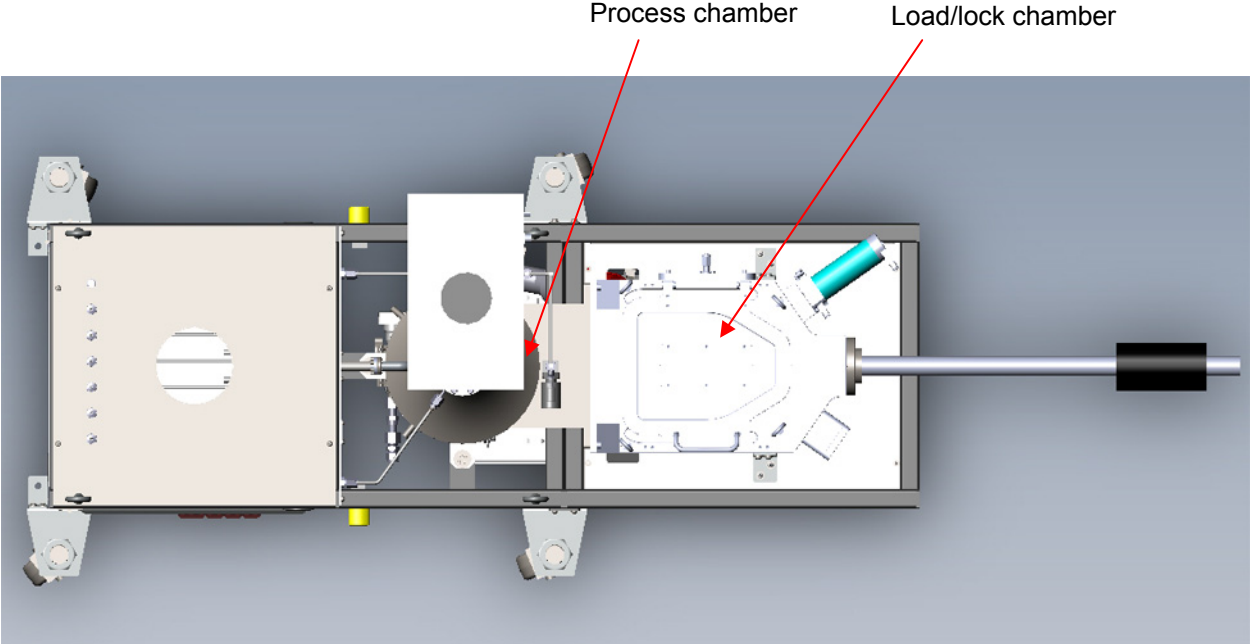
The Cambridge NanoTech Fiji F200 series is our most advanced ALD research and development system. The Fiji is a modular high-vacuum ALD system that accommodates a wide range of deposition modes using a flexible system architecture and multiple configurations of precursors and plasma gases. The result is a new generation ALD platform capable of doing thermal as well as plasma-enhanced deposition.

Cambridge NanoTech has combined its leading ALD expertise with advanced Computational Fluid Dynamics analyses to optimize Fiji F200 ALD process chamber, heater and trap geometry. The hyperboloid chamber geometry combined with the paraboloid substrate heater creates a laminar precursor and remote plasma generated radical flow. This type of design that you can only get from knowledgeable ALD experts, optimizes deposition uniformity and minimizes cycle time and precursor use.

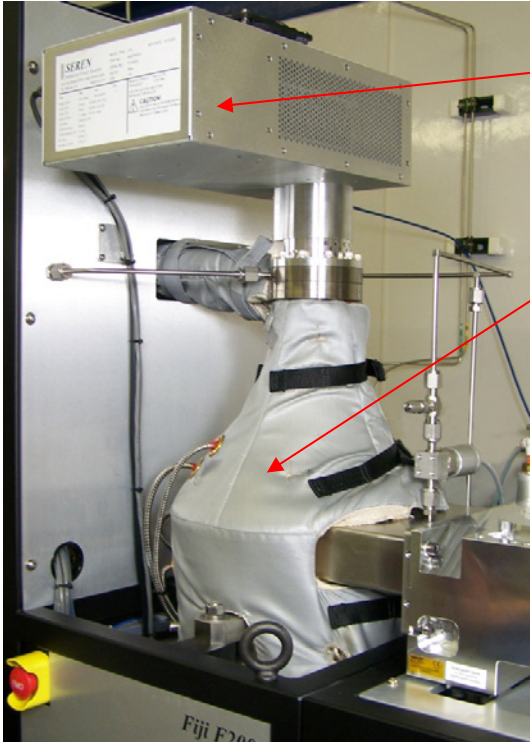
The Fiji F200 is available in several different configurations. The system can be configured with multiple heated precursor lines and plasma gas lines, offering the greatest experimental flexibility in a compact footprint. **This manual covers the Single-Chamber, manual load-lock system shown below:**



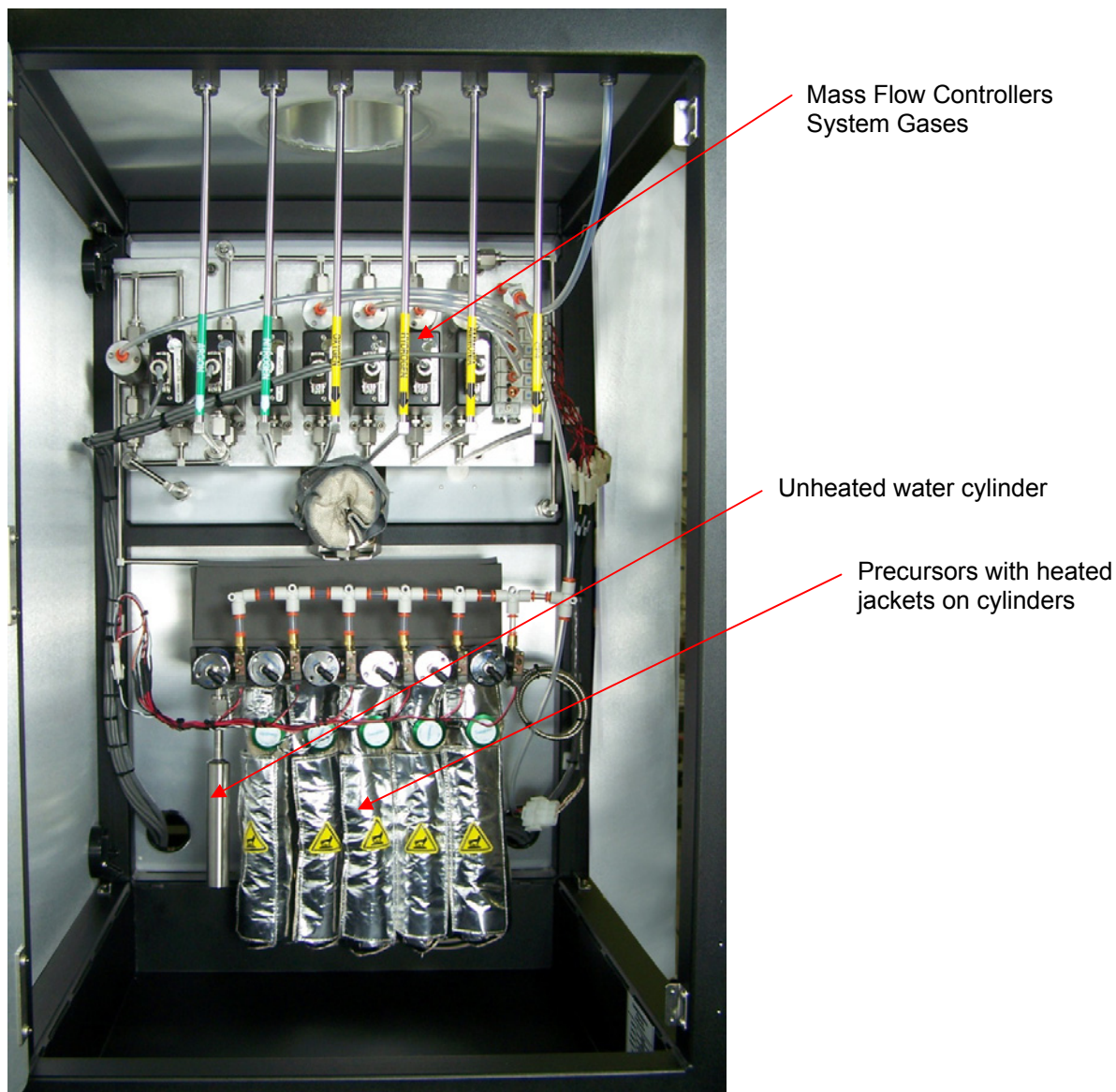
The system contains a load/lock chamber for loading substrates external to the process chamber. The process chamber has a gate-valve to maintain optimum process conditions and minimizing temperature cycling times. EMO buttons are provided on the front and rear of the system.



Top View



Process Chamber



Gas Box – Inside View

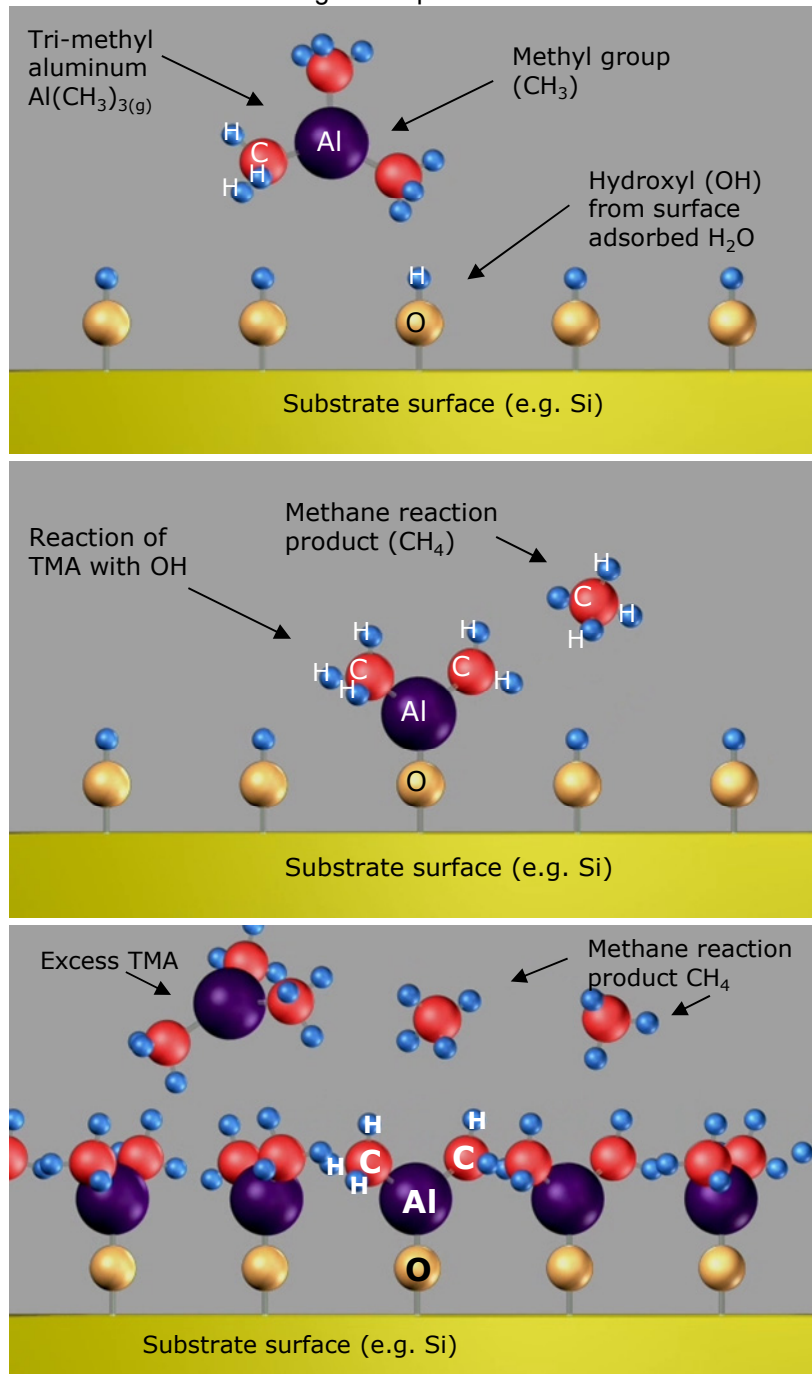
Section 2 Theory

Atomic Layer Deposition: Principle of Al_2O_3 formation

Atomic Layer Deposition (ALD) is a technique that allows growth of thin films, atomic layer by layer. The typical ALD reaction is illustrated via the formation of Al_2O_3 from trimethylaluminum or TMA, $\text{Al}(\text{CH}_3)_3$, and water, H_2O . Recipes for other materials can be found in the literature.

