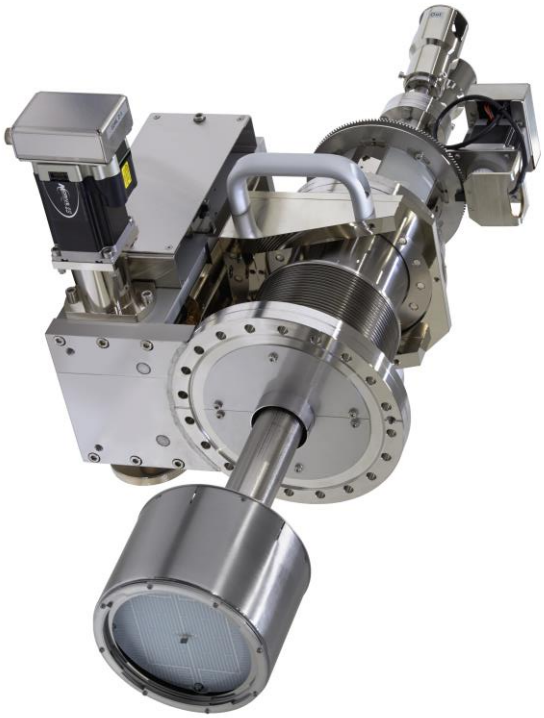
DCA INSTRUMENTS

User Manual

UHV Substrate Manipulator

Automated Transfer System / Manual Transfer System



These are the original English instructions

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The information provided in this documentation contains general descriptions and/or technical characteristics of the performance of the component contained herein. It is the duty of any such user or integrator to perform the appropriate and complete risk analysis, evaluation, and testing of the component 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 component.

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

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Component Modifications/Serial Numbers

Year	Type	Modifications

Document Revisions

Date	Version Number	Document Changes
17-11-21	1.0	Initial draft
22-03-22	1.1	Minor text revisions, address change
02-12-22	1.2	Updated manipulator design
26-01-23	1.3	Minor text revisions

Table of Contents

1 PREFACE

1.1 Purpose of These Instructions

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

This documentation should therefore be regarded as an integral part of the Substrate Manipulator. These instructions are intended for the following product models:

- Silicon Carbide Heaters: Single- and Dual-Zone (system#-440-XX)
- Pyrolytic Boron Nitride coated Pyrolytic Graphite Heater: Single- and Dual-Zone (system#-440-XX)

1.2 Using this manual

To make best use of this manual:

- **Read the entire manual first.** Do not attempt to operate or perform maintenance of any kind on the product before you have thoroughly reviewed this manual.
- **Pay close attention to all safety information!** All UHV applications include inherent hazards and require strict adherence to safety standards. Read the *Critical Information* for critical safety information. Also see *Safety Hazards* in this preface to learn how safety hazards are indicated in this manual.
- **Remember that many DCA products are configurable.** It is not possible to address all aspects of all configurations in a single manual. If you are not finding the information you need, please consult *Additional Resources* in this preface, or contact us using the *Technical Support* information.
- **Refer to all graphics in context.** The graphics in this manual may not exactly match your product. Graphics are intended to illustrate only the features relevant to the topic at hand. Any optional, configurable, or missing features are identified, if contextually relevant.

1.3 Explanation of Safety Warnings

⚠WARNING

Indicates a hazardous situation which, if not avoided, could result in death or serious injury.

⚠CAUTION

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

NOTICE

Indicates information considered important, but not hazard-related.

1.4 Intended User

This manual is intended for trained UHV-Process professionals, technicians, and persons under the direct guidance of such individuals. If you are not among these groups, please do not attempt to use the information in this manual to operate the equipment.

Read and understand this manual and its safety instructions before using this product. Failure to do so can result in serious injury or component/system damage.

The manufacturer is not liable for cases of material damage or personal injury caused by incorrect handling or non-compliance with the safety instructions. In such cases, the warranty will be voided.

1.5 Obtaining Documentation and Information

1.5.1 Additional Resources

In addition to these user instructions, the following related documentation should be read:

- Eurotherm 3500 Series
- TDK Lambda power supply unit
- 01_UHV System DCA User Manual (if applicable)
- 02_ System Bakeout DCA User Guide (if applicable)
- 03_Contol Software DCA User Manual (if applicable)
- 8.11/8.12/8.13/8.14_Substrate Manipulator Drive DCA User Manual

1.5.2 List of Component Manuals Ordering Documentation

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

1.5.3 Other languages

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

1.5.4 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.

1.5.5 Technical Support and Service

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

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2 CRITICAL INFORMATION

This chapter provides important safety information, product cautions and a summary of important notes about your DCA component.

2.1 Safety Precautions

Carefully study this user guide and any related documentation listed in 1.5.1. Only properly trained personnel should operate or maintain the product.

The manufacturer cannot be held liable for damage resulting from errors, unintended or unprofessional use of the Substrate Manipulator.

The manufacturer 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.

2.1.1 Personal protective Equipment

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

2.1.2 Installation safety information

⚠CAUTION

Heavy weight! Risk of user injury. Use suitable lifting equipment (e.g., hoist with rope/cable) when transporting, lifting, or unpacking the component.

Inspect the Substrate Manipulator for damage before installation. If there is any visible damage, do not install the Substrate Manipulator and notify the manufacturer within one week of receiving the product.

2.1.3 Maintenance safety information

All cleaning and maintenance tasks shall only be carried out by qualified and skilled personnel. To ensure the optimal performance of the Substrate Manipulator, regular maintenance shall be carried out by qualified personnel in accordance with the DCA's instructions.

Maintenance and inspection should be done on a regular basis. If there is any visible damage, a strong odour, or excessive overheating of components, stop using the Substrate Manipulator.

⚠CAUTION

Equipment Modifications to the Substrate Manipulator are not permitted. Any alterations made to the Substrate Manipulator without written permission from the manufacturer will void the warranty. Unauthorized alterations may lead to hazardous situations.

See the Appendix for an overview of the spare parts. You can always order spare parts by contacting the manufacturer.

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

The Substrate Manipulator may feature safety marks in areas that pose 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.

2.1.4 Repair and modification Safety information

⚠CAUTION

DO NOT attempt to repair the substrate manipulator without permission and explicit instructions from DCA. Contact DCA Instruments if the manipulator requires repair. Do not attempt to modify the substrate manipulator before consulting DCA Instruments.

2.1.5 Safe Disposal

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.

2.2 Graphical Symbols

2.2.1 Explanation of safety information on the system

Table 1 below provides safety information relevant to the Substrate Manipulator. 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 / Caution	Hazard Location
	**ENTANGLEMENT/CRUSHING** Exposed gears and moving parts can cause injury. Turn power off before servicing. Keep fingers, hands, hair, loose clothing, gloves, and tools away from moving parts.	Substrate Manipulator
	**ELECTRICITY** May cause electric shock or burn. All electrical connections must be ready before switching on the power supplies. Power supplies must be turned off before any maintenance.	Electronic rack Substrate Manipulator

	**HEAVY WEIGHT** Risk of user injury. Use lifting aids when removing or replacing.	Substrate Manipulator

2.2.2 Personal Protective Equipment

PPE	Instruction
	Wear protective clothing
	Wear respiratory protection when opening the chamber with hazardous/toxic materials.

3 INTRODUCTION

3.1 Product Description

The **Substrate Manipulator** is intended for the manipulation of a substrate within a UHV process chamber, this includes the motion, heating, and temperature monitoring of the substrate. The substrate manipulator is typically mounted to the top of the process chamber in a vertical orientation such that the substrate growth surface is face-down in the centre of the chamber.

Heating is performed using a carefully designed heater element made from silicon carbide (SiC) or pyrolytic-graphite encased in pyrolytic boron nitride (PBN-PG). The wafer size and/or distribution of wafers within the carrier, determines whether a single zone or a dual zone (centre and outer) heater element is implemented. Both SiC and PBN-PG materials offer excellent thermal stability and temperature uniformity across the entire wafer. The SiC heater element is particularly suited to environments that require operation at higher partial pressures e.g., 5 x 10^{-5} Torr. Additionally, SiC heater manipulators include water-cooling to prevent electrical contacts from oxidising at higher operating temperatures.

Each manipulator is equipped with a magnetically coupled direct rotary drive that allows true UHV operation. The substrate rotation is motorised and is driven by a stepper motor. Vertical motion may be motor or manually driven depending on the chosen features. All electrical wiring is conducted through the inner tube of the rotary drive to shield them from deposits.

The manipulator substrate stage (used to transfer and support the substrate), has one of two possible designs:

- Fork-style (Fig. 3-1) - compatible with the DCA automated transfer systems, or
- Bayonet-style cup (Fig. 3-3) - compatible with the DCA manual transfer systems.

In addition, the accessories listed in Table 2 are required to operate the UHV Substrate Manipulator. The Substrate Manipulator should only be used with the original accessories supplied. If these items are not supplied with the Substrate Manipulator, the correct models must be confirmed with DCA before use.

Table 2 Summary of components/accessories included with the UHV substrate manipulator and their intended use.

Accessory	Description
TDK Power Supply Unit (PSU)	The PSU model supplied fulfils the power requirements of the heater element, this is dependent on the heater size and design (i.e., single/dual zone).
Motor control unit (MCU)	The MCU controls and powers the stepper motor(s), the MCU model is dependent on the manipulator drive features.
Eurotherm PID Controller	Monitors the thermocouple temperature and controls the output power to provide better than ±0.1°C thermal stability.
Cabling and rack kit	LEMO power cable(s) and a thermocouple cable are included and are bakeable to 200°C.

The Substrate Manipulator shall not be operated outside of the scope set out in this user manual. Safety interlocks may be implemented to protect the component from error conditions that may occur, and these should be enabled during normal operation.

