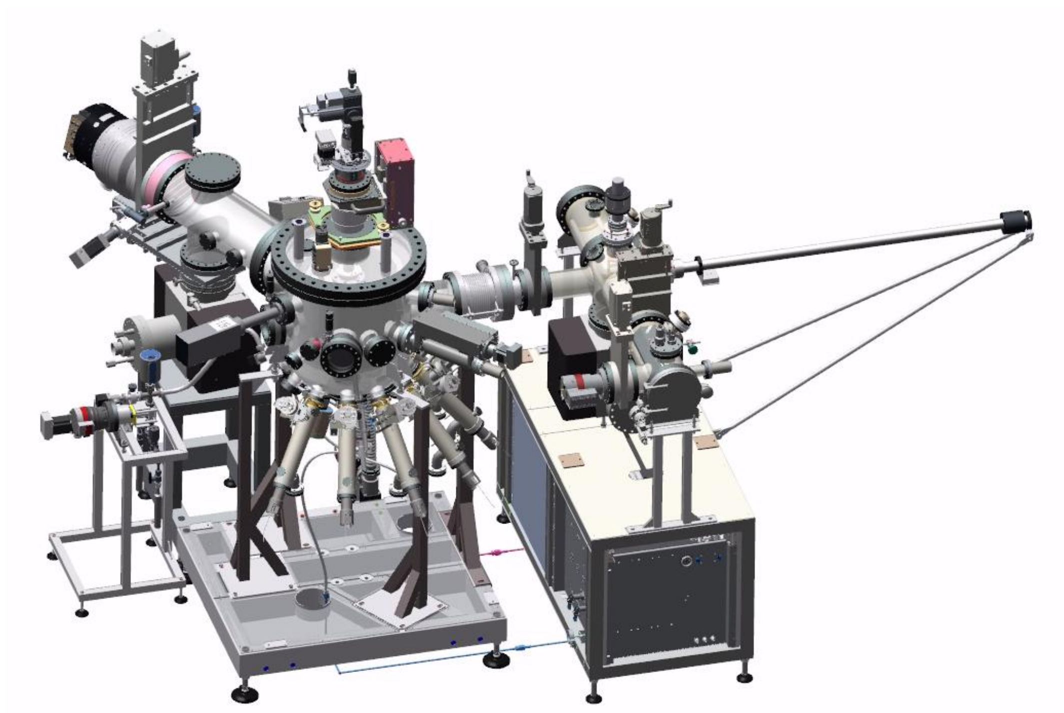
User Manual

2287 UHV Deposition System

R450 Molecular Beam Epitaxy Process Chamber with Linear Buffer Chamber



These are the original English instructions

June 2025
Version 1.00
Document number: 01
EN

DISCLAIMER

DCA Instruments Oy makes no representations or warranties with respect to this manual and, to the maximum extent permitted by law, expressly limits its liability for breach of any warranty that may be implied to the replacement of this manual with another. Furthermore, DCA Instruments Oy reserves the right to revise this publication at any time without incurring an obligation to notify any person of the revision.

The information provided in this documentation contains general descriptions and/or technical characteristics of the performance of the system contained herein. This documentation is not intended as a substitute for and is not to be used for determining suitability or reliability of these machines for specific user applications. It is the duty of any such user or integrator to perform the appropriate and complete risk analysis, evaluation, and testing of the machines with respect to the relevant specific application or use thereof. Neither DCA Instruments Oy nor any of its affiliates or subsidiaries shall be responsible or liable for misuse of the information that is contained herein. If you have any suggestions for improvements or amendments or have found errors in this publication, please notify us.

All pertinent state, regional, and local safety regulations must be observed when installing and using this machine. For reasons of safety and to help ensure compliance with documented system data, only the manufacturer shall perform repairs to components.

When devices are used for applications with technical safety requirements, the relevant instructions must be followed.

Failure to observe this information can result in injury or equipment damage.

DCA Instruments Oy

Aerotie 6, Turku 20360 Finland

+358 (0)2 2382500

www.dca.fi

System Modifications

Year	Type	Modifications

Document Revisions

Date	Version Number	Document Changes
2025-06-06	1.0	Initial draft

Table of Contents

1 PREFACE

1.1 Description of the User

These instructions are intended for the end-user of the System.

The end-user can be described as each person who interacts directly with the system. The end-user typically includes, but is not limited to Maintenance personnel or technicians, Operator, Dismantling personnel.

All use of the system shall only be carried out by an authorized and a properly qualified and skilled person who:

- Has read and understood this manual
- Has undergone training by DCA Instruments Technical Staff
- Is aware of all possible dangers and acts accordingly

The required maintenance and/or inspection work as stated in this user manual is allowed by the aforementioned persons, unless clearly indicated when this is not allowed.

1.2 Purpose of These Instructions

Thank you for purchasing this UHV Deposition System. The purpose of this document is to make you familiar with the features and functions of the system, so that you can safely operate it as an end-user.

This documentation should therefore be regarded as an integral part of the system. These instructions are intended for the following model:

- 2287 UHV Molecular beam epitaxy system

1.3 Explanation of Safety Warnings

⚠DANGER

Indicate a hazardous situation which, if not avoided, will result in death or serious injury.

⚠WARNING

Indicates a hazardous situation which, if not avoided, could result in death or serious injury, and/or may result in significant system damage.

⚠CAUTION

Indicates a hazardous situation which, if not avoided, could result in minor or moderate injury, and/or minor system damage.

NOTICE

Indicates information considered important, but not hazard-related.

1.4 Obtaining Documentation and Information

1.4.1 Supplementary information

Besides these user instructions, additional documentation relevant for the system operation can be found listed in APPENDIX IV - RELATED DOCUMENTATION. The documentation may be supplied in hard- and softcopies.

1.4.2 List of Component Manuals Ordering Documentation

Documentation, user instructions and technical information can be requested by contacting DCA Instruments Oy at info@dca.fi.

1.4.3 Other languages

This is the English user manual. Manuals in other languages are available upon request.

1.4.4 Documentation Feedback

If you are reading DCA Instruments Oy product documentation on the internet, any comments can be submitted on the support website. Comments can also be sent to info@dca.fi.

We appreciate your comments.

1.4.5 Support and service

For other service-related questions, information, technical assistance or ordering user instructions, please contact the manufacturer:

DCA Instruments Oy

Aerotie 6, Turku 20360 Finland
+358 (0)2 2382500
info@dca.fi
www.dca.fi

2 SAFTEY INSTRUCTIONS

2.1 How to Use the Product Safely

2.1.1 Safety information related to the intended use and reasonably foreseeable misuse;

The system shall only be used for applications as described by DCA Instruments. DCA Instruments cannot be held liable for damage resulting from errors, unintended or unprofessional use of the system.

DCA Instruments is not liable for cases of material damage or personal injury caused by incorrect handling or non-compliance with the user guide. In such cases, the warranty will be voided.

The CE mark on the machinery indicates that the manufacturer declares that the system complies with the requirements of the relevant European health, safety, and environmental protection legislation.

2.1.2 Personal protective Equipment

The system should be handled per general UHV practices. Powder-free protective gloves should be used to avoid contamination.

Wear suitable PPE when operating the system. This may include a full-body gown, safety glasses, and/or respiratory face mask.

When handling liquid nitrogen, ensure appropriate cryogenic gloves are worn to protect the hands from potential burns.

Follow the advice from the relevant Material Safety Data Sheets (MSDS) when opening the process chamber or if handling the materials.

2.1.3 System limitations and restrictions

Interlocks are installed to protect the equipment in the event of an error condition (see section 11).

2.1.4 Installation safety information

⚠ CAUTION

Installation the system shall only be carried out by DCA Instruments technical personnel only. Installation of the system without the approval or guidance of DCA Instruments shall void the warranty. DCA Instruments will not be held responsible for any user injury or system damage caused by the incorrect installation of the system.

Check the system for damage before installation. This may be indicated by the shock/tipping sensors mounted to the crate(s). If any sensor shows signs of tampering or shock/tipping, or there is any visible damage to the crate, do not install the system and contact DCA Instruments immediately.

2.1.5 Maintenance safety information

All cleaning and maintenance tasks shall only be carried out by qualified and skilled personnel. To ensure the operational safety of the system, regular maintenance shall be carried out by qualified personnel in accordance with the manufacturer’s instructions.

Maintenance and inspection should be done on a frequent basis. If there is any visible damage, instability during operation, or excessive overheating of components, stop using the system.

Alterations to the system and technical modifications are not permitted without written permission of the manufacturer.

Any alterations made to the system without written permission from the manufacturer will void the warranty. Unauthorized alterations may lead to hazardous situations.

See the APPENDIX II - ACCESSORIES, CONSUMABLES, AND SPARE PARTS for an overview of spare parts. You can always order spare parts by contacting DCA Instruments.

Only clean the machine with a lint-free cleanroom compatible cloth and suitable solvent (e.g., ethanol or IPA).

The system features safety marks/warning symbols in areas that present a risk of injury or with other important instructions. Always replace missing or damaged safety marks immediately. If you replace safety marks with new ones, make sure that you place the new safety marks in the same places.

2.1.6 Repair and modification Safety information

⚠CAUTION

DO NOT attempt to repair components without permission and explicit instructions from the manufacturer. Contact DCA Instruments if the system/component requires repair. Do not attempt to modify the system/components before consulting DCA Instruments.

2.1.7 Safe Disposal

Certain chemicals that are used for cleaning shall be disposed of in an environmentally friendly way, as should cloths and other materials that come into contact with lubrication agents or oil. Read the instructions for the chemicals for more information, if applicable.

Do not dispose of electric equipment, accessories, and packaging together with household waste material (only for EU countries). In observance of European Directive 2012/19/EC on waste of electric and electronic equipment and its implementation in accordance with national law, electric equipment that have reached the end of their life shall be collected separately and returned to an environmentally compatible recycling facility.

Refer to the MSDS for instructions on how to safely dispose of materials used with the system.

2.2 Graphical Symbols

2.2.1 Explanation of safety information on the system

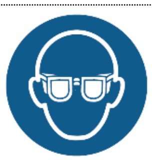
Table 1 below provides safety information relevant to this system. The labels are located as close as possible to the relevant area it is applicable to.

Table 1 Explanation of safety information relating to the system and the location of safety labels.

Symbol	Warning	Hazard Location Label #
	**MOVING/ROTATING PARTS** Risk of entanglement/crushing. Exposed gears and moving parts can cause injury. Keep fingers, hands, hair, loose clothing, gloves, and tools away from moving parts. Turn power off before servicing.	Substrate Manipulators Beam Flux Monitor
	**ELECTRICITY** May cause electric shock or burn. Trained personnel only.	Electronic racks
	**HOT SURFACE** Contact with skin may cause burns. Do not touch during or soon after bakeout.	Bakeout Tent Sources
	**OVERPRESSURE – RICK OF EXPLOSION** Risk of Overpressure! Can lead to serious injury or death. Never block the ‘OUT’ VBC connector during Liquid Nitrogen cooling! Never introduce cooling water into the cryopanel with Liquid Nitrogen!	Chamber Cryopanel (LN_2)
	**RF VOLTAGE** Contact with Internal RF source can cause burns and/or electrical shock. Disconnect and lock-out power before removing cover.	RF Source
	**X-RAY RADIATION** Electron beam from RHEED may generate X-Ray radiation. Avoid staying near windows.	RHEED System

	**LASER RADIATION** Avoid direct exposure to beam. Laser protective eyewear required.	Manipulator laser heater Manipulator Pilot laser
	**HEAVY OBJECT** Use lifting aids when removing or replacing.	Manipulator Heavy Sources
	**MAGNETIC FIELD** May interfere with pacemakers. Pacemaker wearers stay back 1 meter.	Ion Pump
	No access for people with active implanted cardiac devices.	Ion Pump
	The CE Marking on the product is the manufacturer's declaration that the product complies with the essential requirements of the relevant European health, safety, and environmental protection legislation.	

2.2.2 Personal Protective Equipment

PPE	Instruction
	Wear suitable protective gloves when handling liquid nitrogen. Wear UHV gloves when handling contaminated components
	Wear eye protection when handling liquid nitrogen.
	Wear protective clothing

	Wear respiratory protection when opening the chamber with hazardous/toxic materials.

3 SYSTEM OVERVIEW

3.1 Purpose

The **Ultra-high vacuum (UHV) Deposition System** (Fig. 3-1) is intended to deposit material on a 10x10 substrate which will be used for the semiconductor research purposes.

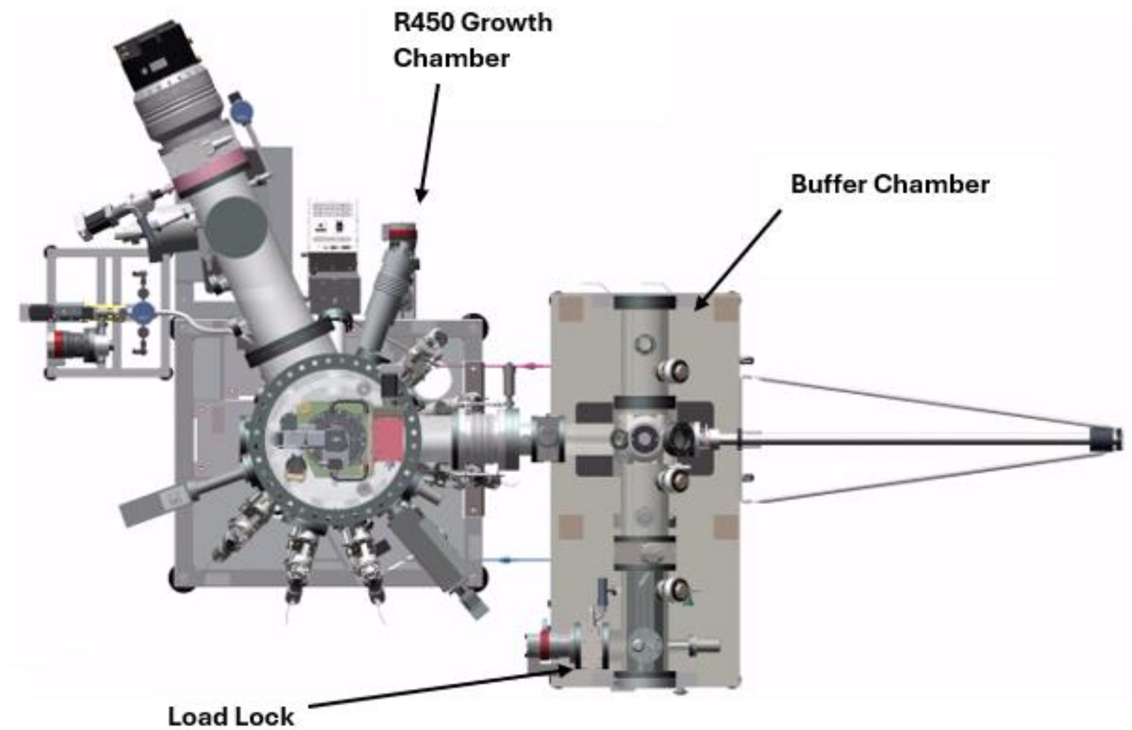


Fig. 3-1 Top-down view of the DCA system, which includes a R450 growth chamber, Buffer chamber (Buffer) and load lock (LL).

Table 2 Summary of tools included in the UHV deposition system and their intended use.

Tool	Description
R-Series MBE R450	The R-series Molecular Beam Epitaxy chamber is designed for oxide-growth. The chamber can be equipped with a differentially pumped module that protects sources during operation at higher partial pressures. Special modules may be used to allow material loading without venting the main process chamber.
LBC	The UHV linear buffer chamber serves to transfer wafers from the load lock to the connected adjacent chambers. The modular design allows the LBC to be extended to add additional chambers in future. The LBC may be comprised of the following modules: • Transfer (allows wafer transfer to the connected processing chamber) • Storage (allows wafers to be stored under UHV)
LL	The Load lock allows wafers to be loaded and unloaded to the UHV deposition system. LL also features heating stage to degas wafers at 200 ^{o}C before transferring them to LBC.

The UHV Deposition System shall not be operated outside of the scope set out in this user manual. System interlocks (section 11) are implemented to protect the system from error conditions that may occur, and these should be enabled during normal operation.

The UHV Deposition System shall be used with the original accessories and components supplied with the system only. The accessories and components supplied with each tool are described in the following sections.

Only use the system within the specified performance limits as described in these instructions.

Use the system, accessories, and tools etc., in accordance with these instructions, taking into account the working conditions and the work to be performed. Use of the system for operations different from those intended, could result in a hazardous situation.

3.2 System Component Overview

Table 3 Quick reference table showing components included in the UHV Process Chamber.

Component	D1
Substrate Manipulator	External laser stage
Vacuum gauging	Ion gauge Convectron gauge Baratron
Pumping	Vacion Plus 300 Ion Pump Titanium Sublimation Pump HiPace 1200 Turbo Molecular Pump HiPace 80 Neo Turbo Molecular Pump
Sources	HTEC-10 x 3 OMEC-23 x 2 LTEC-23 x 2 DCAX-30 - RF Plasma Source (O_2) Gas injector (Oxygen) Dual MOPI source
BFM	✓
QCM	x
RGA	SRS 200amu
Bakeout system	✓

3.3 Software Features

System operation can be performed:

i. Locally at the electronic rack using the human machine interfaces (HMIs) of the different component controllers (e.g., Eurotherms (ET), Motor Control Units (MCU), general user interface (GUI), or,
ii. Remotely at the PC via the computer software interface.

Systems with automated transfer use sophisticated logic software implemented by a PC-based controller (PCC). The digital periphery (DP) of PCC is behind the right panel of the electronic rack (ER).

3.3.1 DCA Control Software

The system is provided with a DCA Control Software package (based in LabView). The software provides users with comprehensive control of the MBE growth process with the following modules:

- System status and control
- Recipe generation
- Recipe execution
- Data logging/Chart viewing (max. 3 charts simultaneously)
- Bake-out control

For each module listed above, the computer can control and monitor the components required:

- Effusion cells and sources (that are connected to DCA supplied Eurotherms)
- All linear shutters
- Vacuum gauge controllers
- BFM positioning and pressure/flux readout
- Substrate manipulator, azimuthal position, and the main shutter
- All Eurotherm temperature controllers
- Pneumatic GVs
- Interlock status
- Bakeout heater controller
- Oxygen RF atom beam sources

NOTICE

Refer to the DCA Software Manual for instructions on how to operate the Control PC interface. An overview of the MBE systems' communication, functions, and controllers is provided in Appendix VI.

3.4 Product Compliance

This product complies to all relevant European Directives. The Declaration of Conformity can be found in the appendix. The Product is in conformity with the following relevant product safety standards:

Applied harmonized standards:

- EN ISO 12100-1, Safety of machinery. General principles for design. Part 1: Basic terminology, methodology
- EN ISO 12100-2+A1, Safety of machinery. General principles for design. Part 2: Technical principles and specifications
- EN 60204-1, Safety of machinery. Electrical equipment of machines. General requirements
- EN 50081-1, Electromagnetic compatibility (EMC). Generic emission standard

- EN 50082-1, Electromagnetic compatibility (EMC). Generic immunity standard

4 PROCESS CHAMBER

4.1 R-Series Oxide Chamber

The R-Series is dedicated to performing high-quality oxide growth. The compact chamber design has a small footprint and is perfectly suited for research laboratories. The R-series chamber is extremely versatile as it allows deposition from multiple source types simultaneously, including gases, metal-oxide precursor injectors, RF source or effusion cells.

The R-Series can be upgraded to a differentially pumped module (DPM), which serves to maintain the structural integrity of components such as effusion cells whilst the deposition chamber operates under partial pressure. The DPM has a secondary pumping and vacuum gauging system; this creates a vacuum differential between the growth chamber and the components so that may operate at a suitable vacuum level.

The standard features of the R-Series chamber are summarized in Table 4 below.

Table 4 Summary of the R-Series standard features.

Feature	R450
Uniform oxide deposition on wafers up to:	10x10 mm
Vertical cylindrical chamber high-quality 316L steel, diameter:	450 mm
Top LN_2-cooled cryopanel with VBC connectors	✓
Main shutter with e-p rotary motion	✓
NW100CF VP with manual rotary shutter w/ white LED light ring	✓
NW38CF heated VP & e-p rotary shutter (for optical pyrometer)	✓
NW40CF Effusion cell ports compatible	11
Stainless steel support frame	✓

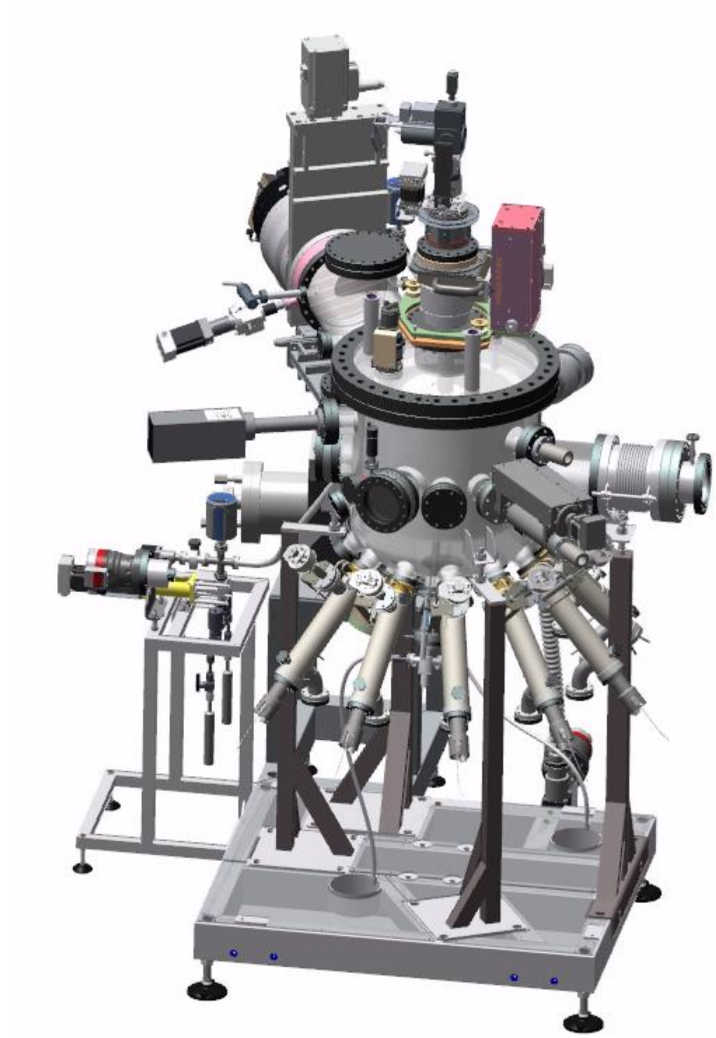


Fig. 4-1 Schematic (1/2) of the R-Series chamber.