Step 1: Introduction and adsorption of precursor A to the surface.

The precursor, trimethylaluminum reacts with hydroxyl groups on the surface of the substrate, liberating methane. The reaction is self-limiting as the precursor does not react with adsorbed aluminum species.

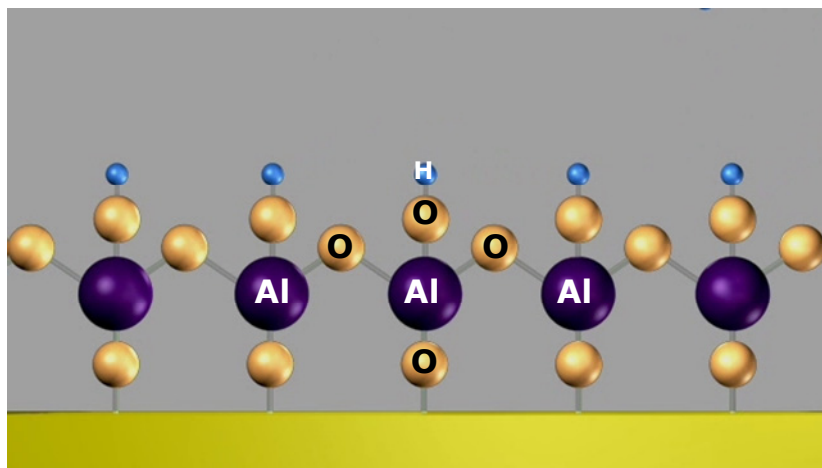
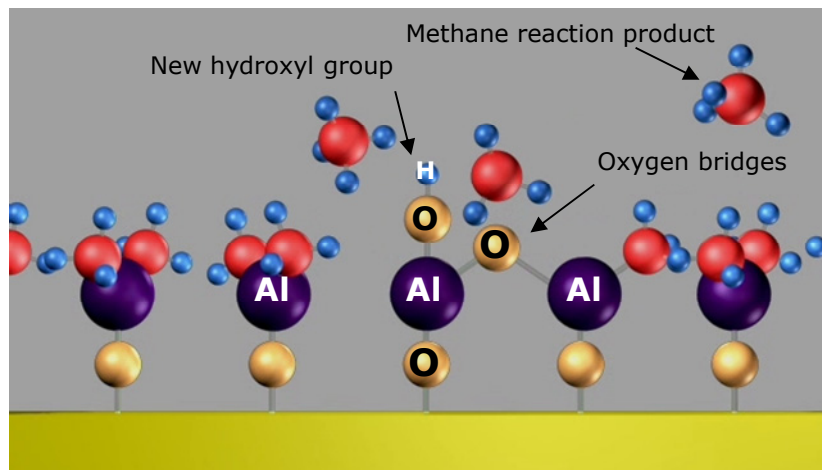
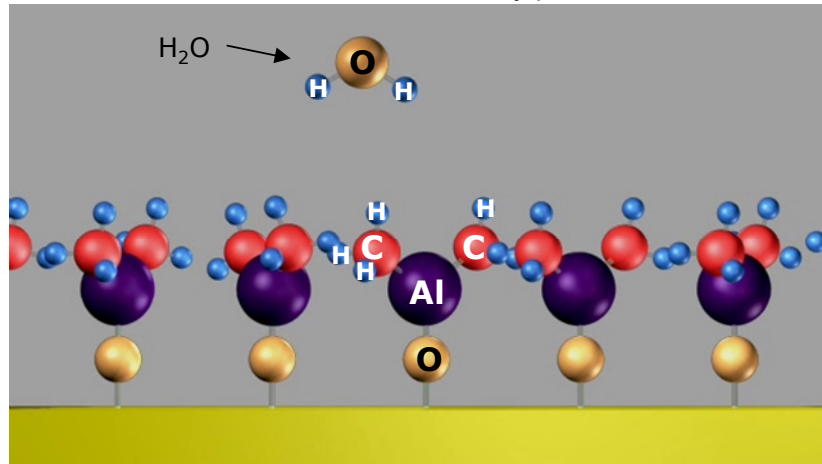


Step 2: Removal of the unreacted precursor and reaction products.

Unreacted precursor and the methane (CH_4) liberated from the reaction are removed by simple evacuation of the sample chamber or by flowing inert gas over the surface.

Step 3: Introduction and adsorption of precursor B to the surface.

Water reacts with the methyl groups on the deposited aluminum atoms forming both Al-O-Al bridges, as well as new hydroxyl groups. The formation of hydroxyl groups readies the surface for the acceptance of the next layer of aluminum atoms. Methane is liberated as a by-product



Step 4: Removal of the unreacted precursor and reaction products via evacuation and/or inert gas flow.

Step 5: Repeat to create layers

The process begins again with the introduction of precursor A followed by B. Atomic layers are built up one after the other.

Modes of Operation

There are two main modes of operation:

1. Continuously flowing carrier gas while pulsing (adding) precursor and pumping continuously
2. Pulsing precursors with stop valve closed and pumping in-between pulses

This research system can operate in either mode

Pyrophoric Precursors



DANGER! FIRE HAZARD

Trimethylaluminum (TMA) is a liquid at room temperature and is pyrophoric. This means that it burns upon exposure to air. TMA reacts with water vapor in the air. For this reason, the TMA bottle may only be opened in a glove box with inert atmosphere by experienced professionals such as at the chemical supply companies (Strem, Sigma-Aldrich etc).

Section 3 Installation

Introduction

The Fiji F200 ALD system is shipped fully assembled. Some minor assembly is required prior to operation. Carefully inspect all supplied parts for damage before proceeding with installation.

Installation must be performed by qualified personnel observing all safety regulations and procedures. Helium leak checking of the entire assembled system is advised.

Facility Requirements Checklist

Item	Details	Verified
System Dimensions	<p>Refer to system installation drawing for dimension. Be sure to leave a minimum of 91.5 cm (36") around all sides of the equipment for operation and service.</p> <p>FRONT/BACK/SIDES: Be sure to allow a minimum of 36" of free service space around all sides of the equipment. This space may be shared with other equipment/tools.</p> <p>TOP: You must provide sufficient space above the system to make facility connections. Consult Cambridge Nanotech with any questions.</p>	
System Power	<ul style="list-style-type: none"> • United States. (220 VAC is two lines at 110 VAC 60 Hz that are out of phase by 180 degrees): F200: 4 wire 220 VAC 60 Hz 50A. Connections = (L1 = 110 VAC 60 Hz (line 1 = red), L2 = 110 VAC 60 Hz (line 2 = black), N (neutral = white), G (ground = green) [color scheme by US National Electrical Code] • Europe. (220VAC is one line at 230 VAC 50 Hz) F200: 3 wire 220 VAC 50 Hz 50A. (L1 = 220VAC 50 Hz (line 1 = Brown), N (neutral = Blue), G (ground = green-yellow) [color scheme by IEC (International Electrotechnical Commission)]) Note! A jumper MUST be added to the power distribution box when the system is installed in Europe. See <i>Installation</i> Section for details. <p>Wire must be 6-8 AWG stranded. Current <35 Amps in continuous operation.</p> <p>The final disconnect device is the main circuit breaker CB1 on the power distribution box (PD Box).</p> <p>Note! A jumper MUST be added to the power distribution box when the system is installed in Europe. See <i>Installation</i> Section for details.</p> <p>Power Distribution (PD) Box Outlets</p> <p>There are 12 outlets on the back of the PD Box. The outlets are protected by CB4, a 15 A circuit breaker on the PD Box. Therefore, the combined current for all 12 outlets is 15 A.</p>	

Gas Cabinet Exhaust	<p>A 4" diameter exhaust duct port is provided at the top of the system. This port must be connected to an appropriate facility exhaust to handle the chemical hazards present in the system supply gases. Exhaust draw should be 200 CFM at 0.5" W.C.</p> <ul style="list-style-type: none"> • A metallic exhaust line from the pump to the exhaust. • Precursor cabinet- flexible or hard connection, with clamps to a 4" duct at top of the cabinet • Exhaust should be capable of handling any toxic gases and related effluents from your system. <p>All processes are run through the system pump. Each user's environmental requirements are different due to the chemical processes being employed. Consult the MSDS sheets of the precursors and contact your local safety office for appropriate venting precautions.</p>																																	
Facility Gases	<p>The system has been configured for use with the following gases. Follow all standard practices for handling and connection of appropriate high-purity components, tubing, and metal gaskets to make all connections.</p> <table border="1" data-bbox="467 793 1352 1108"> <thead> <tr> <th>Gas</th> <th>Supply Pressure</th> <th>Flow/Consumption</th> <th>Connection</th> </tr> </thead> <tbody> <tr> <td>CDA or N₂</td> <td>80 – 100 PSIG</td> <td></td> <td>1/4" Swagelok®</td> </tr> <tr> <td>Ar</td> <td>30 PSIG</td> <td>10 SLM</td> <td>1/4" Butt weld tube</td> </tr> <tr> <td>N₂</td> <td>30 PSIG</td> <td>1 SLM</td> <td>1/4" Butt weld tube</td> </tr> <tr> <td>O₂</td> <td>30 PSIG</td> <td>1 SLM</td> <td>1/4" Butt weld tube</td> </tr> <tr> <td>H₂</td> <td>30 PSIG</td> <td>1 SLM</td> <td>1/4" Butt weld tube</td> </tr> <tr> <td>Ammonia</td> <td>30 PSIG</td> <td>1 SLM</td> <td>1/4" Butt weld tube</td> </tr> <tr> <td>CF₄</td> <td>30 PSIG</td> <td>1 SLM</td> <td>1/4" Butt weld tube</td> </tr> </tbody> </table> <p>Process Gases: Recommended Research grade Ar (99.9995%)</p>	Gas	Supply Pressure	Flow/Consumption	Connection	CDA or N ₂	80 – 100 PSIG		1/4" Swagelok®	Ar	30 PSIG	10 SLM	1/4" Butt weld tube	N ₂	30 PSIG	1 SLM	1/4" Butt weld tube	O ₂	30 PSIG	1 SLM	1/4" Butt weld tube	H ₂	30 PSIG	1 SLM	1/4" Butt weld tube	Ammonia	30 PSIG	1 SLM	1/4" Butt weld tube	CF ₄	30 PSIG	1 SLM	1/4" Butt weld tube	
Gas	Supply Pressure	Flow/Consumption	Connection																															
CDA or N ₂	80 – 100 PSIG		1/4" Swagelok®																															
Ar	30 PSIG	10 SLM	1/4" Butt weld tube																															
N ₂	30 PSIG	1 SLM	1/4" Butt weld tube																															
O ₂	30 PSIG	1 SLM	1/4" Butt weld tube																															
H ₂	30 PSIG	1 SLM	1/4" Butt weld tube																															
Ammonia	30 PSIG	1 SLM	1/4" Butt weld tube																															
CF ₄	30 PSIG	1 SLM	1/4" Butt weld tube																															
Precursors/ Chemicals	<ul style="list-style-type: none"> • Distilled water • Chemical precursors (i.e. TMA) loaded into cylinders <p>Fiji systems ship with one water cylinder (no valve) and with valved precursor cylinders populating the remainder of the precursor lines.</p> <p>Common chemical precursors can be found, for example from Strem or Sigma-Aldrich. http://www.sigmaaldrich.com/materials-science/micro-and-nanoelectronics/cvd-ald-precursors/precursors.html http://www.strem.com/catalog/d/mocvd/ Trimethylaluminum (TMA) is a good precursor to have in order to test the operation of the system. It can be purchased from Sigma-Aldrich prepackaged in an appropriate cylinder, P/N # 66301. Cambridge Nanotech recommends using distilled water as a precursor.</p>																																	
Environmental Specifications	<table border="1" data-bbox="467 1696 1352 1854"> <thead> <tr> <th>Category</th> <th>Specification</th> </tr> </thead> <tbody> <tr> <td>Operating Temperature</td> <td>15-40°C (60-100°F)</td> </tr> <tr> <td>Humidity</td> <td>Max 80% at 30°C (50% at 40°C)</td> </tr> <tr> <td>Storage Humidity</td> <td>0-95% relative humidity, non-condensing</td> </tr> <tr> <td>Operation Altitude</td> <td>Max 2000m</td> </tr> </tbody> </table>	Category	Specification	Operating Temperature	15-40°C (60-100°F)	Humidity	Max 80% at 30°C (50% at 40°C)	Storage Humidity	0-95% relative humidity, non-condensing	Operation Altitude	Max 2000m																							
Category	Specification																																	
Operating Temperature	15-40°C (60-100°F)																																	
Humidity	Max 80% at 30°C (50% at 40°C)																																	
Storage Humidity	0-95% relative humidity, non-condensing																																	
Operation Altitude	Max 2000m																																	

Unpacking

Unpack the crate carefully and inspect the system for damage that may have occurred during shipping. Notify the carrier immediately if any damage is found. Retain the shipping cartons and packing material for the carrier's inspection and for repackaging in case reshipment is necessary.