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

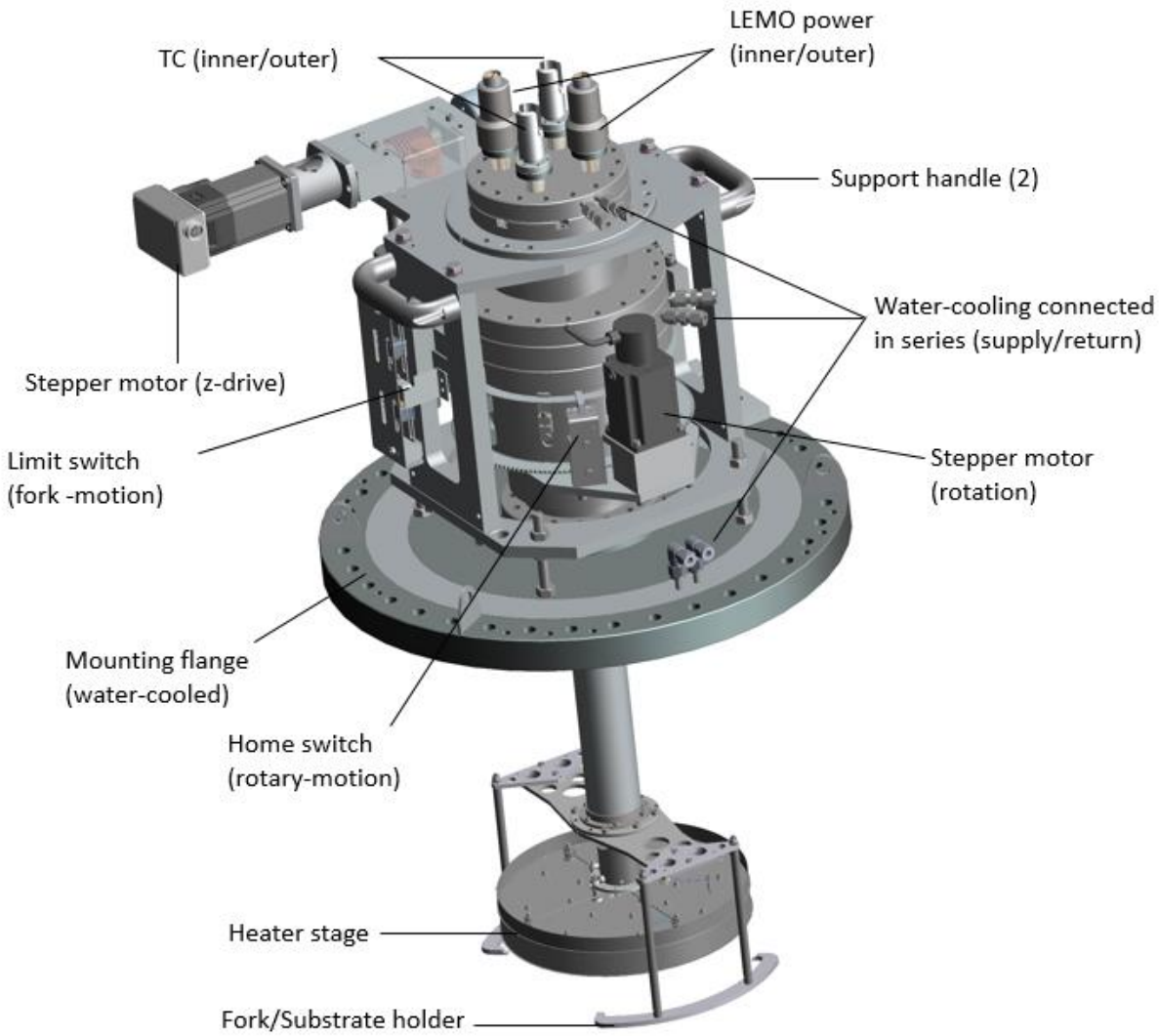


Fig. 3-1 Example of a substrate manipulator with fork-style stage, compatible with automated transfer systems.

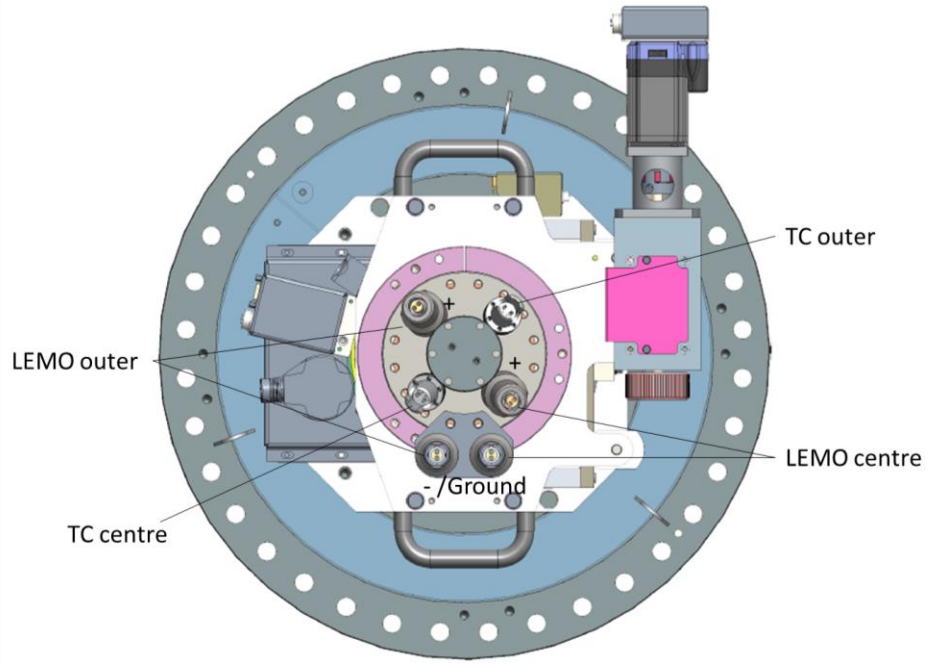


Fig. 3-2 Top view of the 12”/4x4” Substrate Manipulator, with the LEMO and TC contacts identified.

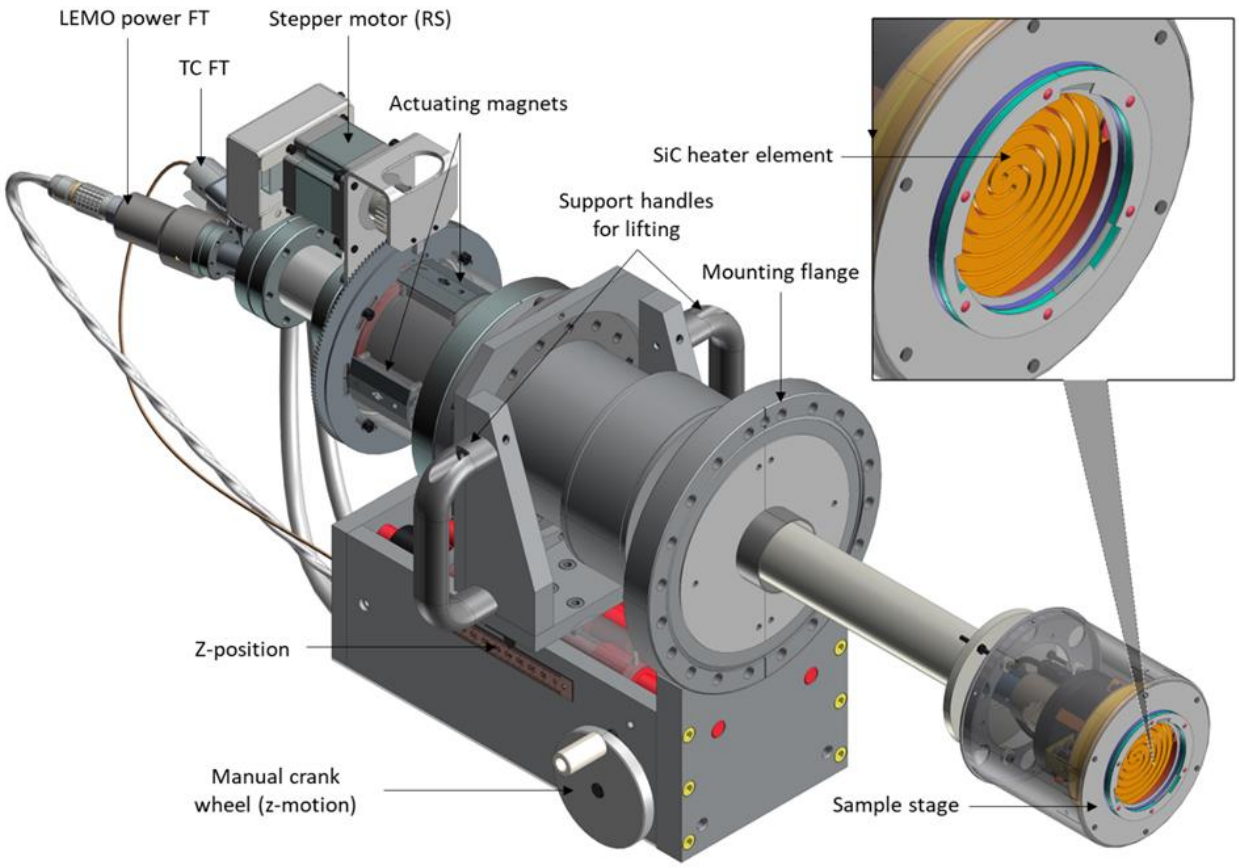


Fig. 3-3 Example of a substrate manipulator with a bayonet-style stage compatible with manual systems.

3.2 Product Standard Features

The UHV Substrate Manipulator standard features are summarised in Table 3, special features (if applicable) are described separately.

