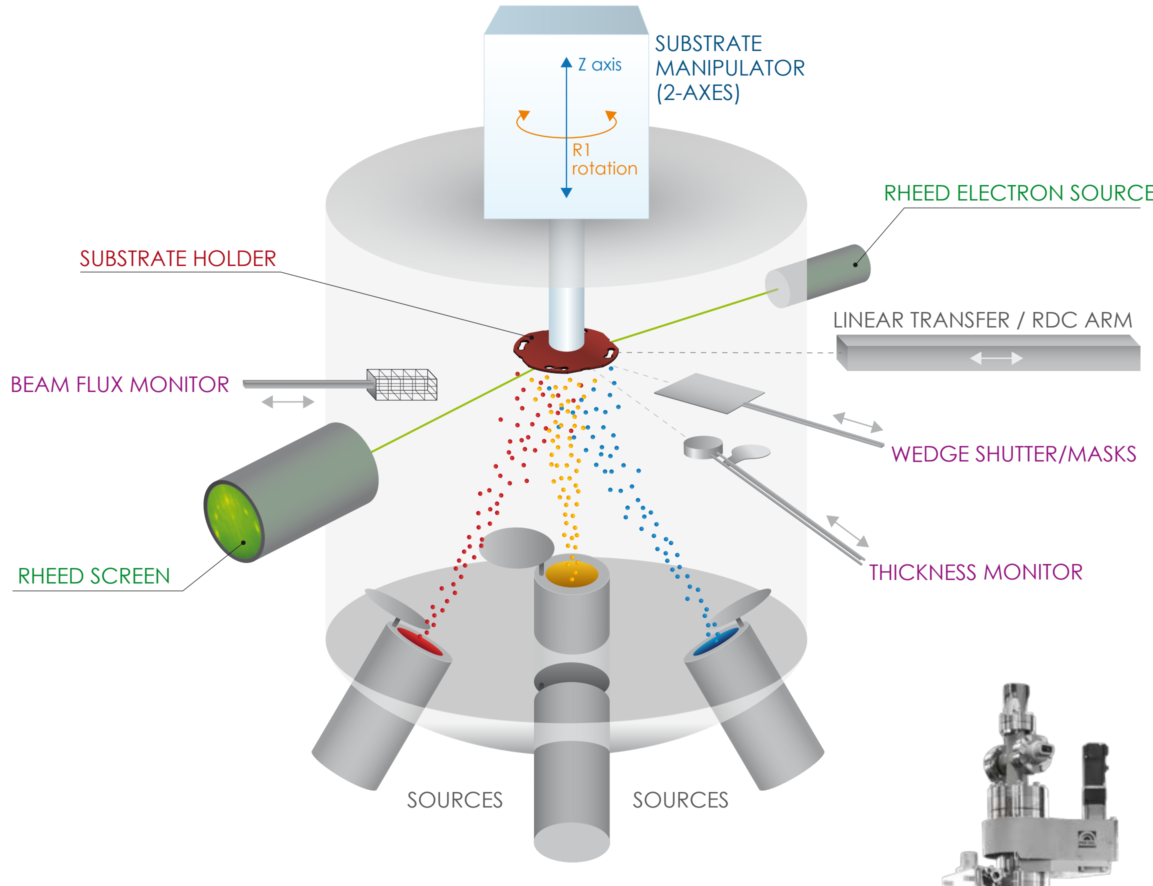
**Precision** and **Vacuum** Technology

# **MBE** SYSTEMS

Advanced solutions for thin layers growth technology

The MBE multi-chamber or standalone system for thin-film deposition of single crystals feature in-situ characterisation of magnetic properties, topography, crystallography, film thickness and more. The basic UHV MBE systems comprise a deposition process chamber together with a load lock chamber. The MBE process chamber can be equipped with electron beam evaporators, effusion cells (e.g. high- or low-temperature, valved cracker sources (single or multi-filament), quartz balances, RHEED instruments, high power E-guns and others. The process chamber base pressure is guaranteed in the range of $5\times10^{-10}$ - $5\times10^{-11}$ mbar (dependent on the application and pumping specification). The deposition process can be controlled over a wide temperature range (from $LN_2$ up to 1400˚C) and can be fully software programmed and controlled via PLC controller. The system can also feature in-situ RHEED analysis.

## THIN FILM GROWTH by MBE TECHNOLOGY




## PROCESS CHAMBER

The process chamber is constructed from stainless steel in cylindrical geometry, but different geometries are also available on request.

The chamber is equipped with connecting flanges in UHV standard in different sizes for connecting current and future equipment, including:

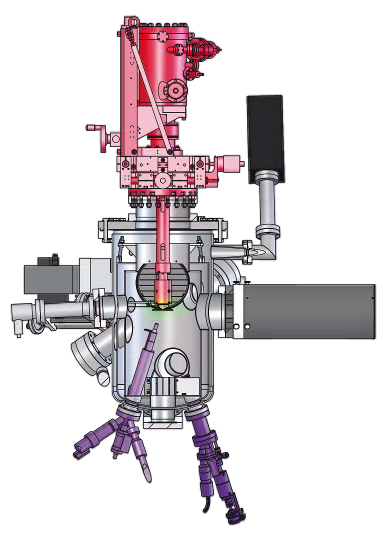
- **evaporation sources**,
- **substrate manipulator**,
- **pumping system**: combination of different types of pumps (e.g. forevacuum pumps, ion pumps, cryo-pumps, turbo pumps, titanium sublimation pumps) individually selected to achieve the best pumping performance according to application demands,
- **transferring system**: entry port for linear transfer/radial distribution chamber/transferring tunnel,
- **RHEED electron source** (and RHEED screen),
- **residual gas analyser**
- **quartz balances**
- **viewports** (observation windows with shutters)
- **heated viewports** for diagnostic
- **beam flux monitor**
- **vacuum gauges**

All technical specification and details of MBE equipment presented on the following pages can be customized to the customer needs and for specific applications.

## STANDARD CHAMBER DIAMETERS

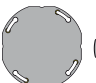
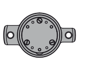
Different standard sizes of chamber are available depending on the type and number of evaporation sources and on the substrate size: Ø300, Ø450 and Ø570mm (other sizes on request).

### model 300



**Manipulator**
- 2 axes ZR1 (standard)
  4 axes XYZR1 (option)
- heating and cooling

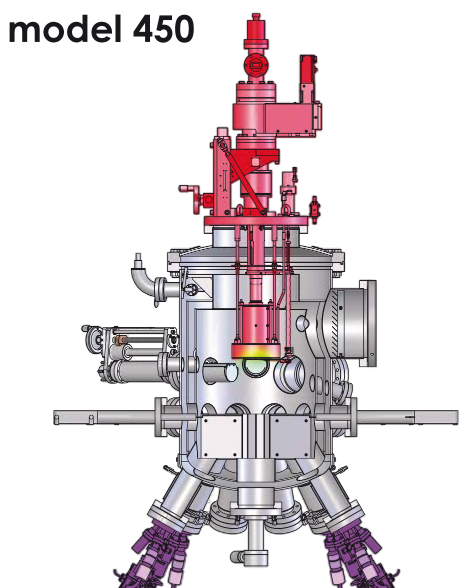
**Substrate holder**

- Substrate size up to 2" (recommended)

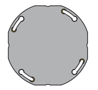
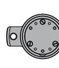
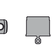
**Sources ports**
example configuration:
- 7 ports DN 40CF
- 1 port DN 63CF