CAUTION: Avoid Particulate Contamination.

If the unit is to be used in a cleanroom environment, DO NOT unwrap any item until immediately before installation.

Required Equipment and Supplies

Tubing:

- All gas connections use standard $\frac{1}{4}$ " VCR[®] or Swagelok[®] fittings. Use standard fitting equipment and techniques to make high-purity leak-tight fittings.

Tools:

- Level
- Tubing cutter
- Metal tubing tools/fixtures: tubing cutter, tubing bender and related tools, if applicable
- Helium leak checking equipment
- Cleanroom wipes
- Standard electrical and mechanical tool kits

Installation Procedure

Step 1: Move the System into Position

1. The system should be moved into position with great care to prevent damage. Please consult professional movers. Lifting bolts are provided in multiple locations.



CAUTION: PINCH HAZARD!

Protect yourself from any pinch or crush hazard.

Step 2: Level the System

1. The system is equipped with leveling feet. Adjust each carefully to level the system, front and back, side to side. Use of a precision bubble level on multiple surfaces is recommended.
2. Lock each adjusting foot in position, being sure to check the level and make any minor adjustments to maintain a level system.

Step 3: Connect Vacuum Fittings

1. Connect the system vacuum flange connections to your vacuum pump/s tubing. Use a centering ring and new o-rings.



Use 4 clamps for each connection flange, or use a locking ring to firmly secure the connection.

Note: LEAK HAZARD. HANDLE CAREFULLY.

Always treat the vacuum connection flange faces with care and cover them with plastic caps if not in use, scratching can cause leaks. Replace each o-ring after use.

Note: OBSERVE VACUUM REQUIREMENTS.

Customer must supply and connect the Fiji system to a vacuum pump adequate for the system. On systems supplied with vacuum pumps, please refer to the pump manuals.

Each pump shall be guaranteed to pump nitrogen at the specified nominal pumping speed at the required pressure. Pump speed shall not see a reduction of more than 20% during processing.

Step 4: Connect Cabinet Exhaust

1. The Fiji system requires cabinet exhaust. The exhaust connection is located at the top of the system. The connection is a 4" diameter duct with a flow of 200CFM and a draw of .5" W.C.

The approximate heat load generated by the Fiji system is 3kW.



WARNING: Hazard Gas Exhaust Potential.

While the cabinet exhaust is primarily for thermal exhaust of the heat generated by the system, unanticipated release of supply gases and/or chamber gases may present hazards.



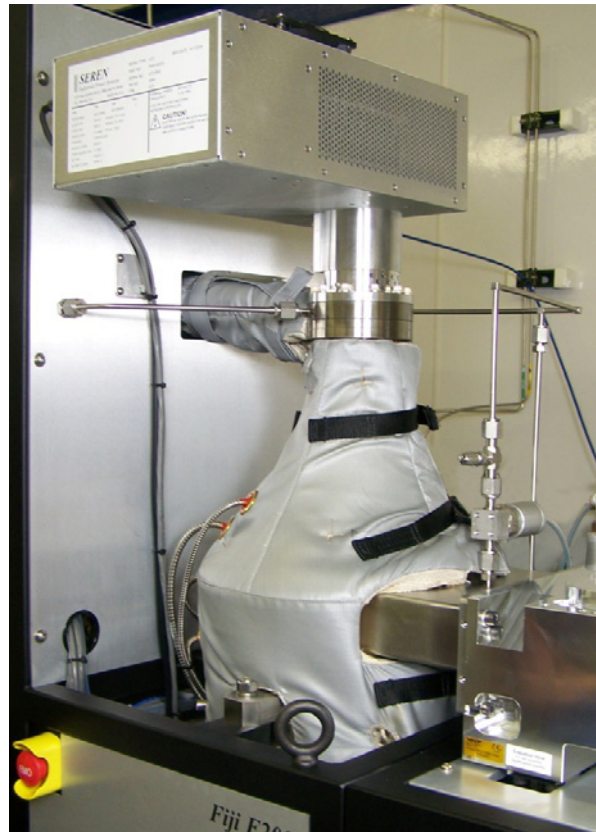
Connect the system only to an exhaust system that has been approved for your process effluents and your process gases.

Step 5: Connect Plasma Source and Lines

1. Carefully remove any packing materials/covering then re-install the plasma source at the top of the chamber.

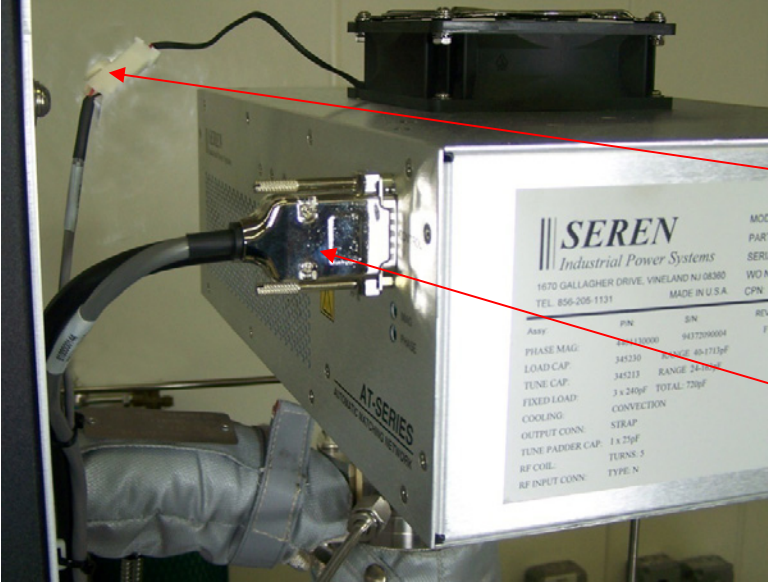


As shipped



Installed Plasma Source, Wiring, Gas Line

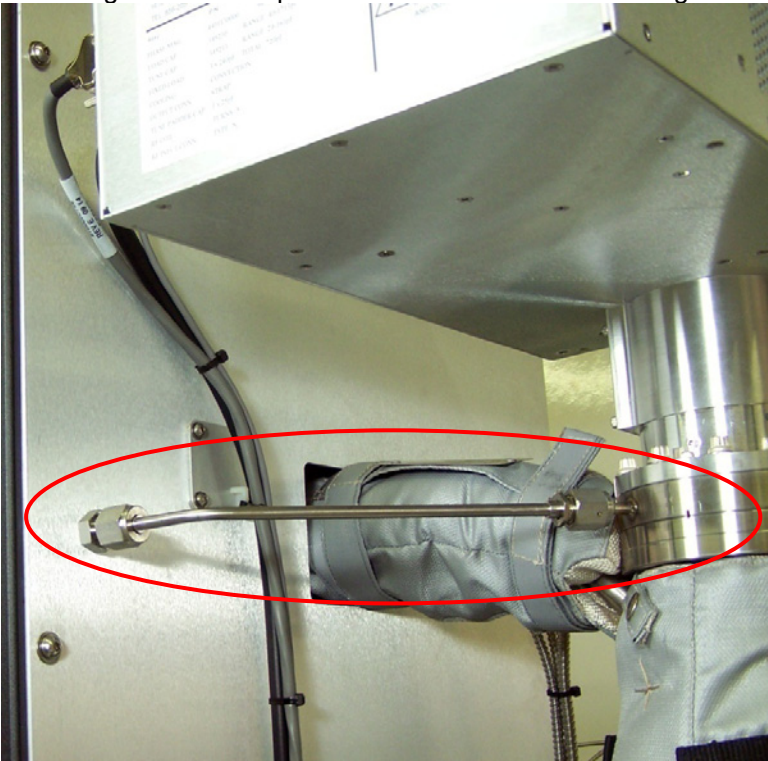
2. Connect control wiring connector to the plasma source and fan wiring to plasma fan.



Plasma fan power connector

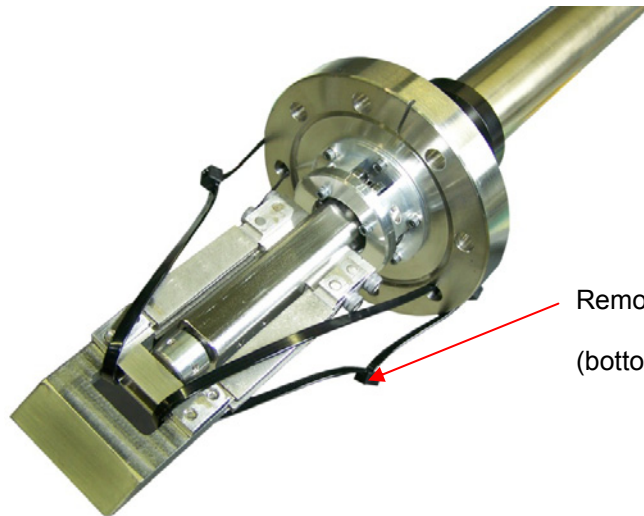
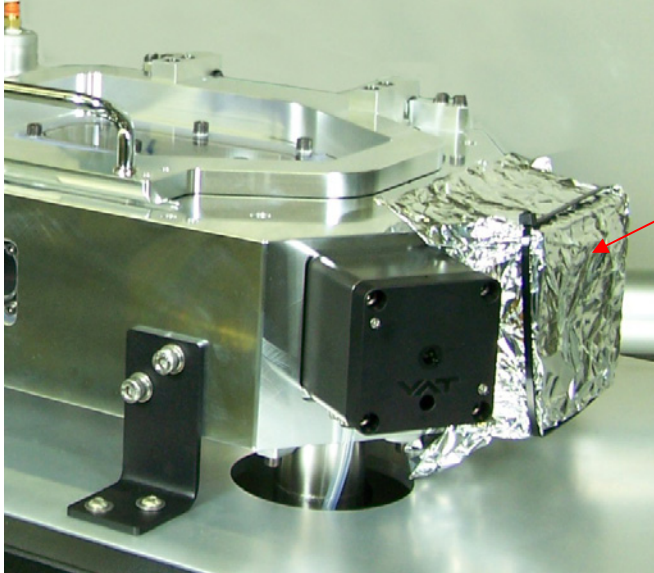
Plasma control wiring connector

3. Connect gas line to the process chamber connection using new metal VCR® washers:



Step 6: Install the substrate carrier arm

1. Carefully remove the packing materials from the substrate chamber and remove the shipping tie-wraps from the substrate end effector.



2. Carefully insert the substrate carrier into the transfer chamber and secure the carrier with the provided bolts. The carrier must be inserted so that when the carrier end is rotated, the end effector lifts a substrate up (flat end on top).

Step 7: Connect Input Power to the System

1. Connect an appropriate power cable per the system specifications to the power distribution box.
 - United States. (220 VAC is two lines at 110 VAC 60 Hz that are out of phase by 180 degrees):
F200: 4 wire 220 VAC 60 Hz **50A**. Connections = (L1 = 110 VAC 60 Hz (line 1 = red), L2 = 110 VAC 60 Hz (line 2 = black), N (neutral = white), G (ground = green) [color scheme by US National Electrical Code]
 - Europe. (220VAC is one line at 230 VAC 50 Hz)
F200: 3 wire 220 VAC 50 Hz **50A**. (L1 = 220VAC 50 Hz (line 1 = Brown), N (neutral = Blue), G (ground = green-yellow) [color scheme by IEC (International Electrotechnical Commission)]