Fig. 4-2 Schematic (2/2) of the R-Series chamber.

4.1.1 Pumping and vacuum gauging

The pumping system for the R-Series main chamber is summarized in **Error! Reference source not found.** below.

Table 5 List of the R-Series pumping system features.

Pumping	R450
Base pressure (Torr)[1]	5 E -10
Pumping module port	NW250CF
Pfeiffer HiPace 1200 TMP	✓
NW200CF VAT e-p gate valve (TMP)	✓
Ion Pump	✓
NW150CF VAT e-p gate valve (IP)	✓
Titanium sublimation pump	✓
MPCq (Multi-pump Controller - Ion Pump/TSP) 4UHV & TSP controllers	✓
Scroll Pump	✓
VPI shut-off valve	✓
Pfeiffer HiPace 80 Neo TMP (for RHEED and MOPI)	✓

[1] After 48-hour bakeout, manipulator and sources at room temperature, and LN_2-cooled cryopanel

NOTICE

Refer to the separate Pump Manuals for detailed operating and maintenance instructions.

4.1.2 Vacuum gauging

Vacuum gauging of the R-Series main chamber and DPM is performed using:

- Inficon nude ion gauge (IG) with dual thoria-coated iridium filament from UHV (5 x 10^{-11} Torr) to HV (1 x 10^{-4} Torr)
- Convectron gauge (CV) from HV (1 x 10^{-4} Torr) to atmosphere (760 Torr)

An Inficon vacuum gauge controller (VGC) is provided to monitor the gauges and provides a wide measurement range from UHV to atmosphere. The VGC has six available relays for SPs and is located in the MBE electronic rack.

The vent line for the system includes an over-pressure relief valve and Bourdon pressure gauge.

NOTICE

Refer to the separate Inficon Vacuum gauge Controller Manual for detailed operating instructions.

⚠CAUTION

ELECTRICAL HAZARD! Before connecting/disconnecting the VGC or removing/connecting cables to the IG, ensure there is no power supplied to the VGC. If power is not removed this can cause user injury or damage the controller!

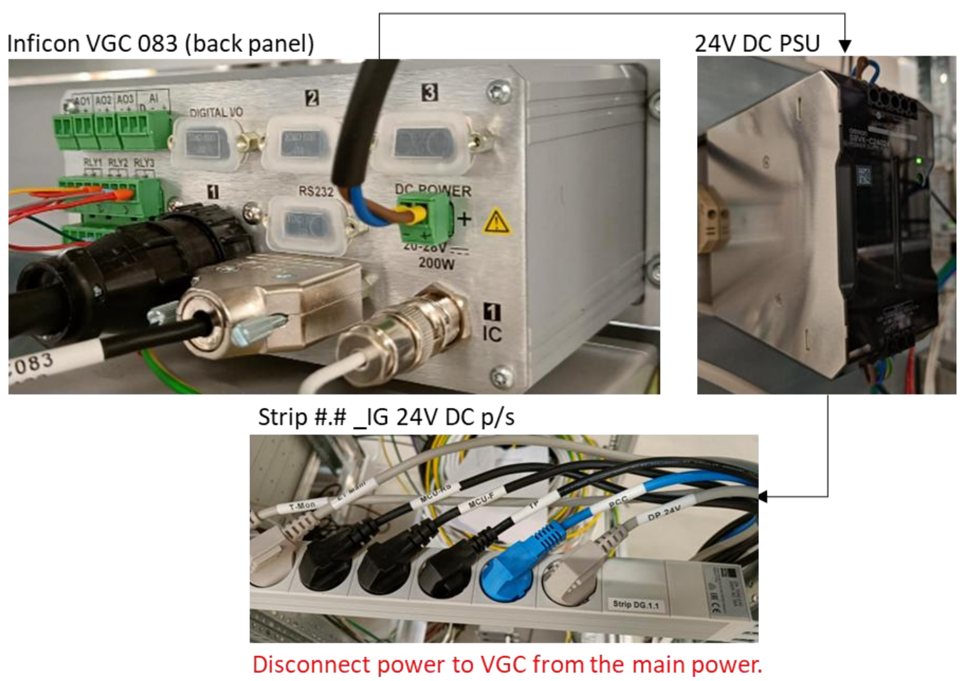


Fig. 4-3 Switch off the VGC from the front panel, then stop the power supply from the 24V DC power supply by removing the correctly labelled plug from the Power Strip.

4.1.3 R-Series Effusion Cell Module

Effusion cells are mounted to the R-Series chamber via a designated EC module (Fig. 4-4) that allows it to be isolated from the main chamber. Two EC module versions are available, and their individual features can be compared in **Error! Reference source not found.**. A heating jacket is used to bakeout the EC module.

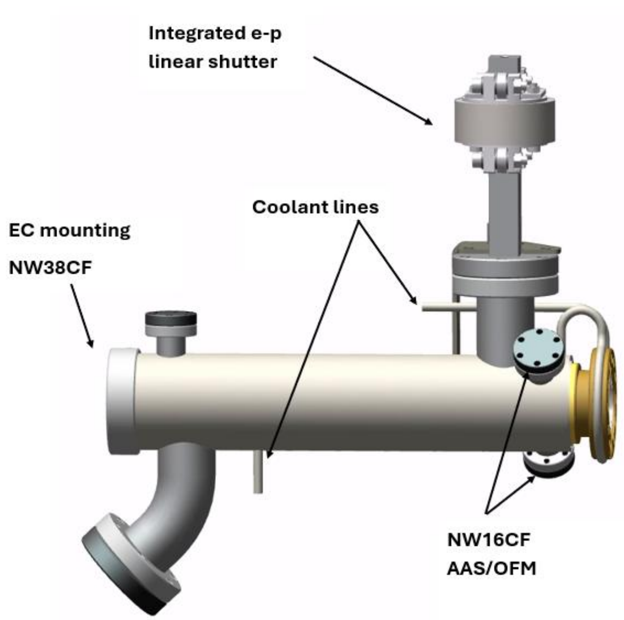


Fig. 4-4 Schematic of Effusion cell (EC) module compatible with the R-Series.

Table 6 Summary of the R-Series standard features.

Feature	EC Module_38
EC mounting port	NW38CF
Integrated water-cooling	✓
Integrated e-p linear shutter	✓
Connection port to DPM	✓
NW16CF AMRAV (vent/pump)	x
VAT Manual GV	x
NW16CF AAS/OFM ports (2)	✓

4.2 Substrate Manipulator

NOTICE

Refer to the separate DCA Substrate Manipulator, DCA Substrate Manipulator Drives (MCU-RS/Z/F), and Eurotherm 3504 Manuals for detailed maintenance and operating instructions.

The substrate manipulator serves multiple essential functions;

i. forms part of the wafer transfer system (i.e. when loading/unloading the wafer to the chamber),
ii. performs wafer motion during analysis/growth (e.g. to ensure uniform deposition), and
iii. controls and monitors the wafer temperature.

The manipulator stage design and features are dependent on the type of process environment and heater size required to ensure excellent thermal uniformity across the entire wafer.

NOTICE

This system utilizes external laser stage for manipulator heating. Therefore, some items mentioned in DCA Substrate Manipulator- manual is not accurate and it should be used as a guideline, not as a actual manual. If some items are not mentioned, please contact DCA instruments for more information.

4.2.1 Laser Manipulator

This substrate manipulator features a external laser heating stage to heat sample under UHV conditions.

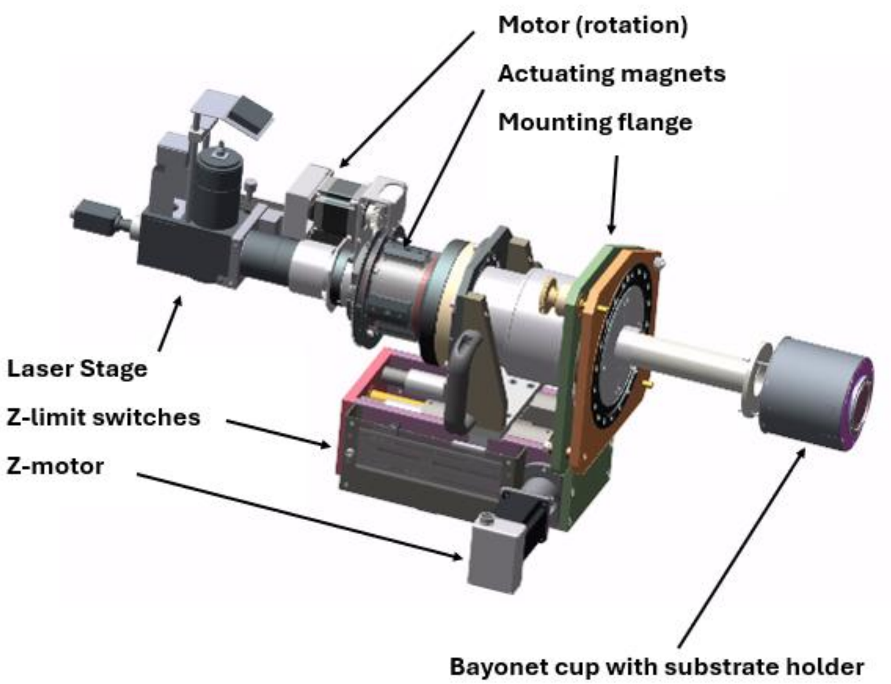


Fig. 4-5 Substrate manipulator for a manual UHV Deposition System.

Table 7 Summary of the substrate manipulator main features.

Manipulator features	R450 / M600
Heating	External laser stage
Max. temperature	1400°C
Sample rotation[2]	✓
Z-motion [3]	✓
Water-cooling	External chiller
Power supply	External laser PS

4.3 Analytical Components

4.3.1 Beam Flux Monitor (BFM)

The DCA-BFM (Fig. 4-6) precisely measures the beam equivalent pressure (BEP) from effusion cell sources in the MBE chamber. This is calibrated to provide a beam flux and determine the source deposition rate.

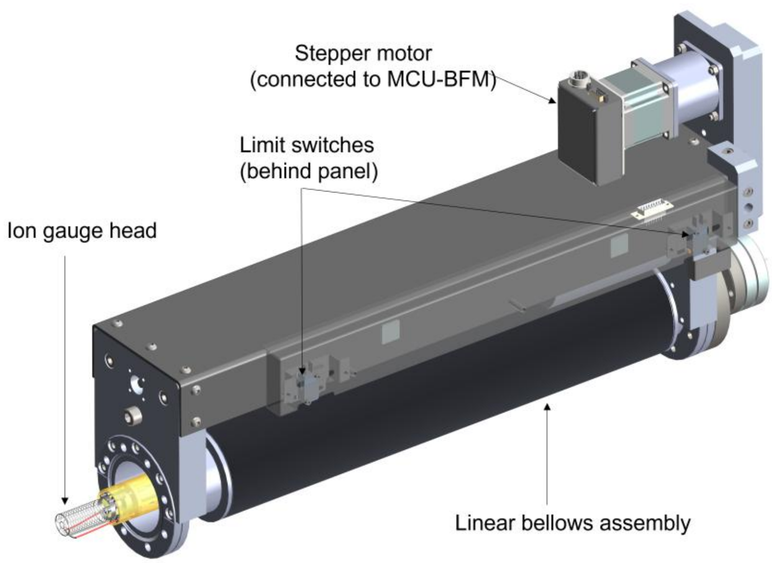


Fig. 4-6 Motorized beam flux monitor with linear bellows assembly.

The BFM comprises of a B-A UHV nude ion gauge with VacGen (VG) twin-tungsten filament that is mounted onto a linear bellows assembly. A stepper motor drive controls the linear motion and positions the IG either beneath the substrate surface or fully retracts it behind the cryopanel to prevent excessive coating. The stepper motor can be operated locally from the MCU-BFM, or remotely via the PC.

An Inficon IGC with 3-digit display (IGC-BFM) is provided to monitor the BEP.

[2] Stepper motor with a magnetically coupled rotary drive for continuous rotation up to 60rpm. All electrical wiring is conducted through the inner tube of the rotary drive, shielding them from deposits. The stepper motor is powered and controlled by the MCU-RS

[3] The stepper motor is powered and controlled by the PSU-Z and is used to lower/raise the manipulator stage to the transfer or growth position.

NOTICE

Avoid exposing the BFM ion gauge to high temperature metals (e.g. Ti) as this can coat the filament and prevent an accurate reading. Exchange the BFM ion gauge head if this has occurred.

NOTICE

Refer to the separate DCA Motor Control Drives MCU-BFM for detailed maintenance and operating instructions.

⚠CAUTION

ELECTRICAL HAZARD! Before connecting/disconnecting the VGC or removing/connecting cables to the IG, ensure there is no power supplied to the VGC. If power is not removed this can cause user injury or damage the controller!

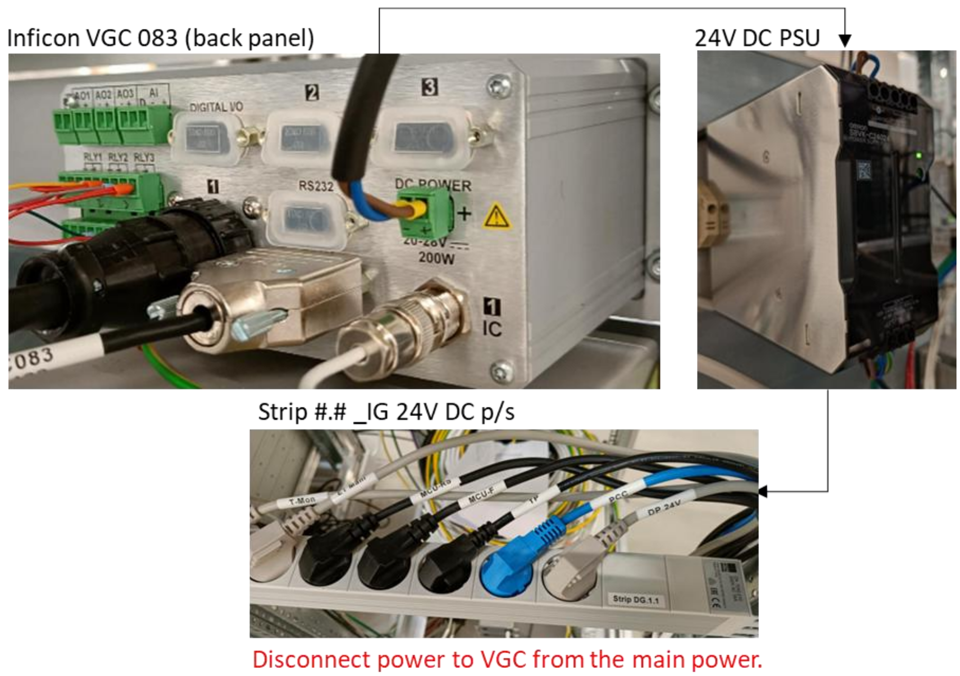


Fig. 4-7 Switch off the VGC from the front panel, then stop the power supply from the 24V DC power supply by removing the correctly labelled plug from the Power Strip.

4.3.2 Residual Gas Analyzer (RGA)

The chamber is equipped with a Stanford 200 amu SRS residual gas analyzer with dual Faraday/Multiplier detector. The RGA functions as a mass spectrometer and allows users to monitor the deposition process and identify the presence of contaminants in the vacuum system.

The RGA system includes:

- SRS 200 amu RGA with dual Faraday detectors,
- Windows based RGA software with spectrum data saving capability,
- PC computer with 19” flat panel display (same as the system computer)

NOTICE

Refer to the separate SRS RGA manual for operating instructions.

4.4 Sources

4.4.1 Source Configuration and Overview

The source ports are equidistant from each other around the circumference of the source flange. The effusion cells and crackers are angled at 44° to optimize both the deposition angle and maximum filling level of the sources.

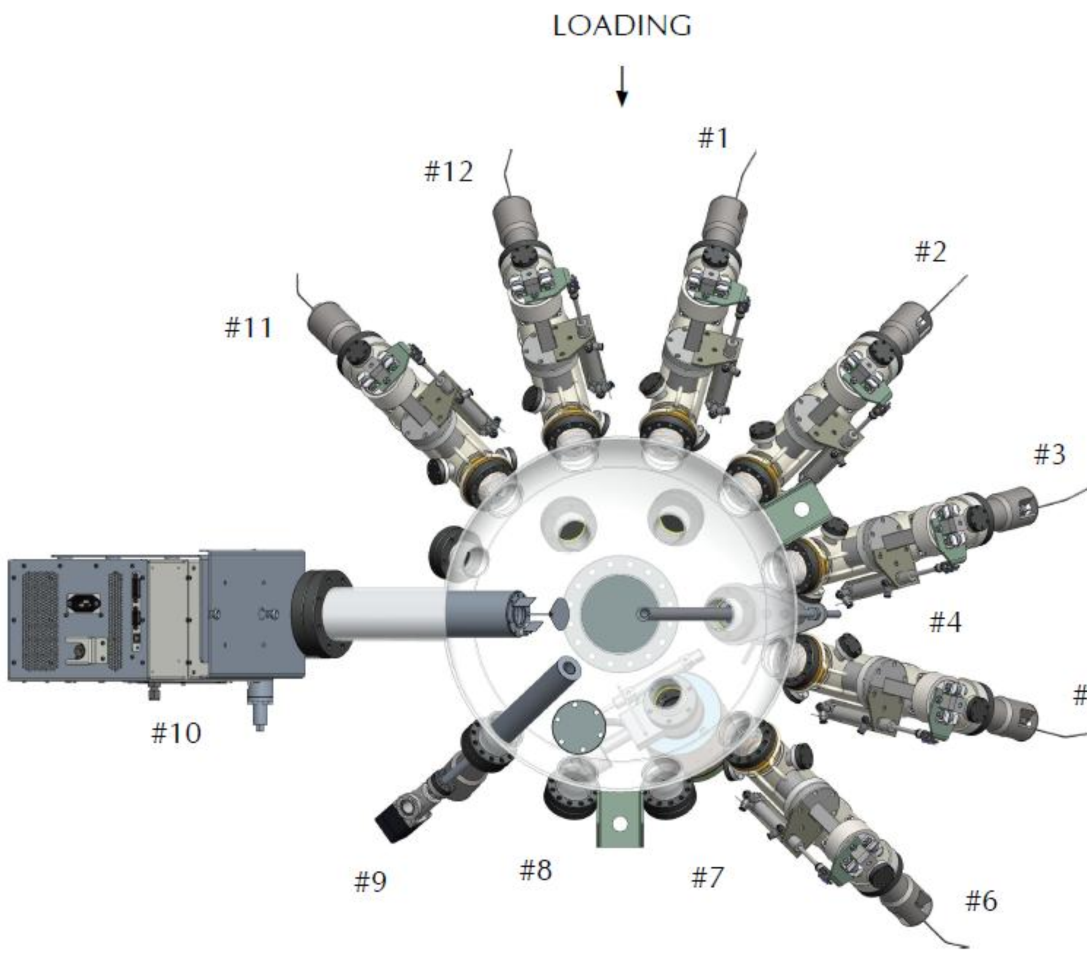


Fig. 4-8 Top-down cross-section of an example R-series MBE with the source ports numbered clockwise from the transfer port.

A summary of the sources provided with each process chamber is given in the table below.

Table 8 Summary of sources equipped with the P-Series chamber and their associated serial numbers.

Port #	Source[4][5]	Material	Crucible (DCA#)	Power Supply- Loop#	S/N
1	LTEC-SF-23	Sr	PBN (11029)	GEN40-19 – **L2**	2287-01
2	LTEC-SF-23	Ba	Ta (12248)	GEN40-19 – **L3**	2287-02
3	HTEC-SF-10	Ba	W (11040)	GEN40-19 – **L4**	2287-03
4	O2 injector	O2	-	-	-

[4] All EC sources are water-cooled, C-type thermocouple on crucible cup, with DN100CF mounting flange and 292mm in vacuum length (-WC-C-100-L292).

[5] All Valved crackers are the standard design, with apertures for 3-inch wafers, DN100CF mounting flange, and 292mm in-vacuum length. (-S-3-100-292).

5	HTEC-SF-10	As	W (11040)	GEN40-19 – **L5**	2287-04
6	HTEC-SF-10	Al	W (11040)	GEN40-19 – **L6**	2287-05
7	**-**	-	-	-	-
8	-	-	-	-	-
9	MOPI source	TTIP, VTIP	-	GEN60-12.5 (Main) - **Injector** Power supply - **Jackets**	-
10	DCAX-30	O2	Quartz 37 x 0,5mm (14228)	GENH 600 -1.3 – **Ion deflection**	-
11	OMEC-23	AlOx	AlOx (39756)	Julabo Magio – **L8**	2287-06
12	OMEC-23	AlOx	AlOx (39756)	Julabo Magio – **L9**	2287-07

Fig. 4-9 Top-down cross-section of an example M-series MBE with the source ports numbered clockwise from the transfer port.