### model 450



**Manipulator**
- 2 axes ZR1 (standard)
  4 axes XYZR1 (option)
- heating and cooling

**Substrate holder**

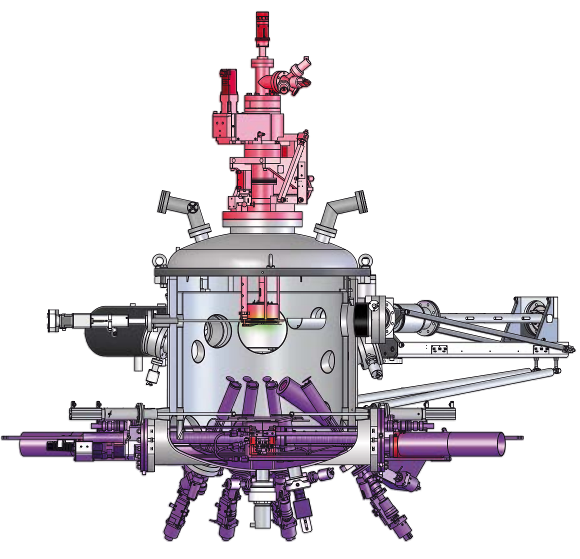




- Substrate size up to 4" (recommended)

**Sources ports**
example configuration:
- 10 ports DN 63CF

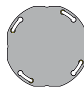
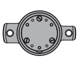
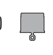
Additional 10 ports DN 63CF for shutters

### model 570



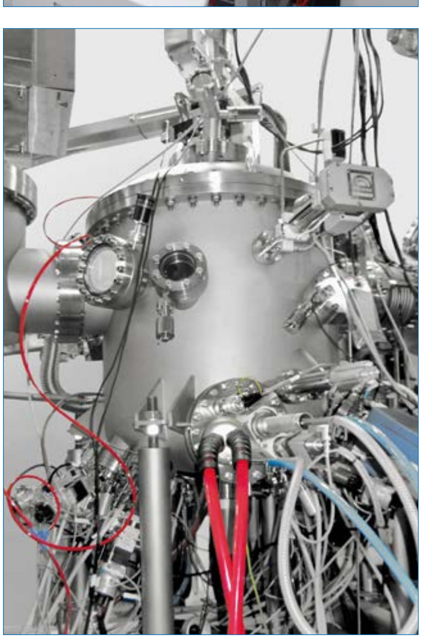
**Manipulator**
- 2 axes ZR1 (standard)
  4 axes XYZR1 (option)
- heating and cooling

**Substrate holder**

- Substrate size up to 6" (recommended)

**Sources ports**
example configuration:
- 8 ports DN 63CF
- 2 ports DN 160CF



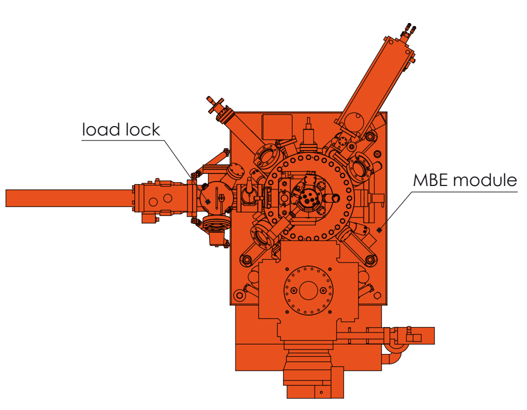
Stand-alone MBE system with load lock chamber.

- Base pressure better than $2\times10^{-10}$ mbar
- 4-axes manipulator with direct and e-beam heating up to 1200 °C and $LN_2$ cooling
- Load lock with linear transfer for fast and easy flag style sample holders introduction
- Process chamber contains ports for e.g. RHEED gun, ion gun, beam flux monitor, quartz balances etc.

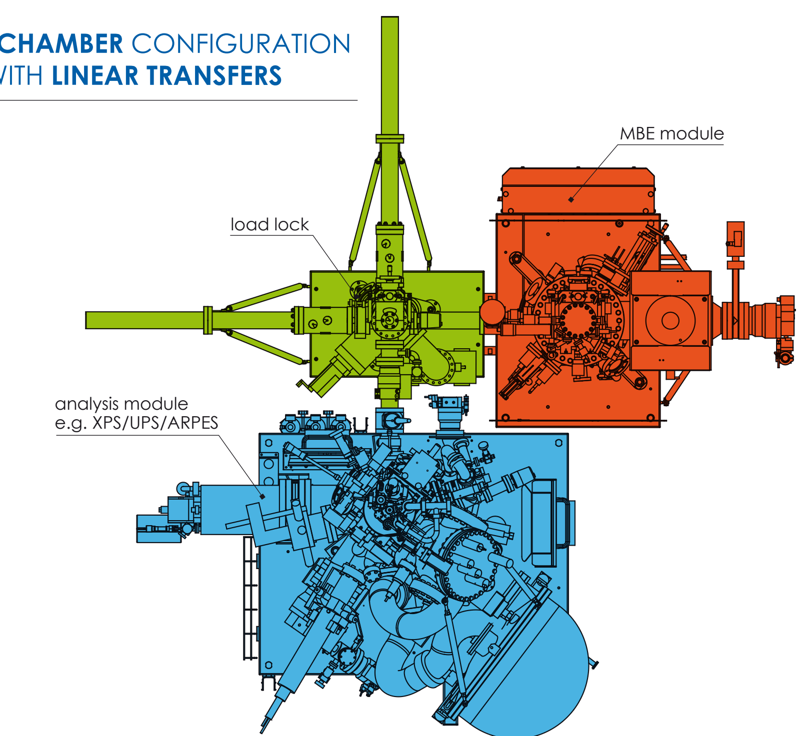
Multi-technique photo emission UHV system for super resolution ARPES measurements with integrated MBE chamber.

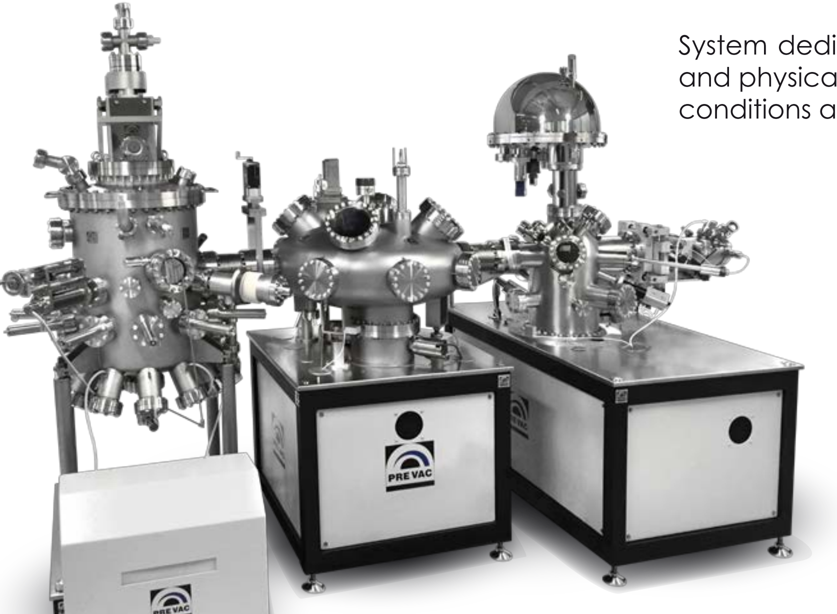
- Base pressure for MBE chamber: $2\times10^{-10}$ mbar
- 15kV electrostatic focused RHEED electron source
- 4-axes manipulator with RES heating up to 1000 °C and $LN_2$ cooling for MBE chamber
- Transferring system with load lock and storage chambers for 12 flag style sample holders
- Analysis module with ultra high resolution photo-electron analyser and PREVAC RMC50 monochromatic X-ray source