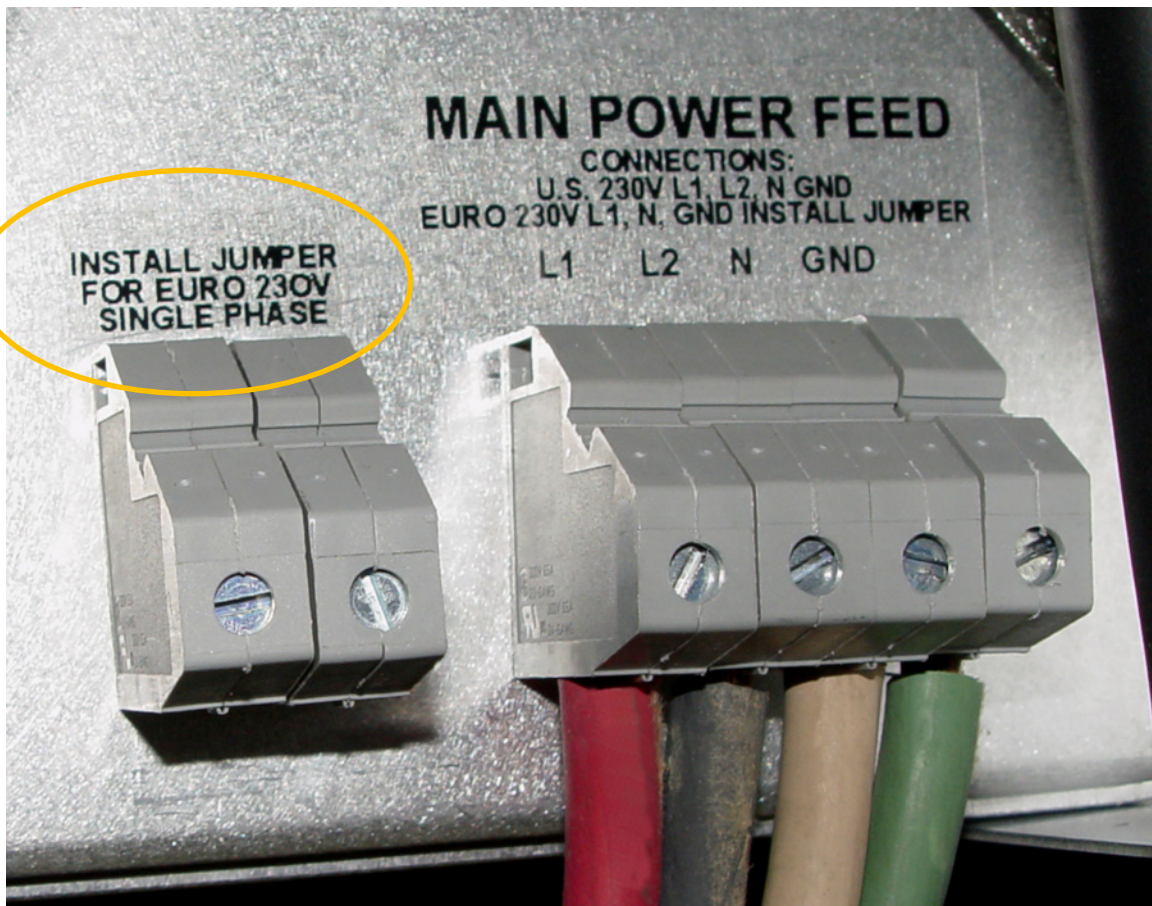
Wire must be 6-8 AWG stranded. Current <35 Amps in continuous operation.

For non-USA installations, you MUST install a jumper for EURO use, as indicated on the box.



DANGER! SHOCK HAZARD.

A trained electrician should perform this installation in accordance with all applicable local wiring codes including any required conduit installation.

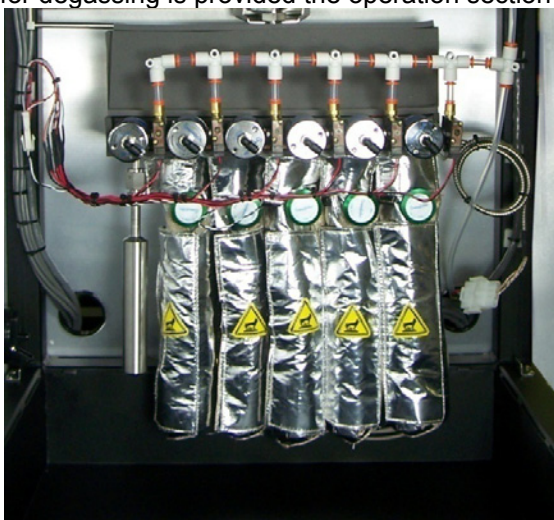


Step 8: Fill and Install the H₂O Cylinder

1. The H₂O cylinder is connected by a VCR[®] fittings. A new metal gasket should be used every time a connection is made. Extra care should be taken in order to keep VCR connecting surfaces from scratches. Once disconnected, use plastic covers and plugs to protect polished VCR face surfaces.

The H₂O cylinder is located at the rear of the Fiji enclosure (position 1), to hold the H₂O for processing. This cylinder must be removed from the system and filled with DI water. The cylinder can hold up to 25cc of DI water. Remove plumbing connection and clamp to remove cylinder. Replace the cylinder and tighten clamp to secure. Reconnect the plumbing manifold.

CAUTION! Do not over tighten VCR fittings. Once connected, first hand tighten and then tighten by a 45°. Do not open any valves on the cylinder. The space that is formed between the VCR fitting and the ALD valve is called the headspace and has to be evacuated prior to first time use. The instructions for degassing is provided the operation section of this manual.



Step 9: Install the Precursor Cylinders

The precursor cylinders are connected by metal face seal VCR[®] fittings. A new metal gasket **MUST** be used every time a connection is made. Extra care should be taken in order to keep VCR connecting surfaces from scratches. Once disconnected, use plastic covers and plugs to protect polished VCR face surfaces.

Precursor cylinders are filled in a glove box by a chemical supplier. Insert the cylinder and secure it in place. Connect plumbing line from outlet valve on the cylinder to the precursor valve. These connections are VCR.

CAUTION! Do not over tighten VCR fittings. Once connected, first hand tighten and then tighten by wrench an additional 45°. Do not open any valves on the cylinder. The head space must be evacuated a minimum of three times before opening the outlet valve on the precursor cylinders.

Never disconnect manual valves from the precursor cylinders, only authorized manufactures can replenish and clean precursor cylinders. Always disconnect cylinder-valve assembly with manual valve closed

Once the manual valve is attached to the ALD valve, the space that is formed between these two valves is called the headspace and has to be evacuated prior to the opening of the manual valve. The instructions for degassing is provided in the Operation section of this manual.

Note: The arrow on the manual valve attached to the precursor should be pointed toward the cylinder with the chemical.

**DANGER! FIRE HAZARD**

Precursors such as Trimethylaluminum (TMA) is a liquid at room temperature and is pyrophoric. This means that it burns upon exposure to air. TMA reacts with water vapor in the air. For this reason, the TMA bottle may only be opened in a glove box with inert atmosphere by experienced professionals such as at the chemical supply companies (Strem, Sigma-Aldrich etc).

Note: Not all precursors need to be heated

Note: Process chemicals are customer supplied.

Step 10: Connect Facility Gases

1. Connect all facility gases as required. Follow all standard practices for handling and connection of appropriate high-purity components, tubing, and metal gaskets to make connections.
2. Leak check each line.
3. Typically, each line should be purged with inert gas prior to the introduction of a potentially reactive gas such as Oxygen or Hydrogen, etc. Consult with CambridgeNanotech for specific instructions to properly purge each delivery line to ensure safety.

**DANGER! HAZARDOUS GASES.**

All gas fittings should be performed by properly licensed and trained plumbers for the specific gas types used on this system. All connections and lines must be leak-checked to ensure safety from fire, explosion, and/or release of toxic or other gas hazards.



Section 4 Operation

Initial Startup

Step 1: Verify Installation

1. Verify that all facility installation requirements and facility feeds have been completed and that all tubing has been properly installed. The system must be helium leak checked. Any facility and/or external sensors should be certified to be working properly before proceeding.
2. Verify that the load lock lid is closed securely and that all system panels are in place and closed.
3. Verify that the cabinet exhaust meets performance specifications.
4. Turn on the system's vacuum pump and verify draw.
5. Turn on all facility supplies.

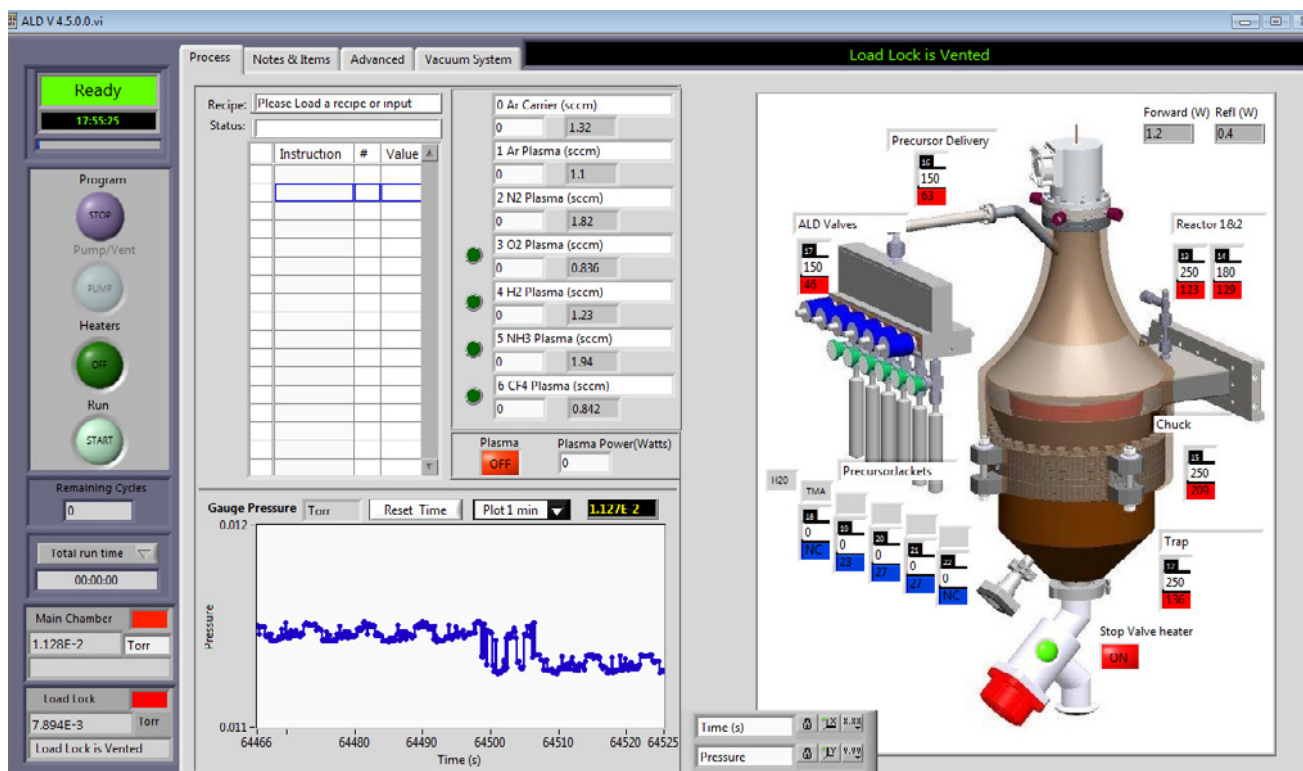
Step 2: Power-up the System

1. Verify the Emergency Stop buttons are unlatched (turn to the right).
2. Press the RESET button on the power distribution box.
3. Turn on the following circuit breakers:
 - CB1 MAIN (Main Power)
 - CB2 EBOX 1 (Chamber A Control Box Power)
 - CB3 not used
 - CB4 OUTLETS (Various system controller outlets/connection supplies)
4. Turn on the power switch on the E-box.
5. Open the computer drawer and turn on the laptop computer. Allow the computer to boot-up.
Note: After boot-up, you may close the laptop at any time as it will continue to run in the closed position.
6. For automatic operation, switch the Plasma Controller control to the REMOTE position.

Step 3: Start the Control Software

1. Start the software on the laptops by double-clicking the "**ALD.xx.exe**" program icon.

- Press the Run button (white arrow) in the top left corner.
The arrow turns black once the program is running, as shown below:



Step 4: Turn on the Heaters

IMPORTANT: The heaters should remain on during all system use to prevent condensate of precursor material in delivery lines and in the process chamber, chuck, and trap assemblies.

- Use the graphical display to enter the following values for each heater in the white boxes
 - ALD Valves: 150°C
 - Precursor Delivery: 150°C
 - Process Chamber: 250°C
 - Chuck: 250°C
 - Trap: 250°C
 - Precursors: process dependent
Consult Cambridge NanoTech for recommendations for your specific precursors.

WARNING: Temperature of the precursors should not exceed safety or decomposition temperature of the chemical used.
- Wait until the temperature reaches the set point for each heater, as displayed in the colored box below each input.

Step 5: Degas the System

Degassing the system removes air from the lines and the “head-space” between precursor valves and the system’s ALD valves. You **MUST** degas the system every time you startup or change a precursor bottle. Refer to the “Software Reference” section of this manual for instructions on writing and running recipes/software instruction.