4.4.2 DCA Effusion Cells

The DCA effusion cells supplied with the UHV system are equipped with a power supply for each individual heating element (e.g. STEC-DF has two power supplies), LEMO power cable(s), TC cable(s) and Eurotherm (ET) PID controller. These are connected as shown in Fig. 4-10 and are assigned a specific Loop # for that source.

The ET uses a PID feedback loop to control the power input to the filament(s) and maintain a stable temperature throughout the process. The PID Loop # is marked on each TC and LEMO cable, ET, and PSU to ensure that these are only connected to the assigned source. The set-points, ramp rate, and interlocks can be controlled locally from the ET, or remotely via the PC.

Bakeable water-cooling lines are supplied for each effusion cell.

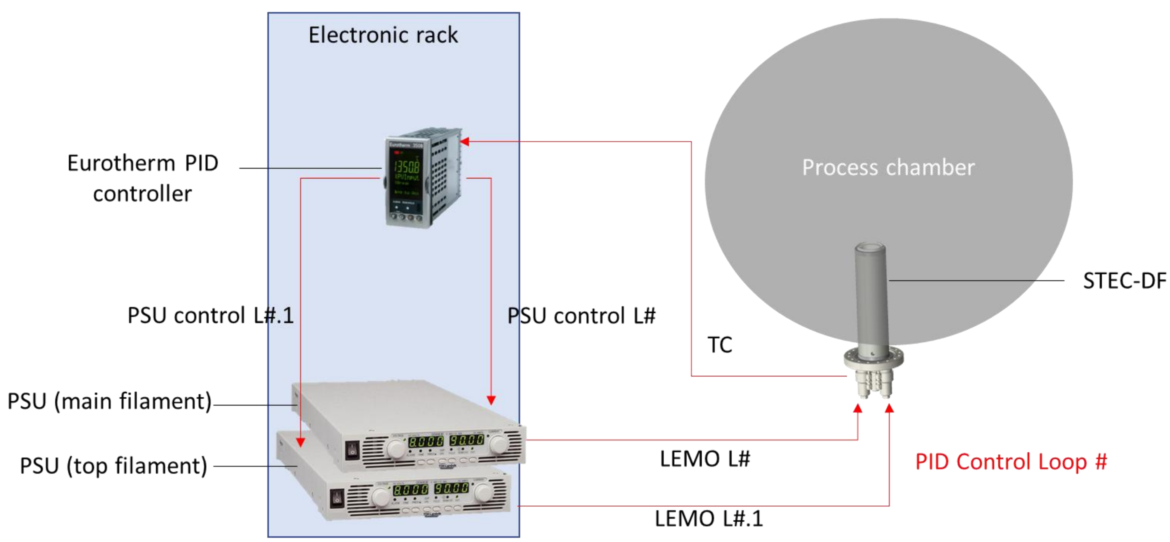
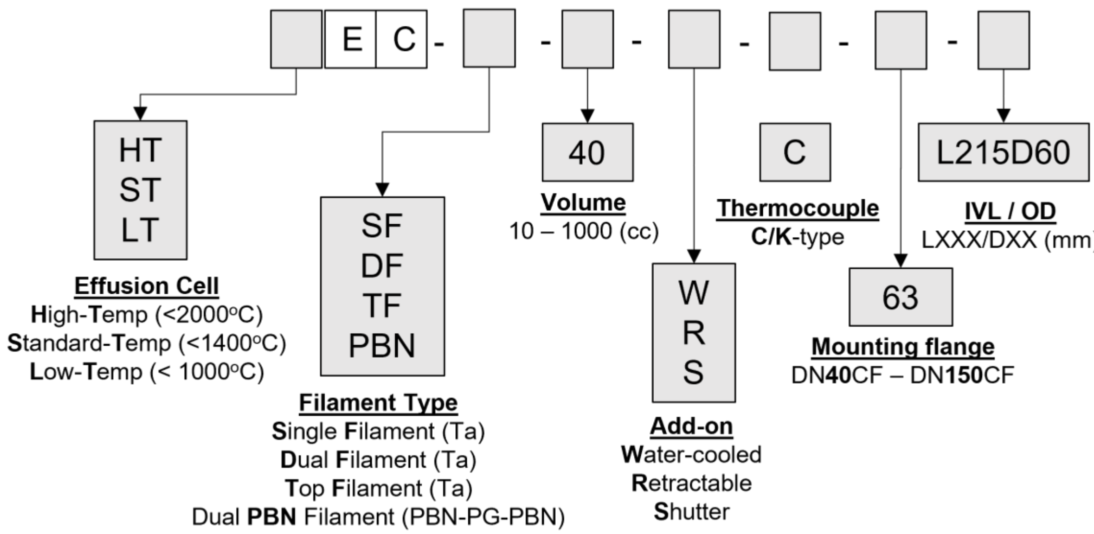


Fig. 4-10 Schematic showing an example of the PID Loop for a dual-filament effusion cell.

Effusion Cell Configuration Overview (E.g. STEC-SF-40-W-C-63-L215D60)



NOTE 1:
High temperature EC has a single twin-tungsten filament.
Standard temperature EC may have either single/dual Ta filament or dual PBN-coated PG filament
Low temperature EC has a single Ta top filament

NOTE 2:
Compatibility of the crucible with the chosen source material is the user's responsibility.
Crucible materials available: Ta, W, AlOx, PBN, Graphite, PG, others available upon request. Crucible volumes: 6-1000 cc (dependent on EC type). Special high-capacity crucibles available for Ga/In, and cold-lip crucible for Al.

Fig. 4-11 Effusion cell model configuration identifies the cell type and the included features.

NOTICE

Refer to the separate Effusion Cell DCA User Manuals, Eurotherm 3500 Series Manual, and TDK Lambda Power Supply Manuals for detailed features, operation, maintenance, and installation instructions.

⚠WARNING

Use ONLY the assigned power supplies for the source, ensure the Loop # matches to all the components. Incorrect assignment can lead to user injury or system damage.

4.4.3 RF Atom Source (DCAX-30)

The RF plasma source (Fig. 4-12) is used to generate an atomic beam of oxygen for the purpose of substrate surface preparation or during the growth process.

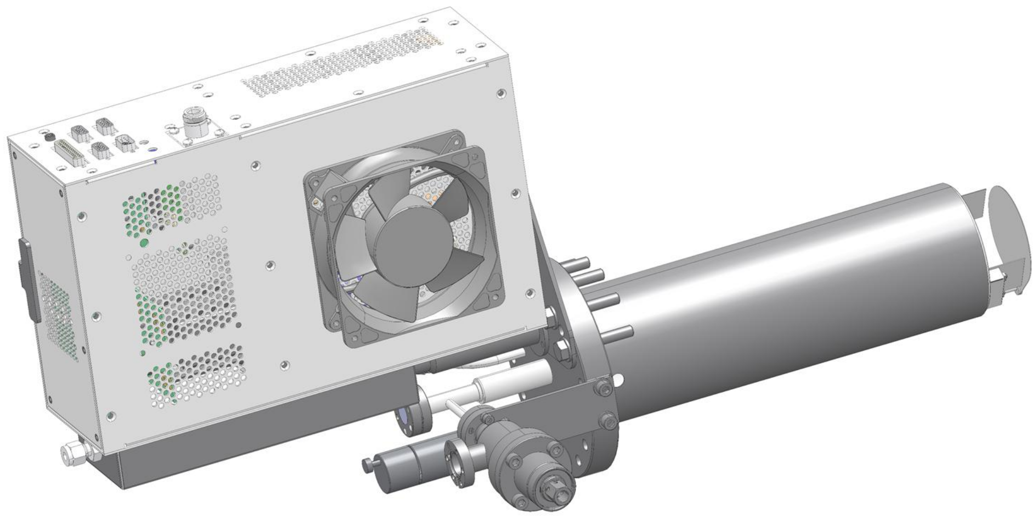


Fig. 4-12 DCAX RF Plasma Source suitable for oxygen.

Each DCAX-30 RF plasma source is equipped with:

- Electro-pneumatic rotary shutter
- Quartz Discharge Bulb for Oxygen (dwg. # 8165-672-21_B)
- DN16CF all-metal right angle valve (connected to the gas delivery system)
- RF generator - Comet 600W
- Comet AGS RF Autotuning unit
- Ion trap with TDK power supply GEN600-1.3
- 0.1- 5 sccm Mass flow controller (see Gas delivery system – section 4.6)

NOTICE

Refer to the DCA RF Atom Source Manual, Comet RF Generator & Autotuning Manuals for detailed operating and maintenance instructions

4.5 Shutters

Shutters on plasma and sources are tantalum, but they could feature either a tantalum, molybdenum, or PBN shutter blade depending on the source material and specifications. Each shutter is driven by an electro-pneumatic actuator that features a magnetic coupling to the shutter shaft. This ensures there is sufficient driving force even after heavy deposition on the shutter blade.

If the shutter motion appears jarred or sticky, first adjust the pneumatics according to section 9. If the motion does not improve, the linear shutter needs to be serviced (i.e. material may have accumulated on the shaft).

The linear source shutters can be removed individually from the growth chamber through the shutter mounting port.

Shutter control (i.e. open/close) can be performed locally from the HMI (SVICU) in the electronic rack or remotely from the PC workstation.

Table 9 Shutters provided with the UHV Deposition System.

Shutter (Component)	Port #	Chamber	Material	Mounting flange	Dwg. #	Qty.
Linear (EC)	1-3, 5-6, 11-12	R450	Ta	DN40CF	21-451	7
Main shutter e-p, linear	-	R450	Ta	DN40CF	2287-363	1
Liner (pyrometer)	-	R450	AISI304	DN40CF	21-362-15 A	1
Window shutter, manual (VP CF100)	-	R450	AISI304	DN100CF	SHUT-100 B	1

4.5.1.1 Cell nipple integrated shutter

The R-Series chamber is equipped with integrated source shutters mounted in the cell port (Fig. 4-13). The shutter blade design is dependent of the size of the source, with wider blades required for larger sources to ensure sufficient coverage of the source opening.

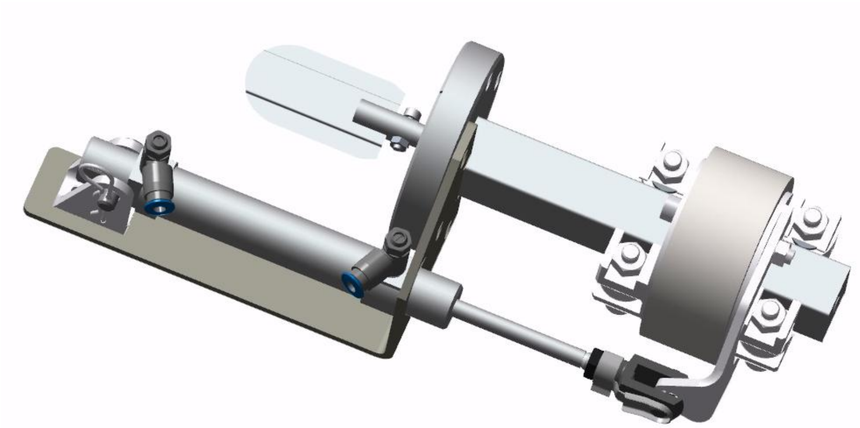


Fig. 4-13 Example of e-p R-series linear source shutters with Ta blade. These are mounted in the cell nipple.

4.5.2 Rotary Shutter

An electro-pneumatic rotary shutter with Ta blade is mounted in R-Series chambers as the main shutter, and plasma sources.

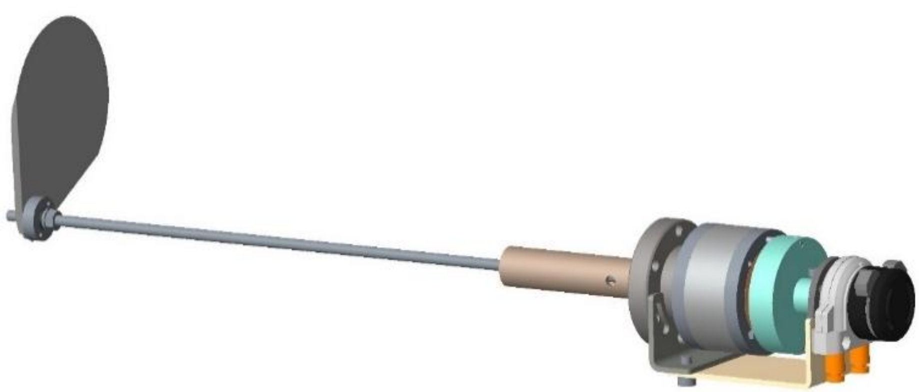


Fig. 4-14 Electro-pneumatic rotary shutter for ion source mounted to base chamber flange.

4.6 Gas Delivery System

The gas delivery system (Fig. 4-15) controls and monitors the gas flow to the chamber/source. The gas panel is located on the LBC. Manual switches for the gas supply are located on the outer panel. The back panel supports the e-p shut-off valves (SOVs) for the supply (from the gas source), process/run (to the process chamber/source) and pump (to the scroll pump). The gas flow rate is controlled using the specified MFC in connection with SVICU system. This allows the user to set the flow locally (at the touch screen) or remotely via the PC workstation.

NOTICE

Refer to the Bronhorst MFC manual for detailed operating instructions.

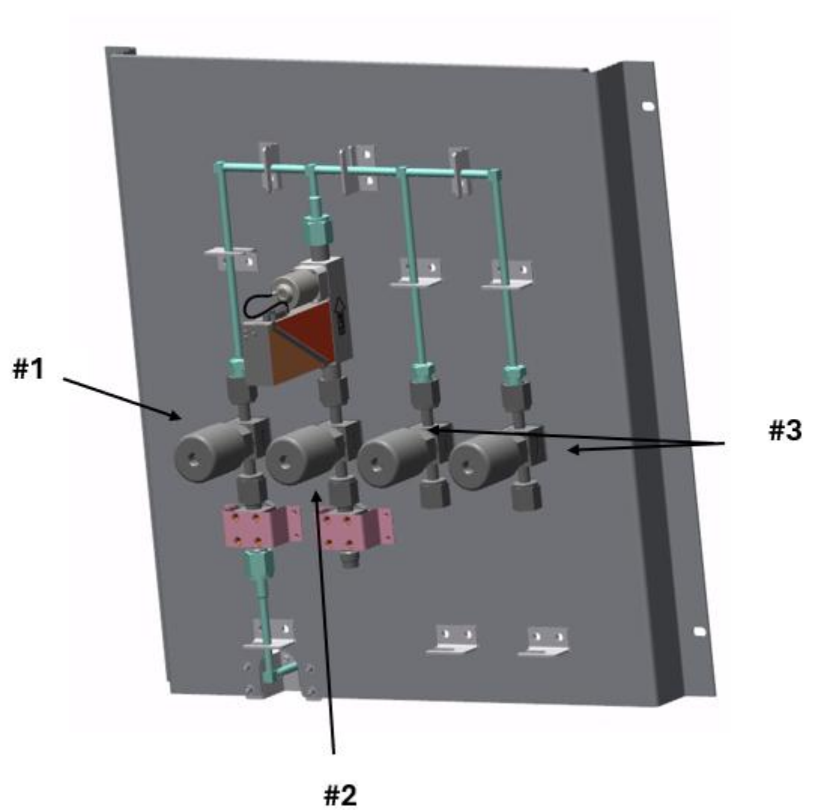


Fig. 4-15 Schematic of the gas distribution panel. In the panel there is pump line (#1), supply line (#2) and two run lines (#3, ATS & injector)

5 TRANSFER SYSTEM

5.1 Linear Buffer Chamber (LBC)

The UHV linear buffer chamber (LBC) facilitates the wafer transfer in the UHV Deposition System. The modular design allows additional LBC modules to be added without limitations.

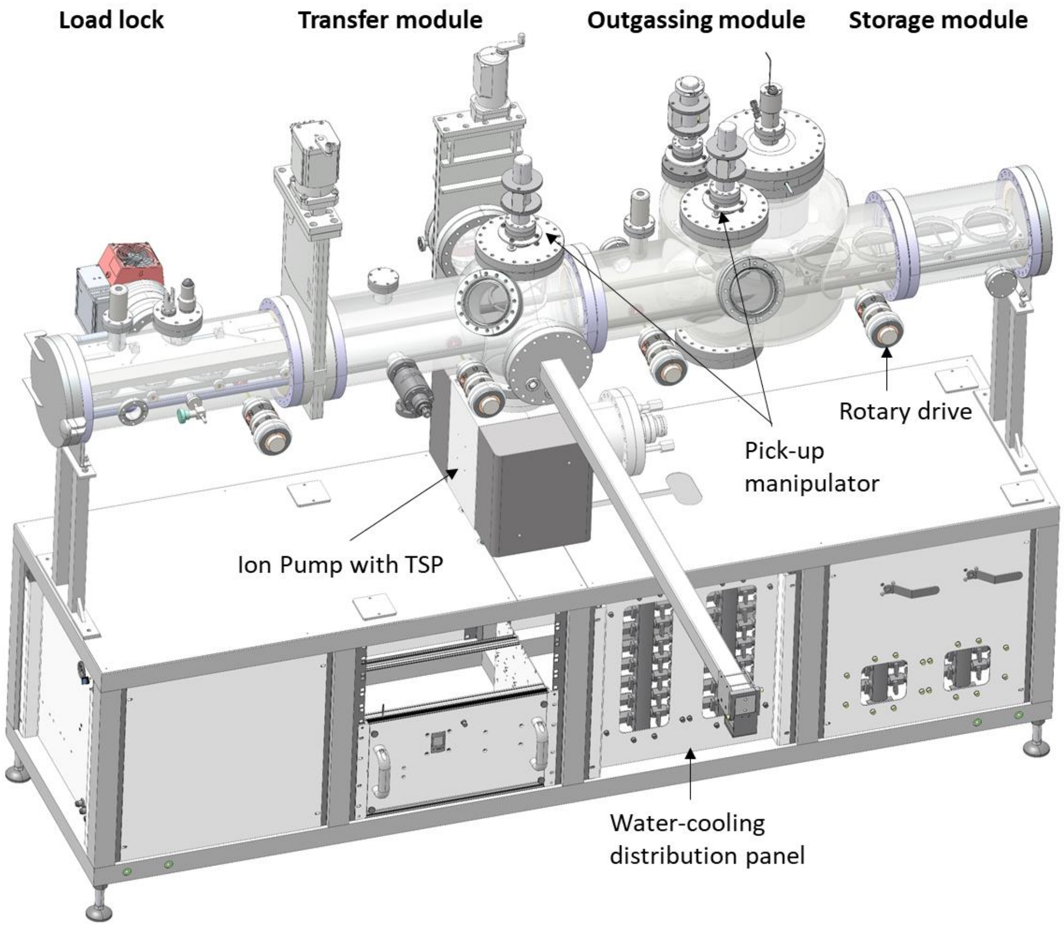


Fig. 5-1 Example schematic of the linear buffer chamber for manual transfer, including transfer module (to process chamber), outgassing module (for sample preparation) and storage module (with space for an additional trolley).

These modules are included in the LBC.

- **Transfer module** – enables transfer to the adjacent process chamber; it features a pick-up manipulator (PUM), magnetically-coupled transfer arm, and support roller.

- **Storage/spacer module** – provides space for an additional wafer trolley to allow wafer storage under UHV conditions.

The LBC is mounted to a support table. The support table houses the cooling distribution panel for the process chamber and water-cooling box (see section 8.1.1) with flow meter and flow control valves for the TSP pump.

Standard features of the LBC are listed below:

Table 10 Standard features of the LBC (manual transfer system).

LBC Features	Wafer size (≤ 2”)
Magnetically coupled transfer arm	Enables wafer transfer to/from adjacent chambers
VAT GV to chamber (Manual)	NW100CF
VAT GV LL/LBC separation (Manual)	NW150CF
Magnetically coupled rotary actuators	Equally spaced along the LBC, they smoothly guide the wafer trolley along the rails to the desired position for transfer.
Magnetically coupled pick-up manipulator (PUM)	Vertical pick/place spring mechanism for wafer transfer
Wafer Trolley Capacity /(configuration)	9 (2 x 5)
Pumping system [6]	Agilent Vacion plus 300 IP (300 l/s pumping capacity). 4UHV controller and power supply Agilent TSP Filament cartridge Tsp controller Bakeable high voltage cable.
Vacuum gauging	Inficon Nude IG with dual yttria coated iridium filament Inficon VGC (3-digit display)

A wafer trolley is included with the system, this is used for loading wafers to the load lock and performing transfers within UHV the LBC. The trolley dimensions and capacity are dependent on both the wafer size and the space available within the LBC (see Table 10).

The standard wafer trolley features two levels for each cup in order to maximize the available capacity. Each cup can hold two wafer carriers, one above the other due to the different slot indents. One top-level space must remain vacant in to allow for the redistribution of samples.

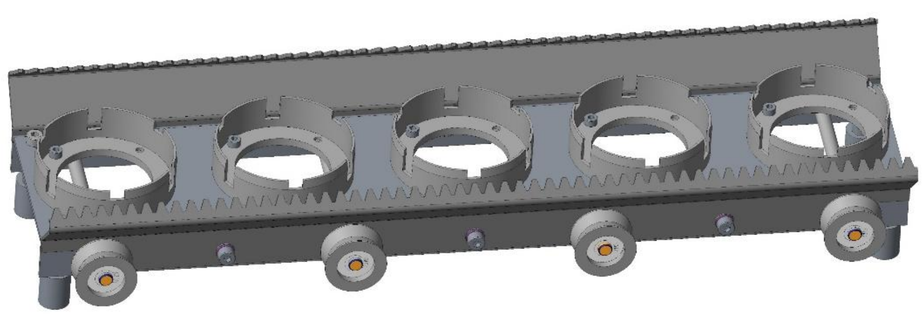


Fig. 5-2 Example features two stacks of five and a total capacity for nine wafers..

[6] The LBC is roughed and vented via the LL. Base pressure after 24-hour bakeout is < 10-9 Torr.