Table 3 Standard features of a single-zone substrate manipulator for the specified substrate size and configuration.

Feature	1.5”	2”	3”	4”	6”
Mounting flange					
Heater element	SiC	SiC /PBN-PG	SiC /PBN-PG	SiC /PBN-PG	SiC
Z-motion [1]	50 mm	50 mm	50 mm	50 mm	50 mm
Continuous Rotation [2]	0.1 - 60 rpm	0.1 - 60 rpm	0.1 - 60 rpm	0.1 - 60 rpm	0.1 - 60 rpm
Power connection	LEMO x 1	LEMO x 1	LEMO x 1	LEMO x 1	LEMO x 1
Thermocouple [3]	S-type x 1	S/C-type x 1	S/C-type x 1	S/C-type x 1	S-type x 1
Cooling-lines, Swagelok	6 mm	6 mm	6 mm	6 mm	6 mm
Max. temperature (@ 5E-5 Torr, Si surface)	900°C	900°C	900°C	900°C	900°C
Max. temperature (@ UHV, Si surface)	1000 °C	1000 °C	1000 °C	1000 °C	1000 °C
Max. temperature (@UHV, TC)	1150 °C	1150 °C	1150 °C	1150 °C	1150 °C

[1] Z-motion is only applicable for manual systems, the motion may be performed using a stepper motor or manually via a hand crank wheel. The stepper motor is powered and controlled by the MCU-Z/PSU-Z and is used to lower/raise the manipulator stage to the transfer or growth position. For automated transfer systems, the z-motion is replaced with a “fork-motion”. The fork stepper motor is controlled by the MCU-F and is used to transfer wafers between the robot end effector to the manipulator fork.

[2] Rotation is performed using a stepper motor with a magnetically coupled rotary drive for continuous rotation. The stepper motor is powered and controlled by the MCU-RS.

[3] The thermocouple is located between the heater element and the substrate in the centre. For dual-zone heaters, a second thermocouple is positioned toward the centre of the outer heater element. The thermocouple(s) connects to a Eurotherm PID controller for feedback control of the DC power supply. This regulates the substrate temperature and achieves a temperature stability of ±0.1 °C. For Silicon carbide heaters the thermocouple is S-type and for PBN-PG it is C-type.

Maximum chamber pressure	5E-5 Torr	5E-5 Torr	5E-5 Torr	5E-5 Torr	5E-5 Torr
Max. bakeout temperature	200 °C	200 °C	200 °C	200 °C	200 °C
Power supply (PBN-PG)	-	GEN 80-19	GEN 150-10	GEN 150-10	-
Power supply (SiC)	GEN 80-19	GEN 80-19	GEN 80-19	GEN 100-24	GEN 100-24
Weight (approx.)	17 kg	20 kg	25 kg	25 kg	25 kg

Table 4 Standard features of a dual-zone substrate manipulator for the specified substrate size and configuration.

Feature	4”	3x2”	3x3” /7x2”	8”	4x4”/7x3”	12”
Mounting flange	See Schematic	See Schematic	See Schematic	See Schematic	DN400CF	DN450CF
Heater element	PBN-PG	PBN-PG	PBN-PG	SiC	PBN-PG	SiC
In-vacuum length	See Schematic	See Schematic	See Schematic	See Schematic	See Schematic	See Schematic
Z-motion [4]	50 mm	N/A	N/A	N/A	N/A	N/A
Continuous Rotation [5]	0.1 - 60 rpm	0.1 - 60 rpm	0.1 - 60 rpm	0.1 - 60 rpm	0.1 - 60 rpm	0.1 - 60 rpm
Power connection	LEMO x 2	LEMO x 2	LEMO x 2	LEMO x 2	LEMO x 2	LEMO x 4
Thermocouple [6]	C-type x2	C-type x 2	C-type x 2	S -type x 2	C-type x 2	S -type x 2
Cooling-lines, Swagelok	6 mm	6 mm	6 mm	6 mm	6 mm	6 mm
Max. temperature (@ 5E-5 Torr, Si surface)	-	-	-	900°C	-	900°C

[4] Z-motion is only applicable for manual systems, the motion may be performed using a stepper motor or manually via a hand crank wheel. The stepper motor is powered and controlled by the MCU-Z/PSU-Z and is used to lower/raise the manipulator stage to the transfer or growth position. For automated transfer systems, the z-motion is replaced with a “fork-motion”. The fork stepper motor is controlled by the MCU-F and is used to transfer wafers between the robot end effector to the manipulator fork.

[5] Rotation is performed using a stepper motor with a magnetically coupled rotary drive for continuous rotation. The stepper motor is powered and controlled by the MCU-RS.

[6] The thermocouple is located between the heater element and the substrate in the centre. For dual-zone heaters, a second thermocouple is positioned toward the centre of the outer heater element. The thermocouple(s) connects to a Eurotherm PID controller for feedback control of the DC power supply. This regulates the substrate temperature and achieves a temperature stability of ±0.1 °C. For Silicon carbide heaters the thermocouple is S-type and for PBN-PG it is C-type.

Max. temperature (@ UHV, Si surface)	1000 °C	1000 °C	1000 °C	1000 °C	1000 °C	1000 °C
Max. temperature (@ UHV, TC)	1150 °C	1150 °C	1150 °C	1150 °C	1150 °C	1150 °C
Max. chamber pressure	-	-	-	5E-5 Torr	-	5E-5 Torr
Bakeout temperature	200 °C	200 °C	200 °C	200 °C	200 °C	200 °C
Power supplies	GEN 150-10 x2	GEN 150-10 x2	GEN 150-10 x2	GEN 100-24 x2	GEN 150-16 x2	GEN100-33 GSP200-50
Weight (approx.)	25 kg	28 kg	35 kg	40 kg	40 kg	40 kg

3.3 Product Special Features

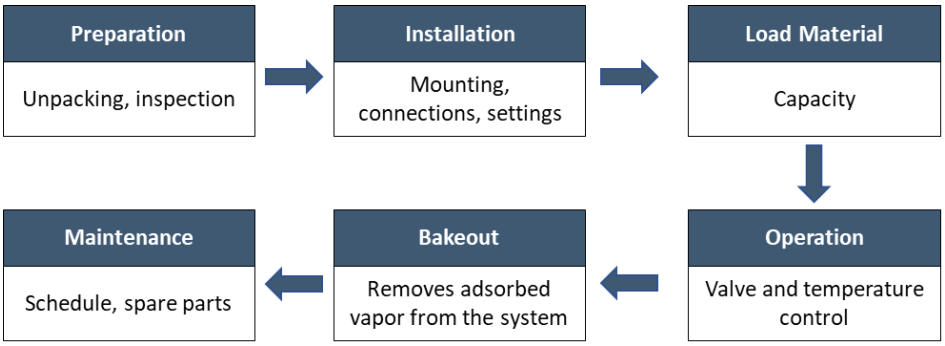
The special/customer features of the UHV substrate manipulator are described below.

Table 5 Description of special features included with the UHV Substrate Manipulator

Special Features	Serial #
Substrate bias contact with position limit switch	N/A
Mounting hoist (assists with removal from UHV process chamber)	N/A
Second Z-drive with stepper motor – allows additional adjustment of the working distance	N/A
Water-cooled panel surrounding substrate area	N/A
LN_2-cooled panel surrounding substrate area	N/A
X-Y table for horizontal motion	N/A
Integrated rotary shutter	N/A
Tantalum shield surrounding in-vacuum section to protect from deposits	N/A

3.4 Operational Flow Chart

The flow chart gives an overview of the processes required for the UHV Substrate Manipulator. Each process is described in the following chapters of this manual.


Preparation
Unpacking, inspection
Installation
Mounting, connections, settings
Load Material
Capacity
Operation
Valve and temperature control
Bakeout
Removes adsorbed vapor from the system
Maintenance
Schedule, spare parts

4 PREPARATION

4.1 Unpacking

⚠CAUTION

HEAVY WEIGHTS! – Do not lift items greater than 25 kg without the assistance of a suitable lifting assembly. The lifting assembly must only be attached to the designated hooks/support handles on the manipulator flange. Do not lift the manipulator from the bellows, rotating tube, or heater package. Ensure there is a secure connection before attempting to lift.

When the UHV Substrate Manipulator is first received, first check the external shipping box for any obvious signs of physical damage. Secondly, inspect the status of any impact or shock sensors attached to the shipping box. If any kind of mishandling of the box during transportation is suspected, please contact DCA immediately.

If the shipping box has been cleared after the initial inspection, the manipulator can then be carefully unpacked from the shipping box. The UHV Substrate Manipulator is shipped with a protective tube to shield the in-vacuum parts. This is attached to the manipulator with bolts and an O-ring for sealing. After removing the packaging material that secures the manipulator in place, move the manipulator with the protective tube to a clean area (e.g., cleanroom or similar contamination free space). This may require a lifting tool if the weight exceeds 25 kg, refer to section 4.1.1. In the clean area, the protective transfer tube (Fig. 4-1) may be removed. Refer to section 4.1.2 on how to handle the component.

Fig. 4-1 Protective transfer tube with slots to secure the manipulator mounting flange.

After unpacking the manipulator from the shipping container and removing the protective tube, inspect for any signs of damage that may have occurred during the shipment. Notify DCA immediately if any damage or loose screws are found.

If the component will not be mounted to the vacuum system immediately, it should be stored within the protective tube. The shipping container and protective tube should be stored safely so that the manipulator may be shipped back to DCA for repair/maintenance if needed.

NOTICE

Handle the manipulator in a clean area with powder free gloves to prevent contamination.