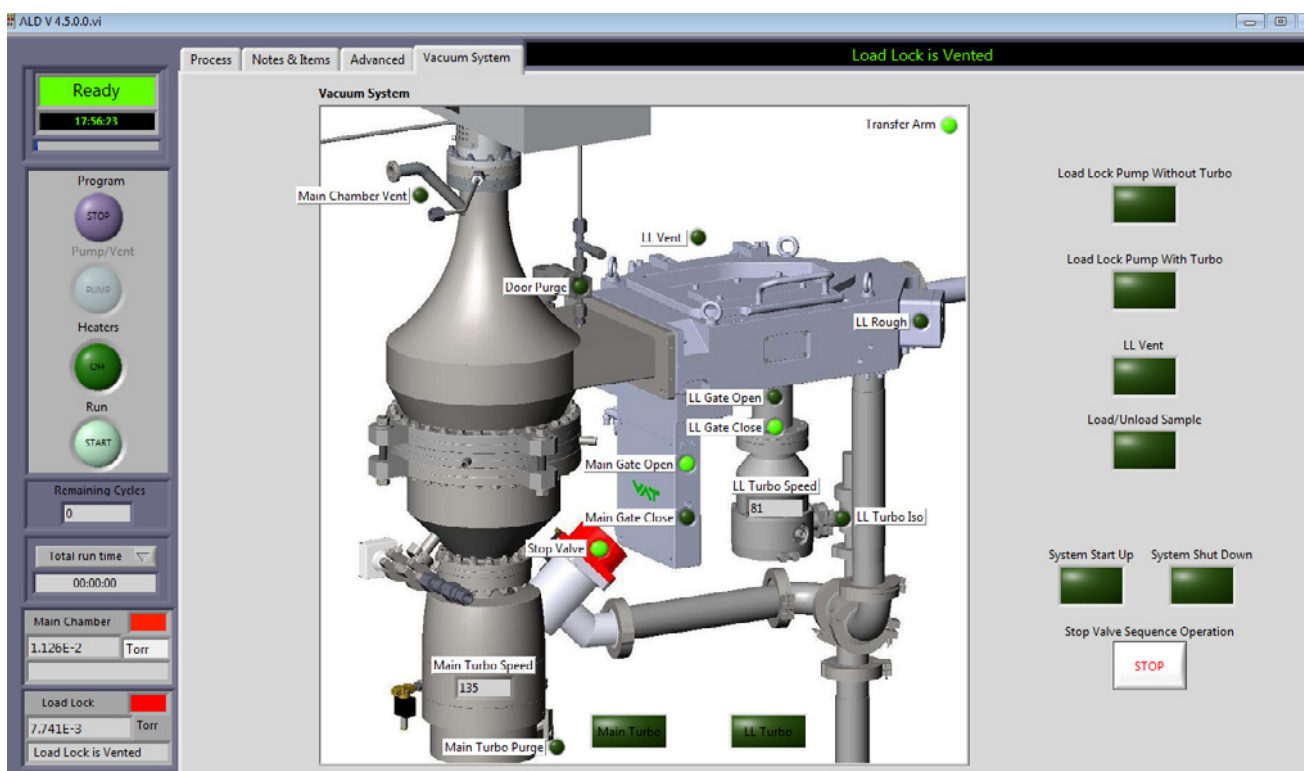
Degas the System Procedure																								
Step	Action			Details																				
1.	Press the Pump Button to open the vacuum valve and begin the pump-down of the process chamber.																							
2.	Note the base pressure of the system (which will be <~100 mTorr or less).																							
3.	Enter a value of 100 sccm for the Carrier Gas Flow.																							
4.	Degas the water cylinder. This is done by writing and executing the following instruction set (recipe): “Valve 0” Pulse time of 1 second, and the Wait time set to approximately 15 seconds, then repeat 5 times or until no pulses are seen. <table border="1" data-bbox="277 913 787 1262"> <thead> <tr> <th></th> <th>Instruction</th> <th>#</th> <th>value</th> <th>Notes</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>Pulse</td> <td>0</td> <td>x</td> <td>Pulse for 1 second</td> </tr> <tr> <td>1</td> <td>Wait</td> <td></td> <td>15</td> <td>Wait for 15 seconds</td> </tr> <tr> <td>2</td> <td>Goto</td> <td>0</td> <td>5</td> <td>Go to instruction # 0 (Pulse) and repeat sequence 5 times.</td> </tr> </tbody> </table>				Instruction	#	value	Notes	0	Pulse	0	x	Pulse for 1 second	1	Wait		15	Wait for 15 seconds	2	Goto	0	5	Go to instruction # 0 (Pulse) and repeat sequence 5 times.	
	Instruction	#	value	Notes																				
0	Pulse	0	x	Pulse for 1 second																				
1	Wait		15	Wait for 15 seconds																				
2	Goto	0	5	Go to instruction # 0 (Pulse) and repeat sequence 5 times.																				
5.	After the water source degassing run is done and the temperatures have stabilized note the base pressure of the system.																							
6.	Degas the headspace between the ALD and manual valve of the precursors by writing and executing the instruction set (recipe) below. “X” corresponds to precursor cylinder #. <p>Pulse time of 1 second, and the Wait time set to approximately 15 seconds. Keep the manual valve on the precursor <u>closed</u>, while degassing.</p> <table border="1" data-bbox="386 1694 787 1858"> <thead> <tr> <th></th> <th>Instruction</th> <th>#</th> <th>value</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>Pulse</td> <td>x</td> <td>1</td> </tr> <tr> <td>1</td> <td>Wait</td> <td></td> <td>15</td> </tr> <tr> <td>2</td> <td>Goto</td> <td>0</td> <td>100</td> </tr> </tbody> </table> <p><i>Precursor Cylinder degas recipe</i></p>				Instruction	#	value	0	Pulse	x	1	1	Wait		15	2	Goto	0	100					
	Instruction	#	value																					
0	Pulse	x	1																					
1	Wait		15																					
2	Goto	0	100																					

7.	When the base pressure during this run is the same as the base pressure of the system then this area has been degassed. Approximately 100 cycles will degas a precursor headspace.	Note: Degas the headspace of atmospheric gases before opening the manual valve every time the space between manual and ALD valves has been exposed to air. Also degas this area after closing the manual valve if the ALD valve is to be removed.
8.	Repeat the above degassing steps for each precursor cylinder.	

Step 6: Load a Substrate into the Load/Lock Chamber

1. Verify that the substrate loading arm is fully retracted (pull to the right).
2. Press the **LL Vent** (Load/Lock Vent) button to ensure the load lock is at atmospheric pressure then lift open the load door.

Note: An evacuated system can take 2-2½ minutes to reach atmospheric pressure.



3. Carefully place a substrate onto the carrier plate.
4. Close the load/lock lid.
5. If you are just starting up the system, press the **System Start Up** button to bring the process chamber and load/lock to proper pressure (refer to the *Software Reference* section of this manual for details).
6. Press the **Load Lock Pump Without Turbo** or **Load Lock Pump With Turbo** button.

Note:

Load Lock Pump Without Turbo brings the chamber to approximately 500 mTorr.

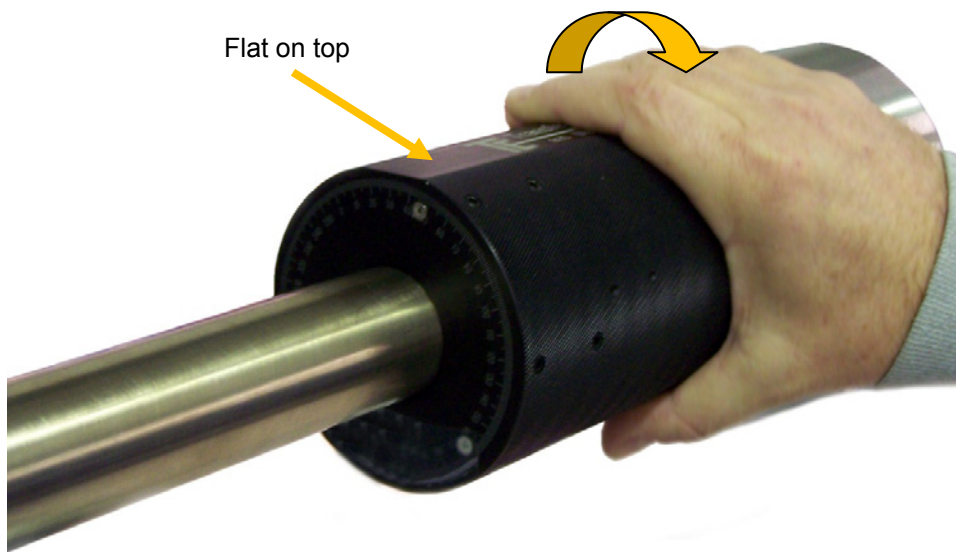
Lock Pump With Turbo brings the chamber to approximately 10^{-5} Torr.

Step 7: Move the Substrate into the Process Chamber

1. Press the **Load/Unload** button to load or unload a sample. After the pressure in the main chamber and in the load lock is equilibrated, the main gate valve separating the two chambers will be automatically opened. After the gate valve is opened, the transfer arm can be used to perform the load or unload. **The following series of steps is to LOAD the sample.**

CAUTION: DO NOT PRESS ANY BUTTONS UNTIL AFTER THE SUBSTRATE IS LOADED AND THE LOAD ARM IS FULLY RETRACTED OUT OF THE PROCESS CHAMBER.

2. Rotate the transfer arm's magnetic coupling so that the flat portion faces up. This raises the wafer carrier.

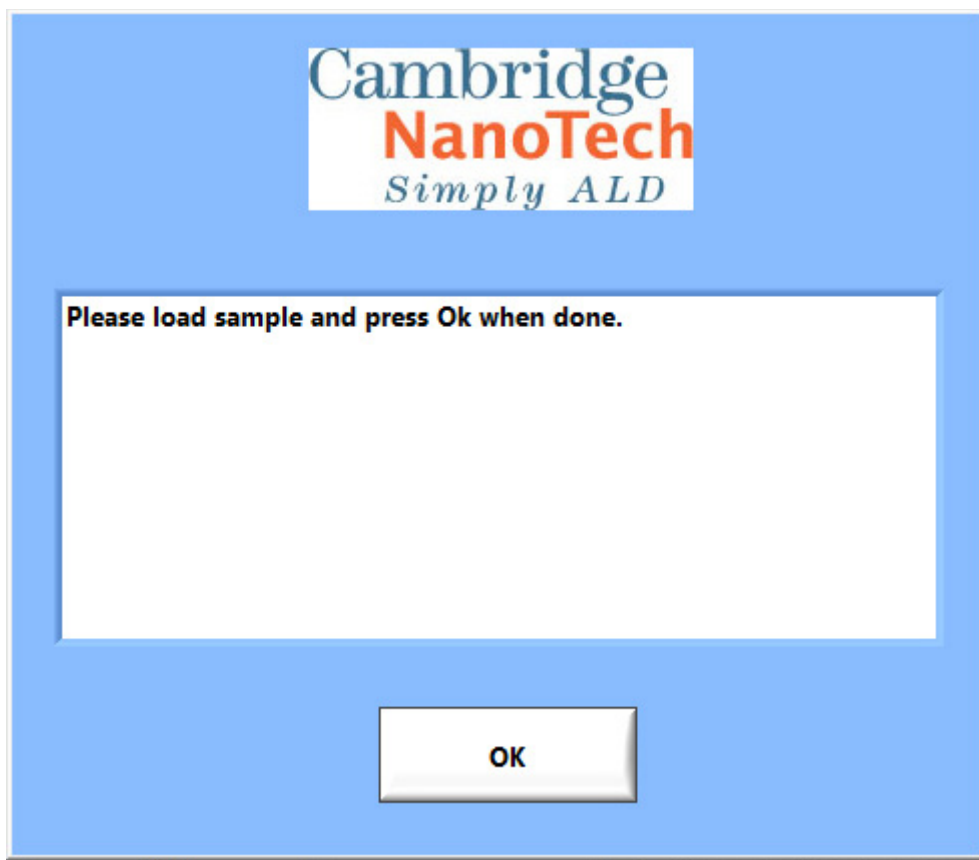


3. While keeping the FLAT section of the magnetic coupling facing UP, carefully slide the substrate carrier arm to left. The collar should move to the left until just before the left stop on the rail (1/8" from the stop).

Note: You may hear/feel some sliding as the wafer holder enters the chuck. This is normal; however you should not encounter any significant resistance.

4. Gently release the magnetic coupling, it will rotate until the flat portion is towards the rear of the system. This is the neutral position, lowering the substrate carrier onto the process chamber's chuck.
5. Gently move the transfer arm out of the process chamber by moving the magnetic coupling to the right. Look into the window on the load lock and verify that the substrate holder is in position in the process chamber.
6. Be sure to slide the magnetic coupling to the far right end stop depressing the transfer arm interlock switch. This provides the signal to the interlock circuit that the arm is out of the process chamber and will not be crushed by the gate valve.
7. Press OK on the popup dialogue box and the main gate valve will close.

CAUTION: DO NOT PRESS OK UNTIL THE LOAD ARM IS FULLY RETRACTED OUT OF THE PROCESS CHAMBER or you will break the load arm.



Step 8: Perform a Growth Run

1. With the substrate loaded and the process chamber ready for processing, open the vacuum valve for the chamber and allow the chamber to reach base pressure.
2. Load or create your process recipe as necessary for your run.