## **STAND-ALONE** CONFIGURATION




## **MULTI-CHAMBER** CONFIGURATION WITH **LINEAR TRANSFERS**





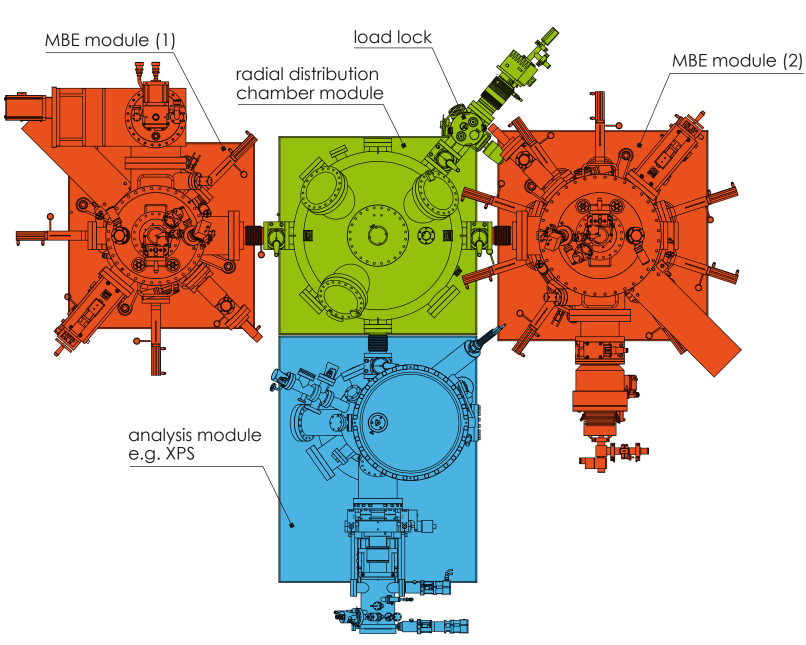

System dedicated for investigation of the chemical and physical properties of solid state surfaces in UHV conditions and for thin film growth process.

▪ MBE chamber with 10 effusion cells and 10 electro-pneumatic shutters,
▪ High precision 2-axes manipulator with oxidation resistant heater and water cooling shield,
▪ Deposition rate measurement system and beam flux monitor,
▪ Radial distribution chamber (UFO) with load-lock chamber for fast introducing & transferring the 2" PTS sample holders between chambers under UHV conditions,
▪ Analysis module with base pressure range $5 \times 10^{-11}$ mbar,

Multi-chamber deposition cluster tool dedicated for metallic multi-layers deposition from magnetic materials.

▪ MBE chamber with E-guns for 12 materials and 8 effusion cells,
▪ 2-axes manipulator with EB heating up to 1400°C in the process chamber,
▪ Radial distribution chamber (UFO) semi-automatic transfer/distribution for reliable movement of up to 3" plate style sample holders between chambers,
▪ MOKE chamber for Kerr effect analysis (for flag style sample holders),
▪ Integrated SPM chamber with additional tip and sample loading system,
▪ Two preparation chambers,
▪ Low vibration design.

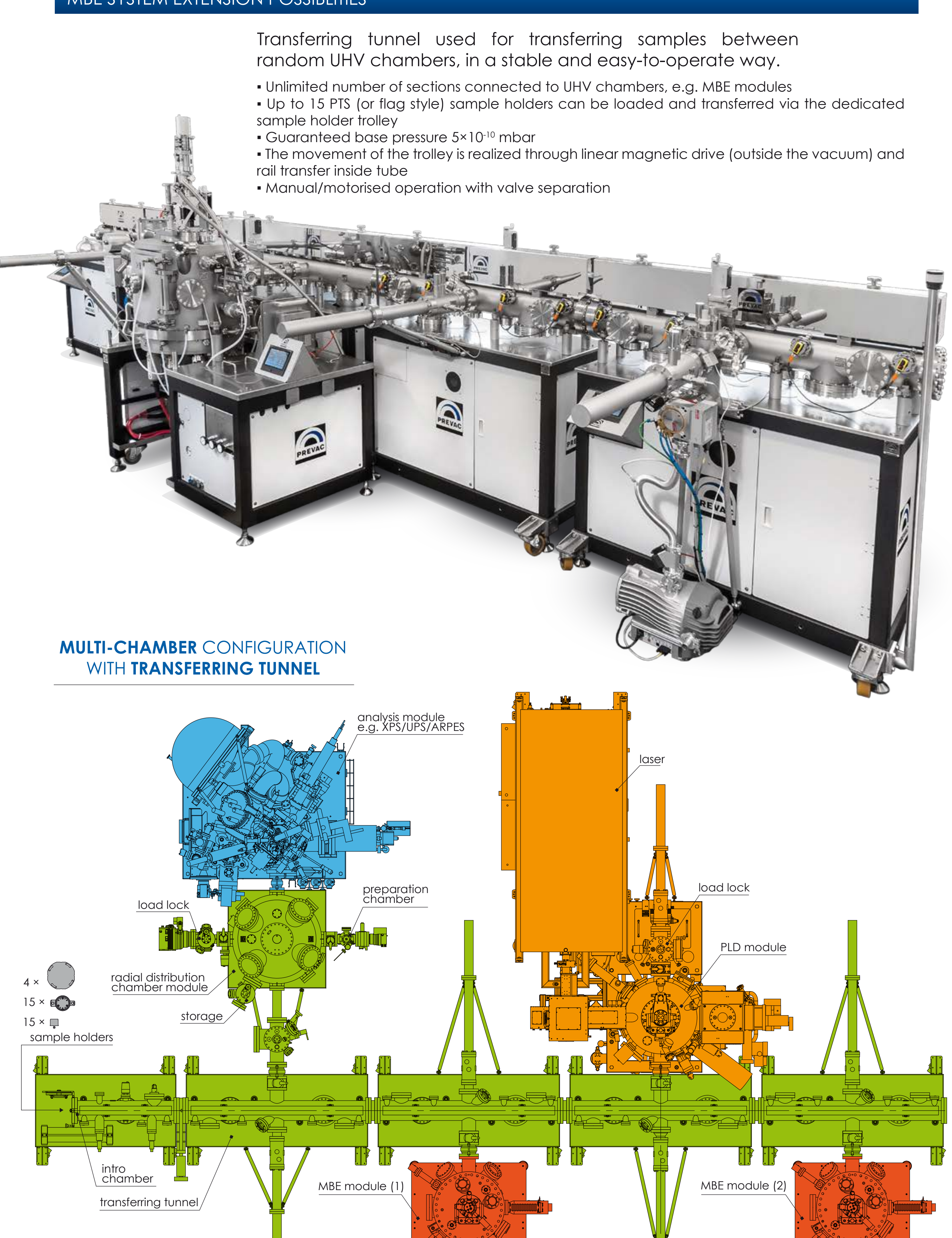
## **MULTI-CHAMBER** CONFIGURATION WITH **RADIAL DISTRIBUTION CHAMBER**



## MBE SYSTEM EXTENSION POSSIBLITIES

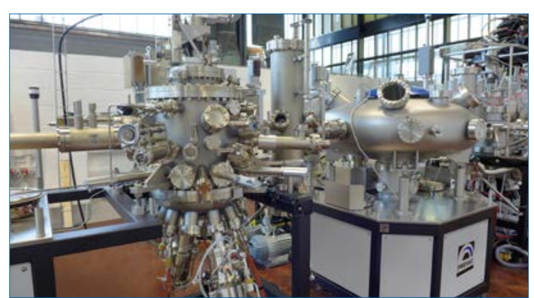
Transferring tunnel used for transferring samples between random UHV chambers, in a stable and easy-to-operate way.

- Unlimited number of sections connected to UHV chambers, e.g. MBE modules
- Up to 15 PTS (or flag style) sample holders can be loaded and transferred via the dedicated sample holder trolley
- Guaranteed base pressure $5 \times 10^{-10}$ mbar
- The movement of the trolley is realized through linear magnetic drive (outside the vacuum) and rail transfer inside tube
- Manual/motorised operation with valve separation




### **MULTI-CHAMBER** CONFIGURATION WITH **TRANSFERRING TUNNEL**

MBE deposition system with easy access and replaceable bottom flange with different source configurations.