4.1.1 To lift the components safely:

1. Use the designated hooks/handles provided on the manipulator when attaching the lifting assembly.
2. Use the support handles when attempting to lift the manipulator manually.
3. Move slowly and ensure the manipulator is well supported to prevent it from colliding with nearby objects.
4. Avoid contact with the in-vacuum region of the manipulator unless wearing clean-room compatible gloves.
5. When placing the manipulator on a surface, ensure it is supported by the mounting flange so that it can withstand the weight and it is stable (i.e., will not freely rotate or topple) without support.

4.1.2 To handle the components safely:

1. Handle outer vacuum sections only using UHV cleanroom compatible gloves.
2. DO NOT handle in-vacuum parts that may be contaminated with material.

4.1.3 Storing the component

ALWAYS store the Component in a dry, clean, well-ventilated area.

Store the component out of reach of unauthorized persons and do not allow persons unfamiliar with the component or these instructions to operate it.

4.2 First Inspection

When receiving the component for the first time or after a maintenance service, it is advisable to check the resistances of the heater assembly and thermocouple via the respective feedthroughs. Consult the test report(s) provided for the measured resistances for the power (LEMO-LEMO) and thermocouple (TC-TC).

NOTICE

Consult the manipulator test report for the expected contact resistances and performance.

The thermocouple wires are electrically insulated from the manipulator body, so the resistance between thermocouple contacts and the manipulator body should be infinite. The positive contact of the LEMO power feedthrough is in contact with the manipulator frame. Note that the contact resistances may change with prolonged use, for example due to contamination.

If necessary, the heater element and connections may be inspected by removing the bayonet cup (manual systems only). Use a suitable lubricant such as methanol to loosen the screws if required.

If the contact resistances do not match the test report(s) provided, please contact DCA for advice on how to proceed.

5 START-UP

5.1 Installation of the Substrate Manipulator

⚠CAUTION

Installation of the substrate manipulator must only be performed by DCA Instruments personnel or a trained professional who has read and understood these instructions.

5.1.1 Water-cooling (if applicable)

For substrate manipulators equipped with water-cooling (either for cooling electrical contacts or a cooling panel that surrounds the substrate stage), it is important to ensure the cooling-lines are connected to the appropriate in/out connectors so that sufficient flow is achieved.

In the vertically oriented manipulator position the cooling water should enter the panel through a long tube (marked IN) reaching to the panel bottom. The cooling water should exit the panel through a short tube (marked OUT) close to the top of the panel. If the position of the manipulator is different, consider the right water connection to fill the panel completely before the cooling water exits the panel.

It is recommended to check the temperature of the cooling water exiting the manipulator during the first heating to confirm there is sufficient cooling. Typically, a cooling flow of about 0.5 l/min is required with 2 bar pressure difference. The cooling water temperature should be above ambient dew-point temperature to prevent condensation on the cooling lines.

⚠CAUTION

Only switch on/off the water-cooling when the heater has cooled below 100°C.

5.1.2 Connecting the cables

Each cable supplied with the manipulator is labelled with the corresponding accessory it is to be connected to. To avoid damage to the manipulator/accessories, check the labels carefully before connecting.

⚠CAUTION

Switch off motor control units and power supplies before plugging or unplugging any cables.

When the manipulator is mounted to the UHV process chamber, perform the following actions:

1. Connect the power cable to the power supply and to the LEMO connector of the manipulator. For dual-zone manipulators the cables and feedthroughs are marked Loop X (center) and Loop X.1 (outer).
2. Enable the Eurotherm control of the power supply by connecting the control cable between the power supply and the Eurotherm.
3. Connect the thermocouple cable to the manipulator TC connector and the Eurotherm.
4. Connect the control cables to the stepper motors mounted to the manipulator and to the appropriate motor control units.

5. (If applicable) Connect the handheld remote control to the rotation motor control unit.
6. Connect the z-motion interlock sensor cable.

5.1.3 Limit switches

The manipulator linear assembly for z-motion includes two sets of limits; the first is a mechanical limit that relates to the maximum possible travel of the linear drive, the second is a stepper motor limit that is factory set and should not be adjusted without consulting DCA first. The motor limit determines the safe travel distance for the manipulator fork (automated transfer systems) or the bayonet substrate stage (manual transfer systems).

⚠CAUTION

If the motor limits are adjusted, ensure that the stepper motor does not exceed the mechanical limits! This may cause misalignment of the manipulator and hinder the rotation.

5.2 Check the Eurotherm Settings

NOTICE

Refer to the Eurotherm 3500 Series User Manual for detailed operating instructions.

The supplied Eurotherm is preprogramed by DCA Instruments for use with the substrate manipulator.

The maximum voltage from the power supply can be limited through the Eurotherm setting *powerHi*. For example, setting the *powerHi* parameter to 80% for an 80-19 power supply means the maximum voltage is limited to 64 V. The *powerHi* is preset at the DCA factory to be slightly above what is required to achieve the maximum temperature. The *powerHi* may be modified by the user, consult the DCA test report and refer to the Eurotherm manual if necessary.

During normal operation, it is recommended to use the automatic PID control with a suitable temperature ramp for heating and cooling. A suitable temperature ramp is between 60-100 °C/min.

If unsuitable PID control coefficients are being used, this can lead to severe power oscillations. If the power oscillates when performing the first heating test, auto-tune the PID parameters at a low temperature. The auto-tuning should then be repeated at a mid-point of the operating temperature range to achieve optimum stability in the whole range.

Example: If the typical operating temperature range for the process is between 700 °C and 900 °C, the Eurotherm PID auto-tune should therefore be performed at 800 °C.

Eurotherm control software is provided as part of the DCA UHV System, however this can be modified or set-up separately by the user. Refer to the Eurotherm 3500 Engineering handbook for details.

NOTICE

Before operation it is recommended to familiarize yourself with the following operations from the Eurotherm control panel:

- Setting a ramp rate (**RR**)
- Setting a **OPHi**
- Setting a setpoint (**SP**)
- Switching between auto mode and manual mode
- Tuning the PIDs
    - Setting PID-values manually
    - Turning Auto-Tune on
- Changing the voltage ratio (for dual-zone only)

5.3 Continuity Test

The continuity test should be performed once the following are fulfilled:

- all cables are connected,
- power supplies and motor control units are powered up,
- Eurotherm settings are confirmed
- And if applicable, water-cooling lines are connected, and suitable flow is established.

To perform the continuity test:

1. Set the Eurotherm to manual mode.
2. Slowly apply power (1-5%) to confirm there is current flow. If current flow is not achieved, consult the troubleshooting section in Section 10.
3. Confirm the correct control settings between the Eurotherm and power supply. The Eurotherm control signal is in the range 0-10 V, with 10 V corresponding to the highest power supply output i.e., the maximum voltage of the power supply.
   Example: For an 80-19 power supply, a 5 % Eurotherm control signal would result in a 4 V output from the power supply.

Two control settings are available for the power supply: 0-5 V and 0-10 V. The power supply is pre-set with the 0-10 V control range at the DCA factory. However, if the power supply has the 0-5 V control setting, this would show a 5% control signal of 8 V from an 80-19 power supply. The power supply control settings can be changed according to the instructions given in the power supply manual.

5.4 Outgassing

If the manipulator includes a PBN-PG heater element that has been exposed to the open air for more than 3 days (e.g., after first receiving the manipulator or if removed from the system), the manipulator heater should be outgassed in vacuum at 120°C for 8 hrs and then at 200°C for a further 8 hrs before operation.

SiC heater elements do not require outgassing treatment prior to operation.

6 OPERATION

6.1 First heating cycle

After completing the continuity test and confirming the power supply control settings, the substrate manipulator should undergo a heat cycle to verify the performance complies with the supplied test report.

NOTICE

Because the Eurotherm PID settings are tuned for higher temperatures, it is recommended to start heating the manipulator in manual mode. This avoids the possibility of large voltage oscillations (between maximum and zero) in auto mode.

⚠WARNING

During operation:
Do not exceed the maximum specified manipulator temperature and power limits.
Ensure the pressure is kept below 5E-06 Torr during operation.

NOTICE

If water-cooling is included, closely monitor the flow during the first heating cycle to ensure the water does not start to boil in the cooling lines at high temperatures.

To perform the first heating cycle, continue from the continuity test in section 5.3:

1. Gradually increase the manipulator temperature in Manual-Mode to 300°C.
2. Once at 300°C, confirm the ramp rate has a suitable setting set (e.g., 60-100 °C) and change the Eurotherm PID control to Auto-Mode.
3. Set the manipulator temperature to the maximum specified temperature (refer to the specification table/test report).
4. While the manipulator temperature is increasing, monitor the following closely:
    a. Coolant flow (if applicable) - ensure the water remains cool to the touch and does not start to boil in the lines. If the coolant water feels warm or hot, stop heating the manipulator, ramp down to room temperature, and refer to Troubleshooting section 10.
    b. Current and voltage readings - record any abnormal behaviour (e.g., significantly different outputs compared to the test report) or large oscillations. If abnormal behaviour is observed, stop heating the manipulator, ramp down to room temperature, and refer to Troubleshooting section 10.
5. Once the manipulator has reached the maximum operating temperature, confirm the thermal stability by dwelling at the max. temperature for 30 mins.
6. After establishing thermal stability, set the manipulator to 20 °C and allow to ramp down.
7. Switch the water cooling on/off only when the manipulator has cooled to below 100 °C.

6.2 Limiting the Voltage / Current

If necessary, it is possible to limit the current using the control dial on the power supply front panel. The standard DCA set-up is voltage controlled, whereby the current is determined by the resistance of the component. It is possible to change the set-up to be current controlled, refer to the power supply manual for instructions. The actual power supplied to the manipulator is determined by the product of voltage and current. Consider that the power consumption is greatly affected by the sample configuration. For example, a blank molybdenum block will require less power than a large silicon wafer.

6.3 Safety Interlocks

Safety interlocks are implemented to ensure the substrate manipulator enters a safe state for the user and the UHV system in the event of an error condition.