WARNING! POTENTIAL DAMAGE TO TURBO PUMPS

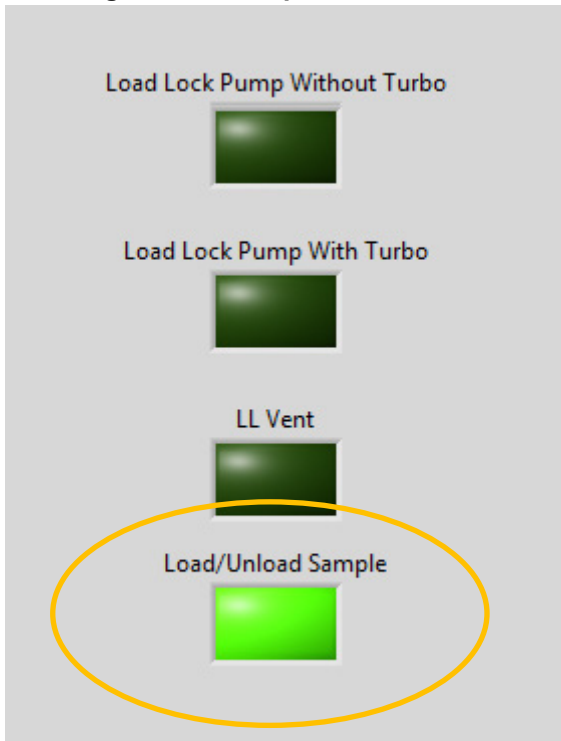
Excessive dosing of precursors like Trimethylaluminum (TMA) can result in precursor gases escaping the Fiji's integrated vapor trap causing deposits to form in the turbo pump. Film deposits in the turbo pump will greatly shorten the life of the turbo pump. It is recommended that the proper precursor dosage be determined by starting with the lowest precursor pulse time and increasing pulse times only as necessary. Please use standard Cambridge NanoTech Fiji recipes as a guide or contact Cambridge NanoTech support (support@cambridgenanotech.com) for consultation.

3. Enter the plasma energy level if desired. The plasma power during a recipe can only be controlled as a parameter in the recipe, not from the control screen when a recipe is running.
4. Press the **Start** button.

Specific recipes and settings for plasma steps vary. Please consult your process engineer and/or Cambridge NanoTech.

Step 10: Remove the Substrate Carrier from the Process Chamber

1. Press the "Load/Unload" button. After the pressure in the main chamber and in the load lock is equilibrated, the main gate valve separating the two chambers will be automatically opened. **The following series of steps is to UNLOAD the sample.**



CAUTION: DO NOT PRESS OK UNTIL YOU HAVE UNLOADED THE SUBSTRATE CARRIER AND THE LOAD ARM IS FULLY RETRACTED OUT OF THE PROCESS CHAMBER.

2. Verify that the flat portion on the magnetic coupling is facing towards the rear of the system.
3. Slide the carrier arm to the left, into the process chamber slowly.
4. Within the last 2" of movement the end effector will interact with the substrate carrier (wafer holder). Slide the end effector in the last 2". The end effector will adjust itself to the correct height to slide in properly.
5. Rotate the magnetic coupling so that its flat portion faces up (maximum height) WHILE sliding it to the right 4". This maneuver takes some practice (you must raise the substrate carrier while gently pulling the collar to the right). If successful the substrate carrier will now be captured on the end effector of the carrier arm.
6. Slide the magnetic coupling to the right while keeping it at maximum height, this will extract the wafer holder from chamber.
7. Be sure to slide the coupling to the far right end stop, depressing the interlock switch. This will ensure that the load arm is clear of the process chamber gate valve.
8. Press OK on the popup dialogue box to close the main gate valve.

CAUTION: DO NOT PRESS OK UNTIL THE LOAD ARM IS FULLY RETRACTED OUT OF THE PROCESS CHAMBER.

9. Press the **LL Vent** button to vent the load/lock.
Note: An evacuated system can take 2-2½ minutes to reach atmospheric pressure.
10. Open the load lock door and remove the substrate.

Control buttons:

Program – stops the program.

Pump/Vent – when the word “pump” is displayed it will initiate a pump down of the system. First a window pops up asking if the door is in the proper position. Hit OK when the door is confirmed closed. When the word “VENT” is depressed the main vacuum closes and the vent valve is opened. The flow for MFC-1 is maximized and flow is also directed through a flow restrictor. This brings the chamber back up to atmospheric pressure.

Heaters – Turns ON/OFF all the heaters. When all the heaters are turned off, all the temperature setpoints are set to 0°C.

Run – starts/aborts an ALD deposition process. When a process is running, “Program”, “Pump/Vent” and “Heaters” buttons are grey and not clickable. To abort a run, simply click on “Run” button once



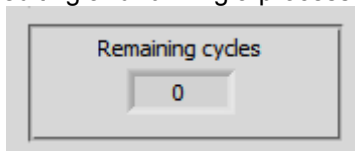
Input and display boxes:

Flow rate control – The Flow rate control section displays the current setpoint (left side, white area) and the actual current flow rate (right side) for each of the system gases.

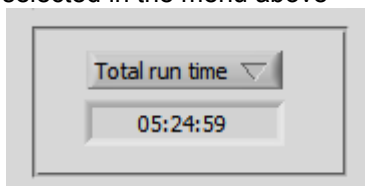
Notes: The buttons on the left allow you to open or close a valve. Bright green is open. When the hydrogen or oxygen valves are closed, the gas interlock forces a several second argon purge of the gas lines.

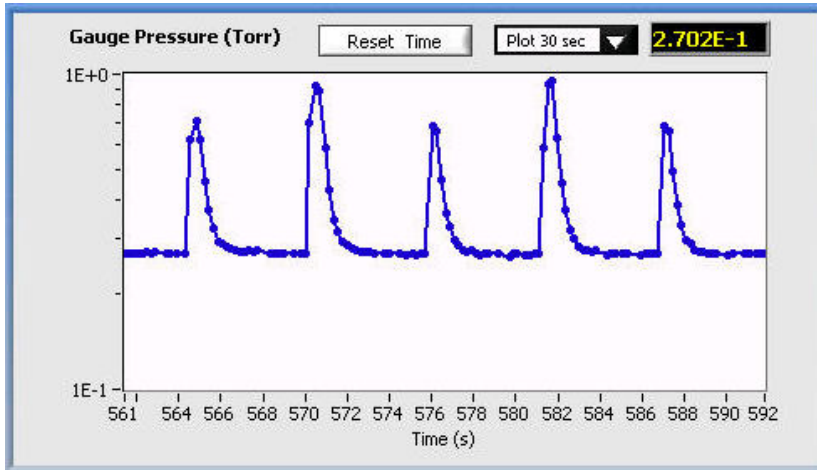
Plasma control – Enter the Plasma Power (Watts) into the white box.

Remaining cycles – displays the number of cycles to be completed in the current loop in a running process or the completion time of a process depending on item selected from the drop down list. More details about a editing and running a process are given below



Run time – the text box shows the total time, the time left or the done time of a process depending on item selected in the menu above



Process Chamber Pressure Plot Area:

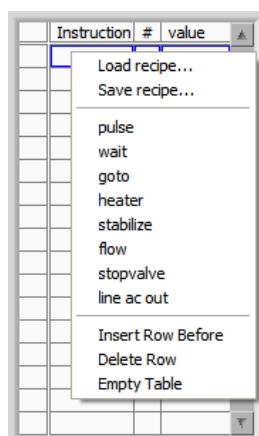
This plot tracks the process chamber pressure reading from the pressure gauge installed in the pumping line assembly. Pulses of the precursors show up clearly on the plot. Length of time plotted can be reset by selecting a new length and pressing the "Reset Time" button.

Recipe Table

This table allows programming, loading and saving of the sequence of a process (recipe). Editing of the table is accomplished by selecting commands in a context menu (right-click menu) and typing in numerical values. After right click, the row that the mouse cursor is pointing to becomes selected and is highlighted with a blue frame.

Each command line in the table consists of an automatically assigned line number, an instruction, and two numerical parameters: “#” and “value”.

Function	Use
Loading/Saving a recipe	clicking on menu item “Load recipe...” or “Save recipe...” brings up a load/save file dialog allowing access to recipe files saved in computer data storage
Inserting/deleting a row	clicking on menu item “Insert Row Before” adds a new row before the selected row. Clicking on “Delete Row” deletes the selected row
Adding/Changing an instruction	clicking on a menu item from “pulse” to “line ac out” first clears the selected row, and then puts the text of the menu item into the instruction cell.



Note: Not all commands are displayed in the sample screen above.

Command	Use	Usage
Pulse (#, value)	Opens the “#” ALD valve for “value” seconds and then closes the valve, which completes a precursor pulsing.	The valid value of “#” is 0, 1, 2, 3, 4, and 5, corresponding to cylinder (0 = water, 1-5 = precursor cylinders) that the ALD valve is connected to on the electronic box. The range of “value” is 0.010 to 10 seconds.
Wait (, value)	Lets the program to wait “value” seconds before executing the next command. This command is usually used right after a “pulse” command for purging the pulsed precursor.	Can be any non-negative number.
Goto (#, value)	Jump to line number “#” for “value” times	“#” must be a non-negative integer and no greater than the largest line number in the recipe. “value” must be a positive integer
Heater (#, value)	Sets number of heater and temperature	Example: Heater 9 200
Stabilize (#)	Waits until heater # has reached its setpoint within 2 degree	Example: Stabilize 9
Flow (#, value)	Sets MFC # to flow rate “value”.	A# = MFC number Value = any non-negative number up to limit of gas MFC.
Stopvalve (, value)	Opens or closes the main vacuum valve.	closes (value=0) or opens (value=1)
Line ac out (#, value)	The power controller contains multiple plugs for optional/accessory equipment (for example, ozone generators, etc.)	# = 240 – 110V output plug position Value of 0 = OFF Value of 1 = ON
Plasma (value)	The wattage for the plasma setting	0 – 300 Watts A setting of 0 is used to turn the rf off.

Below is an example of growing multiple layers of different materials.

	Instruction	#	value
0	pulse	0	0.015
1	wait		5
2	pulse	1	0.015
3	wait		5
4	goto	0	800
5	pulse	0	0.015
6	wait		5
7	pulse	4	0.015
8	wait		5
9	goto	5	700

Line 0 to 4 corresponds to the growth of 800 cycles of the first material using precursors 0 and 1:

- 0 pulse gas 0, for 0.015 seconds
- 1 wait 5 seconds
- 2 pulse gas 1 for 0.015 seconds
- 3 wait 5 seconds
- 4 goto Line 0, and repeat this loop 800 times

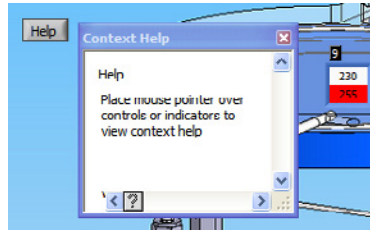
Line 5 to 9 corresponds to the growth of 700 cycles of the second material using precursors 0 and 4.

Line numbers of both **goto** instruction and the line that **goto** jumps to are colored to help identify the range of a **goto** loop.

It is advised to double-check all the parameters in a process sequence before starting a run

Help Button:

Help button activates context help. Place the cursor over a control to read detailed descriptions



Heater Control Area:

The heater control area (right side of screen) allows direct control of each heater.

Individual input/display clusters corresponds to a control circuit from the electronic box.