- Base pressure range better than 5x10$^{-11}$ mbar
- Main frame prepared for use with dedicated lifting trolley (bottom flange dismounting)
- $LN_2$ cooling shroud surrounding deposition area and cooling baffles between effusion cells to limit cross-talk and contamination
- Internal liner/shield for protecting the wall of process chamber against coating of evaporated materials
- Load lock with linear transfer for introducing 2" plate style sample holders
- 2-axes manipulator with heating up to 1200°C

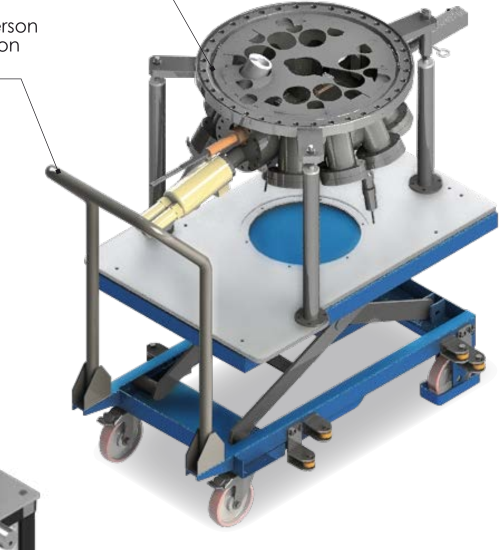
## MULTI-CHAMBER CONFIGURATION WITH RADIAL DISTRIBUTION TRANSFERRING SYSTEM

MBE module (2)
organic deposition module
laser
MBE module (1)
PLD module
storage
storage
storage
radial distribution chamber module
load lock
load lock
load lock
buffer chamber
radial distribution chamber module
storage
buffer chamber
storage
STM module
load lock
metal deposition module (1)
metal deposition module (2)

Possibility of expanding the system with additional deposition chambers by transferring systems based on e.g. radial distribution chambers.

## REPLACEABLE BOTTOM FLANGE

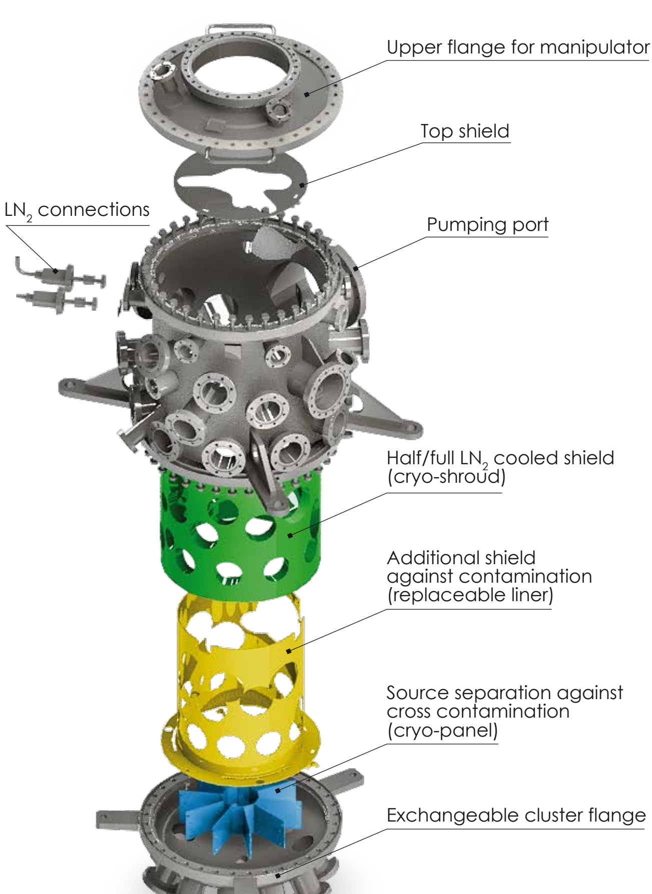
The bottom flange with sources can be fully accessed or replaced using the dedicated lifting trolley.



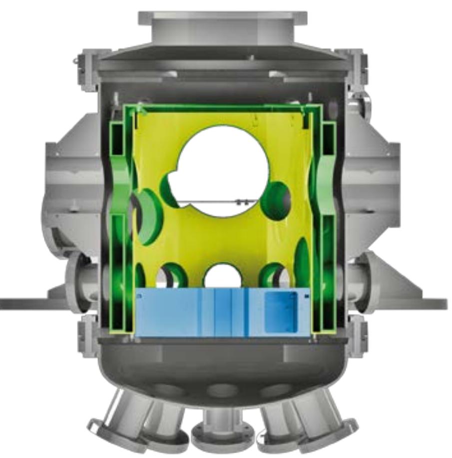

One versatile trolley can be used to replace both the bottom flange, cryo-panel and liner (for easy cleaning).

Thanks to the possibility of replacing the bottom flange with sources, one depositon chamber can be adapted to different applications.

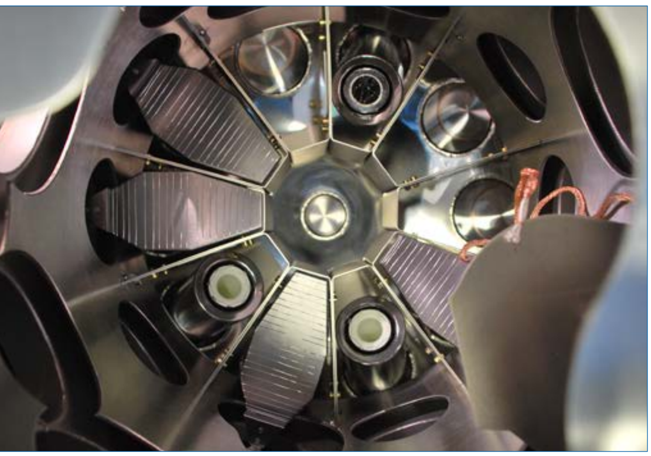
## PROCESSING CHAMBER SUBASSEMBLIES




Exploded view of the deposition chamber.



Arrangement of the cryo-panel, shroud and liner.



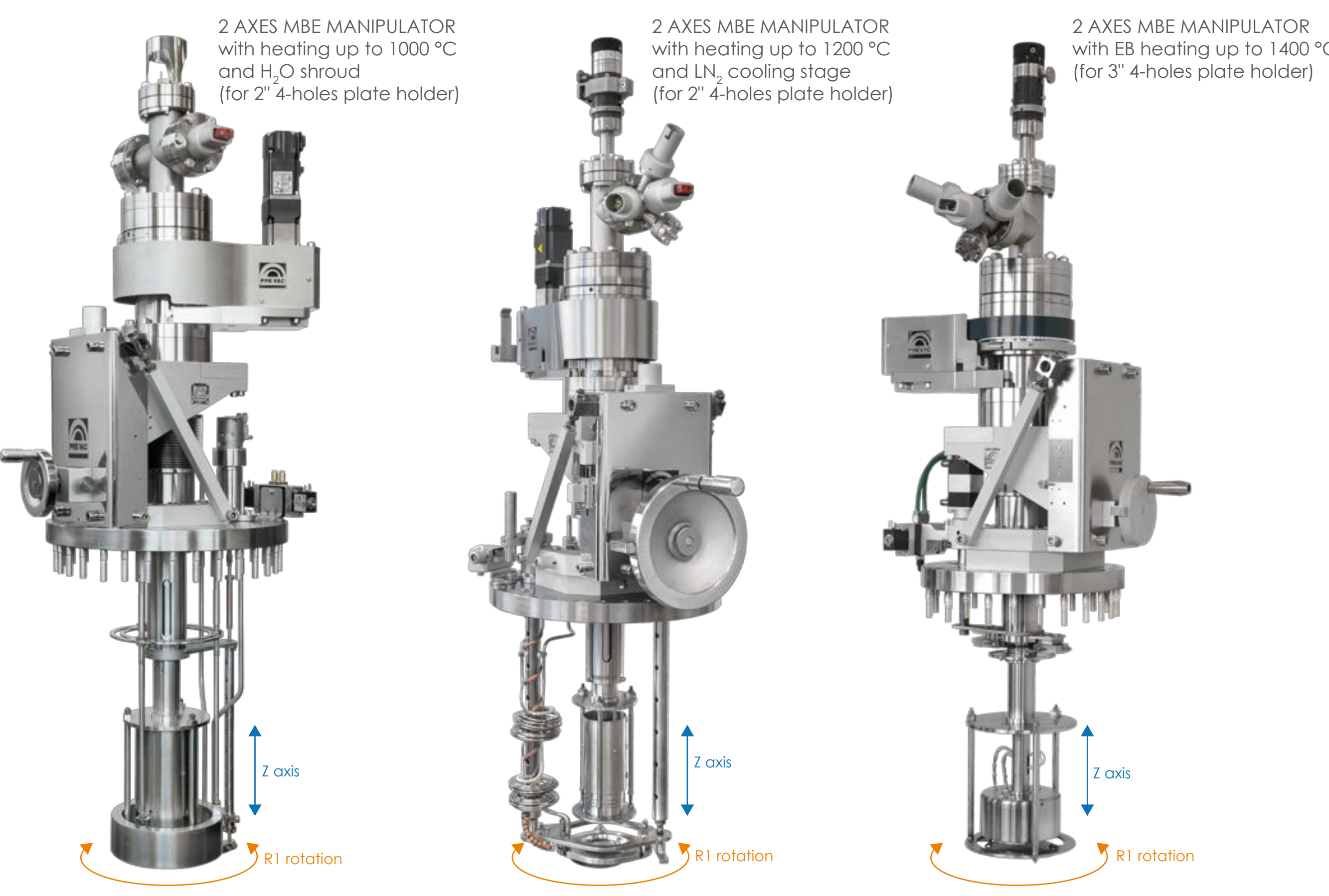
Cross contamination barriers in the processing chamber.