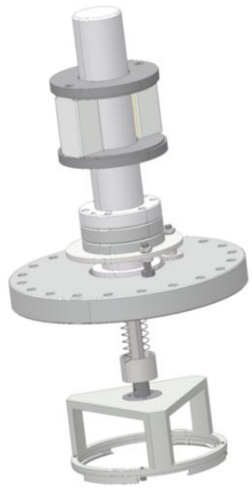


Fig. 5-3 Schematic of a magnetically coupled pick-up manipulator (PUM) in the LBC.

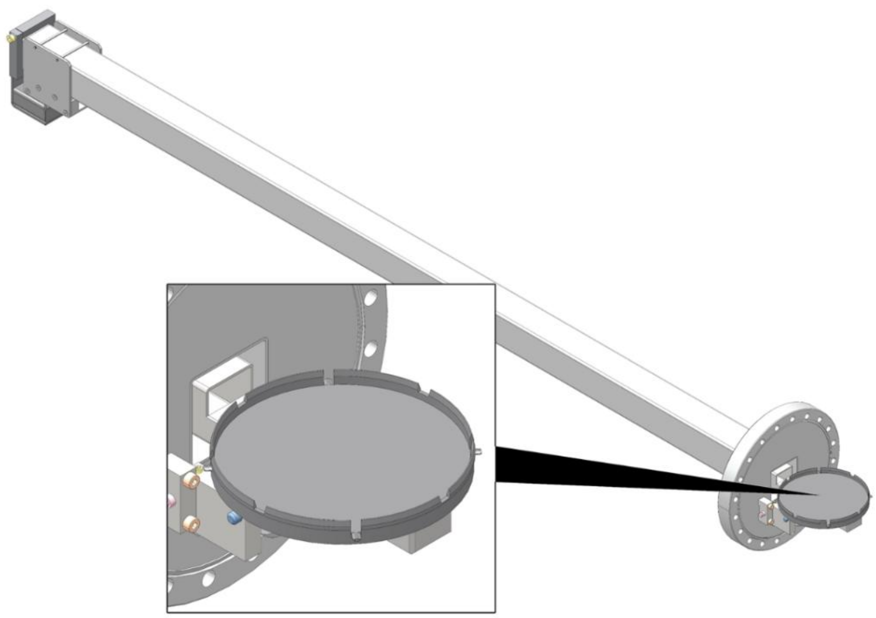


Fig. 5-4 Magnetically-couple transfer arm for transfer wafers to/from the LBC to the adjacent process chambers.

The magnetically coupled transfer arm (Fig. 5-4) transfers wafer between the LBC and the adjacent process chamber. A support roller situated between the LBC and process chamber provides additional support and ensures the transfer arm remains level during the transfer.

5.2 Manual System Load lock (LL)

The LL (Fig. 5-5) forms an essential part of the UHV deposition system as it allows samples to be loaded without interrupting the UHV conditions in the rest of the system. The cylindrical chamber features a Viton-sealed quick-access door to allow easy sample loading and unloading.

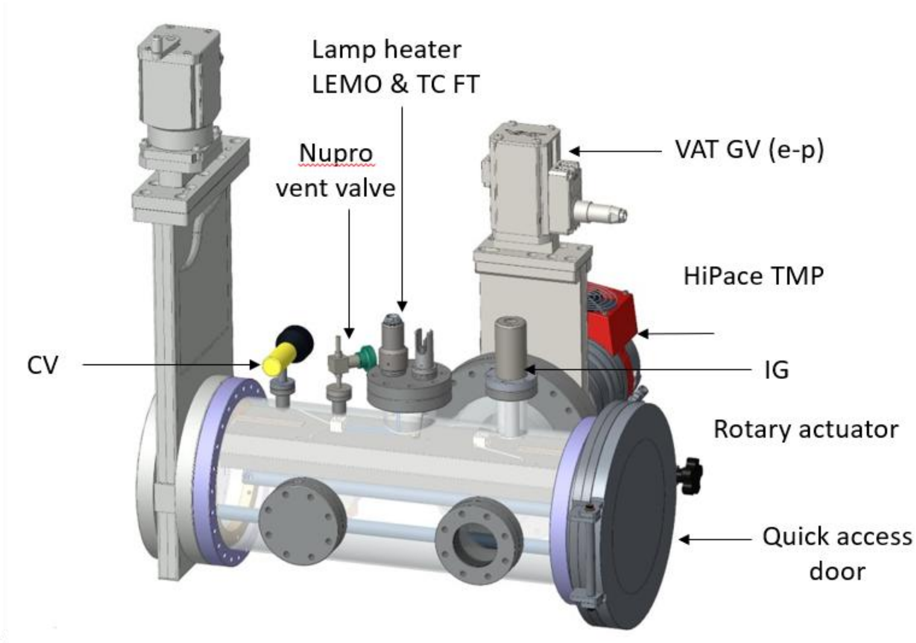


Fig. 5-5 Example of a load lock chamber (LL) with its primary features labelled.

5.2.1 Pumping system

The LL pumping system is comprised of:

- HiPace80 Neo TMP controlled via the OMNI controler (in the ER)
- NW100CF VAT e-p GV (for pump isolation)
- Dry scroll pump for roughing (HiScroll 6)

Dry nitrogen is used to vent the chamber via the TMP vent valve. The Nupro vent valve can be opened if required, but only after the TMP has reached a complete stop.

NOTICE

Refer to the Pfeiffer HiPace and OMNI Controller manuals for detailed operating and maintenance instructions.

5.2.2 Vacuum gauging

LL vacuum gauging is achieved with:

- Inficon nude IG (dual yttria coated iridium filament)
- PGE050 convectron gauge
- Inficon VGC (VGC- LL) with 3-digit diplay and six available SPs.

5.2.3 LL Outgassing

An internal IR lamp heater stage allows quick outgassing of the wafer trolley and wafers before they are transferred to the LBC. This is an essential step for maintaining the UHV of the LBC. The controller for the LL heater is located in the ER. The maximum temperature for degassing is 200 °C. The LEMO (power cable) and TC feedthroughs for the heater stage are shown in Fig. 5-5.

Fig. 5-6 Load lock lamp heater controller of the IR lamp heater allows the user to set the temperature (max. 200 °C) and duration.

The LL lamp heater controller (Fig. 5-6) features a Eurotherm that allows the user to set the duration and temperature for the degas process. Pressing the green start button would initiate the process. The LL lamp heater is interlocked with the LL vacuum pressure (VGC-LL) .

5.2.4 Sample Carriers

A summary of the sample carriers provided with the system is provide in **Error! Reference source not found.** below.

Table 11 List of sample carriers provided with the system.

DCA #	Dwg. #	Substrate (Carrier Size)	Material	Quantity
40112	2287-140-03	10x10 (2” carrier)	Ta	4
-	2240-145-09	2” Flag type	Ta	1

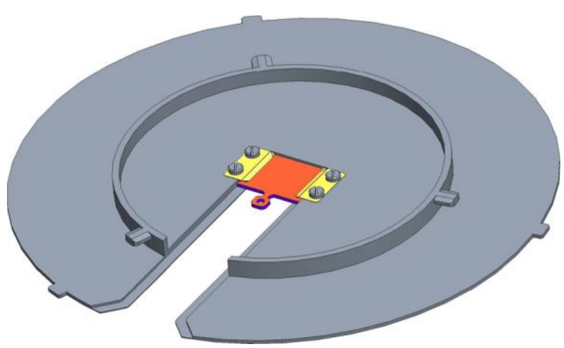


Fig. 5-7 Example of a modified 2” sample carrier designed for mounting flag-style carriers.

6 ELECTRONIC RACKS

Each chamber of the system is partnered with an electronic rack that houses the necessary peripheries (i.e. power supplies, component controllers, HMIs, PCC etc.) required to operate the DCA system (Fig. 6-1). Each electronic rack has an ID label in the top-right corner. The layout of each electronic rack is provided with the system schematics.

6.1 Emergency Power Off (EPO)

An emergency power off (EPO) button is located at the top of each electronic rack and forms a closed loop. When activated from any rack, the power supply to the entire system will shut-off immediately. The EPO controller is housed in the CDC-ER.

⚠WARNING

The EPO should only be used in the event of an electrical emergency that presents a risk to the user. Using the EPO may cause harm to the system as a proper shut-down procedure is ignored.

Water-cooling lines are purged in the event the EPO is activated.

Fig. 6-1 The electronic racks house the peripheries, PC-based computer, power distribution panels, and EPO for the entire UHV deposition system.

7 SHUTTER, VALVE, INTERLOCK CONTROL UNIT (SVICU)

An SVICU is provided for each process chamber. The SVICU houses the PLC and provides local control of shutters, GV, interlocks and coolant in the deposition chambers. The touchscreen panel is separated into three sections:

- System status indicators (top-left)
- Menu selection (top-right) – displays menu options for Shutter, Gate valve, Interlock and Setup (if applicable). The current menu selected menu is highlighted green and shown in the bottom section.
- Current selected menu: Shutter, Gate valve, Interlock controls or Setup (bottom)

The sections below describe the default SVICU set-up, but system layout is modified according to need.

7.1 System Status & Shutter Control

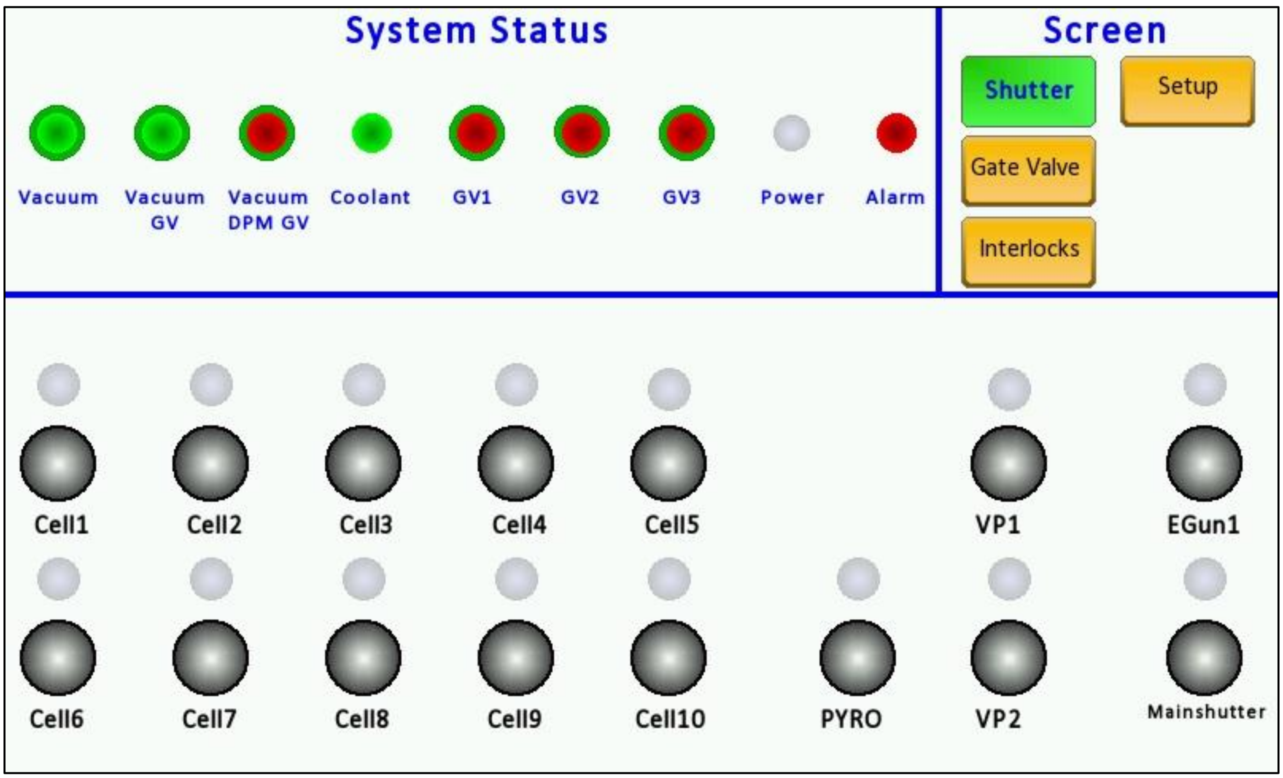


Fig. 7-1 SVICU: System status (top-left), Screen selection (top-right), system default shutter screen (bottom).

The SVICU may feature six System Status indicators in the top screen, the names of these are edited based on software need but in this example they are:

- ***Vacuum*** monitors VGC-D1/D2/LBC and indicates Vacuum status (SP3).
- ***Vacuum GV*** monitors VGC-D1M/D2M and represents Vacuum status (SP4) for GV-Interlocks.
- ***Vacuum DPM GV*** monitors VGC-D1D and represents Vacuum status (SP4) for GV-Interlocks.
- ***Coolant*** monitors the flow meter of the water-cooling distributor and detects if coolant flow drops below the trip point.
- ***GV1 –*** monitors pump 1 controller (e.g., TMP pump speed conditions)
- ***GV2*** – monitors pump 2 controller
- ***GV3*** – monitors pump 3 controller
- ***Power*** *(if applicable)* - relies on feedback from the UPS to determine whether a power failure is present.

- ***Alarm*** - Acts as the latching mechanism for interlocks. Any new alarm causes the Alarm indicator to blink red. An alarm can be acknowledged by pressing the ‘Reset’ button in the Interlocks panel. If the error, which has triggered the alarm is still present, then the corresponding alarm remains pending, and the corresponding interlock remains active. A pending alarm changes the Alarm LED to steady red. Otherwise, the alarm is deleted and only then is the corresponding interlock reset. The Alarm indicator turns off if this is true for all alarms.

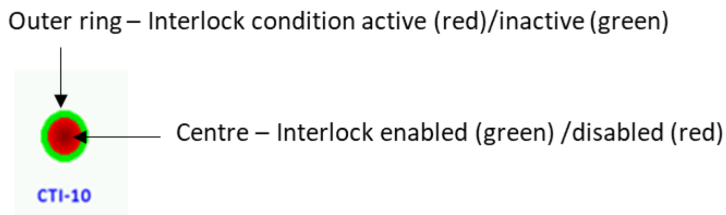


Fig. 7-2 Example of the Vacuum Interlock status for a CTI-10 pump. Interlock is disabled but the error conditions have not been triggered.

The status indicators (excluding Alarm) may have three appearances:

- **Green** - indicates the interlock is enabled and the error conditions (e.g. vacuum level/coolant flow) are not active.
- **Red** - indicates the interlock is enabled and the error conditions are currently active.
- **Red within a green ring** - indicates the interlock has been disabled but the error conditions are not active (Fig. 7-2).

Select ‘Shutter’ from the top-right menu to view the Shutter control screen (Fig. 7-1). The screen shows the shutter status and black buttons above the shutter # or shutter name (e.g. Mainshutter). Press the black button to open/close the shutter. The indicator above the black button is lit green if that shutter is open.

Shutters #1-7 are source shutters. The (factory default) shutter numbering starts clockwise from the loading port (Fig. 4-8). The main shutter, pyrometer, O-Inj (Oxygen injector) and plasma shutters can be controlled from this screen.

7.2 Gate Valve Operation

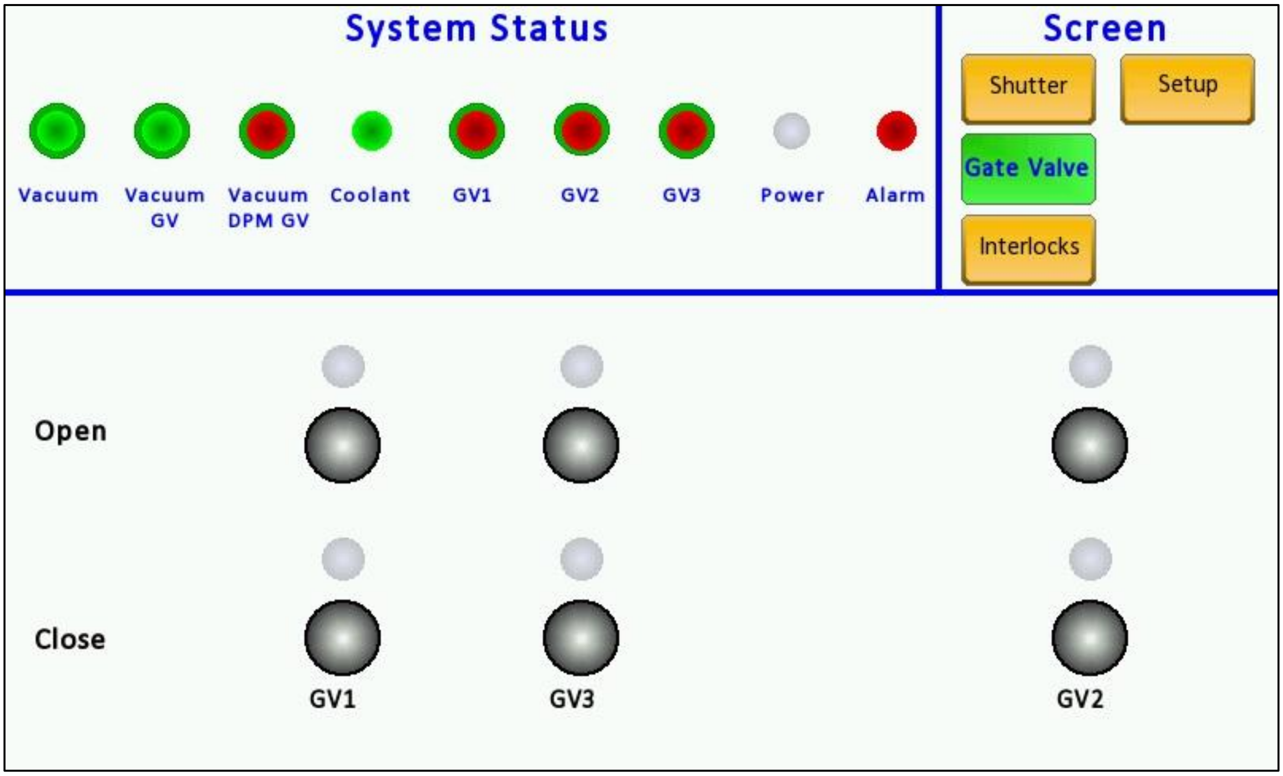


Fig. 7-3 SVICU: Gate valve panel (bottom) allows operation of the process chamber gate valves. The indicator above the button is green/red when the GV is open/closed, respectively.

To open/close the GVs, select the black button on the 'Gate Valve' screen (Fig. 7-3). The green/red indicator above the black button indicates if the valve is open/closed, respectively.

7.3 Interlock Control

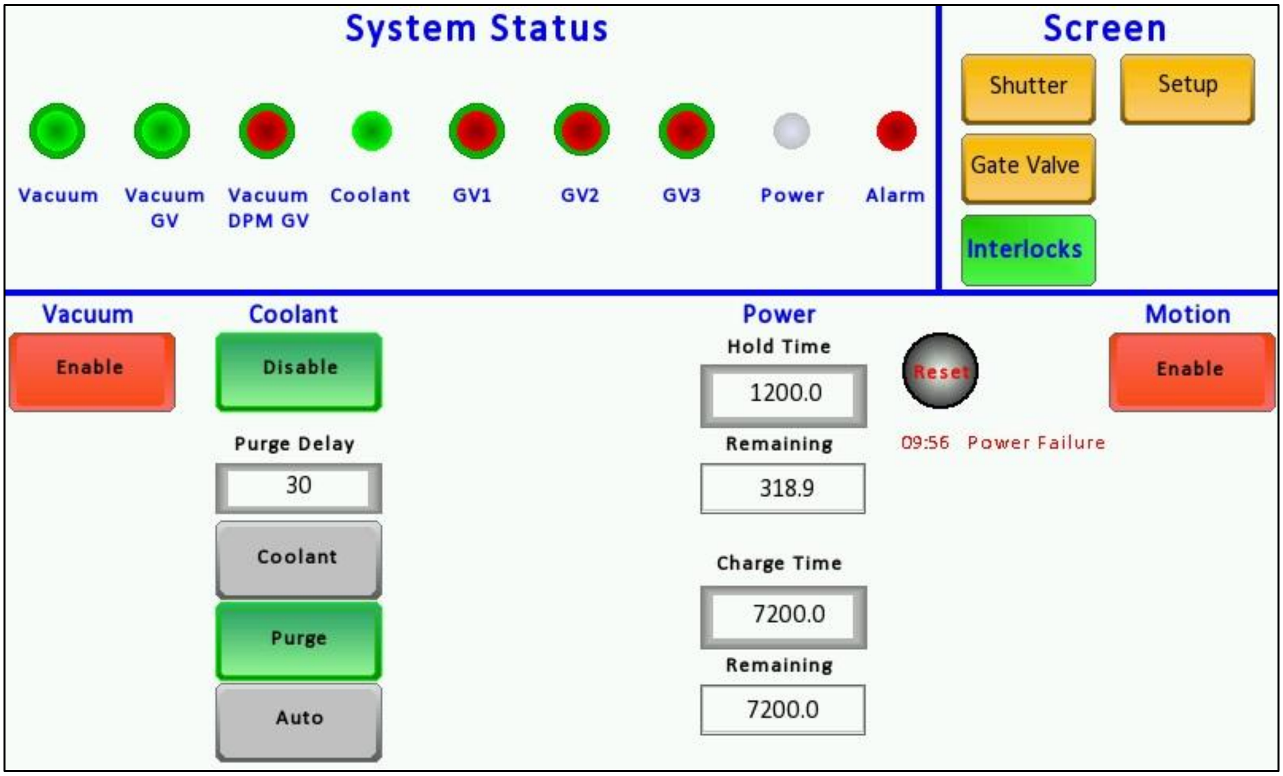


Fig. 7-4 SVICU: Default Interlocks panel (bottom) – Enable/disable Vacuum, Coolant and Motion interlocks, set Coolant Mode and set UPS options (if applicable).