A z-motion interlock cable is included with all DCA systems. The z-motion interlock protects the manipulator from collisions with other components that may occupy the same space at the same time. An audible alarm alerts the user to stop motion (e.g., in jog mode) to avoid a potential collision.

The Eurotherm controller which accompanies the manipulator has two interlocks set – a vacuum interlock and coolant interlock. If the interlock signal is not supplied (e.g., there is no water-cooling), the interlock must be disabled from the Eurotherm controller (set to “1”) for normal operation. If the vacuum interlock is triggered, power supply to manipulator heater will be switched off. If the coolant interlock is triggered, the coolant will be automatically purged and power supply to the manipulator heater will be switched off.

6.4 Motion Control

6.4.1 Rotation

The manipulator rotation may be performed remotely using the DCA software (if provided), or locally from the motor control unit or its handheld remote.

The manipulator rotation speed and azimuthal angle are controlled by the motor control unit, MCU-RS (Fig. 6-1). The rotation speed can be increased or decreased using the INC/DEC switch on the front panel. The MCU-RS is programmed with a default rotation speed and this pre-set value will be recovered whenever the MCU-RS is reset.

The rotation direction can be set as counter-clockwise or clockwise using the CCW/CW switch on the MCU-RS front panel. Stop the rotation before changing the direction.

The handheld remote control can be used to set the direction, start/stop the rotation, and jog the manipulator using the jog-/jog+ switch.

The azimuthal angle control with “zero” position setting is available with the DCA system software.

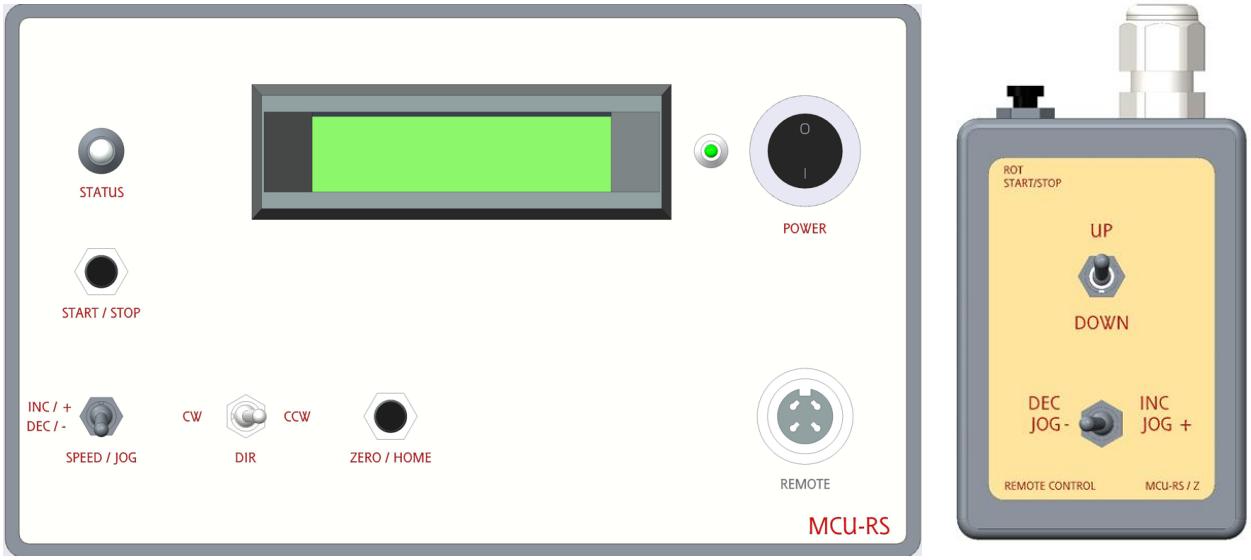


Fig. 6-1 Example of the motor control unit, MCU-RS (left) and the handheld remote control (right).

NOTICE

Refer to the separate Substrate Manipulator Drives DCA User Manual for detailed operating instructions.

6.4.2 Manual Z-motion

For linear drives equipped a crank wheel, the z-motion is performed manually using the handle provided. One full rotation of the handle equates to 0.5 mm linear travel. Clockwise rotation moves the manipulator downward and counter-clockwise rotation moves the manipulator upward. The current z-position is indicated on the metric ruler mounted to the side of the manipulator and also shows position limits.

6.4.3 Motorised Z-motion

⚠CAUTION

Switch off the motor control unit before plugging or unplugging any cables.

For linear drives equipped with a stepper motor, the z-motion is performed either remotely using the DCA software (if provided), or locally from the motor control unit or its handheld remote.

The motor control unit provided for z-motion is dependent of the system type and the manipulator features. For automated transfer systems, the manipulator z-motion is performed by the MCU-F (fork) and it is only used to perform wafer transfer. Emergency jog is the only situation in which this will allow manual operation. For manual transfer systems, this may be either the MCU-Z (Fig. 6-2) or PSU-Z. The MCU-Z offers greater functionality over the PSU-Z, with a screen to monitor the position and set-points for the growth and transfer positions, among other features.

The PSU-Z is comprised of a power supply and remote control with a toggle switch for jogging the manipulator up or down.

NOTICE

Refer to the separate Substrate Manipulator Drives DCA User Manual for detailed operating instructions.

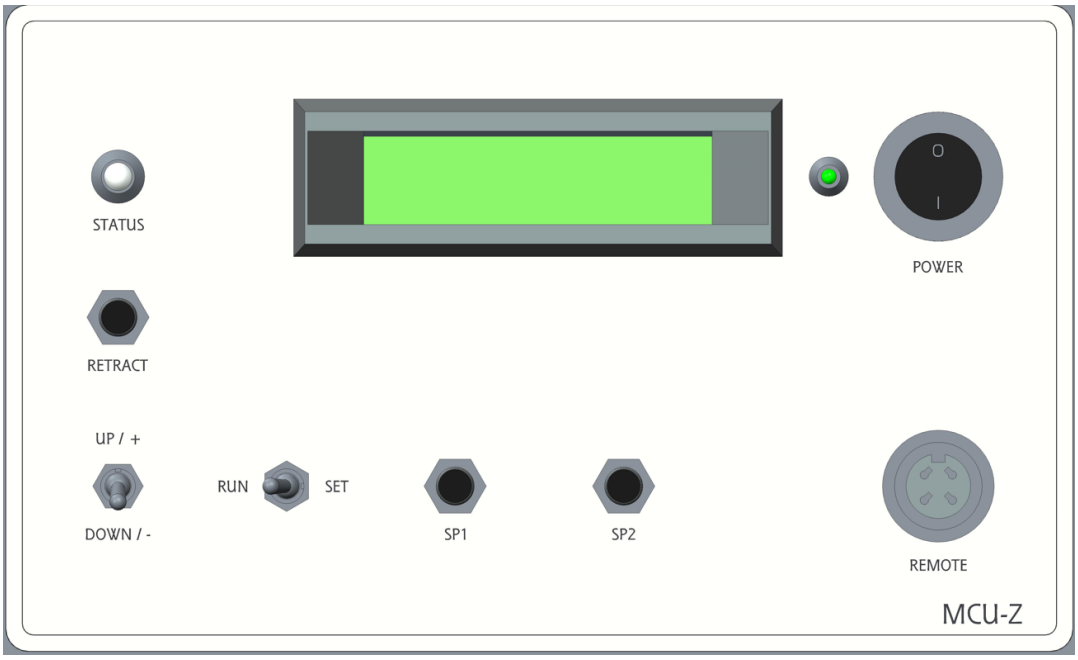


Fig. 6-2 Example of the motor control unit, MCU-Z.

6.5 Dual-zone heaters

Manipulators with dual-zone heaters are typically configured to have a central and outer zone. Each heater element has a separate thermocouple and PID control loop. The Eurotherm parameter L20S (Loop 2 Offset) controls the temperature set-point for the outer element.

Example: When L20S = -15 and the center heater set-point is 700°C, the outer heater set-point will be 685°C.

The L2OS has been factory set to ensure optimal uniformity across the substrate, however this may be modified by the user. The default factory setting is supplied on the test report.

7 BAKEOUT

This chapter describes how the manipulator should be prepared for bakeout. Manipulator versions may vary and appear different from the schematics in this manual; however, the principals and instructions remain valid and should be adhered to.

The manipulator is bakeable up to 200°C. The LEMO power cables and thermocouple wiring delivered by DCA, are also bakeable.

NOTICE

Refer to the separate 02_Bakeout System manual for further instructions.

7.1 Preparation

To prepare the substrate manipulator for bakeout perform the following:

1. Stop the water-cooling (if applicable) and purge water from the lines. The purge gas flow should be in the opposite direction to the coolant flow to ensure no water remains in the cooling tubes/panels.
2. Disconnect and remove the following items from the substrate manipulator:
   - Non-bakeable water-cooling lines and any plastic Swagelok quick connectors.
   - Stepper motor cabling **- power off the MCU first before removing any cables!**
   - Rotatory and z-motion stepper motor(s) (see Fig. 7-1, Fig. 7-2, Fig. 7-3), **ensure the red plastic coupling is also removed as this is not bakeable**.
   - Z-limit switch assembly, not that the trigger plate should remain in place (see Fig. 7-5and Fig. 7-6)
3. Finally clean all dirt and fingerprints and cover the bellows with Aluminium foil.