## MBE MANIPULATORS

The 1-2 axes motorised MBE manipulator is a high precision, high rigidity, UHV specimen manipulator of modular construction, suitable for a range of R1 motorised continuous substrate rotation and Z translation. Manipulators are prepared to heat the substrate up to 1400°C (EB heating, UHV conditions) with accuracy +/- 1°C.

### OPTIONS

- $H_2O$ shroud
- $LN_2$ or $H_2O$ cooling
- side or integrated wedge shutter (possible with $H_2O$ cooling option)
- XY stage (for PTS & flag style holders only)
- shutter on/off




### RECEIVING STATION with $LN_2$ cooling stage

The station includes the substrate (standard up to 6 inch sample holder) positioner and allows precise angular position of substrate in relation to linear shutter.

### HEATER MATERIALS

| | |
|---|---|
| Graphite | flexible (stable in form), minimal outgassing at the high temperatures, heating up to 1000°C (UHV conditions) |
| Graphite + PBN coating | flexible (stable in form), minimal outgassing at the high temperatures, heating up to 1000°C (UHV conditions) or up to 800°C (reactive gases) |
| Graphite + SiC coating | hard, light and stable in form, heating up to 1000°C (UHV conditions, reactive gases) |
| SiC solid (β) | extremely hard, light and stable in form, low thermal expansion, durable to mechanical and electrical shocking, heating up to 1200°C (UHV conditions, reactive gases) |

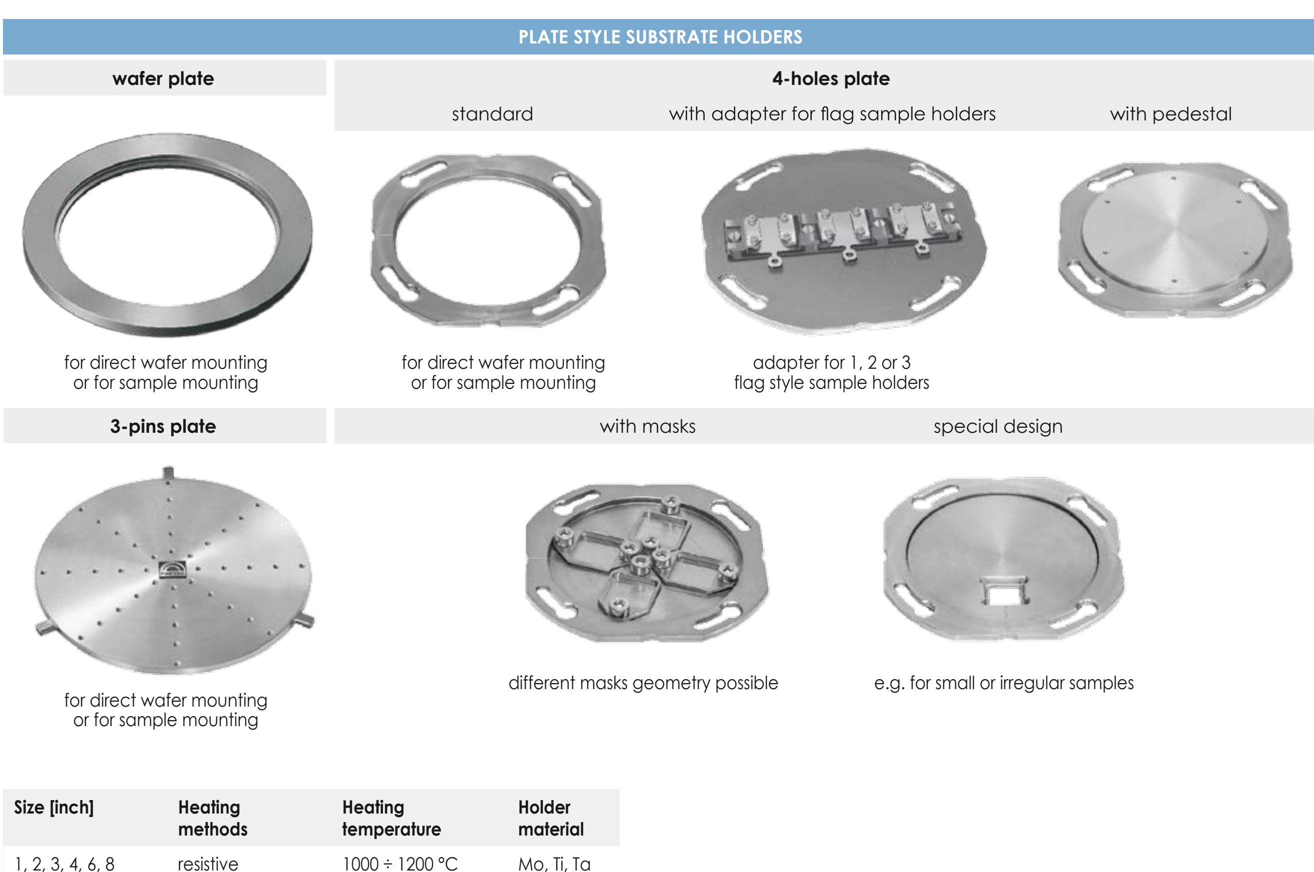
### TECHNICAL DATA

| | |
|---|---|
| Standard base flange | DN 100CF to DN 300CF (depending on the sample size, other on request) |
| Base pressure range | $10^{-11}$ mbar |
| Shutter | integrated or external (wobble-stick), pneumatic or manual |
| Heating methods | resistive, electron bombardment |
| Substrate temperature | up to 1200 °C (RES), up to 1400 °C (EB) |
| Cooling method | $LN_2$, $H_2O$ |
| Z range | 50 mm (other on request) |
| positional control | handwheel / motorised* |
| resolution (manual/motorised) | 500 µm / standard 10 µm |
| R1 range | 360° continuous |
| positional control | motorised* |
| XY range (option) | ± 12.5 mm |
| positional control | micrometer/motorised* |
| resolution (manual/motorised) | 5 µm / 1 µm |
| Max speed | up to 60 rpm |
| Bakeout temperature | up to 150 °C / 200 °C (on request) |

* stepper motor or servomotor - depends on application.
Manipulator can be prepared for customer motors or drivers - on request.