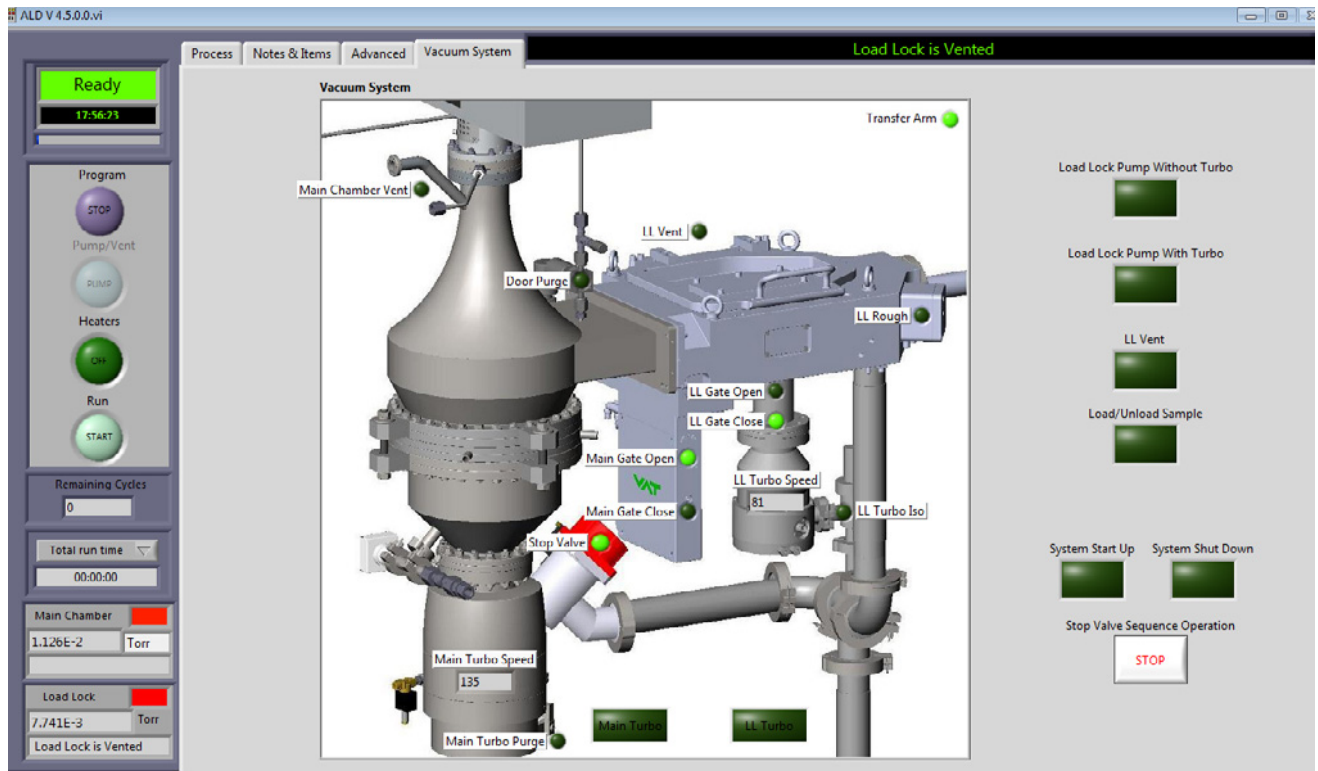
Enter the temperature set point into the white area.

The current temperature reading is shown in the red area.

Note: If an RTD is not connected to the corresponding port, the temperature reading displays n /a.

Vacuum page:

This page contains controls to all vacuum functions, required to load/unload samples. This page also contains program control buttons previously detailed.



Note: Control of each individual valve is allowed on this page. A valve can be opened/closed from this page for troubleshooting purposes

Button	Function
Load Lock Pump Without Turbo	Brings the load lock chamber to 500 mTorr using only the rough pump
Lock Pump With Turbo	Brings the load lock to 10 ⁻⁵ Torr using the turbo pump
LL Vent	Vents the load/lock chamber. Note: it can take 2 to 2 ½ minutes for the load/lock to reach atmospheric pressure.
Load/Unload Sample	Opens gate valve to allow you to load a substrate. Extreme care must be taken before pressing any buttons after opening the gate valve: CAUTION: DO NOT PRESS OK IN THE DIALOG BOX UNTIL THE LOAD ARM IS FULLY RETRACTED OUT OF THE PROCESS CHAMBER.
System Start Up	To be used only when both chambers are vented and the turbo pumps are off. Automatic sequence is as follows: <ol style="list-style-type: none"> 1. Opens up the main gate valve between the load lock and the process chamber and opens up the load lock rough pump valve. 3. Pumps both the main chamber and the load lock chamber to 1 Torr. 4. Closes load lock's rough pump valve. 5. Opens up the load/lock's turbo gate valve them pumps the system down 5x10⁻⁹ Torr.

-
6. Closes the LL gate valve, turns the turbo off, closes the main gate valve.
 7. Opens the Stop Valve and turns on the Main Turbo pump.
 8. System is ready to begin processing.

(Note: During install, the Door Purge is preset to 50 sccm. Do not adjust without consulting Cambridge NanoTech.)

System Shutdown

Turns off the system turbo pumps.

Stop Valve Operation Sequence

If you press the Stop button the valve operation sequence will stop and you can then manually open/close valves as desired. Use this only for system troubleshooting purposes, as directed by CambridgeNanoTech.

Appendix A Troubleshooting, Process Questions

Frequently Asked Questions

OEM manuals for the pressure gauge, mass flow controller, and optional equipment are listed in PDF format on the install CD.

Please find some of the most frequently asked questions for the Fiji ALD systems below. For an updated list please check our website.

Do I need Cambridge NanoTech to install the system?

Cambridge NanoTech personnel will startup the Fiji system. We recommend purchasing the precursor material at least 4 weeks before expected delivery of the system, since the lead time of the precursor material can vary. The required customer supplied items can be found on the quote, or in a detailed specifications document (inquire). It is very important to read the manual; this can not be said enough. It is also useful to contact Cambridge NanoTech Inc. support if things are not clear. We also provide instant messenger support, which is especially useful for international customers (MSN messenger and Yahoo messenger, Please inquire!).

Process Questions

The base pressure sometimes goes up, is there something wrong with my gauge?

During deposition one usually overdoses the precursor by a small amount in order to get uniform films and good saturation of each cycle. This means that the residual precursor goes into the pumping port, trap and line, can deposit all the way in the pump. The gauge consists of a heated filament and temperature sensor. Over time, the coating also deposits onto the filament, and one can recalibrate the sensor to new calibration settings. One needs to calibrate at atmospheric pressure, and at a pressure lower than $1e-5$ Torr. This means that once every 6 months one could take off the gauge and place it on a turbo pump and recalibrate. Please refer to the gauge manual PDF that was provided on your CD.

My system is quite dirty, how should I clean it?

Over time a thicker coating develops in the process chamber and pumping line. This can flake off, especially if the process chamber and other components are heat cycled. Heat cycling can accelerate flaking because of the difference of thermal expansion of stainless steel and ceramics such as Al_2O_3 . It is best to keep the heat cycling to a minimum.

When I mount the nitrogen manifold, it seems to torque the whole precursor line

When mounting the nitrogen manifold, make sure to NOT turn the male nut on the manifold, and turn the Female nut on the ALD valve 45 degrees ($1/8^{\text{th}}$ of a turn) after hand tightening them.

The NW O-rings in the pumping line are dirty, should I replace them?

The NW O-rings in the pumping line are Viton® O-rings. The O-rings on the chamber and stop valve are Kalrez®. In addition to a coating that can develop during extended use, they can also flatten because of the high temperature of the pumping line (compression set). Because of these reasons, we recommend to always replace the pumping line and chamber O-ring during the semi annual cleaning.

The base pressure of the systems seems to be high.

See the pump manual for semi annual preventative maintenance.

What spare parts do you recommend purchasing?

We recommend a spare gauge, precursor tube, and VCR gaskets. If budget allows we recommend a spare Kalrez O-ring, pump and heated chuck. The pump line will have to be sent out for cleaning and for continued use a spare pump line (bellows) can come in handy. The trap should also be replaced. Used traps can be cleaned and reused.

How do I tighten the VCR fittings?

With VCR fittings in the pumping line, one always has to replace the metal gasket with a new unused gasket. One cannot mount it without a gasket. Hand tighten both nuts and then a total of 45 degrees (1/8th turn) further tightening with two wrenches.

What orientation should I put the precursor line manual valve?

If you are using a manual valve with a green round handle, then the manual bellows valve should be oriented with the arrow pointing in the direction of the precursor cylinder. This is important because otherwise the large area bellows is pointed towards the ALD valve, which increases the purge out time, when one wants to remove the precursor cylinder + manual valve. A special note should be made to the chemical suppliers, that they mount this valve in this proper orientation after filling the cylinder. (Please see the manual.)

If you are using a manual valve with black handle then the orientation is not critical, since it is a symmetric ball valve.

Should I put a heating jacket around a cylinder with TMA or water?

The vapor pressure of TMA and water is high enough at room temperature, so it doesn't need heating. In fact the heating jackets should not even be mounted around the TMA and water cylinder, because the TMA cylinder would get hot through the temperature of the ALD valves. Any precursors with such high vapor pressure do not need heating jackets.

What is the best plot time on the gauge pressure graph?

It is recommended to plot only several pulses, for example 30 seconds or 1 minute total plot time. Setting this value to 1 hour during a run can reduce delay precision, because with a 1 hour plot time many data points need to be refreshed, which consumes a lot of processing resources.

It is possible to set the plot time to 1 hour to get an overview of pulse heights, but plot times > 5 minutes are not recommended during a run.

What valve temperature should I use?

The valves on the system (Swagelok pneumatic ALD valves) we recommend the following: Swagelok valves can be heated up to 200 °C. We recommend the Swagelok valves to be heated to 150°C for non-heated precursors (water, TMA etc). Please ask Cambridge NanoTech Inc. for settings for your conditions before trying anything at random.

What is the dose that I should use for the precursors?

We recommend to ask Cambridge NanoTech Inc. for a recipe before any run since there are many parameters interconnected (substrate material, precursor, temperature, purge time etc.), that one general recipe cannot be mentioned. One general guideline is that the precursor pulse height should be about 1 Torr or less. For TMA and other high vapor pressure materials, one should not pulse for more than about 0.02 seconds, unless Cambridge NanoTech advises otherwise. This is to prevent premature contamination of the system. Also, high vapor pressure materials should not be heated and the heating jacket should be removed to prevent the cylinder from getting hot from the valve heating block above it.

Why is there nitrogen flow and what is the recommended setting?

Nitrogen (or argon) flow is used for various reasons. The first reason is to quickly purge the system between each pulse. It is important that between the precursor pulses, there is no residue (except for the monolayer chemically bonded to the substrate) of precursor in the process chamber. The presence of two precursors at the same time would cause immediate reaction in vapor phase, which can lead to CVD mode deposition (non-uniformity, thick coating, powder formation). So the combination of temperature, nitrogen flow and pump time between pulses prevents two precursors from seeing each other in vapor phase. At low process chamber temperatures (e.g. 100 °C), the pump time needs to be higher (e.g. 30 sec) than at high temperatures (>150 °C, pump time e.g. 8 sec, for TMA). The higher the temperature, thus the faster the cycles. Another reason for nitrogen flow is to prevent flow of precursor from one pulse valve into the other. It is important that the pulse valves only see their own precursor, thus each valve has a constant nitrogen flow. The constant nitrogen flow out of each valve prevents other precursors to enter, and thus prevents deposition in each valve. A recommended nitrogen flow value is 20 sccm. During venting this is increased to 100 sccm, and also while the process chamber is open, this should be the maximum flow value (100 sccm) to prevent air from entering the valve regions. One should immediately close the lid door inserting/removing a substrate and not leave it open.

What is the expo for, should I use it?

Expo deposition means that prior to pulsing a precursor, the main vacuum valve (valve between process chamber and pump) is closed, then one precursor is injected, then the substrate gets exposed during the expo time (for example if expo = 20 seconds, the main vacuum valve opens after 20 seconds). This mode is only used when one needs to coat very high aspect ratio structures (>1:10). The disadvantage of using expo runs is that since the precursor does not simply flow very fast from cylinder through valve through manifold over substrate into pump, instead, it sits in the process chamber for expo seconds, and some of the precursor can migrate to all valves. This can cause some deposition in the valves, especially if the expo time is long. To reduce this effect, one could pulse two times in expo mode (for very high aspect ratio structures) to prevent the process chamber pressure from getting too high during the expo time. If one wants to get better nucleation on hydrophobic substrates, we don't recommend expo mode deposition. Instead, one could pulse two times the same precursor in multi dosing deposition mode (expo=0 seconds), and this would only be needed for say the first few cycles. This may be especially useful for thin gate dielectrics.

Appendix B Manual General Information

General Notes

The manufacturer reserves the right to make changes to the product covered in this manual to improve performance, reliability or manufacturability. Although every effort has been made to ensure accuracy of the information contained in this manual, the manufacturer assumes no responsibility for inadvertent errors. Contents of the manual are subject to change without notice.

Using this Manual

Purpose

This manual provides the following information for the Fiji F200:

- System safety
- System description
- Operation procedures
- Reference materials

Scope

This manual covers the Fiji F200 system only.

Revision History

Revision	Date	Changes
1.0	7/09	New.

Related Documents

Please refer to the *Fiji F200 Maintenance Manual* for details on system maintenance and troubleshooting.

Recommended Training for Operation Personnel

All operators should be familiar with the system operation and documentation, and possess a thorough understanding of the safety considerations and system startup/shutdown procedures. Topics of focus should include:

- System safety
- System/component review
- System startup
- Software operation
- System shutdown

All items are covered in detail in this manual or in related documents to ensure that experienced operators personnel can safely and efficiently perform each task.

Appendix C Safety

Introduction

Read and follow these safety instructions. Task and equipment specific warnings, cautions, and instructions are included in equipment documentation where appropriate.

Make sure all equipment documentation, including these instructions, is accessible to persons operating or servicing equipment.

Qualified Personnel

Equipment owners are responsible for making sure that Cambridge NanoTech Inc. equipment is installed, operated, and serviced by qualified personnel. Qualified personnel are those employees or contractors who are trained to safely perform their assigned tasks. They are familiar with all relevant safety rules and regulations and are physically capable of performing their assigned tasks.