The 'Interlocks' screen (Fig. 7-4) allows the user to enable/disable interlocks for coolant, vacuum and motion.

The coolant mode can be selected from the three options: Purge, Coolant and Auto. A purge delay (time in seconds) can be set.

If Power interlocks are applicable (i.e. the system is equipped with a UPS), the UPS hold time and charge time can be set from the 'Interlocks' screen or via the PC. The hold time indicates the duration which the UPS will provide support for backed-up components before starting the shut-down procedure. The charge time is the duration required to fully charge the UPS. If power failure occurs while the UPS is charging, the system will immediately enter the shut-down procedure.

The Reset button is used to acknowledge any alarms and reset the interlocks if the error conditions that triggered the alarm have been removed.

8 COOLING SYSTEM

8.1 Water cooling

Many components require adequate water cooling for proper and stable operation. For manual systems, this is housed within the linear buffer chamber.

All individual branches with shut-off valves are labelled on the front panel. The source positions are labelled clockwise (top-down view) from the transfer port.

A FESTO flow meter measures the total water flow in the return line. The flow (liters per minute) is displayed on the front water panel. A **trip point** can be set at the flow meter – refer to the FESTO flow meter manual for instructions. If the flow drops below the trip point, the condition will trigger coolant-related interlocks.

Most cooling circuits are emptied on a regular basis due to maintenance or bakeout. In addition, the LN_2 inside the cryogenic panels may cause freezing damage if the water flow is too low. Therefore, it may be necessary to empty the water lines in such cases. For this reason, the coolant system is equipped with electro-pneumatically driven, spring-loaded valves (control valves) that allow easy and automated purging of the coolant circuits. When energized, the valves connect the coolant circuit to the external supply/return lines. In their normal, de-energized state, external supply and return lines are separated from the coolant circuit and then opened towards a purge gas feed (1 bar compressed air) and a pressure-free drain.

The supply and the return lines of a cooling circuit, for example in/out lines of an effusion cell, should be connected to the inlet/supply and outlet/return connection points of the coolant distribution panel.

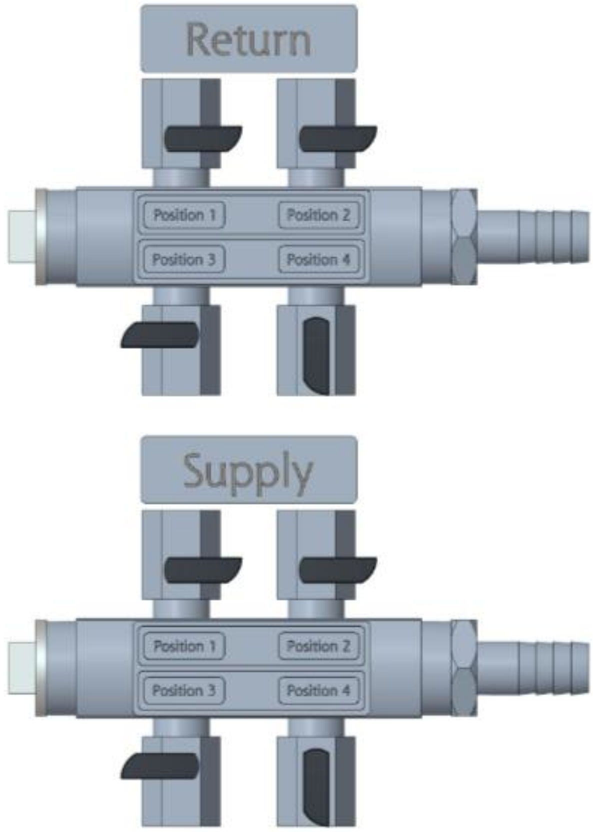


Fig. 8-1 Example of the individual manual valves for water-cooling supply and return lines in the coolant distribution panel. Position 1-3 show the valves in the closed position (i.e. cooling off), and in position 4 the valves are open (i.e. cooling on). Both valves need to be open to allow flow.

NOTICE

Cooling lines can be closed separately on the coolant distribution panel. To avoid high water pressure, the supply (input) valve of a water line should be closed first. Closing a waterline may activate the coolant interlock due to the change in measured return flow.

8.1.1 Linear Buffer Chamber Water-Cooling Box

Within the LBC is a separate water-cooling distribution panel (Fig. 8-2). This is used to supply cooling water to the integrated titanium sublimation pump of the Ion pump. A flow meter on the front panel provides the current flow rate and provides feedback for the safety interlocks. The purge gas (used to purge the cooling lines for bakeout) can be turned on/off from the valve on the front panel.

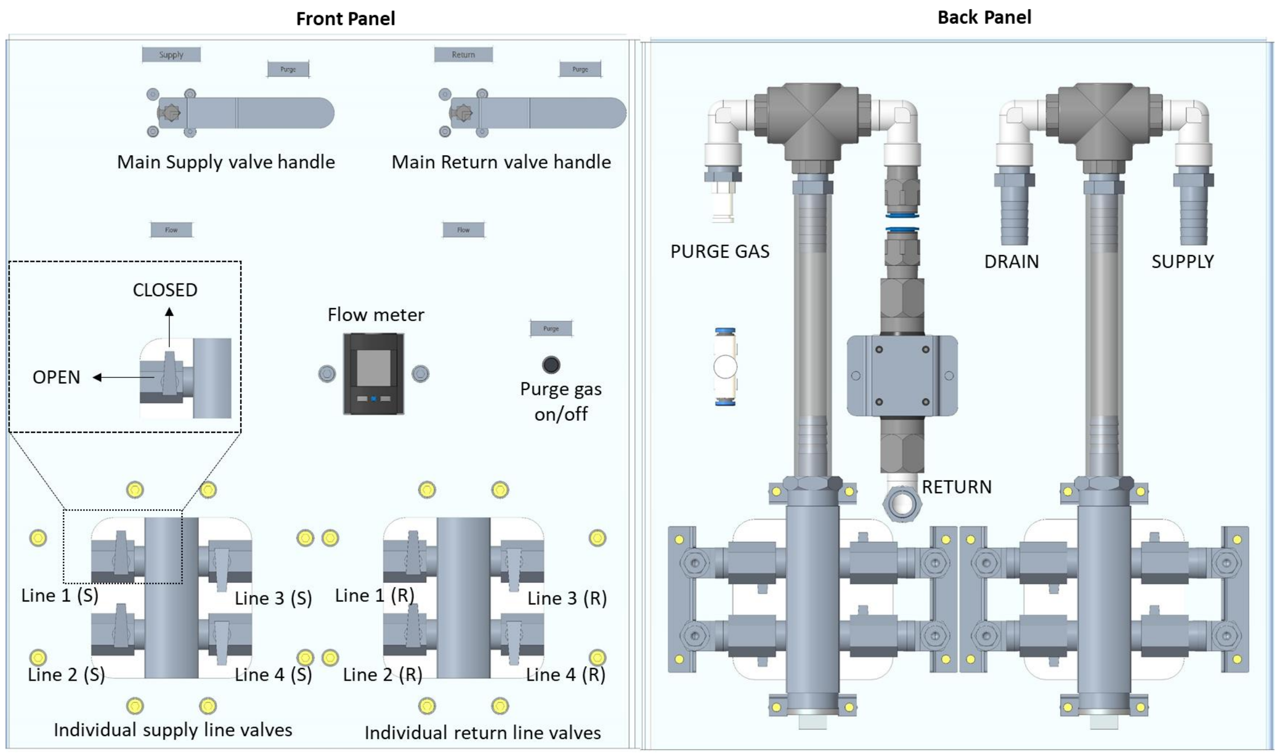


Fig. 8-2 Example of the linear buffer chamber cooling box front panel (left) and back panel (right).

To purge the lines, both manual levers on the front panel must be turned simultaneously to the (horizontal) purge position. Similarly, to fill the coolant lines, both levers must be turned to the flow position (vertical).

Each cooling line can be isolated using the individual supply and return valves (on the lower front panel), both the supply and return valves must be closed. To avoid spikes in the pressure, first close the supply and then the return line.

8.2 Coolant Control

The Coolant status indicator on the touchscreen displays the status of the coolant system and the flow condition.

The Coolant control is accessible from the touchscreen (see section 7.3) and allows one out of three operational modes for the coolant system to be selected: Auto, Purge or Coolant.

8.2.1 Purge Mode

With the selector in ‘Purge’ mode, the control valves are set so that the water lines – provided the shut-off valves are open - are flushed by the supplied gas into the drain.

NOTICE

Gas flow is opposite to the water flow. The valves labelled ‘return’, shut-off the gas supply and the valves labelled ‘supply’, shut-off the drain.

8.2.2 Coolant Mode

In ‘Coolant’ mode, the control valve is forced to allow coolant flow.

⚠WARNING

If water flow is below the trip-point and ‘Coolant mode’ is active, there is a risk that water may freeze in the lines.

8.2.3 Auto Mode

If a cryogenic medium like liquid nitrogen (LN_2) is used for chamber cooling, the cooling system should run in ‘Auto’ mode. In Auto mode, the cooling lines will be automatically purged if the flow rate is detected below the flow trip point. This ensures the lines are empty before the water can freeze in case of a lack of flow.

To restart the coolant flow, the Coolant Mode Selector must be cycled to Purge mode and back to Coolant, or alternatively, the RESET button must be pressed. This will switch the control valve to coolant flow and pause so the flow can establish before it is evaluated.

NOTICE

Independent from the mode selection applied, the system will revert to the purge state under powerless conditions as this is considered the safest state. Failure of the pneumatics will also force the coolant to purge.

⚠WARNING

Do not start the coolant flow when the chamber’s cryogenic shrouds are at very low temperatures for an extended period – this can cause the water entering in-vacuum cooling lines to freeze instantaneously!

8.3 Coolant Manual Override

It is possible to manually override the coolant setting in case of emergency. This can be achieved by turning the blue screw valve located behind the flow meter panel as shown in **Error! Reference source not found.**. This will lock the system in the coolant state (while compressed air is available).

⚠WARNING

Do not manually override the coolant system unless in case of an emergency.

8.4 Liquid Nitrogen Cooling (LN_2)

The cryopanel has multiple functions:

- To improve the vacuum level in a UHV chamber by condensing volatile residual species that are not trapped or removed by the main pumping system. Hence the cryopanel acts as a secondary pumping device. Water (H_2O), carbon monoxide and dioxide (CO & CO_2) and As4 are pumped effectively with a LN_2-cooled cryopanel.
- Enhance the thermal stability and temperature control of components use for growth
- To condense and trap source material emitted from the sources but not incorporated into the growing film.

A cryogenic panel with VBC compatible LN_2 connectors surrounds the upper section of the chamber (Fig. 8-3).

Fig. 8-3 Example of cryopanel surrounding upper chamber section with three VBC connectors.

NOTICE

Ensure the LN_2 filling line is connected to the INLET tube in the chamber. Otherwise, the cooling is not complete. “INLET” or arrow symbol is engraved on the tube.
If water has been used as a coolant in the cryogenic panels, ensure that all water is evacuated from the panels before switching the coolant to LN_2.

⚠WARNING

Risk of frost burn! Contact with freezing liquid can cause burns. Ensure appropriate PPE is worn when handling LN_2.

⚠DANGER

RISK OF EXPLOSION! Ensure the LN_2 “OUTLET” lines are not blocked to prevent overpressure in the LN_2 cryogenic panels.

9 PNEUMATICS

Pneumatics are a key component to the systems operation. The pneumatics use CDA to perform the motions and the electrical signals are controlled using the FESTO controller. This allows remote operation of e-p valves and shutters throughout the system. The pneumatic lines are colored blue and black, these should be connected to the valve positions as shown in **Error! Reference source not found.** or Fig. 9-1.

Pneumatic actuators may need adjustment to increase or decrease the shutter speed setting, this process is described below.

The right-angle valves connected to the blue and black pneumatic lines are indicated by the yellow arrows (**Error! Reference source not found.**Fig. 9-1). To adjust the opening speed, open/close the black line valve (which pressurizes the cylinder during shutter closing and exhausting the cylinder during shutter opening). The closing speed is similarly adjusted by the blue line valve.

To dampen the shutter motion, use the two adjustment screws located on the drive body (red arrows in **Error! Reference source not found.** and Fig. 9-1). The screw closest to the pneumatic valves dampens the opening motion while the opposite screw dampens the closing motion.

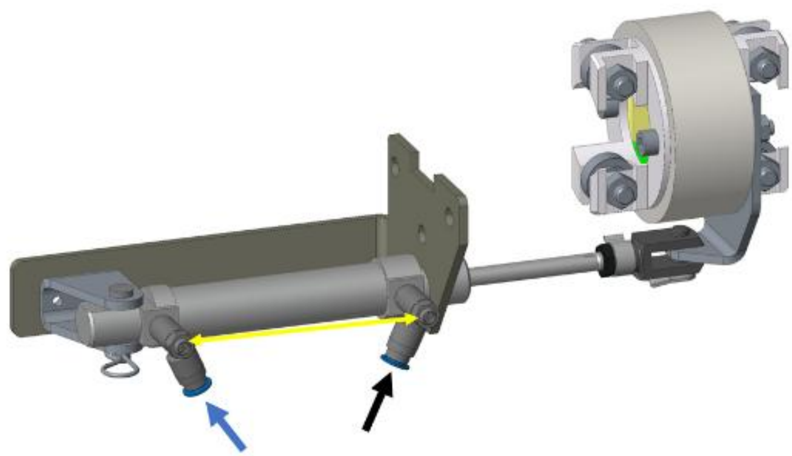


Fig. 9-1 Shutter actuator for integrated linear shutters (e.g. R-Series EC modules). The shutter speed adjustment valves are indicated with yellow arrows. The blue and black arrows represent the pneumatic line inlets.

⚠CAUTION

Insufficient CDA flow may cause GVs or shutters to close unintentionally. This may cause damage to the system if collisions occur. It is recommended that a CDA flow meter is used to monitor the flow rate and alert the user if the flow falls below the recommended level specified in the system requirements.

The FESTO controller (Fig. 9-2) is used to operate the e-p shutters and GVs in the UHV deposition system. The FESTO controller maybe located within the media panel (**Error! Reference source not found.**) or within the LBC support table.

All e-p valves can be shut-off from compressed air simultaneously using the main supply valve (Fig. 9-2, pos. 5).

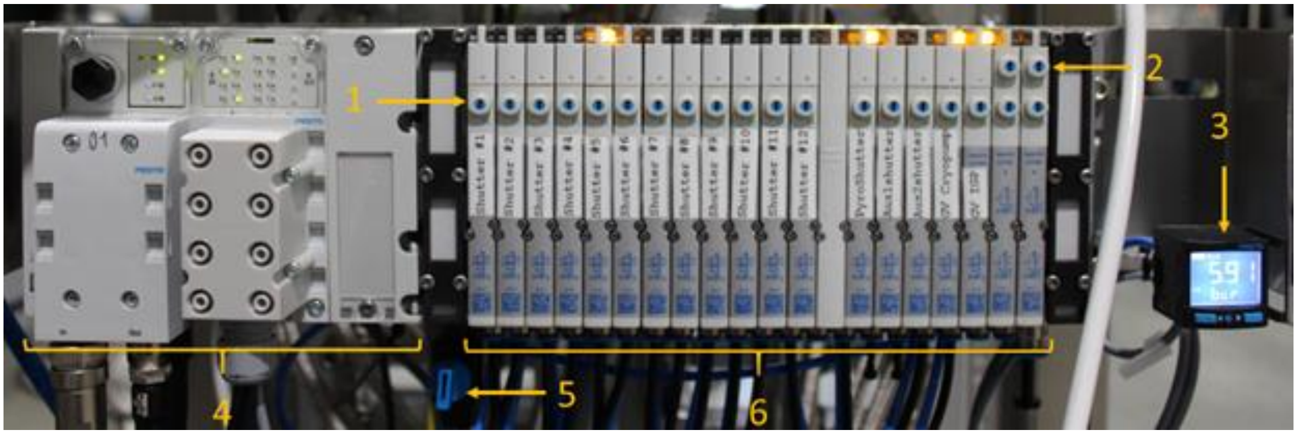


Fig. 9-2 Example FESTO controller for pneumatic valves: 1. Manual override actuator for individual pneumatic lines (single solenoid coil), 2. Manual override actuator (dual solenoid coils), 3. Air flow sensor (if applicable), 4. Digital periphery of FESTO controller with communication Profibus® interface, 5. Compressed air shut-off valve, 6. Pneumatic section of FESTO controller.

The FESTO controller prioritizes the electrical signal over the pneumatic setting, i.e., if a shutter is selected to open from the user interface, the manual override actuator for that shutter (Fig. 9-2, pos. 1) is unresponsive. If however the user interface shows the shutter to be closed, the designated pneumatic actuators can open the shutter.

Dual solenoid valves have two actuators (Fig. 9-2, pos. 2) and perform similarly to that of the single solenoid valves, with the exception that the top/bottom actuator can be used to either close or open the valve or be split between two devices.

Shutters (e.g. sources) are labelled clockwise from the transfer port (as viewed from above).

NOTICE

Refer to the FESTO Controller Manual for detailed operating instructions

10 BAKEOUT SYSTEM

After venting a UHV chamber and exposing it to atmosphere, a bakeout procedure is used to outgas the system, which will remove adsorbed gas species from the chambers' surface and help to achieve base pressure.

The bakeout duration is dependent on the user (typical durations are approx. 48-hours). The bakeout process is programable and can be run using a set recipe file (refer to DCA 03-X Control Software Manual). The bakeout is performed after the on-site installation.

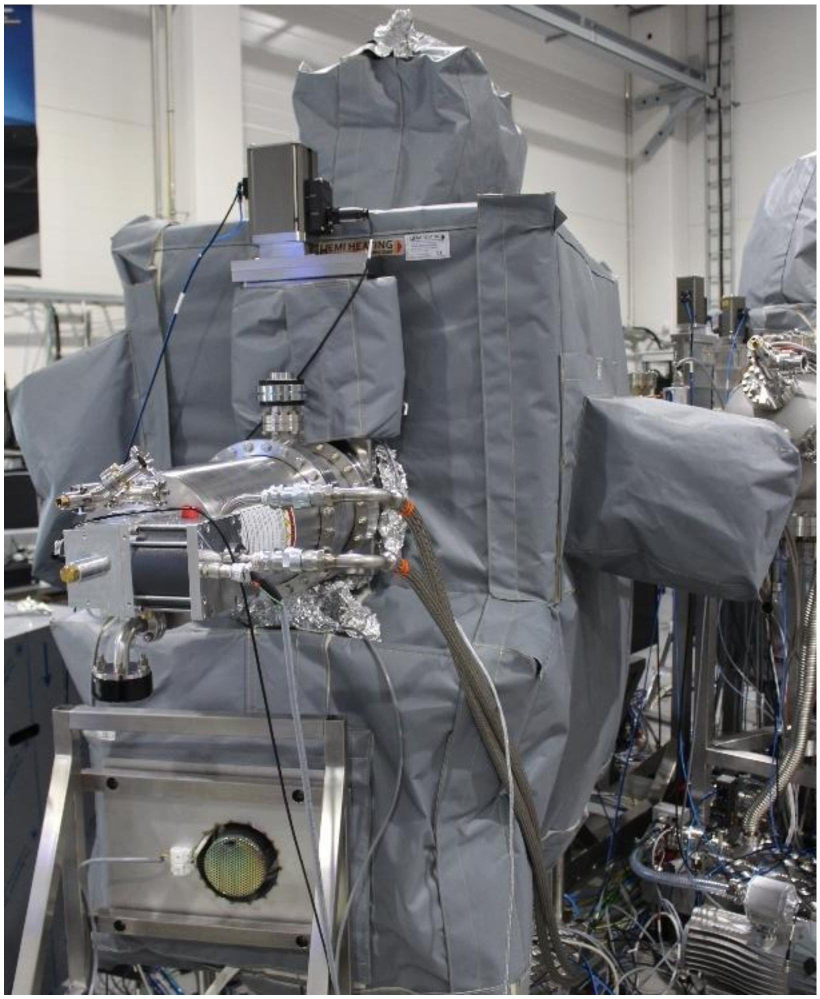


Fig. 10-1 Example of UHV deposition system undergoing bakeout; the bakeout tent (with support frame – not visible), GV heating jacket and bakeout heater are shown.

The bakeout system includes:

- Flexible bakeout tents with high-temperature Velcro fittings for the required tools
- Stainless steel support frame for each tent,
- Mobile bakeout heaters with forced air circulation,
- Temperature controllers with timer and vacuum interlock,

The following additional bakeout items may be included:

- Effusion Cell module heating jacket
- IGP bake-out heater kit

10.1 Bakeout Mode

⚠CAUTION

Refer to the separate DCA UHV System Bakeout Manual and third-party component manuals for bakeout preparation and operating instructions. Improper bakeout protocol may damage components.
Refer to the DCA Technical Specifications document for the maximum bakeout temperatures for the system

To enter Bakeout Mode, connect the interlock cable from the bakeout controller to the similarly labelled cable from the electronic rack. The Bakeout interlock monitors VGC SP2. If the vacuum level exceeds SP2, the bakeout heater will shut down and the timer will pause.

During Bakeout Mode, the motion interlock should be disabled. This is to prevent the audible alarm from activating when the sensors from the motorized components are disconnected.

.

11 SYSTEM INTERLOCKS

In response to certain (error) conditions, specific interlocks may be activated. The term 'interlock' refers to a measure to put and lock a device in a state that is considered safe for the device itself or the integrity of the vacuum system, whichever is applicable.

Interlocks may be either:

- **Non-latching** - interlock resets automatically when the (error) condition is removed, or
- **Latching** – interlock remains active until device is reset by the operator. This prevents devices from returning to normal operation until the overall system status is confirmed to be safe. The 'Alarm' triggered acts as the latching mechanism. The alarm must be deleted to reset the interlock.

Interlocks that can be disabled fall into two groups: Vacuum and Coolant. These interlocks can be disabled from the GUI but should remain enabled whenever possible.