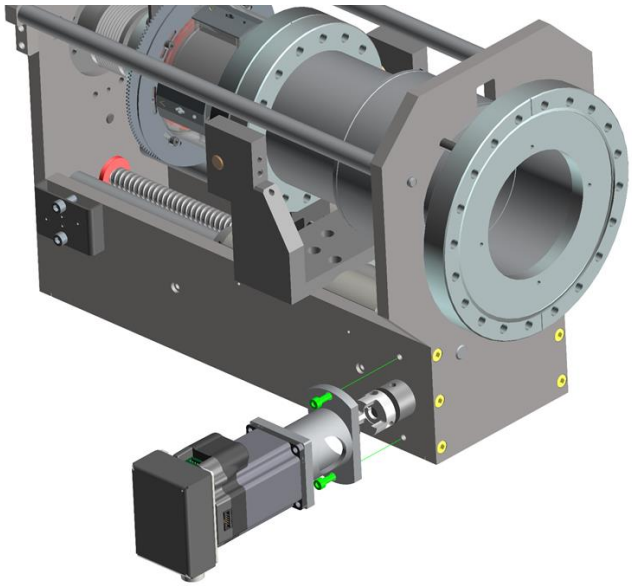


Fig. 7-1 Schematic showing the removal of Z-motion stepper motor from the manipulator (manual transfer system).

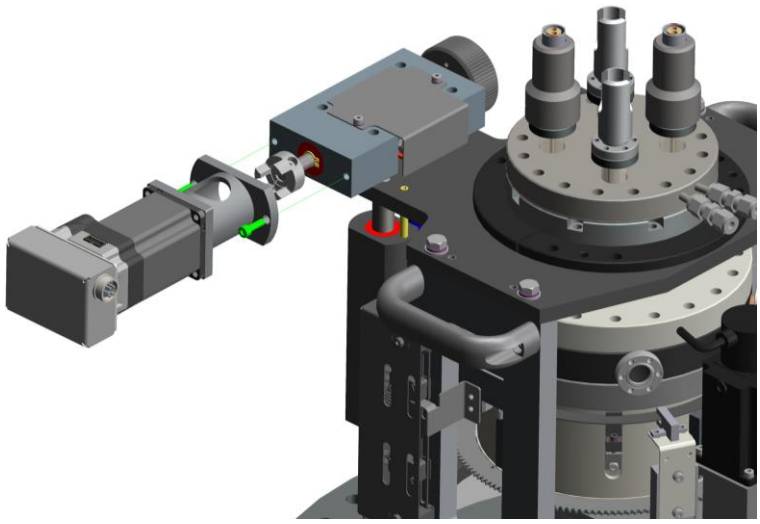


Fig. 7-2 Schematic showing the removal of Z-motion (Fork) stepper motor from the manipulator (automated transfer system).

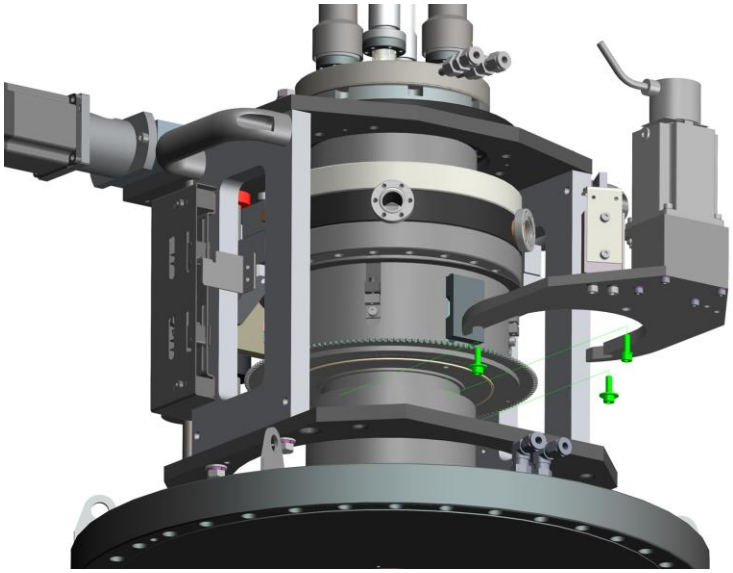


Fig. 7-3 Schematic showing how to remove the rotatory stepper motor (automated transfer system).

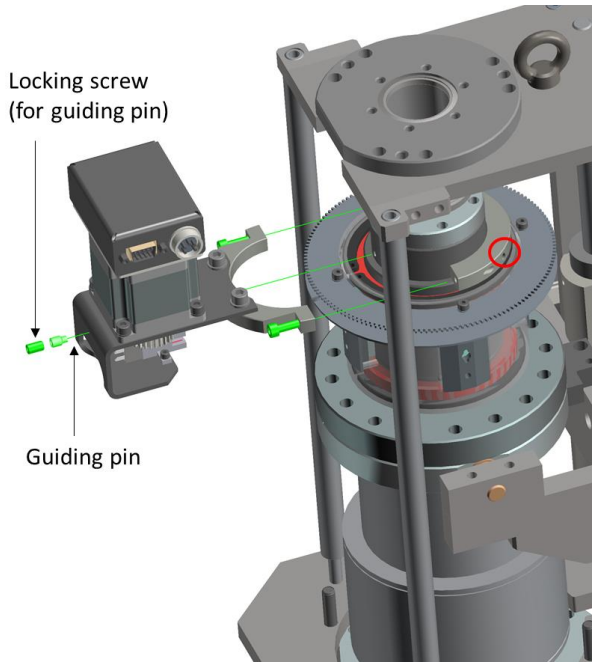


Fig. 7-4 Schematic showing how to remove the rotatory stepper motor (manual transfer system). The guiding pin ensures the correct position of the stepper motor; in some manipulator designs this may be located at the red circle.

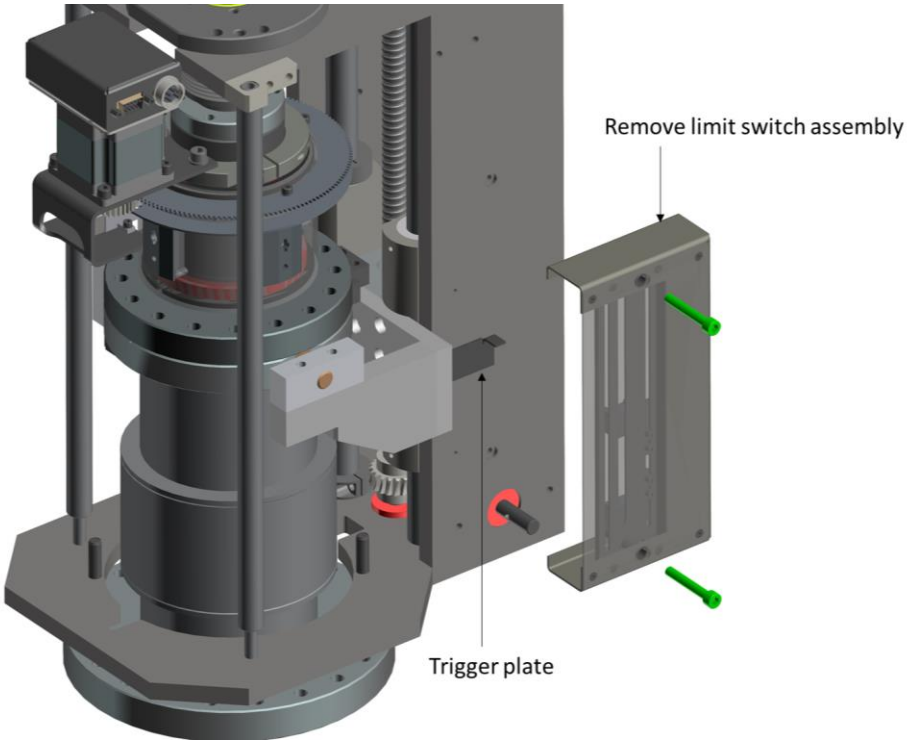


Fig. 7-5 Schematic showing the removal of the limit switch assembly (manual transfer system).

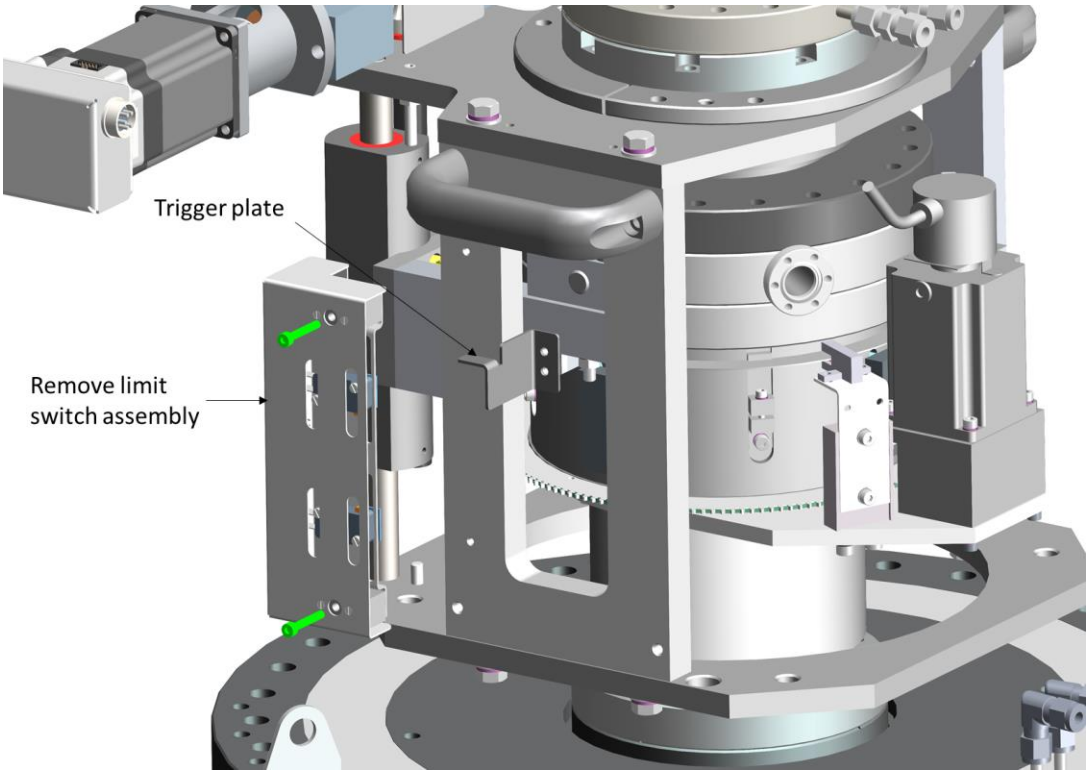


Fig. 7-6 Schematic showing the removal of the limit switch assembly (automated transfer system).