Intended Use

Use of Cambridge NanoTech Inc. equipment in ways other than those described in the documentation supplied with the equipment may result in injury to persons or damage to property.

Some examples of unintended use of equipment include:

- using incompatible materials
- making unauthorized modifications
- removing or bypassing safety guards or interlocks
- using incompatible or damaged parts
- using unapproved auxiliary equipment
- operating equipment in excess of maximum ratings

Regulations and Approvals

Make sure all equipment is rated and approved for the environment in which it is used. Any approvals obtained for Cambridge NanoTech Inc. equipment will be voided if instructions for installation, operation, and service are not followed.

Client Modifications





Modifications to the system including, but not limited to changes to vacuum hardware, electronics, and software, void all warranty and liability.



Definitions for Signal Words

The following are definitions for signal words for this system:

Label	Meaning
DANGER	Indicates an imminently hazardous situation which, if not avoided, will result in death or serious injury.
WARNING	Indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.
CAUTION	Indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury, or damage to equipment.

Safety Symbols

Symbol	Meaning
	<p>SHOCK HAZARD Electric voltage present. Take appropriate measures to protect yourself from electrical shock.</p> <p>The “lightning bolt within a triangle” symbol (reference IEC Publication 417, Symbol No. 5036, and ISO Publication 3864, No. B.3.6) is used in and/or on the equipment to alert the user, operator, or service personnel to the presence of un-insulated voltage within the enclosure of sufficient magnitude to constitute a risk of electric shock. <u>Only authorized service personnel with a thorough knowledge of the voltages existing within the equipment shall remove covers or panels from the product bearing this symbol.</u> This symbol is also used within the product manual itself to identify important operating and/or maintenance instructions, which, if not followed carefully, could result in personal injury or even death.</p>
	<p>RISK OF FIRE The “flame within a triangle” symbol (reference IEC Publication 417, and ISO Publication 3864) is used in and or on the equipment to <u>alert the user, operator, or service personnel to the potential of fire hazard, including that caused by gases which may ignite upon contact with air (pyrophoric gases). Only authorized service personnel with a thorough knowledge of the gases existing within the equipment shall remove covers or panels from the product bearing this symbol.</u> This symbol is also used within the product manual itself to identify important operating and/or maintenance instructions, which, if not followed carefully, could result in personal injury or even death.</p>
	<p>PINCH HAZARD This symbol is used in the product manual to identify a pinch hazard such as a door, panel, fixture, or overall system handling which could cause a pinch or crushing hazard.</p>
	<p>TOXIC MATERIAL HAZARD This symbol is used in the product manual to identify sources of toxic gas materials. While the system is NOT shipped with any precursors or other gases, the customer and end-user must be aware of on-site gas usage and its resulting hazards.</p>

	<p>BURN HAZARD This symbol is used in the product manual to identify sources of burn hazards. Do not touch hot surfaces! Allow the system components to properly cool before performing maintenance tasks or touching hot parts.</p>
	<p>HEAVY/AWKWARD OBJECT LIFT HAZARD! This symbol is used in the product manual to identify procedures where a minimum of two people are required to lift a heavy or unbalanced/awkward object.</p>

Personal Safety

To prevent injury follow these instructions:

DANGER: Do not operate or service equipment unless you are qualified and have fully read and understood the manual and warning labels on the system. Contact Cambridge NanoTech Inc. with any questions in case of uncertainties.

DANGER: Removal of power cables from the system must be performed by a trained and licensed electrician or service personnel.

DANGER: Obtain and read Material Safety Data Sheets (MSDS) for all materials used. Follow the manufacturer's instructions for safe handling and use of materials, and use recommended personal protection devices.

WARNING: Do not operate equipment unless safety guards, doors, or covers are intact and automatic interlocks are operating properly. Do not bypass or disarm any safety devices.

WARNING: Before adjusting or servicing equipment, or touching any of the parts, turn off the heaters in the software, wait until all temperature sensors are at room temperature, then shut off the power supply and unplug the main power and wait until all unmonitored parts have cooled down. Lock out power and secure the equipment.

WARNING: Relieve (bleed off) pneumatic pressure before adjusting or servicing pressurized systems or components, such as gas cylinders. Never disconnect high pressure gas cylinders without specific knowledge. Refer to your supplier for instructions.

WARNING: To prevent injury, be aware of less-obvious dangers in the workplace that often cannot be completely eliminated, such as hot surfaces, sharp edges, energized electrical circuits, and moving parts that cannot be enclosed or otherwise guarded for practical reasons.

CAUTION: DO NOT use this equipment in any manner not specified by the manufacturer. If the equipment is used in a manner other than as specified in this document, the safety protections may be impaired.

CAUTION: Fittings and components damage easily: handle all components with extreme care. DO NOT scratch or over-tighten any component.

CAUTION: End of life statement. De-commissioning of, or any part of, the system shall be in a manner that is consistent with appropriate regulations and guidelines.

Equipment Safety Labels Locations

System hazards are identified via safety labels attached to the cabinet, modules and components of the system where appropriate. Labels help to identify potential system hazards. They do not replace the safety rules and regulations established at the customer's facility. The labels and their location on the cabinet vary with component configuration, but are always placed on panels to alert the trained maintenance technician to a potential hazard.

EMO, Safety Switches

An Emergency Power Off switch is provided on the front panel of the system and on the right and left sides of the system. Pressing the EMO switch shuts down power system. CAUTION: Live feed power remains internal to the system!



DANGER ELECTROCUTION HAZARD!

Pressing an EMO button disables power to the system components and shuts-down the system (turns off plasma generators, returns valves to their default states, removes power from electronics, computers, heaters, etc.). Live power to the system remains at the main power inlet connection and at transformer and main breaker panels. You must lock and tagout power at the facility's remote panel to remove all power from the system. Qualified, trained maintenance electrical technicians must verify the removal of voltage with an appropriate meter prior to working to the system's power supply prior to performing any required work.

Fire Safety

To avoid a fire or explosion, follow these instructions.

- Do not place flammable materials underneath, on or near the unit. Do not place paperwork, clothing etc. on or near the unit.
- Do not run the system unattended. Note that in standby mode, all heaters are at process temperatures with the door/s closed and under vacuum.
- Do not heat materials to temperatures above those recommended by the manufacturer. Make sure heat monitoring and limiting devices are working properly. Note the maximum temperature settings for different parts.

Heater Location	Max. Temperature	Notes
ALD Pulse Valves	200°C	ALD pulse valves are rated to 200°C and should not be heated above that temperature.
Process Chamber	250°C	The heaters are rated at 300°C, but cannot be set higher than 250°C because of the Kalrez™ O-rings.
Trap Heater, Cone Heater	250°C	
MKS Jalapeno Valve	150°C	
Chuck	500°C	Typically set to 250°C.
Precursors	200°C See WARNING!	WARNING: Temperature of the precursors should not exceed safety or decomposition temperature of the chemical used.

- The pump may exhaust small amounts of unreacted precursor. Since Cambridge NanoTech Inc. does not supply the chemicals, responsibility for safe venting and exhausting lies with the customer. General exhaust recommendations include using inert pumping fluid such as Fomblin SV, fireproof metallic exhaust lines to

prevent fire. Refer to local codes or your material MSDS for guidance. Minimize precursor use. Do not add vapor traps in the pumping line, upon exposure to air, large amounts of trapped precursor may ignite or cause chemical burns.

- The system exhaust (4" dia, 200CFM @ .5" W.C.) must be connected to a facility thermal exhaust system. Refer to facility requirements drawing for specifications.
- Know where emergency stop buttons, shutoff valves, and fire extinguishers are located.
- Clean, maintain, test, and repair equipment according to the instructions in your equipment documentation.
- Use only replacement parts that are designed for use with original equipment. Contact your Cambridge NanoTech Inc. representative for parts information and advice.

Electrical Safety

To avoid electric shocks, follow these instructions.



- At the time of installation the stainless steel system cabinet must be grounded by attaching the supplied ground wire to the facilities grounding loop.
- Turn off and unplug the electronic control unit prior to connecting or disconnecting any sensor, heater, valve or other components.
- Do not disconnect live electrical circuits while working with flammable materials. Shut off main power first to prevent sparking

Mechanical Hazards

Mechanical Hazard Locations

The system can cause crushing or pinching hazards, including pinch hazards from the panels during installation/maintenance and doors during operation. Heavy components such as the process chamber pose a potential for injury during system maintenance as these internal system components are heavy. Care must be taken during maintenance to prevent damage or injury.

The system must be secured to the floor with proper seismic tiedowns to prevent tipping.

Electrical Hazards

- United States. (220 VAC is two lines at 110 VAC 60 Hz that are out of phase by 180 degrees):
F200: 4 wire 220 VAC 60 Hz **50A**. Connections = (L1 = 110 VAC 60 Hz (line 1 = red), L2 = 110 VAC 60 Hz (line 2 = black), N (neutral = white), G (ground = green) [color scheme by US National Electrical Code])
- Europe. (220VAC is one line at 230 VAC 50 Hz)
F200: 3 wire 220 VAC 50 Hz **50A**. (L1 = 220VAC 50 Hz (line 1 = Brown), N (neutral = Blue), G (ground = green-yellow) [color scheme by IEC (International Electrotechnical Commission)])

Wire must be 6-8 AWG stranded. Current <35 Amps in continuous operation.

The main input power connection is located at the top of the system. The system may contain transformer/s and power conditioners which present live electric power hazards.



DANGER: Electrical Hazard. DO NOT OPEN COVERS to access electrical equipment with the power on, unless you are certified to perform specific troubleshooting/repair tasks.

Chemical Hazards

To avoid chemical hazards, follow these instructions.

Precursors Fire Hazards

- Know the nature of the precursors you are working with (read MSDS).



DANGER! FIRE HAZARD

Some precursors such as trimethylaluminum (TMA) are pyrophoric--they burn upon exposure to air. Precursors should never be disconnected from the manual valve they were supplied with. Make sure that manual valve is closed before removing the precursor-valve combination from the system.

Pump/purge the space between ALD valve and manual valve before disconnecting any precursor. Always wear proper protection equipment when removing precursors. Precursor replacement should only be conducted by qualified personnel. Read the section on precursor removal before proceeding. Cambridge NanoTech Inc. can be reached for safety assistance with precursor replacement/removal procedure, although the final responsibility lies with the user.

Location of Chemical Supplies

All chemical/gas connectors are located at the top of the system, or through the rear of the system (precursor cylinders). The manufacturer does not supply process chemicals with this system.

Material Safety Data Sheets

Material Safety Data Sheets (MSDS) for every chemical used with the system should be available to all users of the system at all times. Each user should be trained on the specific gases/chemicals used with the system, and be certified in safe operation of the system. The MSDS covering all materials used in the process must be prominently displayed in the immediate vicinity of the machine.

Recommended Practices

Operational Notes

System with Turbo Pumps

WARNING! POTENTIAL DAMAGE TO TURBO PUMPS

Excessive dosing of precursors like Trimethylaluminum (TMA) can result in precursor gases escaping the Fiji's integrated vapor trap causing deposits to form in the turbo pump. Film deposits in the turbo pump will greatly shorten the life of the turbo pump. It is recommended that the proper precursor dosage be determined by starting with the lowest precursor pulse time and increasing pulse times only as necessary. Please use standard Cambridge NanoTech Fiji recipes as a guide or contact Cambridge NanoTech support (support@cambridgenanotech.com) for consultation.

Best Practices

- Connect all input gas and electrical lines according to the manufacturer specifications or best commercial practice. Always check the fittings before operating.
- USE THE BUDDY SYSTEM: ALWAYS perform maintenance procedures in teams of two or more people; one to monitor the surrounding systems, the maintenance environment, your actions and to ensure all documentation and safety steps are followed.
- ALWAYS observe all warning labels.

Help

Always work in teams of two or more when performing any tasks which require the removal of system panels.

Always seek additional help when:

- You are instructed by any procedure.
- You see an emergency or dangerous situation.
- You are not trained or qualified/certified to perform a task.
- You feel uncomfortable performing a task.

Evacuations

In case of an emergency evacuation:

- EXIT the building through the nearest exit and report to your assigned evacuation area.
- DO NOT stop to turn off any machines.
- DO NOT move any carts or equipment during evacuation.
- Obey all commands from the emergency response team.
- Return to the building ONLY AFTER being instructed to do so by the emergency response team.

Action in the Event of a Malfunction

If a system or any equipment in a system malfunctions, shut off the system immediately and perform the following steps:

- Disconnect and lock out system electrical power. Close valves and relieve pressures.
- Identify the reason of the malfunction and correct it before restarting the system

Disposal

Dispose of equipment and materials used in operation and servicing according to local codes