A table summarizing the implemented system interlocks is given below.

Several devices have additional self-protective features built in. The most common units are listed below. Please find detailed descriptions in the respective user manuals.

- Ion gauge filament self-protection (pressure based)
- Turbo pump self-protection (several conditions monitored)
- RGA (pressure based)

⚠CAUTION

Avoid disabling the system interlocks unless the system is standby (i.e. not undergoing transfer, processing). This may lead to system damage and/or user injury!

Table 12 Summary of System Interlocks with activation conditions and the actions implemented to place the system into a safe state.

Interlock	Alarm	Cause	Action	After Alarm Reset
Vacuum - Pump	2.1	Too high pressure for IP	Close pump GV & latch	Open pump GV
Vacuum – Bakeout	2.3	VGC > SP2	Interrupt bake-out heater power (timer continues)	Resume bakeout
Vacuum - Pressure	2.4	VGC > SP3	Close gas supply & latch ET Apply SP2, if SP2 < WSP (Auto) ET Apply A-OP, if A-OP < OP (Man) Cut RF/DC output and latch	
Vacuum - Pressure	2.5	VGC > SP4	Close TMP GV & latch	Open pump GV
Vacuum - TSP	2.5	VGC > SP5	Shut down TSP	
Motion	3	Spatial conflict /collision	Stop motion Sound siren (Manual)	Use emergency jog

Coolant	4	Water flow < trip point	Purge Cut RF/DC output and lock	Change coolant mode to Auto/Cool

12 PROCESS OVERVIEW

The UHV Deposition System is required to undergo multiple preparation steps before the growth process takes place. This chapter gives an overview of the preparation and processes required. This should be used as a general guide only as each system may require special processes that are not described here. An overview of the processes involved is shown in the figures below.

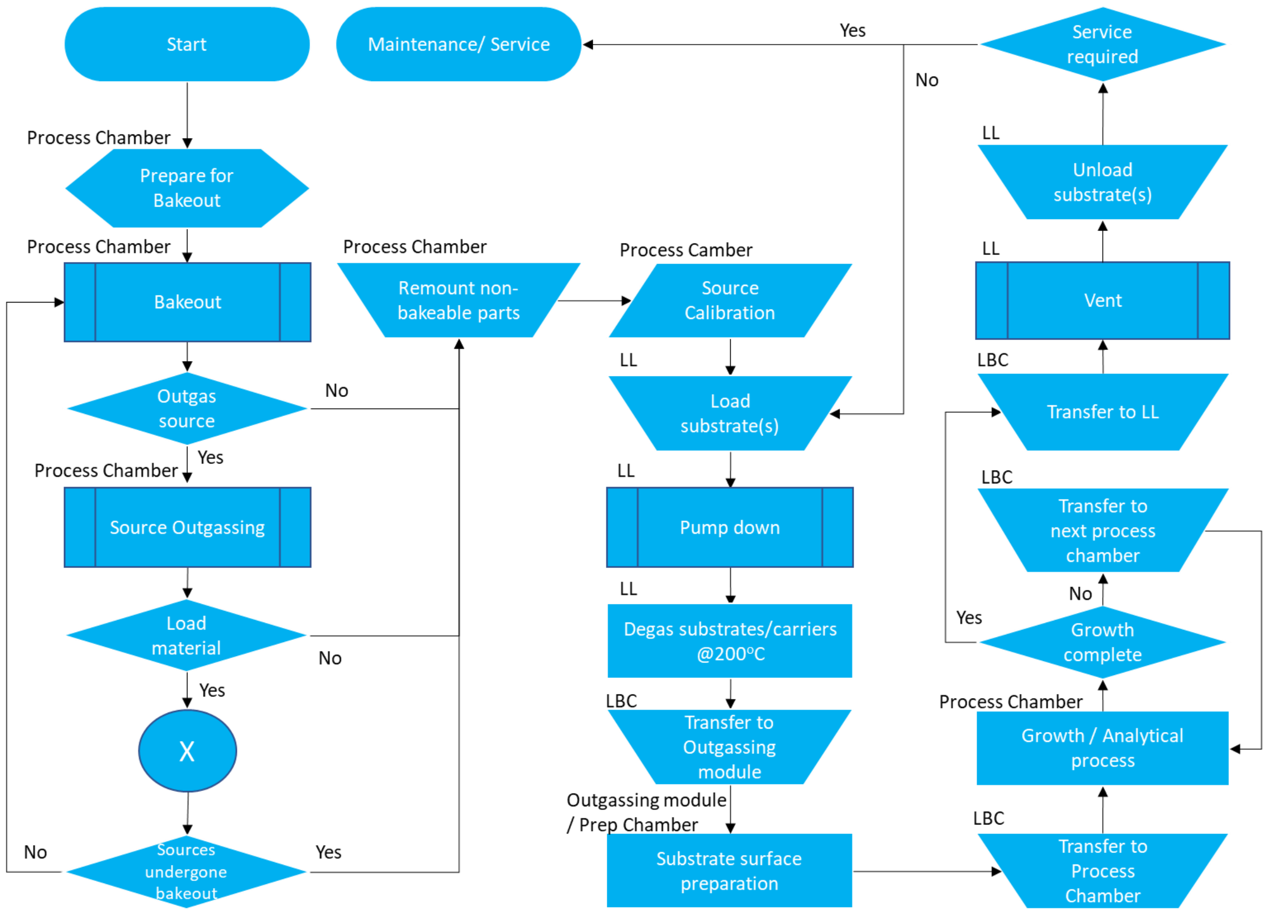


Fig. 12-1 Process overview for the UHV Deposition System with manual transfer.

The list below describes some of the processes required:

- Load / Unload wafers – manual process
- Pump / Vent - automated process performed by the LL
- Transfer
    - performed manually, wafers must be loaded/unloaded using the magnetically coupled pick-up manipulators and transfer arm.
- Substrate surface preparation - may be performed within the LBC outgassing module equipped with a high temperature heating stage or a dedicated sample preparation chamber.
- Process (Deposition/ Cleaning/ Analysis) – performed in the following tool: R-Series chamber.
- Bakeout – performed prior to system operation to remove residual gases and allow the system to achieve base pressure.

13 DESCRIPTION OF WORKSTATIONS

The UHV deposition system has multiple workstations available. The system can be operated from the following locations:

a) At the process chamber's electronic rack via the component peripheries and/or Human Machine Interface (HMI) such as the Shutter Valve Interlock Control Unit (SVICU) for manual systems.
b) At the process chamber, using a remote control for performing jog-operations of the motors or using an analytical component.
c) Remote operation from the desktop PC installed with DCA's Control Software, which is supplied for process chamber. Each PC is positioned within a suitable proximity of the system so that operation can be viewed and halted if necessary.

14 PREPARATION

14.1 How to Transport and Store the System

⚠WARNING

RISK OF TILTING! Always use lifting tools when lifting the machinery. Only lift machinery when it is placed on a pallet and securely fastened.

HEAVY WEIGHTS! – Do not attempt to lift items that exceed 25kg without the assistance of a lifting tool. Use the hooks on the components/system provided to ensure it is attached securely.

Sources, manipulators, and analytical tools should be removed from the system for transport. Solid protective covers must be placed over the in-vacuum regions of these components. Manipulators, sources, and analytical components must be placed horizontally (i.e., supported by the mounting flange) within a suitable sized container. Sufficient padding should be used to secure the item in place and minimize the vibrations during transportation.

Chambers must be secured using support frames within a suitable sized container.

Always make sure that the system is fixed/ secured during transportation, so there is no possibility of sudden movements and or instability.

Transport of the system shall be done by qualified personnel only.

If hazardous/toxic materials have been deposited with the system or source, check the transportation regulations for the correct shipping labels and forms required.

14.1.1 Lifting, handling, and transporting the components

To lift the components safely:

1. Use the designated hooks provided on the components and system when connecting to lifting tools.
2. Move slowly and ensure the component is well supported to prevent it from colliding with nearby objects.
3. Avoid touching the in-vacuum region of the component/system unless wearing clean-room compatible gloves.
4. When placing the component on a surface, ensure it is supported by the mounting flange/support frame that can withstand the weight and that it is stable (i.e., will not freely rotate or topple) without support.

To handle the system/components safely:

1. Consult individual component manuals before handling, mounting, or disassembling.
2. Do NOT disconnect cables from components before switching off the power.
3. Handle outer vacuum sections only using UHV cleanroom compatible gloves.
4. DO NOT handle in-vacuum parts that may be contaminated with material.

14.1.2 Storing the system

ALWAYS store the system/products in a dry, clean, well-ventilated area.

To protect the system/product from dust it should be sealed within a plastic film/wrap.

Store the system/products out of reach of unauthorized persons and do not allow persons unfamiliar with the system or these instructions to unpack the containers.

14.1.3 Installation of the UHV Deposition System

⚠CAUTION

Installation of the UHV Deposition System must only be performed by DCA Instruments technical personnel. The Warranty will be voided if the system has been installed by an outside company/individual not directly authorized by DCA Instruments. For the installation of individual components, consult the individual component manuals.

Prior to operation, the UHV deposition system will be fully mechanical and electrically assembled and connected to the necessary services at the installation site (e.g. electricity, water, gas). The system will be placed under bakeout after the installation.

14.1.4 Reduction of noise

If possible, it is recommended to install He compressors in a separate room to minimize the output noise. The room must be in close proximity to the system (10-20m).

14.1.5 Training of operators

DCA Instruments will train the system operators during the system installation and commissioning at the customer site.

This will include the following aspects:

- Safety features and interlock
- Best practice for operating the system
- Demonstration of system specifications (base pressure, manipulator temperature etc.)
- Identification of components and basic operation
- Cooling system connections and operation
- Software training
- Set-up for system bakeout process

14.1.6 Commissioning the system

The system will be commissioned by DCA Instruments after completing a site acceptance test (SAT) and training of the system operators. During the SAT, the system is tested mechanically, electrically, and performance-wise to ensure it fulfils the SAT specifications.

All safety features related to power, motion, vacuum, and cooling will be checked and confirmed they are fully functional.

14.2 Returning products

To return product to DCA for inspection or repair, follow the guidance in 14.1.1.

14.2.1 DCA products and (non-DCA products still under Warranty)

1. If the product has been installed with the system and in contact with materials, the user must complete the DCA contamination report form and email it to DCA at support@dca.fi along with a description of the issue. Include a copy of the form with the product. An RMA# will be provided.
2. Ensure the product is packed securely with sufficient packing material to minimize the risk of damage or movement within the container.
3. Send the product to the following address and provide a tracking number:
   DCA Instrument Oy
4. Once received, DCA will inspect the product and issue a quotation (if required).
5. After receival of the PO, the item is repaired, tested, and then repacked along with the test and repair report.
6. A notification email will be sent when the item is ready for shipment and a tracking number will be provided.

14.2.2 Non-DCA products (post-Warranty)

Contact the product manufacturer for information on repairs.

Contact the DCA sales department (aftersales@dca.fi) for quotations relating to component accessories or replacement products.

14.3 Removing components from the UHV Chamber

14.3.1 Prepare the laboratory

1. Cool down the process chamber so that it is ready to open.
2. Check an Ar gas supply line is readily available.
3. Check that sharp parts/edges are not exposed in the working area near the process chamber.
4. Arrange as much working space as possible to allow room to maneuver.
5. Prepare flat platforms in front of the flange where the component will be removed.

14.3.2 Prepare the glove bag

1. Clean all tools needed to ensure they are UHV clean (i.e. free of dust/grease)
2. Cut a small hole in the glove bag for the Ar gas supply tube with a valve, fix in position with a cable tie and seal with tape if needed.
3. As before, cut a small hole for the outlet tubing with valve, this should be connected to a scroll pump.
4. Fill glove bag with the needed parts required for the service (e.g. crucible, blank flange, screws etc.), tools, extra gloves, Al foil, clean boxes.

14.3.3 Perform the service

1. Mount the glove bag using cable ties to the component flange that requires service.
2. Filling the bag with Ar, stop the flow and check for leaks (be careful not to over fill).
3. If no leaks are present, flush the glove bag 10-12 times (i.e., fill the glove bag with Ar and pump out, repeat the process to ensure the atmosphere in the glove bag is clean).
4. Vent the process chamber to 105% (slightly over pressure) with Ar.
5. Dismount the component flange. Ar flow should be from the process chamber to the glove bag, if not, increase the Ar supply to the chamber slightly.
6. Perform the necessary service on the component.
7. Once complete, remount the source with a new gasket to close the process chamber.

8. Stop the Ar supply to the chamber.
9. Remove the glove bag from the flange, empty the contents and dispose of the bag according to the guidelines for any toxic materials that may have contaminated it.

14.4 Helium Leak Check

A Helium leak check is an essential part of the UHV system maintenance and should be performed regularly, especially after the following scenarios:

- Servicing the system
- Performing a bakeout process

14.4.1 Recommendations on how to perform a He Leak Check

1. Start the RGA software from the PC, and switch on filament and electron multiplier using the software.
2. Let the RGA settle for few minutes.
3. Start He leak test mode.
4. Pay attention to He level, in normal conditions the level is less than 10^{-11} Torr. If it is higher, this indicates there may be an issue with the pumping system or the cryogenic pump may be saturated and needs to be regenerated.
5. Adjust the He flow rate to be relatively high (~0.1 bar) for the first stage of the leak check. At this stage it is important to establish if there is a leak or not in the system.
6. Always start the process from the top part of the vacuum chamber (as He is lighter than air). Check each flange pair, the welding seams, and other possible sources for a leak. Note that it is also possible that a leak can appear through the chamber wall material, a bellows welding, or even through blank flange.
7. If the Helium level is shown to be increasing, then there is a leak in the system. A sudden increase indicates the leak is near, while a slow increase indicates the leak is further away.
8. If a leak is present and the general area of the leak has been located, reduce the helium flow to minimum in order to pinpoint the leak area more accurately. The helium flow is low enough when it can be barely felt with the tip of the tongue.
9. Once the point of the leak is located it can be fixed by replacing the part or sealing the leak point.

TIP: Occasionally sudden spikes (up and down) may appear, which are normally indicate an error with the RGA electronics unit. Most often these errors are caused by electrical charge changes near or on the unit by accidentally touching the electronics unit or the cables.

NOTICE

Refer to the separate SRS RGA Manual for operating instructions.

15 SYSTEM OPERATION

15.1 System Start-Up

Before performing the system start-up, check the following:

1. All cabling is correctly connected to components and power supplies.
2. The water-cooling distributor is operational, and the flow is above the trip-point.
3. The leakage current breaker and fuses are in good order.
4. Gases (e.g., CDA, N_2-vent) are connected with the specified pressure.
5. Consult the individual component manuals on their start-up procedures.

15.1.1 Switching on the System

The system is equipped with a switch to power up the system (Fig. 15-1). This is located in the top section of the electronic rack with the Master EPO system.

Fig. 15-1 System switch located in the electronic rack with Power and Run LEDs.

To power up the system:

1. Turn the switch to the 'Start' position. The status indicators 'Power' and 'Run' are lit when the EPO system and the PSUs within the racks have power.
2. The switch will then lock into the 'On' position during the system operation.
3. If the switch is only turned to the 'On' position (i.e. not all the way to 'Start'), only the EPO system will be powered and only the 'Power' status LED will be lit.

15.2 System Shut Down

Only perform the complete system shut down when performing maintenance/repair of internal components, or if the system will be in an idle state for a long duration.

To perform system shut-down:

1. Cool down all sources and components with hot elements (e.g. manipulators, IG). Consult the individual component manuals on the correct shut-down procedure.
2. Allow the cryopanel(s) to warm to room-temperature.
3. When all heaters and the cryopanel are at room-temperature, stop the water-cooling and purge the water-cooling lines (GUI-Cooling-Purge Mode).
4. Vent the system according to the process described in Section **Error! Reference source not found.**.
5. Turn power off PSUs in the electronic racks, then disconnect cables if necessary.
6. The system switch can be turned to the off position to fully power down the system.

15.3 What to Do in Emergency Situations

15.3.1 Emergency Power Off (EPO)

At the top of every electronic rack is an EPO button. Pressing this will immediately shut-down power to the entire system. The EPO should only be pressed in the event of the following scenarios:

- Electrical hazard – there is a build-up of charge in the system or an electrical fault that poses an immediate risk to users.
- Explosive/flammable hazard – chemical reactions inside the chamber that may lead to a flammable or explosive hazard.
- Rapid chamber vacuum loss – if the chamber has suddenly experienced a large vacuum leak and there is a risk of damage to hot elements or gases reacting with the outside atmosphere.

⚠CAUTION

Only use the EPO in case of emergency. Improper shut-down procedures can cause damage to parts of the system.

15.4 System Pump-down (Manual System)

15.4.1 Load lock pump-down / Loading wafers

1. Once the substrates/wafers are loaded into the trolley, place the trolley onto the rails in the LL and check the Viton© door seal is clean. Close the door securely using the latch and fastening knob to ensure a good seal.
2. Check the LL vacuum gauge controller (VGC-LL) is switched on.
3. Start the turbo pump by pressing the ON/OFF button on the controller (Fig. 15-2) in the ER.
4. Monitor the pressure status from the VGC-LL to ensure the LL is not pumping against a leak.
5. Enable the vacuum interlock once the turbo pump is operating at full speed and the pressure is $<10^{-5}$ Torr.

Fig. 15-2 Control unit (OMNI Controller) for the HiPace turbo molecular pump (TMP) with Start/Stop button.

NOTICE

The TMP gate valve is interlocked against both the TMP (pump speed) status and the chamber pressure; therefore, the Vacuum Interlock must be disabled on the *SVICU* Interlock Menu.

Refer to the OMNI Controller manual and HiPace Turbo Molecular Pump manuals for detailed operating and maintenance instructions.

15.4.2 Load lock degassing

In order to maintain the UHV conditions in the rest of the system, it is important to degas the trolley, substrates, and carriers in the load lock before transferring the trolley to the LBC.

The degas process can be started from the LL Heater controller (in the electronic rack) by pressing the green button. The temperature and duration are preset to 200ºC and 30minutes. These settings may be modified using the Eurotherm on the front panel of the LL heater controller.

NOTICE

Refer to the Eurotherm manual for detailed operating instructions.

15.4.3 Linear Buffer Chamber (LBC) Pump-down

The linear buffer chamber is roughed via the LL turbo pump. To achieve UHV conditions, an Ion Pump (IP) is used alongside a water-cooled titanium sublimation pump (TSP) for additional pumping capacity. The IP and TSP are operated from the controllers located in the electronic rack (Fig. 15-3).

Fig. 15-3 Agilent UHV4 Ion pump (IP) controller (left) and TSP controller (right).

To start the LBC pump down:

1. Check the LL is vented and the gate valve separating the LBC from the LL is open.
2. Perform the LL pump-down process described in section 15.4.1.
3. Monitor the load lock vacuum gauge controller (VGC-LL) until the pressure is below $1x10^{-4}$ Torr, and switch on the LBC-VGC.
4. Switch on the IP controller in the electronic rack to supply power to the LBC-IP. When VGC-LBC has achieved a pressure < 1×10^{-6} Torr (recommended), touch “HV-1” and “HV-on” at the same time.
5. Close the LL-GV to provide a UHV seal to the linear buffer chamber.
6. To achieve base pressure in the LBC, perform the bakeout process. Refer to the DCA System Bakeout Guide for instructions.

7. After bakeout, start water-cooling to the TSP (refer to section 8.1.1). You can turn on TSP by selecting filament and then select "Sublimation on". You need to confirm this with arrows and press "Set".

NOTICE

Refer to the Agilent 4UHV & TSP Manual for bakeout preparation and operating instructions

15.4.4 Process Chamber Pump-down

The pump-down process is dependent on the pumping system equipped with the chamber as well as the initial condition. The following pump-down process can be applied in the following events:

a) After complete chamber/system shutdown (all pumps are turned off),
b) After a short service period (pumps are operational and isolated from the chamber)

Process A (After complete system shutdown)

1. If the chamber is equipped with a turbo molecular pump:
    a. Check the Vacuum interlock is *DISABLED* from the SVICU. This prevents the turbo pump isolation gate valve from closing during the pump down process as it is interlocked against the pump speed.
    b. Start the TMP from the pump's control panel in the electronic rack (Fig. 15-2).
2. Switch on the chamber's vacuum gauge controller (VGC-D#).
3. When the pressure is < 3x 10^{-5} Torr, *ENABLE the* Vacuum interlock (if not already enabled).
4. Switch on the IP from the 4UHV controller (from the electronic rack) to supply power to the ion pump and start the ion pump from the home screen.
5. Monitor the chamber pressure from the vacuum gauge controller to ensure the pump(s) are not pumping against a leak. Perform a He leak check if the chamber pressure has not reached the expected vacuum level within the expected time, see section 14.4 for advice on performing a leak check.
6. Once UHV has been reached, the chamber can undergo bakeout to achieve the base pressure for the chamber. Refer to the separate DCA Bakeout Guide for instructions.
7. After bakeout allow the system to cool to room temperature.
8. At room temperature, water-cooling can be started by setting the Coolant Control on the SVICU Interlock menu to *AUTO* or *COOLANT* mode. Check the valves in the water-cooling distribution panel are in the correct position for the required sources and components.
9. Once water-flow is established and stable, the cryopanels can be filled with LN_2 for additional pumping capacity. Set the coolant mode to AUTO.
10. The chamber is ready for processing when the base pressure is has been achieved.

Process B (After short service period)

1. If the chamber is equipped with a turbo molecular pump:
    a. Check the Vacuum interlock is *DISABLED* from the SVICU. This prevents the turbo pump isolation gate valve from closing during the pump down process as it is interlocked against the pump speed.
    b. Start the TMP from the pump's control panel in the electronic rack (Fig. 15-2).
2. Switch on the chamber's vacuum gauge controller (VGC-D#).
3. When the pressure is < 3x 10^{-5} Torr, *ENABLE the* Vacuum interlock (if not already enabled).
4. Open the ion pump isolation gate valve.
5. Monitor the chamber pressure from the vacuum gauge controller to ensure the pumps are not pumping against a leak. Perform a He leak check if the chamber pressure has not reached the expected vacuum level within the expected time, see section 14.4 for advice on performing a leak check.