## SUBSTRATE HOLDERS

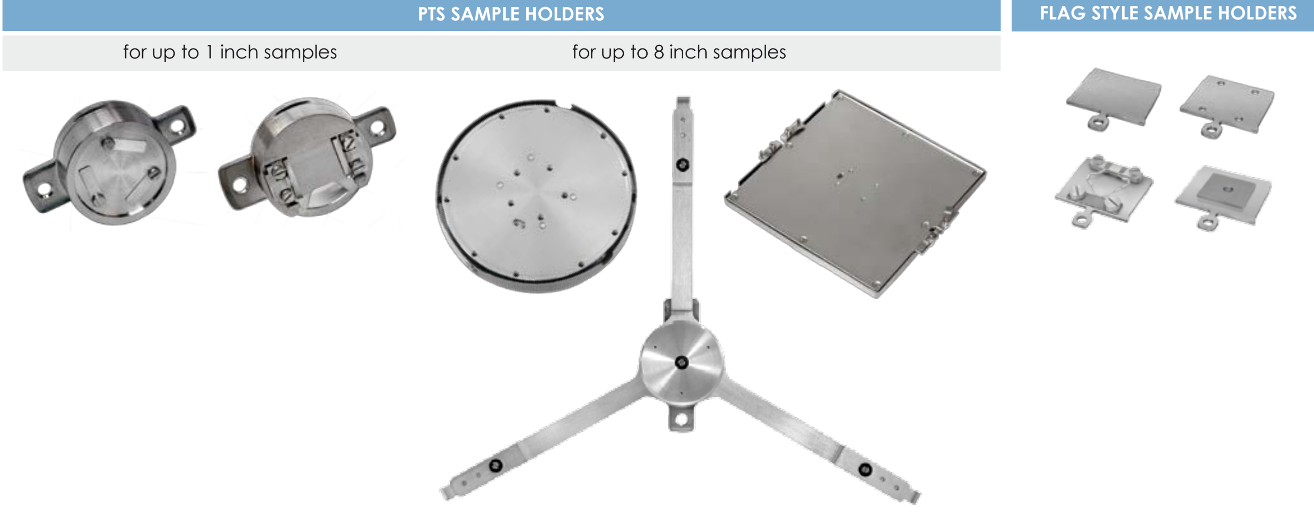
Plate styles substrate holders (for wafers, molyblocs) are dedicated for different deposition techniques, such as MBE, magnetron sputtering, thermal evaporation and others. Available in 1“, 2“, 3“, 4“ diameter size as standard (6“, 8“ and larger on request). The holder can be configured with adaptations for single and multiples of other types of sample holders, for example flag style plates. Standard material is molybdenum or titanium, other materials are available on request.




| Size [inch] | Heating methods | Heating temperature | Holder material |
|---|---|---|---|
| 1, 2, 3, 4, 6, 8 | resistive | 1000 ÷ 1200 °C | Mo, Ti, Ta |
| | EB | 1400 °C | |

NOTE | heating and cooling method and temperature depends on the manipulator

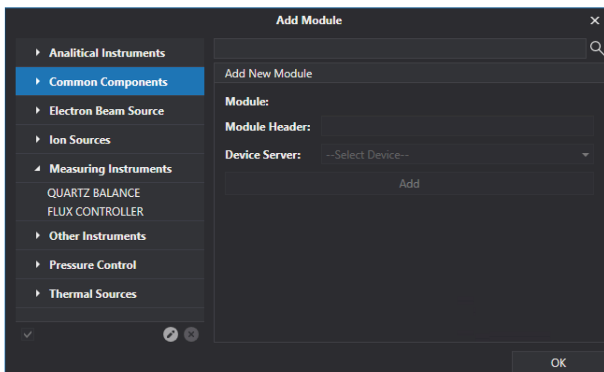
PTS and Flag style sample holders for a very wide range of applications can also be used as well.



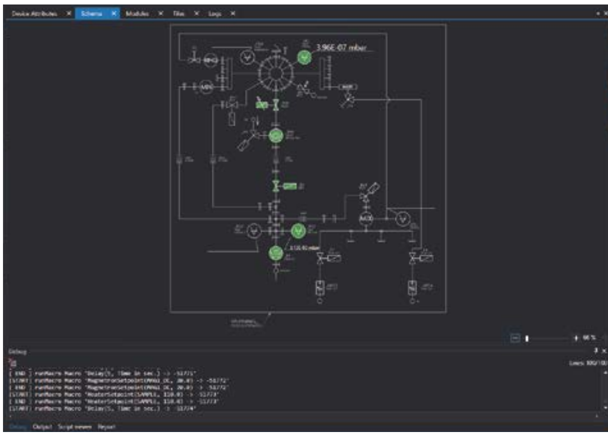
## FULLY AUTOMATED PROCESS CONTROL

Innovative software tool optimized for easy and complete control over the entire deposition process and all components in the system.

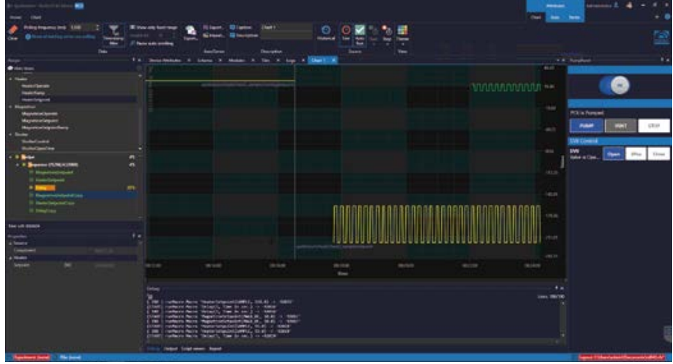
Synthesium comprises a convenient and intuitive graphical user interface allowing two general modes of operation: automated control by predefined recipes or manual control of all system elements.




- **Automatic process of sequences**
  e.g. macros, loops, calibrations, pauses
- **Graphical modules representing status of system elements**
  e.g. sources, substrates, pumps, valves
- **Adjusting parameters of all system components**
  e.g. MFC, valves, pumps, gauges, power supplies
- **Recipe Editor (XManager) with drag&drop operation**
- **Extended recipes with subrecipes (macros) within python script**
- **Password protected access rights using 1 of 9 levels**
  e.g. engineer, scientist, operator
- **Process data stored in MySQL database archiver**
- **Generation of text protocol files with all process information**
- **Remote access by VNC protocol**
- **Multi-level logging** functionality which allows to analyse the source of the problem.



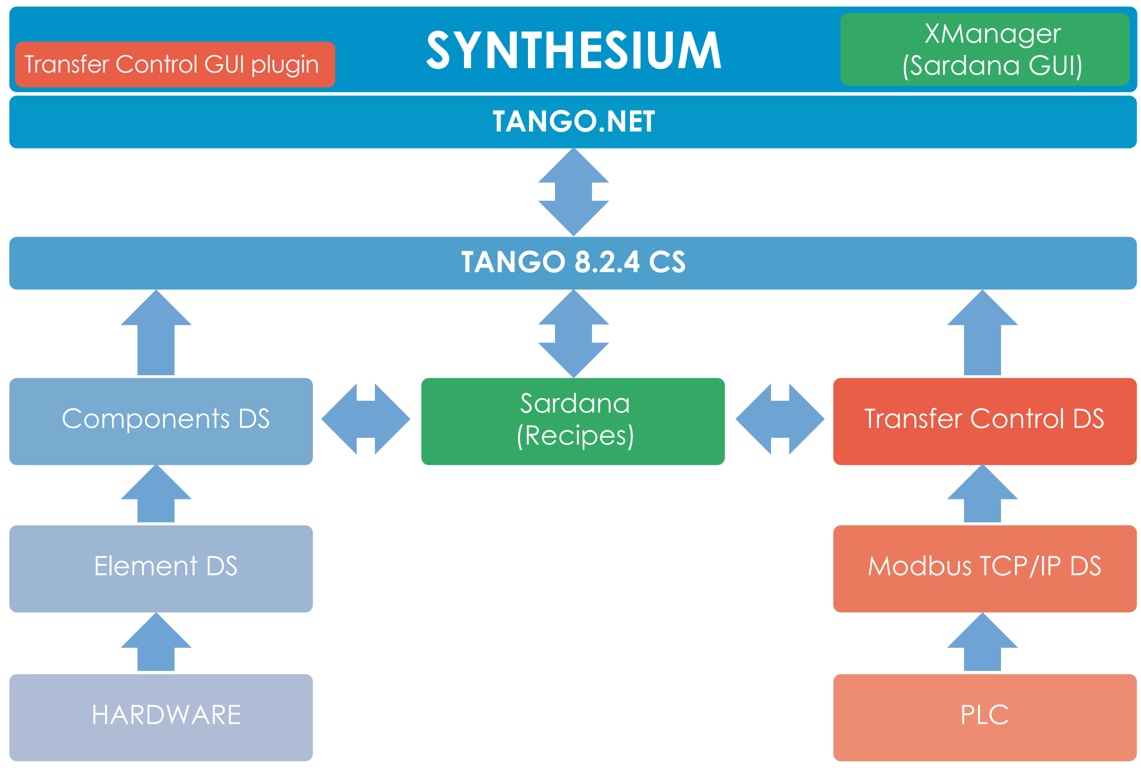
***Schema*** represents graphical diagram of all system components in one place.