8 MAINTENANCE

Regular inspection and maintenance of the UHV substrate manipulator is recommended to ensure the component operates with optimal efficiency and performance.

8.1 Lubrication

To prolong the lifetime of the manipulator and ensure smooth motion, it is recommended to lubricate the manipulator bearings, gears, and screws with Rocol (Sapphire Endure 56) or Fomblin-oil after every 150-200 hrs of bakeout.

Remove the back panel of the manipulator to access the z-motion assembly. The following parts (highlighted red in Fig. 8-1 Fig. 8-2) should be well-lubricated: worm gear, ball screw, vertical bearings, guiding bars and the radial bearings.

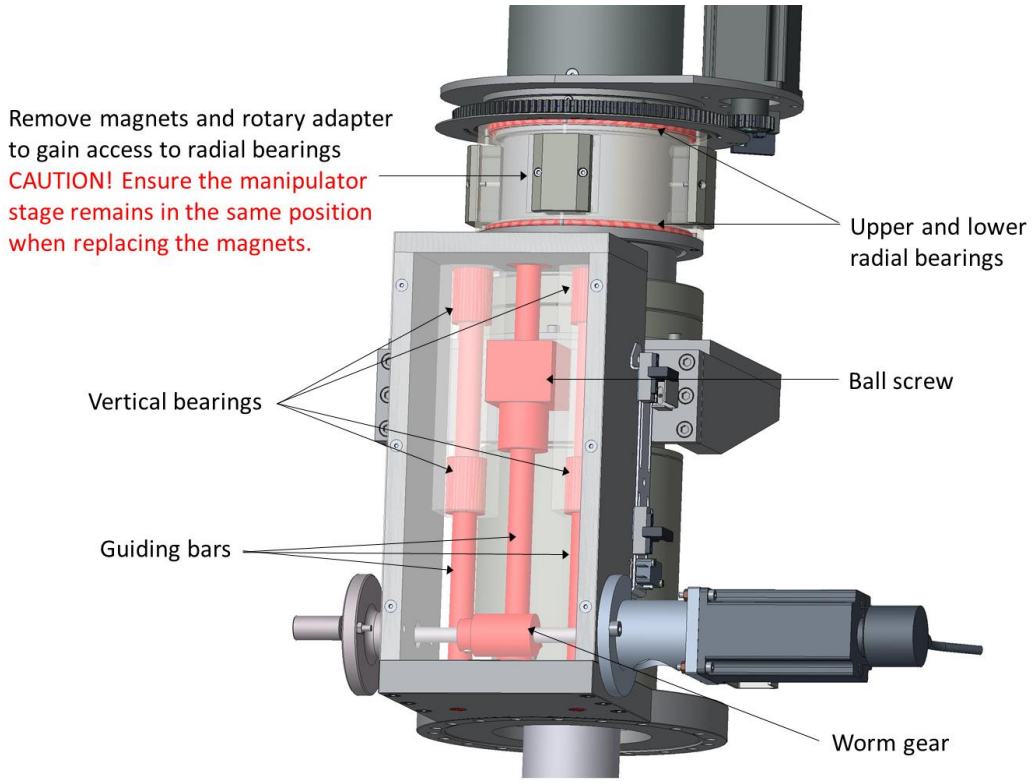


Fig. 8-1 Schematic showing the manipulator parts that require lubrication after bakeout.

To gain access to the lower radial bearings, all four actuating magnets must be removed (ensure the manipulator bayonet cup/substrate stage remains in a fixed position) as well as the rotary motor mounting adapter, then slide the magnet cage upwards. The upper radial bearings can be accessed from above. We recommend using Fomblin-oil in this case, as access is restricted. **When reassembling the manipulator, it is critical to ensure the manipulator bayonet cup/substrate stage is orientated in the same position when replacing the magnets.**

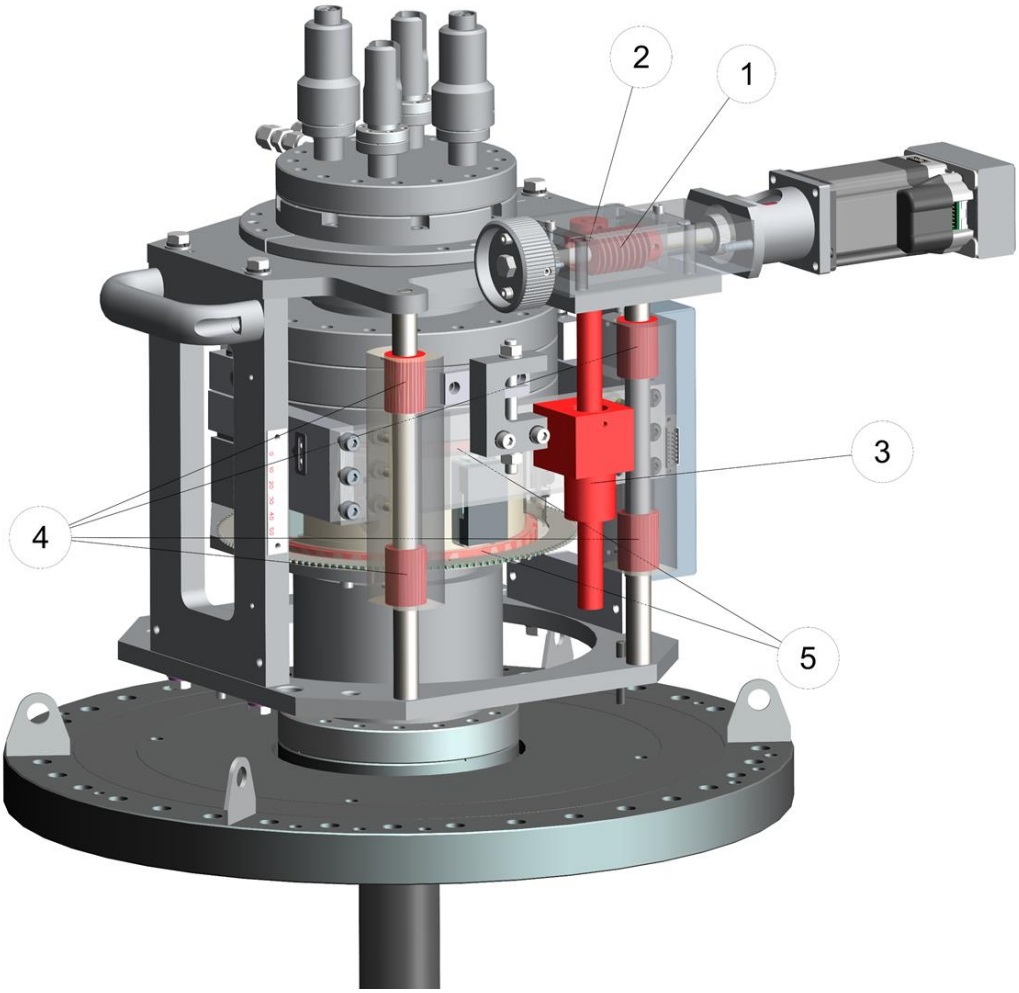


Fig. 8-2 Schematic showing the manipulator parts (highlighted red) that require lubrication after bakeout (automated transfer systems). 1. Worm gear, 2. Guiding bar, 3. Ball screw, 4. Vertical bearings, 5. Upper and lower radial bearings.

8.2 Bearing exchange

If the manipulator motion appears irregular or jerky, this may be caused by the bearings becoming brittle and failing. This may be caused by insufficient lubrication after bakeout, or if the bearing lifetime has been reached. The solution is to exchange the thrust and radial bearings within the manipulator rotary drive. This is a complex procedure and requires the manipulator to be shipped back to the factory for a maintenance service – follow the instructions in Section 9.

If the user wishes to perform the bearing exchange, DCA will provide instructions. **DCA Instruments will not be held responsible for any damage caused by the user while following the instructions provided by DCA.**

If the manipulator is under warranty, do not attempt to repair the manipulator, it must be returned to DCA for service.

9 REMOVAL/PACKING

When shipping the manipulator to DCA for repair or maintenance, complete the Contamination Protocol Form and send it to DCA along with the tracking number (if applicable). If the manipulator is still within the warranty period, DCA will arrange the collection. Please specify the pick-up location, contact information, crate dimensions and weight.

9.1 Removing the manipulator from process chamber

Follow the sections 4.1.1 and 4.1.2 for instructions on how to lift and handle the component.

In some cases, a special hoist is provided to remove the manipulator from the chamber. However, in general a suitable lifting assembly with ropes is required to hoist the manipulator out from the process chamber. It is critical when removing the manipulator from the chamber that it is carefully guided and does not scrape or bounce against the mounting flange (or surrounding equipment)

Wear protective respiratory equipment when removing the manipulator that has been contaminated with toxic materials.

9.2 Packing the manipulator

Users must follow the EU Directive 2008/68/EC when packaging manipulators that are heavily contaminated with toxic material. The packaging must be suitable for the specified toxic material(s) and correctly labelled. The shipping company must be notified that these are dangerous goods and handle the shipping crate appropriately.

Ensure that a completed DCA Contamination Report Form is included within the shipping crate.

After removing the substrate manipulator from the process chamber, place the head to the protective transfer tube (Fig. 4-1).

Secure the substrate manipulator mounting flange to the transfer tube tightly using screws and bolts.

Fig. 9-1 Substrate manipulator shipping crate (left) with packing foam (right).

Prepare the wooden crate, this will include a shock absorber for larger manipulators that are transported in an upright position. For smaller manipulators, the manipulator is laid in a horizontal position and should be secured in place with packing foam or similar material (Fig. 9-1).

Ensure that there is sufficient foam (at least 20cm) to prevent the manipulator coming into contact with the sides of the crate in any direction.

Pack additional foam or other suitable packing materials to prevent the substrate manipulator from vibrating or shifting during the transportation.

Seal the wooden crate securely for shipment

10 TROUBLESHOOTING

Problem	Probable Cause	Recommended Action
No current flow	• The power supply contacts are loose or damaged • The LEMO connector is damaged • The power feedthrough or heater assembly is damaged	Check all contacts. Measure the resistance of the heater assembly at the feedthrough. An infinite resistance implies a damaged feedthrough or heater assembly. Check the heater visually by dismounting the manipulator and removing the cup, if possible.
Sudden drop in heater resistance	• Short circuit in the heater assembly	Measure the resistance of the heater at the feedthrough. Compare the measured value to the expected one. Dismount the manipulator and remove the cup for a visual check, if possible.
Surface temperature measurement problem	• Emissivity is incorrect (affected by various things such as wavelength and viewing angle) • Spot of the pyrometer is not on the sample • There is a reaction on the measured surface such as oxidation • There are reflections on the sample surface • The viewport is not clean	The measurement of surface temperature with a pyrometer is susceptible to many errors. Check your measurement conditions and contact the DCA factory if you have an issue concerning surface temperature which cannot be resolved.
The manipulator is leaking	• A flange, feedthrough or the water-cooling assembly might be leaking.	Carefully leak check all flanges, feedthroughs, and water-cooling tubes. Pay special attention to welded seams. A leak in the cooling assembly should appear as a water leak in the chamber. Water may seal the leak in the cooling tubes, so it is recommended to first purge the water and dry it out to find the leak with He. If possible, check a used gasket for signs of a damaged knife edge.
Cooling water exiting the manipulator is hot	• The water flow rate might be too low • The water inlet temperature might be too high	Check the cooling water set-up for flow and inlet temperature. Monitor the outlet water temperature. Take care to avoid water boiling in the cooling line.

The apparent maximum voltage is less than the power supply rating	• There is a *PowerHi* setting in the Eurotherm/ • The voltage has been manually limited using the dial on the power source front panel/ • There is a short circuit in the heater assembly	Change the Eurotherm setting *PowerHi*. Do this with care and consideration since the power limit might have been pre-set at the DCA factory to prevent overheating. Consult the factory if necessary. Check the contact resistances and compare it to previous results/test reports to make sure you do not have a short circuit in the heater assembly.
Temperature is fluctuating	• The PID parameters are unsuitable • The heater assembly is damaged • The TC wiring is damaged	Retune the PID coefficients using the Eurotherm auto-tune function. If you have trouble completing the tuning, add any value to the parameter D (if originally "off") to get it into use and try to retune. If you cannot stabilize the temperature, try in manual mode to see if the temperature settles with a fixed power. Compare this to previous results. Monitor your current and voltage values to see if resistance is changing now or is different from previous experiments. If the resistance or the power and temperature are very different from before, the problem is most likely in the heater assembly and/or the TC wiring.
Temperature indicated by the thermocouple (matched to power) differs significantly from previous experiments	• The type of sample used may affect power consumption • The sample isn't fully in place • The thermocouple type is entered wrong to the Eurotherm or software • The thermocouple wiring is damaged	Check the conditions of your comparison data. Check that the Eurotherm and software have the right thermocouple type (S/C) entered. Check TC feedthrough resistance
Rotation is noisy or stuck	• Noisy rotation or sticking indicates a bearing problem	Maintenance is needed. Contact the DCA factory
Z-motion is stuck or slow to respond	• The worm gear is dry after bake-out • There is dust in the gearbox	Clean if necessary. Lubricate the gears according to section 7.
Other	• Any other observed anomaly	Contact DCA Instruments technical support.

11 DISPOSAL

11.1 How to Dispose

To dispose the component:

1. Clean all components and chambers from hazardous materials using a professional and authorized company.
2. The main component structure is made from stainless steel and so can be recycled as metal scrap.

11.1.1 Disposal of electronic components

The symbol on the component, 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.

11.1.2 Disposal of packaging waste

Retain packaging if possible until the component 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.

12 WARRANTY

I. DCA Instruments warrants that the UHV Substrate Manipulator 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.

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APPENDIX I - 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

Components

Manufacturer	Item Description	Model
DCA Instruments	Motor Control Unit	MCU-RS
DCA Instruments	Motor Control Unit	PSU-Z
DCA Instruments	Motor Control Unit	MCU-Z
DCA Instruments	Motor Control Unit	MCU-F
DCA Instruments	Stepper motor	Z/RS
Eurotherm	PID Controller	3500 /3216
TDK Lambda	DC Power Supply	Genesys series

Spare/replacement parts

DCA #	Item	Description
GASKETS		
10084	Gasket DN100CF	Copper Silvered
10086	Gasket DN160CF	Copper Silvered
10088	Gasket DN200CF	Copper Silvered
10094	Wheeler Gasket DN300WS	Cu
10096	Wheeler gasket DN400WS	Cu
10097	Wheeler gasket DN450CF	2mm Cu wire seal
SCREWS & NUTS		
12123	Screw Slot-Headed M2x3	Mo DIN84
12098	Screw Slot-Headed M2x4	Mo DIN84
11188	Screw Slot-Headed M2x6	Mo DIN84
11189	Screw Slot-Headed M2x10	Mo DIN84
12542	Screw Slot-Headed M4x6	Mo DIN84
12189	Screw Slot-Headed M4x8	Mo Cylindrical DIN84

12212	Screw Slot-Headed M3x4	Mo DIN84
11796	Screw Slot-Headed M3x10	Mo DIN84
11963	Screw Slot-Headed M2x12	Ta DIN 84
11890	Screw Hex Head M4x10	Ti DIN 912
12249	Screw Hex Head M4x8	Ti DIN 912
12535	Screw Hex Head M3x6	Ti DIN912
12536	Screw Hex Head M3x5	Ti DIN912
11162	Nut M2 Hexagonal	Ta DIN934
11163	Nut M3 Hexagonal	Ta DIN934
11310	Nut M5	Ti DIN 934
11751	Nut M4 DIN934	Mo
11792	Nut M3	Mo
FEEDTHROUGHS		
12216	FT Power DN16CF 2PIN	55A 5kV Copper FA11666
12217	FT TC DN16CF	C-TYPE without plug FA23158
12236	FT TC DN16CF	K-TYPE without plug FA23158-02
INSULATOR		
11829	Insulator Button 10x3.2 S=3	Alumina (Al_2O_3)
11066	Insulator Bead 2.5x1.3 S=2.8	Alumina(Al_2O_3)
BEARINGSS		
11902	Bearing Ball S626XXWS 6x19x6	Stainless Steel Tungsten Disulfide
11659	Bearing Ball S6804XXWS	20x32x7 Stainless Steel Tungsten
12356	Bearing Thrust 51106 30x47x11	Cr. Steel Tungsten
11882	Bearing Ball	
12263	Bearing Kaydon	
HEATER ELEMENTS		
	1.5” Silicon Carbide	Flag-style (dwg.# 9449-440-01)
12209	2” Silicon Carbide	Single zone
12410	3” Silicon Carbide	Single zone
12697	4” Silicon Carbide	Single zone
12862	6” Silicon Carbide	Single zone
11800 (1pc) 11975 (4pc)	8” Silicon Carbide	Dual zone
	12” Silicon Carbide	Dual zone
12692	2” PBN-coated PG	Single zone

11289	3” PBN-coated PG	Single zone, Outgassing LBC module ONLY
11794 (CUP)	4” PBN-coated PG CUP heater	Single zone, suitable for 3” substrates
11293	4” PBN-coated PG	Single zone, Outgassing LBC module ONLY
12411	4” PBN-coated PG	Dual zone
12664	3x2” PBN-coated PG	Dual zone
13026	3x3”/ 7x2” PBN-coated PG	Dual zone
	4x4” / 7x3” PBN-coated PG	Dual zone (dwg. #2226-449-03)
BAYONET CUP		
	1.5” Bayonet Cup, Ta/Mo	Incl. ring set (top, middle& bottom)
	2” Bayonet Cup, Ta/Mo/Inconel	Incl. ring set (top, middle& bottom)
	3” Bayonet Cup, Ta/Mo	Incl. ring set (top, middle& bottom)
	4” Bayonet Cup, Ta/Mo	Incl. ring set (top, middle& bottom)
CABLES		
	S-Type Thermocouple	
	C-Type Thermocouple	
	LEMO Power cable	
	Stepper Motor cable	
	Interlock cable	
	TC assembly, mounted to heater (1 pair)	11048, 11001, 11315
OTHER		
11402	Worm gear	
	Threaded rod	Ti M3 L=TBC
	Heat reflector structure	Ta, 2222-440-09
	Contamination shield	Ta

APPENDIX III - RELATED DOCUMENTATION

#	Document Title	Version #	Author
1	01_XXX_UHV Deposition	1.0	DCA Instruments
2	02_Bakeout System	2.3	DCA Instruments
3	8.11/8.12/8.13/8.14_Substrate Manipulator Drive		DCA Instruments
4	3500 Series and 3216 Process Controllers		Eurotherm
5	Genesys Programmable DC PSs		TDK Lambda