6. Once UHV has been reached, the chamber can undergo bakeout to achieve the base pressure for the chamber. Refer to the separate DCA Bakeout Guide for instructions.
7. After bakeout allow the system to cool to room temperature.
8. At room temperature, water-cooling can be started by setting the Coolant Control on the SVICU Interlock menu to *AUTO* or *COOLANT* mode. Check the valves in the water-cooling distribution panel are in the correct position for the required sources and components.
9. Once water-flow is established and stable, the cryopanels can be filled with LN_2 for additional pumping capacity. Set the coolant mode to AUTO.
10. The chamber is ready for processing when the base pressure is has been achieved.

15.5 System Venting (Manual System)

Venting the tools may be necessary when performing routine system maintenance, but it is otherwise avoided to maintain the UHV conditions of the chambers. The LL however will be regularly vented when loading the sample cassette.

NOTICE

Use dry nitrogen gas for venting. The nitrogen venting panel is equipped with a pressure regulator to protect the system from overpressure.

15.5.1 Load Lock Venting

1. Release the door clamp to avoid overpressure building up in the load lock.
2. Check the wafer trolley position and close the manual gate valve that separates the load lock from the linear buffer line.
3. Stop the turbo pump from the Omni controller in the electronic rack by pressing the Start/Stop button.
4. If required, use manual vent/Nupro valve, **but only when the pump speed is < 50rpm.**
5. Follow the vacuum level on the vacuum gauge controller until it reaches atmospheric pressure, and the door can be easily opened.

15.5.2 Linear Buffer Chamber (LBC) Venting

The LBC is vented via the LL using the following procedure:

1. Check that the transfer gate valves to the adjacent process chambers are closed.
2. Check that the load lock is pumped down and open the manual gate valve to the LBC.
3. Switch off the titanium sublimation pump from the TSP controller in the electronic rack.
4. To prevent condensation forming in the chamber, stop the water-cooling to the TSP and allow to warm to room temperature. Purge the lines from the water-cooling box mounted in the LBC support table (see section 8.1.1).
5. Switch off the ion pump from the 4UHV.
6. Turn off ion gauge filaments in the linear buffer chamber and allow the filaments to cool down sufficiently (approx. 1 minute).
7. Vent the load lock, see section 15.5.1.

15.5.3 Process Chamber Venting

There are two options for chamber venting depending on the purpose:

a) For prolonged periods or extensive maintenance, where the entire chamber will be vented i.e. all pumps will be switched off.
b) For shorter periods to perform material loading for quick servicing e.g., exchanging components/filaments, in which case particular pumps may remain operational but isolated from the process chamber.

1. Check the transfer gate valve to the linear buffer chamber is closed.
2. Perform the shut-down procedure for all sources and analytical components mounted to the chamber, consult the individual manuals for instructions.
3. To avoid condensation forming inside the chamber, stop LN_2 cooling and ensure all cooled parts (e.g. cryopanels) are brought to room temperature.
4. Stop the water-cooling by setting the cooling mode to Purge (from the chamber's SVICU interlock menu). Do NOT start the Purge process if any LN_2 remains in the cryopanel.
5. Disable the Vacuum Interlock from the SVICU interlock menu.
6. If the chamber is not equipped with a convectron gauge, the ion gauge filament must also be turned off (from the Inficon controller) otherwise it can remain on.
7. If not already disabled, disable the Vacuum interlock from the SVICU Interlock menu.

Option A (extensive maintenance/prolonged shut-down):

8. Turn off the IP/TSP from the controller in the electronic rack, ensure the IP-GV remains open.
9. If the chamber is equipped with a TMP, press the Start/Stop button on the controller in the electronic rack to initiate the venting process. The chamber will be vented via the automated vent line connected to the TMP. The disabled vacuum interlock will ensure that the TMP-GV remains open during this process.
10. Once fully vented, the all-metal valves can be closed, and the vacuum gauge controller can be turned off.

⚠CAUTION

For systems manually vented without a convectron gauge, there is a risk of overpressure build up in the chamber. Caution must be applied to during the venting process, and venting should be halted when the pressure approaches atmosphere. Overpressure can lead to a burst rupture disk in the cryogenic pump.

Option B (short duration/quick service):

8. Close the isolation gate valve for the ion pump (if applicable). This pump will remain operational during the venting process but will be isolated from the main chamber.
9. Press the Start/Stop button on the controller in the electronic rack to initiate the venting process. The chamber will be vented via the automated vent line connected to the TMP. The disabled vacuum interlock will ensure that the TMP-GV remains open during this process.
10. The service may now be performed, see also section 14.3.

15.6 Performing Transfers (Manual System)

⚠CAUTION

Always check the pressure status of the chambers before opening gate valves. Acceptable tolerance of chamber pressure difference between is 50 Torr. However, for the integrity of the system, DCA strongly recommends that valves should be opened with pressure differential < 5x10^{-5} Torr (to avoid particle transport).

⚠CAUTION

Risk of system damage! Pay close attention when operating the system with interlocks disabled!

15.6.1 LBC Transfer

To minimize particle disruption during transfer it is important to:

- Check that the chamber modules have minimal pressure differential when opening the manual transfer gate valves,
- When moving the trolley through the LBC using the magnetically coupled rotary actuators, ensure the motion is smooth and slow,

Position the trolley beneath the spring-loaded pick-up manipulator (PUM). The PUM bayonet should be pushed down directly above the carrier and rotated to lock the bayonet in place. The PUM can then be slowly released to lift up the carrier from the trolley. Remove the trolley from the transfer position and repeat the process to transfer the carrier to the transfer arm cup or return to another trolley position.

15.6.2 Process Chamber Transfer

Transferring wafers to and from the process chamber takes place using the magnetically-coupled transfer arm and substrate manipulator.

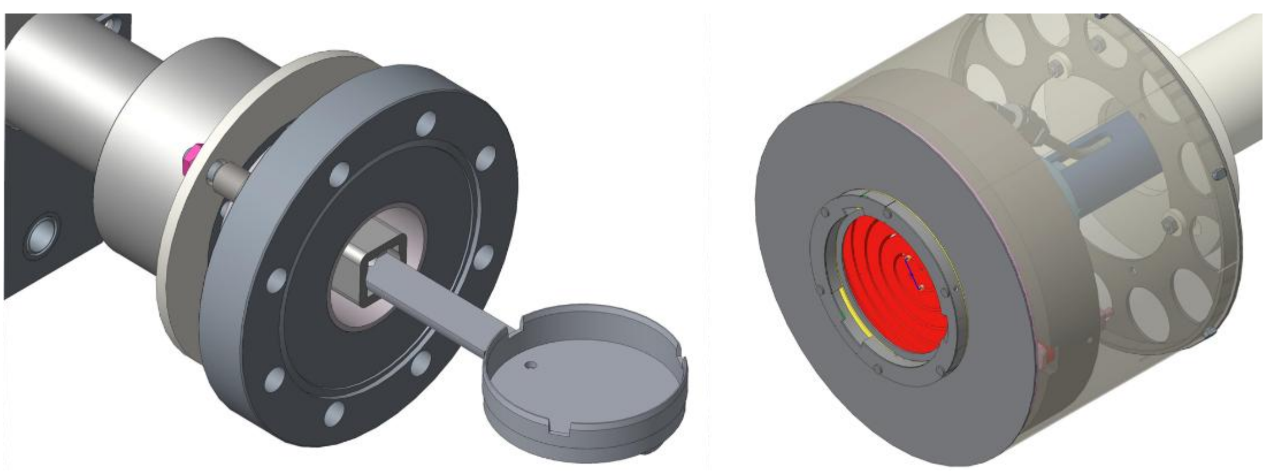


Fig. 15-4 Example of a transfer arm cup (left) and sample manipulator head (right) showing the slot indents of both.

The substrate manipulator is equipped with motorized drives for sample rotation (MCU-RS) and vertical linear motion (MCU-Z or PSU-Z).

The MCU-Z and MCU-RS have pre-set positions (SP1, SP2, and Home). These pre-sets can be adjusted at the MCU. The factory setting for the ‘Home’ position rotates the manipulator head to align with bayonet cup lines. Minimal corrections may be required for the wafer carrier ‘legs’ to slot into the transfer cup openings. The SP1 factory setting is configured to be the lowest z-position that does not conflict with the transfer cup.

For a PSU-Z, there are no available pre-sets, and the vertical motion is performed using a manual jog controller.

NOTICE

Refer to the separate DCA Substrate Manipulator MCU drives for operating instructions.

⚠WARNING

Risk of collision! Do not use MCU SPs to directly lower the manipulator into the transfer cup for loading/unloading.

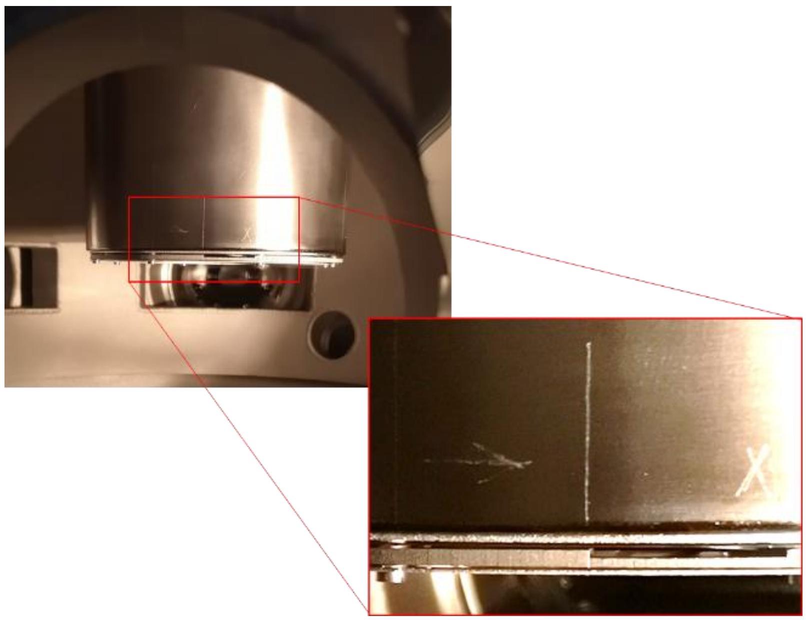
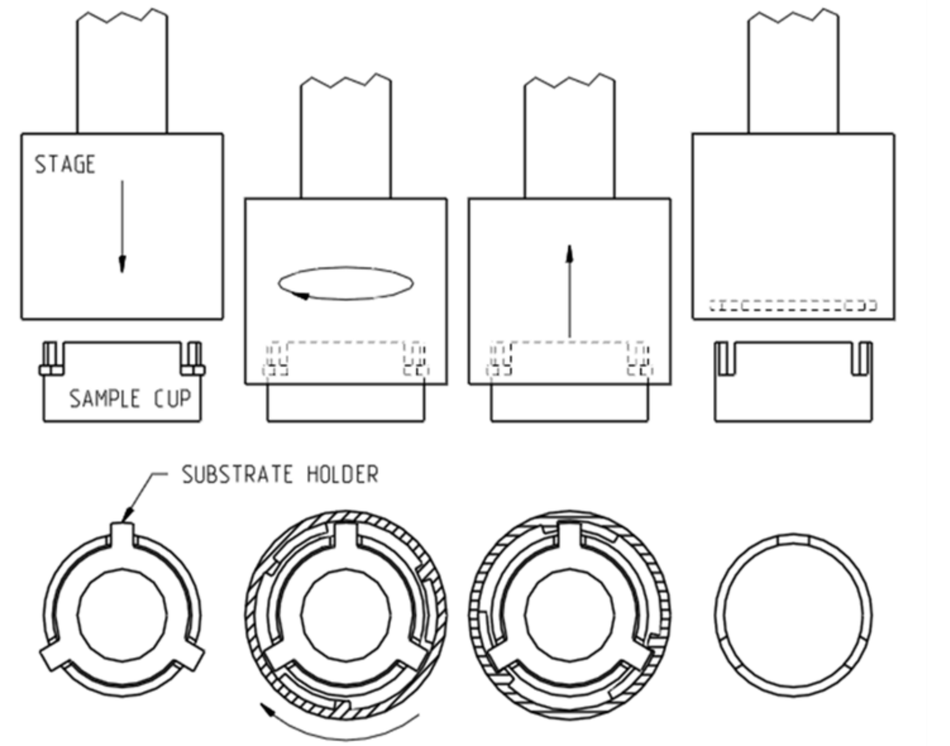


Fig. 15-5 Photograph shows the markings where the carrier pins may enter the sample stage (arrow) and when they are locked in position (X).

15.6.3 Wafer Transfer to the Chamber



Wafer carrier in transfer cup. Carefully lower stage into the transfer cup.

Stage and wafer carrier engaged. Rotate stage CW.

Wafer carrier locked in stage bayonet. Retract heater stage.

Wafer carrier in heater stage. Loading complete.

Fig. 15-6 Step-by-step process for loading a sample to the manipulator stage.

To load a wafer, perform the following steps:

1. Press Home on MCU-RS.
2. Open the TGV (ensure pressure difference is within a suitable range).
3. Slide the transfer arm with the sample into the chamber.
4. Lower the substrate manipulator to transfer position:
   a. For PSU-Z, use the manual jog to lower the manipulator to just above the transfer position.
5. Jog the manipulator RS drive 30° in clockwise direction.
6. Slowly lower the manipulator head to fit into the bayonet cup using the Z jog.
7. To lock the bayonet in place, (i.e. when both cups are engaged) slowly jog RS **(clockwise)** until the mechanical limit is reached. Then reverse slightly in the opposite direction to release any possible tension.
8. Retract the sample manipulator
   a. For PSU-Z, use the manual jog controller to fully retract.
9. Retract the transfer arm.
10. Close the TGV.

15.6.4 Wafer Transfer from the Chamber

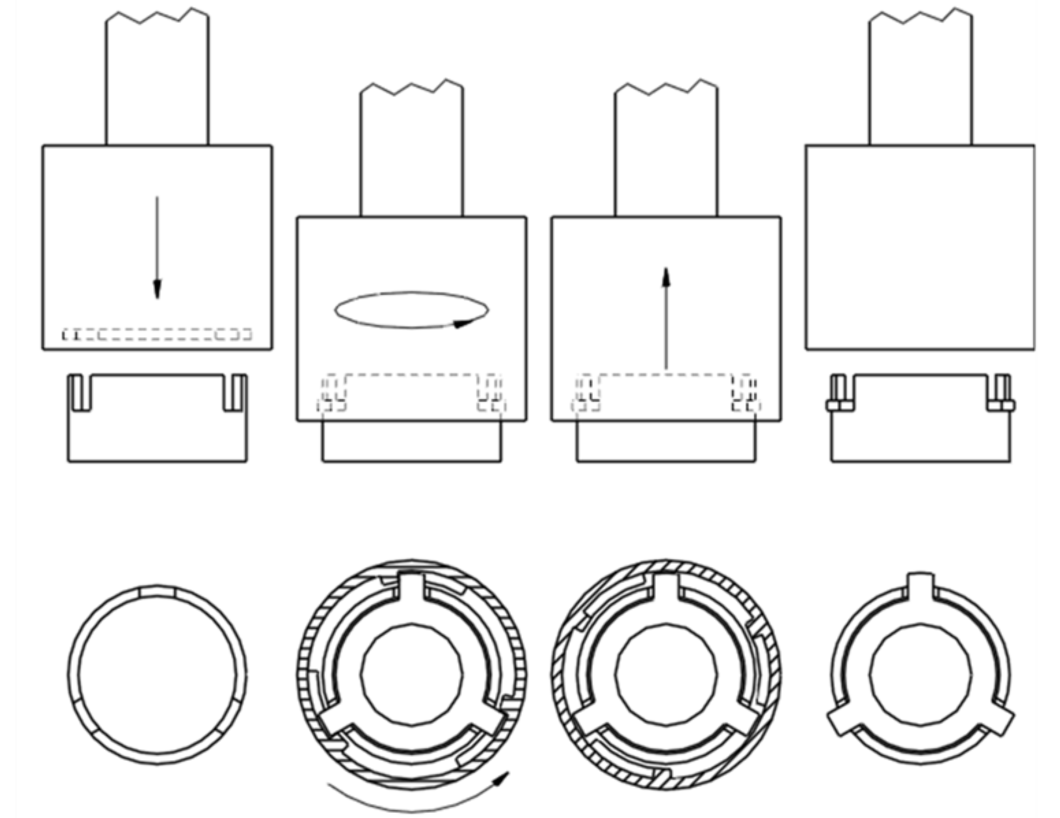


Fig. 15-7 Step-by-step process for unloading a wafer from the manipulator stage.

To load a wafer, perform the following steps:

1. Press Home on MCU-RS and SP1 on MCU-Z.
2. Open the TGV (ensure pressure difference is <0.5Torr).
3. Slide the empty transfer cup into the chamber.
4. Slowly lower the manipulator into the bayonet cup using the Z jog.
5. To unlock the bayonet, (i.e. when both cups are engaged) slowly jog RS **(counterclockwise)** until the mechanical limit is reached. Then reverse slightly in the opposite direction to release any possible tension.
6. Retract the sample manipulator.
7. Retract the transfer arm.
8. Close the TGV.

⚠CAUTION

Always monitor the transfer through the VP. If any tension or pressure is observed on the manipulator stage or transfer arm, immediately abort the transfer, and readjust the position to ensure a smooth transfer.

16 MAINTENANCE

Regular inspection and maintenance of the UHV system is recommended to ensure the system operates at maximum efficiency and achieves optimal processing performance.

This chapter provides a brief checklist of DCA and non-DCA components that should be regularly checked throughout the system lifetime.

16.1 Pumps

The following pumps are provided with the system and the parts that require maintenance are listed.

Pump	Maintenance required	Maintenance interval
Turbo molecular Pump (Pfeiffer HiPace):	Lubrication and bearing exchange	
Rough pump (Pfeiffer):	Exchange tip seal, gaskets, and bearings	6-12 months
Titanium sublimation pump (Agilent):	Exchange filaments	

16.2 Electrical

The following electrical tests should be performed regularly:

- Breaker
- Leakage current breaker (LCB)
- Grounding

Additional electrical maintenance:

- Exchange any cables or connectors that appear to be worn or damaged.
- The uninterruptable power supply (UPS) battery has a set lifetime dependent on usage (approx. three years). The battery should be monitored for the suggested replacement date – refer to the separate component manual.

16.3 Mechanical

16.3.1 Gears

Gears require regular lubrication especially after the bakeout process (recommended after at least 200hrs bakeout)

The following components should be checked:

- Valved cracker source (DCA)
- Substrate manipulator (DCA)
- Motorized beam flux monitor (DCA)
- Motorized quartz crystal microbalance (DCA)
- Robot assembly in the CDC
- Load lock/storage chamber cassette drives

Refer to the maintenance section in the individual DCA component manuals on how to perform the lubrication.

16.3.2 Screws

Check and tighten any loose screws in the following:

- Support tables and feet,
- Adjustment screws,
- Locking screws at motor clutches,
- Locking screws of XY-table of robot axes.

16.3.3 Bearings

Bearings of the DCA substrate manipulator and CDC robot assembly need to be exchanged regularly. The interval depends on several factors, e.g., materials used in the system, usage, and the number of baking cycles.

If the bearings are damaged, this can cause jarred/uneven motion and may even result in damage to the system if the error occurs during transfer. It is therefore recommended to contact DCA for a maintenance service if the motion appears irregular. Consult the DCA factory before attempting to exchange the bearings.

16.4 Cleaning

Cleaning can be performed using a dedicated vacuum cleaner or lint-free (cleanroom compatible) wipes with IPA/Ethanol to remove dust.

The frequency of cleaning the system depends on the deposited materials and the usage. Heavily contaminated surfaces should be cleaned to prevent flakes of material from peeling off and affecting the deposition.

Check the following:

- Chamber shrouds,
- Shields
- Shutter blades
- Drives (and any moveable parts)

16.5 General

Regular leak checks should be performed to ensure a good base pressure is maintained.
Filament/cathode exchange may be required in ion gauges and the hydrogen atom beam source.
Effusion cells do not require additional maintenance except for cleaning/degassing when loading new material.
If gases are present, check gas sensors are operational and are in good working order to prevent overexposure.

16.6 Replacing product labelling

Replacement safety labels may be ordered from the manufacturer. The location of the safety labels is given in Table 1.

17 DISPOSAL

17.1 How to Dispose the System

To dispose the system:

1. Clean all components and chambers from hazardous materials using a professional and authorized company.
2. The chambers are stainless steel and so can be recycled as metal scrap.
3. For all other components, consult the individual manuals.

17.1.1 Disposal of electronic components

The symbol on the machine, the accessories or packaging indicates that this device must not be treated as unsorted municipal waste but must be collected separately! Dispose of the device via a collection point for the recycling of waste electrical and electronic equipment if you live within the EU and in other European countries that operate separate collection systems for waste electrical and electronic equipment. By disposing of the device in the proper manner, you help to avoid possible hazards for the environment and public health that could otherwise be caused by improper treatment of waste equipment. The recycling of materials contributes to the conservation of natural resources. Therefore, do not dispose of your old electrical and electronic equipment with the unsorted municipal waste.

17.1.2 Disposal of packaging waste

Retain packaging if possible until the system is no longer needed. The same packaging should be used when returning products to the manufacturer for repairs.

The packaging is made of environmentally friendly materials, which may be disposed through your local recycling facilities. By disposing of the packaging and packaging waste in the proper manner, you help to avoid possible hazards for the environment and public health. The symbol on the packaging indicates that the packaging is made of PAP.