The system offers additional, **extended chart module** (also available as an stand alone application).

## SOFTWARE ARCHITECTURE

Synthesium software is based on **TANGO technology** and is extremely easy to extend with new hardware. All recipes and new hardware modifications can be achieved by using open-source tools or, for example, in **Python Script**.



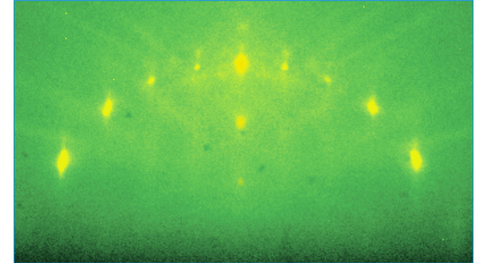

## RELATED EQUIPMENT

### INSTRUMENTS FOR DIFFRACTIVE SURFACE CHARACTERISATION

**RHEED** Reflection High-Energy Electron Diffraction

Technique widely used to characterise the surface of crystalline materials at atomic level:

- real-time monitoring during thin-film growths
- easy instalation in various types of deposition chambers without interfering with other components

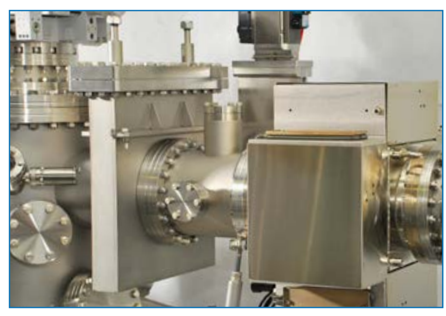


## ANCILLARY EQUIPMENT

To meet the requirements of the specific experiments, a range of devices and solutions can be applied. For example:

- Thanks to the **$LN_2$ cold trap** (cryogenic filter, selenium trap) and use of chambers and manipulators adapted to work with corrosive materials such as Se, Sb or Te, equipment can be optimized for **topological insulator research**,
- The use of **magnetic traps** for secondary electrons makes it possible to use very strong e-beam sources in the chamber. It excludes problems of sample damage and allowing experiments with organic samples (reducing the number of defects on samples and possible stresses). It is much appreciated while **growing of elements from groups IV.**
- By using **heated viewports** it is possible to constantly observe the growth process without the risk of window contamination with the applied material. When connected to ports with specific geometry and placement, heated viewports allow for mounting the precise temperature measurement system (e.g. pyrometer or BandiT system) for research of **phase transformations** in materials.

Viewport with heating.



$LN_2$ cold trap between MBE chamber and pumping system.

## EVAPORATION SOURCES

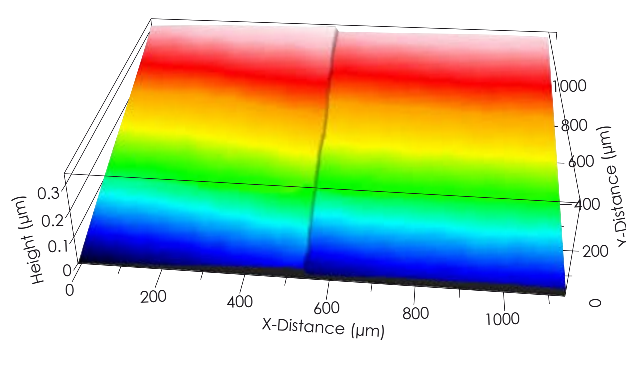
Depending on the application, the optimal working distance can be set for specific sources to ensure the best homogeneity of the growing layer, due to the specially designed chamber geometry.

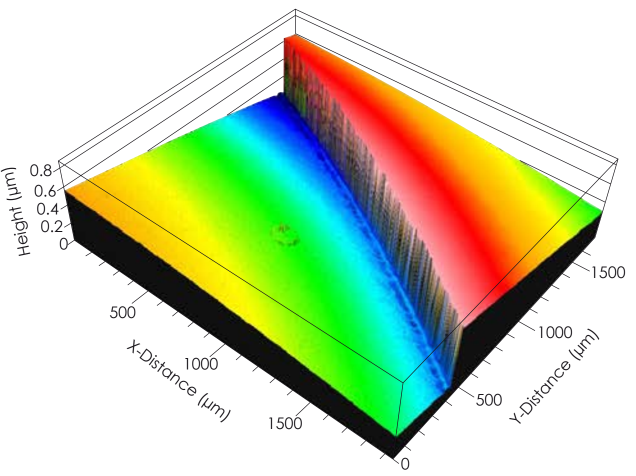
Growth chamber can be designed to be used with any available on the market evaporation source like electron beam evaporators, high power e-guns or effusion cells (e.g. high or low-temperature, valved cracker sources, single or multi-filament). Effusion cells come in many different designs classed as near-ideal, open-tube, conical, nozzle-jet, point-source, etc. with different names (including Knudsen cells, Kcells and proprietary names). The main differences between them are beam intensity (which affects film deposition rate) and angular distribution (which determines film thickness uniformity).

Our MBE deposition tools are suitable for various applications alike:

| Application | Sources | | | |
|---|---|---|---|---|
| | Effusion Cell | E-beam evaporators | Valved Cracker Source | Sublimation Source |
| Metals | Al, Co, Ni, Cu (etc.) | Mo, Pd, Ta, W, Pt | | |
| group III/V | Be, Al, Ga, In | | P, As, Sb | C, Si doping |
| group II/VI | Be, Zn, Cd | | S, Se, Te | |
| group IV | Ge, Sn, Pb | Si, Ge | | B, P, Sb doping |
| Oxides | Mn, Fe, Ni, Ga, Bi, Eu | | | |
| Topological Insulators (TI) | Ge, Sn, Te, Bi, GeSb | B | Se, Te | |

Homogeneous layer growth




## HEATING POWER SUPPLY

The **HEAT3-PS** is used for resistive heating or electron bombardment heating. The power supply can also be used for effusion cell evaporators. The unit is equipped with a PID temperature controller. Ramp heating function control sample temperature to protect sample from damage. Sample overheating can also be protected by setting the voltage and current limits. The unit can be operated in auto mode (with temperature control) or manual mode (without temperature control).

- **Dual heating mode: resistive and electron bombardment**
- **wide range temperature measurement** (1.4-2470 K)
- **2D real time chart module**
- fully manual or **PID temperature controlled** (by setpoint and ramp)
- high efficiency
- **Second DC module** available (option): two resisting heating zones with independent control
- **Shutter control function** (e.g. shutter of source or manipulator)

# RELATED EQUIPMENT

## THICKNESS MONITORING

**Thickness Monitor Controller TMC13** is the latest technology electronics designed for monitoring and controlling any coating and deposition processes. Up to six channel inputs and two additional vacuum gauge channels together with 7" TFT display makes this unit really unique and universal.

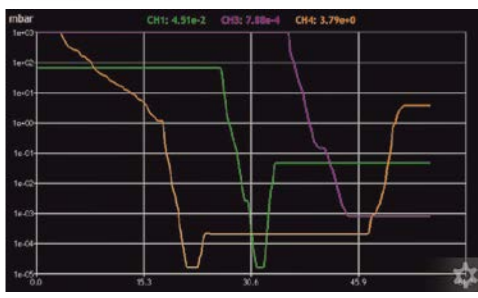
- **Six channels for quartz balance**
- **2D real time chart module** (option)
- Two inputs for most active vacuum gauges
- Up to 8 shutters and I/O reprogrammable
- Relay outputs
- Frequency resolution 0.1 Hz (for TM13) or 0.01 Hz (for TM14)
- Operation of up to two multi-crystal sensor heads (pneumatic or stepper motor)
- Two reprogrammable analog outputs for rate and thickness monitoring with 16 bits resolution

The **Quartz Balance QO 40A1** instrument provides a real-time, progressive indication of coating thickness during deposition, allowing the production of coatings of high accuracy and reproducibility. Customized insertion length 130 - 500 mm (other on request). Available with or without integrated manual/electro-pneumatic shutter.

## PRESSURE MEASUREMENT

The **MG15 Ion Multi Gauge Controller** is able to support four active gauges and up to three passive gauges, extending the measurement range to $2\times10^{-12}$ mbar. The unit is fully software controlled. The unit can be remotely controlled via one of available interfaces.

- **Measurement range from atmospheric to $2\times10^{-12}$ mbar**
- Pressure plots
- Pressure trend graphs
- Measurement filtering (low, med, hi)
- Supports Ir/W/Thoria filaments
- Bayard-Alpert overpressure protection
- Selectable measurement units: mbar, Torr, Pascal
- Gas specific correction with one customized setting
- Unit over-temperature protection
- Controls almost all commercially available Bayard-Alpert gauges
- Degassing of Bayard-Alpert with power and time limit
- 10 individually programmable set-points with threshold and hysteresis functions
- User-defined channel names
- Possibility of active gauges self-identification
- **Real time pressure charts** with data export possibility (option).
- **Flux monitor** (option)
- Black Box version available (option) - without 7" TFT display

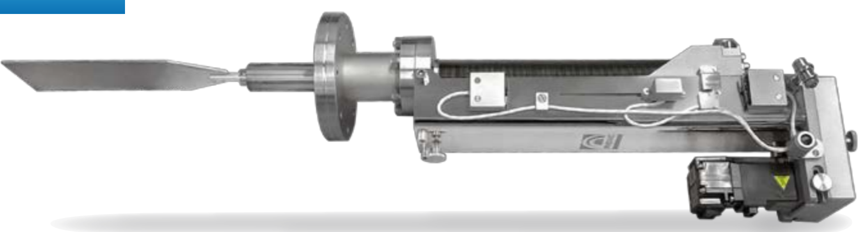



Real time pressure charts

The **Beam Flux Monitor** allows measurement of the beam flux during evaporation process.

## WEDGE SHUTTER / MASKS

Special shutter (wedge tool) for gradient film deposition. It helps preparing the specific patterns on the substrate during deposition process. The wedge plate can be equipped with a set of masks adapted to customer's requirements.

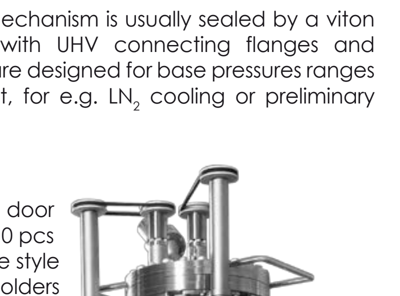


## RELATED EQUIPMENT

### LOAD LOCK CHAMBER

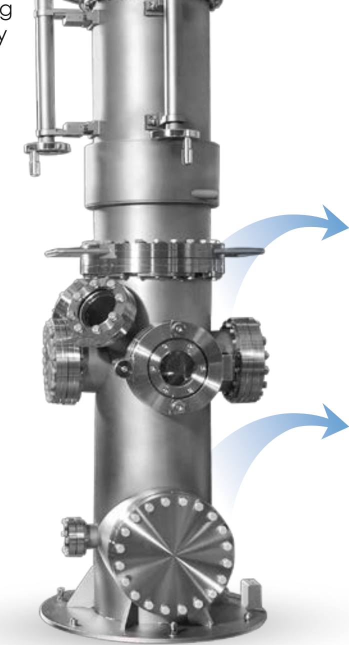
Load lock chambers provide a fast and clean method of introducing samples into UHV systems. The load lock chamber mechanisms combine with our range of load lock chambers to provide the most versatile sample loading conditions at various positions on the UHV system.

Load lock chambers are typically equipped with:
- load lock chamber mechanism
- pumping system
- viewports
- pressure gauges



The top port of the load lock chamber mechanism is usually sealed by a viton gasket. The chambers are equipped with UHV connecting flanges and additional ports for future versatility. They are designed for base pressures ranges $10^{-7}$ - $10^{-9}$ mbar. A range of options exist, for e.g. $LN_2$ cooling or preliminary sample heating by halogens or heaters.

Load lock with door access for 5 pcs 6" PTS sample holders



Load lock with door access for 10 pcs 2" 4-pins plate style sample holders and halogen heating possibility

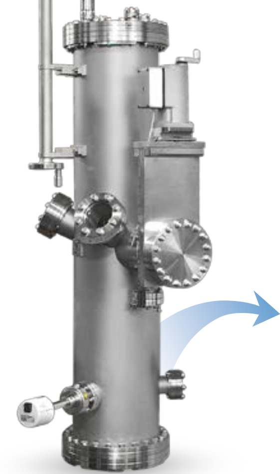
### STORAGE CHAMBER

The standard storage chambers allow to store up to 10 sample holders under UHV conditions. The storage chamber mechanism combines with our range of storage chambers.

Storage chambers are usually pumped via the distribution chamber pumping set (independent pumping is also possible if requested) and may be equipped with options for cooling or heating.

Storage for 30 pcs 6" PTS sample holders

Storage for 6 pcs Flag sample holders



Storage for 12 pcs 2" 4-pins plate style sample holders

## PREVAC **MBE SYSTEM** KEY POINTS

■ **Versatile, easy to extend** with other deposition or analytical techniques (by radial distribution or tunnel transferring system) and **low running operating cost** system design.

■ **Applications**: ideally suited for growth of elements from groups III/V, II/VI as well as other heterostructures.

■ Field-proven chamber design with combination of various typical or non-standard components made by PREVAC, as well as from other manufacturers, allows layer by layer precise MBE growth.

■ Possibility of mounting wide range of source options.

■ **Horizontal substrate holder transfer system** with face down wafer geometry & load lock chamber for easy sample introduction to the processing chamber without braking its vacuum.

■ Systems for **different substrate holders size** (from 10×10 mm to 8 inch) and shape (also for other manufacturer's holders).

■ Possibility for **In-situ characterisation tools**, e.g. RHEED, beam flux monitor, quartz balance, pyrometer or BandiT temperature measurement system.

■ **Synthesium process control software** allows integration and perfect cooperation of sources of various types and manufacturers, and enables easy recipe writing, automated growth control and extensive data recording. Allows integrating new additional components based on Tango open source device.

■ **Fully automated transferring system** (option).

■ Standard **manipulator with stable, long-life heater** element made of solid SiC and receiving station to achieve high temperatures up to 1200°C.

■ The bottom flange with sources can be **fully accessed** or **replaced** using the dedicated **lifting trolley**.

■ **$LN_2$ cooling shroud** surrounding deposition area and cooling baffles between effusion cells to limit cross-talk and contamination.

■ Internal **liner/shield** for protecting the wall of process chamber against coating of evaporated materials.

■ **Heated viewports** for constant observation of the growth process without the risk of window contamination with the applied material.

■ High-efficient pumping system adapted to the individual system configuration.

■ Each part of system is carefully, precisely tested. Helium leak testing and operation at maximum conditions is performed in each chamber to reach the high standard of our products.

If you need any further information, please do not hesitate to contact our sales department

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