17.1.3 Disposal of batteries

The machine contains a battery. Batteries may not be disposed of with the usual domestic waste. They may contain toxic heavy metals and are subject to hazard our waste regulations. For this reason, dispose of used rechargeable batteries at a local collection point.

18 WARRANTY

I. DCA Instruments warrants that the UHV deposition system is free from defects in material and workmanship for a period of 12 months from the completed installation date.

II. DCA Instruments shall incur no liability under this warranty if

   a. the allegedly defective goods are not returned prepaid to DCA Instruments within thirty (30) days of the discovery of the alleged defect and in accordance with DCA Instruments' repair procedures; or
   b. DCA Instruments' tests disclose that the alleged defect is not due to defects in material or workmanship.

III. DCA Instruments' liability shall be limited to either repair or replacement of the defective goods, at DCA Instruments' option.

IV. DCA Instruments makes no express or implied warranties regarding the quality, merchantability, or fitness for a particular purpose beyond those that appear in the applicable DCA Instruments user's documentation. DCA Instruments shall not be responsible for consequential, incidental or punitive damage, including, but not limited to, loss of profits or damages to business or business relations. This warranty is in lieu of all other warranties.

V. Upon expiration of the system warranty, DCA Instruments will release the source code under the following strict conditions:

   a. DCA Instruments software support will be limited to the version written and delivered by DCA Instruments.
   b. The source code is not circulated outside the lab.
   c. No support or upgrade will be offered by DCA Instruments to any and all MBE control software modified by the customer.

NOTICE

UHV systems are delicate instruments. DCA Instruments is not responsible for proper handling, disposal and putting safety into action.

19 APPENDIX I – SYSTEM REQUIREMENTS

During the installation service provided by DCA, all necessary assembly will be completed, and all the components included in the system will be mounted for initial testing. After the installation service, the system is ready for bakeout. Check the individual manuals for instructions on how to start-up after maintenance or repair.

19.1 Electricity

Line Voltage (Phase-Phase), nominal: 400 VAC, 50 Hz

Module	Rack	Inlet Fuse	Connection
LL&B	LL&B	3x 32A	CEE Plug 32A (3L+N+PE, 6h, IP44)
D1	D1.1	3x 63 A	CEE Plug 63A (3L+N+PE, 6h, IP44)

Standard set-up is approx. 4m cable (free length) entering the rack through the top cover.
Remote pumps and power supplies are wired through the system's power panels (EPO system).
DCA recommends separating the power supply for the PCs.

19.2 Gases

		Compressed Air	Nitrogen	Oxygen
Min.	psig	87.9	2.9	19
	bar	6.0	0.2	1,3
Max.	psig	117.2	14.6	35,2
	bar	8.0	1.0	2,4
Flow		pneumatic drives, coolant purge-out: < 9 l/s	For venting	HIC: < 5 sccm
Connection		FESTO Quick Star 8mm	FESTO Quick Star 6mm	Swagelok 4VCR (male at system inlet)
Quality		filtered (<40µm), lubricated (oil:VG32)	dry, clean, oil-free	6N or better

This system has one connection point for: compressed air, nitrogen, argon, and hydrogen.

For location of connection points see the Vacuum and Gas Diagram provided.

19.3 Cooling Water

Quality - filtered, mechanically clean, optically clear, no turbidity, no sediments, chemically neutral.

Cooling-water property	
Oxygen content:	max. 4 mg/kg
Chloride content:	max. 100 mg/kg
Calcium carbonate content:	max. 75 ppm
Consumption of potassium permanganate:	max. 10 mg/kg
Carbon dioxide content:	undetectable
Ammonia content:	undetectable
Resistivity:	min. 500 kOhm cm
pH-value:	7- 8
Temperature:	15-30 °C
Inlet Pressure:	max. 4.5 bar
Pressure differential:	min. 2.5 bar

19.4 Water Flow

				Flow (l/min)			
			QTY	Spec	Measured	Subtotal	Total
D1 (R450)	TMP HP1200		1	1,7			1,7
	Water Distribution Panel w/ e-p purge						4,5
		Manipulator	External	-			
		Cells	7	0,5		3,5	
		Atom source	1	1,0		1,0	
		TSP	1	0,5		0,5	
Buffer	TSP		1	2,0		2,0	2,0
						L/min	8,2
						Gal/min	2,2

	Connection type (Hose fitting)		
	Supply	Return [7]	Drain [8]
TMP	8mm [9]	8mm	
Water distribution panel	19mm [10, 11]	19mm[11]	19mm[11]

19.5 Cryopanel Cooling

Cooling panels with VBC connectors:

Chamber	Connection	Mating Connector[12]
R-Series	1x Supply, 2x Return (1 Return is blanked off)	VBC Male

[7] The water system does not have any mechanism for removing air from the lines. During start-up (recover from purge-mode), the residual gas in the lines is pushed into the RETURN branch which then needs an external device for de-aerating.

[8] Open return (non-pressurized). In purge-mode the mixture of purge gas and water is pushed into the DRAIN branch.

[9] Hose OD 8 mm

[10] Hose ID 19 mm

[11] One connection point per line. Lines are internally distributed. Location of connection points: see drawing.

[12] Drawings available on request

19.6 Safe Earth-Ground

Min. 16mm^2 Cu wire to common system's grounding plate (<3 m).
Min 25 mm^2 Cu wire to common system's grounding plate (<8 m)
Min [50x1] mm^2 Cu strap to common system's grounding plate (<20 m)

19.7 Climate

Humidity (rel):	5-75 % non-condensing
Room temperature:	18-25^{o}C

19.8 Technical specifications

Chamber	Max. Bakeout Temp. (°C)	Base pressure [13] (Torr)
R-Series	200	$< 5 \times 10^{-10}$
LBC	200	$< 10^{-9}$
LL	N/A	$< 2 \times 10^{-6}$ $< 5 \times 10^{-8}$

19.9 Factory Settings

19.9.1 Gases

Compressed air: 4-6 bar (60-90 psi)
Oxygen: 1,3 bar (19,0 psi)
Nitrogen: 1.0 bar (15 psi)

19.9.2 Vacuum Gauge Controller – Set-points

The VGC are factory set in Torr, but this be changed to mbar (using the Inficon software).
These set-points can be modified by qualified personnel. The modification procedure is described in the Inficon VGC manual.

The vacuum setpoints below are used to activate particular interlocks to protect the system and the user(s) in the event of error conditions (see section 11).

[13] Base pressure of process chambers is after 72-hr bakeout and LN_2-cooled cryopanels (if applicable). For LL, the base pressure is given after a 30-min pump down and after performing the outgassing.

Chamber	R-Series	LBC	LL
SP1 (ATS Transfer)	-	-	-
SP2 (Bakeout)	8.00E-06 (Low) 8.50E-06 (High)	8.00E-06 (Low) 8.50E-06 (High)	8.00E-06 (Low) 8.50E-06 (High)
SP3 (Vacuum-1)	1.00E-05 (Low) 1.50E-05 (High)	1.00E-05 (Low) 1.50E-05 (High)	1.00E-05 (Low) 1.50E-05 (High)
SP4 (Vacuum-2)	-	4.00E-05 (Low) 4.50E-05 (High)	-
SP5 (Vacuum-2)	8.00E-06 (Low) 8.50E-06 (High)	8.00E-06 (Low) 8.50E-06 (High)	-
SP6 (Vented)	7.40E+02 (low) 7.60E+02 (High)	-	7.40E+02 (low) 7.60E+02 (High

Vacuum-1: Process, LL GV
Vacuum-2: TSP Gate valve
Vacuum-3: Titanium sublimation pump

20 APPENDIX II - ACCESSORIES, CONSUMABLES, AND SPARE PARTS

For ordering accessories, consumables and/or spare parts, please contact:

DCA Instruments Oy
Aerotie 6, Turku 20360 Finland
sales@dca.fi
+358 2 238 2500

20.1 Supplied accessories/components

Manufacturer	Item Description	Model
Agilent	Ion Pump & controller Titanium sublimation pump & controller	Vacion Plus, 4UHV
Bronkhorst	Mass flow controller	
Comet	RF generator Matching Network	Cito/Cito Plus AGS
DCA Instruments	Beam Flux Monitor (BFM) DCAX- RF Source Effusion cells	
Eurotherm	PID Controller	3500 Series
Inficon	Vacuum Gauge Controller Inficon ion gauge PGE050	VGC083A Ion gauge Convectron
Julabo	OMEC cell heating bath	Magio MS-BC4
MKS	Baratron	AA02A DA02B
Pfeiffer Vacuum	Turbo molecular Pump Scroll pump	HiPace 80 Neo, HiPace 1200 OMNI Control 200, DCU002 HiScroll6, HiScroll12
SRS	Residual gas analyzer	RGA200
TDK-Lamba	Power supplies	Genesys Programmable DC PSU
VAT	Gate valves AMRAV	

20.2 Consumables

DCA #	Item	Description
CRUCIBLES		
11029	PBN - 23cc	
39756	Al2O3 - 23cc	
11040	Tungsten - 10cc	

PLASMA SOURCE CAVITY		
14228	Quartz Discharge Bulb (w/ 37x 0.5mm Ø holes)	8165-672-21_B

20.3 Spare/replacement parts

DCA #	Item	Description
GASKETS		
10075	Gasket DN16CF	Copper Silvered
10077	Gasket DN40CF	Copper Silvered
12375	Gasket Oversized – DN40CF	Copper Silvered, ID 38.8mm
12341	Gasket DN50CF	Copper Silvered, for LN2 FT in cryopanel
10081	Gasket DN63CF	Copper Silvered
10084	Gasket DN100CF	Copper Silvered
10086	Gasket DN160CF	Copper Silvered
10088	Gasket DN200CF	Copper Silvered
10100	Gasket DN250CF	Copper Silvered
10097	Gasket Wheeler DN450WS	Copper wire seal 2mm, R450 chamber
VIEWPORTS		
10121	Viewport DN63CF	VPZ63 MOORE'S EVIC
11994	Viewport Lead Glass Screen	DN100CF 100mm VPZ100LG MOOREÍS
10371	Viewport RHEED Screen DN160CF	AISI304 STAIB
10373	RHEED Screen DN100CF	AISI304 STAIB
CARRIERS		
40112	10x10 (2” carrier)	2287-140-03
	2” Flag type	2274-045-09

21 APPENDIX IV - RELATED DOCUMENTATION

#	Document Title	Version #	Author
1	02_Bakeout System User Manual	2.4	DCA Instruments
2	03_Control Software User Manual	1.0	DCA Instruments
3	05_Substrate Manipulator User Manual	1.3	DCA Instruments
4	06_Beam Flux Monitor User Manual	1.01	DCA Instruments
5	8.12_Substrate Manipulator Drive (MCU-RS, PSU-Z)	1.0	DCA Instruments
6	8.6_ Throttle Valve Drive (MCU-TV)	1.01	DCA Instruments
7	10.1_High-Temperature Effusion Cell (HTEC)	1.01	DCA Instruments
8	10.5_Low Temperature Effusion Cell (LTEC)	1.0	DCA Instruments
9	11_RF Atom Source DCAX-60/30	1.0	DCA Instruments
10	12_ Metal Organic Precursor Injector Source (MOPI)	1.01	DCA Instruments
11	DCA_MCU-VA_v. GAL 1.3	1.3	DCA Instruments
12	DCA Test Reports	-	DCA Instruments
13	DCA Electrical Wiring diagrams	-	DCA Instruments
14	Vacion Plus 300 Ion Pump		Agilent
15	4UHV Ion pump controller		Agilent
16	Titanium sublimation pump controller		Agilent
17	Mass flow controller (MFC)		Bronkhorst
18	AGS Matching Network		Comet
19	citoPlus RF Generator		Comet
20	3500 Series and 3216 Process Controllers		Eurotherm
21	Pneumatics Valve Terminal Type MPA	534241	FESTO
22	Pressure Sensor	SPAN	FESTO
23	Water flow meter	SFAW	FESTO
24	Vacuum gauge Controller VGC083A		Inficon
25	PGE050 convectron		Inficon
26	Heating Circulator MS Magio		Julabo
27	Baratron		MKS
28	HiPace 80 Neo /1200 TMP		Pfeiffer Vacuum

29	Electronic Drive Unit OMNI Control		Pfeiffer Vacuum
30	Display and Operating Unit DCU 002		Pfeiffer Vacuum
31	HiScroll 6, 12		Pfeiffer Vacuum
32	RGA Operation manual		Stanford Research System
33	Genesys Programmable DC PSs		TDK Lambda
34	VPI valve		Varian
35	UHV Gate Valves & AMRAVs		VAT

22 APPENDIX V - DECLARATION OF CONFORMITY FOR MACHINERY

EC declaration of conformity (DoC) of the machinery
Declaration according to Directive 2006/42/EC, as amended (hereafter called Machinery Directive). This language version of the declaration is verified by the manufacturer (original declaration).

We (manufacturer):

Business name: DCA Instruments
Address: Aerotie 6, FIN-20360 Turku
Country: FINLAND

Declare under our sole responsibility for the following machinery:

Generic denomination: Multi-Chamber MBE Deposition System
Function: Deposition of thin film materials on semiconductor wafers
Model: R450, Buffer, LL
Type: R450 with manual transfer & Bufferline
Serial number: 2287
Commercial Name: UHV material deposition system:

that all the relevant provisions of the Machinery Directive are fulfilled,

that the machinery also complies with the provisions of the following European Directives:

- **DIRECTIVE 2014/30/EU relating to electromagnetic compatibility**
- **DIRECTIVE 2014/35/EU relating to low voltage**

that the machinery is in conformity with the following standards and/or other normative documents:

- EN ISO 12100-1, Safety of machinery. General principles for design. Part 1: Basic terminology, methodology
- EN ISO 12100-2+A1, Safety of machinery. General principles for design. Part 2: Technical principles and specifications
- EN 60204-1, Safety of machinery. Electrical equipment of machines. General requirements
- EN 50081-1, Electromagnetic compatibility (EMC). Generic emission standard
- EN 50082-1, Electromagnetic compatibility (EMC). Generic immunity standard

Place and date of issue (of this DoC): Turku, Finland 6 June 2025

Signed by or for the manufacturer:

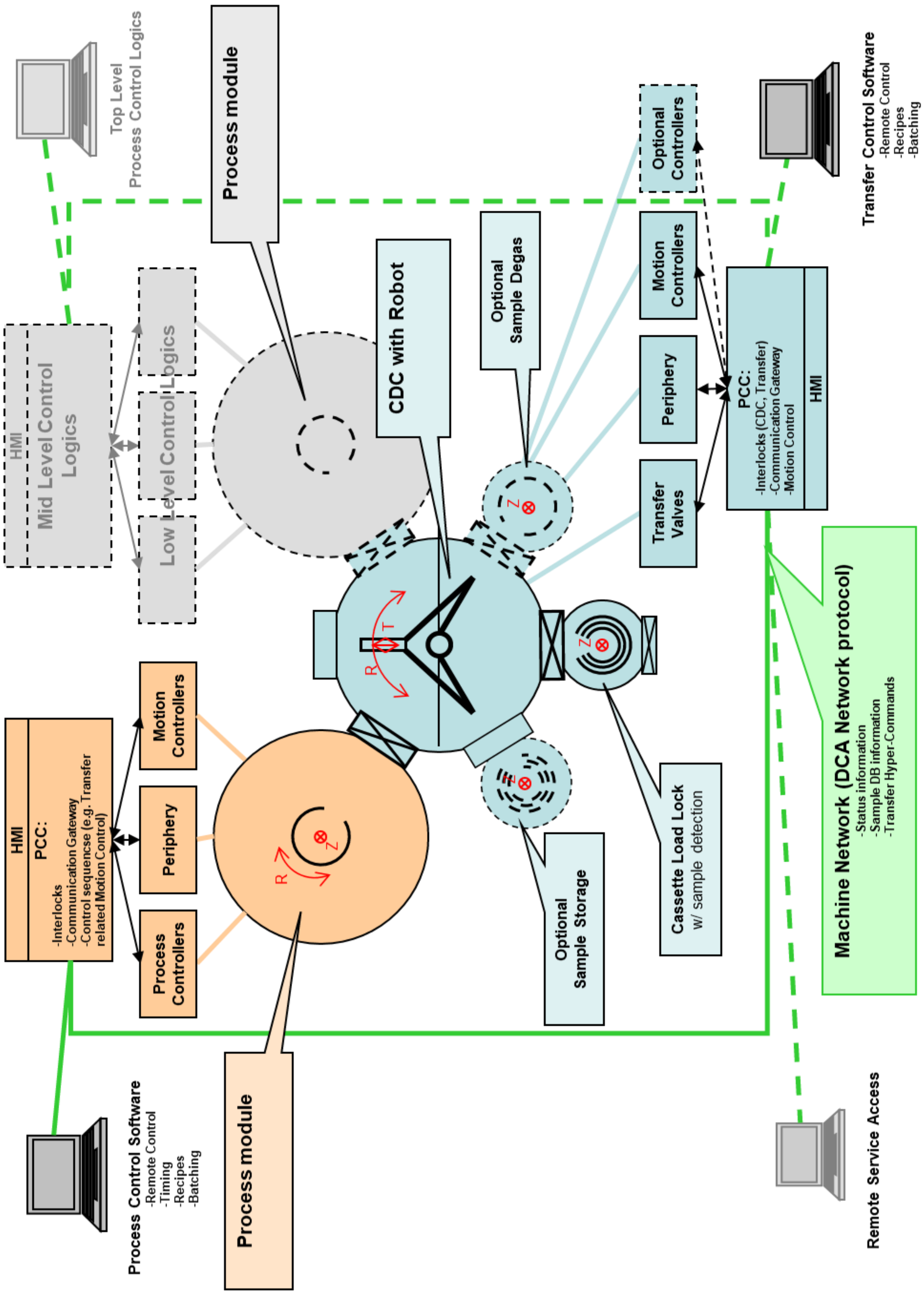
DCA Instruments Oy
Turku, Finland

Name: Heini Jalkanen
Title: CEO

23 APPENDIX VI - SCHEMATICS

Item	Drawing #
Gas & Vacuum	2287_P&ID_v2
Complete System	2287-000-01____28-04-2025
LL	2287-100
Carrier assembly	2287-140
Buffer	2287-200____20-03-2025
Buffer bake-out	2287-231_B
R-Series Chamber	2287-300____12-05-2025
Bakeout tent	2287-341
EC nipple	2287-360
BFM	365-10
Substrate manipulator	2287-440_B
LTEC cell	662-20
HTEC cell	660-01
Main Shutter	2287-363
Rack D1	2287-510-01_B
Rack LL-Buffer	2287-511-01
MOPI source	2287-640_B
OMEC-cell	2287-660
Gas Panel	2287-730_B

24 APPENDIX VII – PCC MONITORING, CONTROL & COMMUNICATION



25 GLOSSARY

Explain the meaning of all terms used in this document.

Term	Meaning
AAS	Atomic absorption spectroscopy
AC/DC	Alternating/direct current
AMRAV	All metal right angle valve
ATS	Automated transfer system
BEP	Beam equivalent pressure
BFM/BFC	Beam flux monitor/Beam flux calibrator
CCG	Cold cathode gauge
CDA	Compressed dried air
CDC	Central distribution chamber
CMVC	Corrosive material valved cracker source
CRP	Cryogenic pump
CF	ConFlat Varian flange
CM	Capacitance Manometer
CV	Convection gauge
D#	Deposition chamber # (e.g. 1,2,3)
Diff/DPM	Differential pumping module/manifold
EBS/EG	Electron beam source/ E-beam gun
EC	Effusion cell
EIES	Electron impact emission spectroscopy
EMO	Emergency motion off
E-P/E-pn	Electro-pneumatic
EPO	Emergency power off
ET	Eurotherm
FT	Feedthrough
GSM	Global System for Mobile communication
GUI	General user interface
GV	Gate valve
HABS	Hydrogen atom beam source
HMI	Human machine interface
HTEC	High temperature effusion cell
ID	Inner diameter
IG	Ion gauge

IGP/IP	Ion getter pump / Ion pump
INTL	Interlock
IR	Infrared
LBC	Linear buffer chamber
LED	Light emitting diode
LL	Load lock
LTL	Loading tool (for automated transfer systems only)
LTEC	Low temperature effusion cell
MBE	Molecular beam epitaxy
MCU	Motor control unit
MFC	Mass flow controller
MPC	Multi-pump controller (for Titanium Sublimation Pump/Ion Pump)
MPS	Mobile pumping stage
MS	Main shutter
OD	Outer diameter
ODS	Ozone delivery system
OFC	Oxygen-free copper
OP	Optical pyrometer
P2A	Pressure to atmosphere
PBN	Pyrolytic Boron Nitride
PCC	PC-based controller (automated system)
PID	Proportional integral derivative
PLC	Programmable logic controller
PLV	Piezo leak valve
PRS	Phosphorus recovery system
PSU	Power supply unit
PUM	Pick-up manipulator
QCC/QCM	Quartz crystal controller/microbalance
RF	Radio frequency
RGA	Residual gas analyzer
RHEED	Reflection High-Energy Electron Diffraction
RP	Rough Pump
RPM	Rotations per minute
RTC	Rotary transfer cup
SOV	Shut-off valve
SP#	Set-point #

ST	Storage chamber
STEC-SF	Standard temperature effusion cell - single filament
STEC-DF	Standard temperature effusion cell dual filament (Ta)
STEC-PBN	Standard temperature effusion cell PBN dual filament
SVICU	Shutters, valves, interlocks control unit
TC	Thermocouple
TGV	Transfer gate valve
TMP	Turbo molecular pump
TP	Touchscreen panel
TSP	Titanium sublimation pump
UHV	Ultra-high vacuum
UPS	Uninterruptable power supply
VBC	Vacuum Barrier Corporation
VGC	Vacuum gauge controller
VP / VPS	Viewport / Viewport shutter
Xfer	Transfer
Xtal	Quartz crystal sensor

NOTES: