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AVS 68

THE CHALLENGES OF HEATING A SAMPLE

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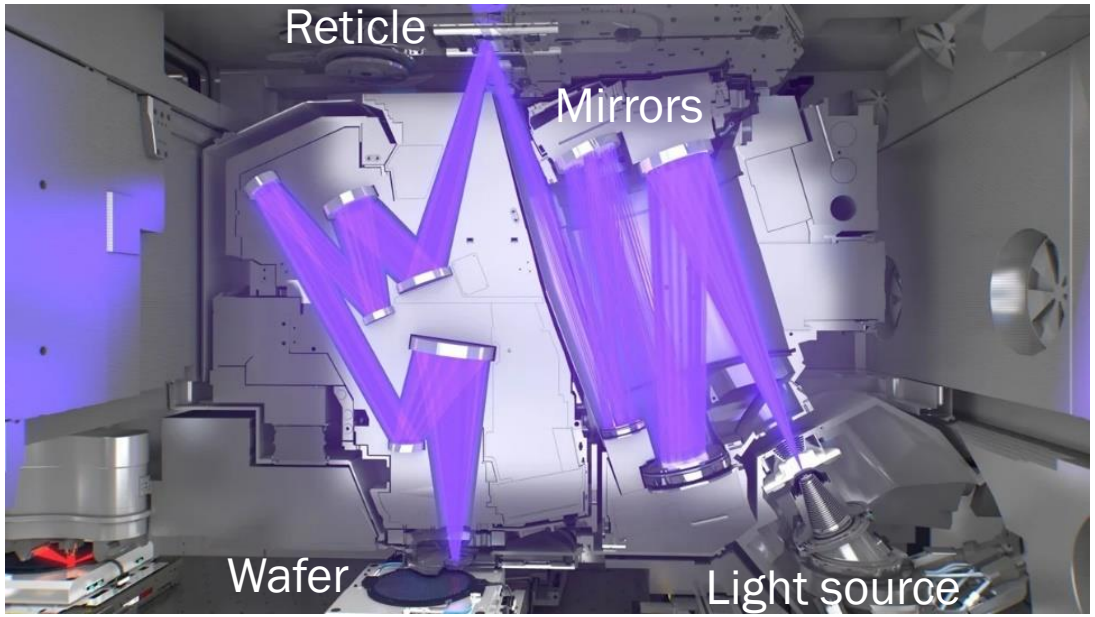
THE CHALLENGES OF HEATING A SAMPLE

CONTENTS

- What is the problem
- EUV exposure tool (EBL2)
- Boundary conditions
- Solution

EXTREME ULTRAVIOLET (EUV) LITHOGRAPHY

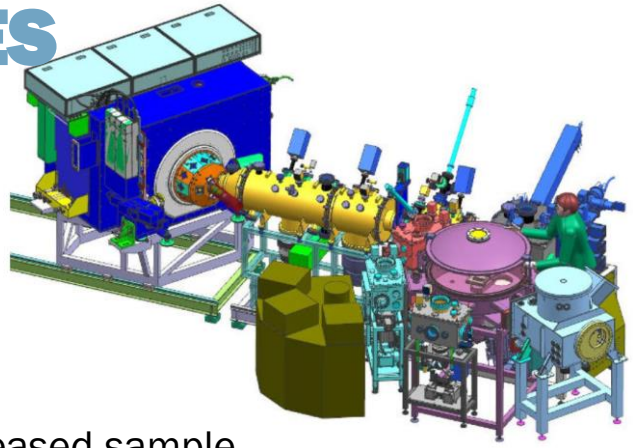
- Advanced Lithography Scanners
  - Use short wave length light EUV (13.5nm) for patterning of wafers with nm resolution
- EUV is absorbed by lenses and by air
  - Multi-layer Mirrors for high reflection with extreme (sub nm) flatness
  - Scanner operates in low pressure H_2 atmosphere (few Pa)
- An EUV scanner is a harsh environment for many materials due to
  - EUV
  - Plasma
  - Hydrogen ions / radicals
  - Heat



(Source ASML)

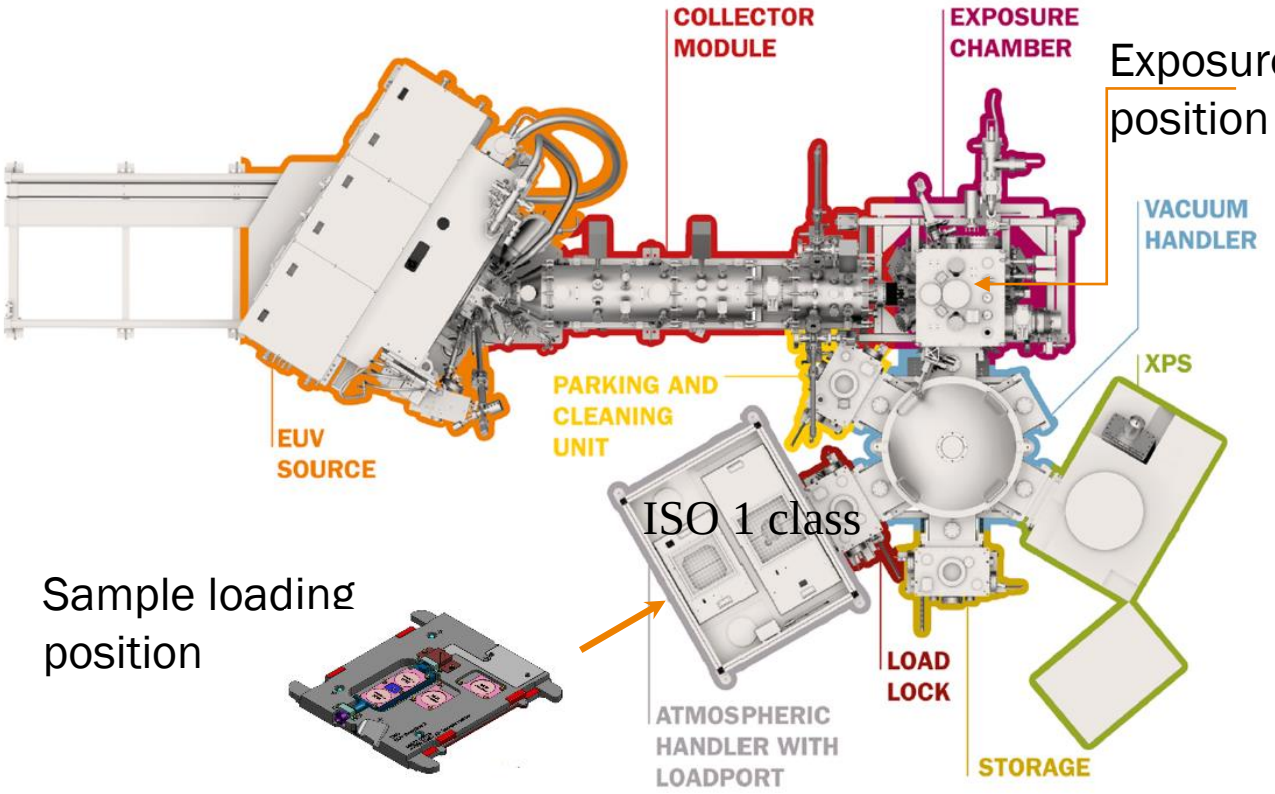
ACCELERATED LIFE TIME TESTING OF SURFACES

EUV EXPOSURE TOOL (EBL2)



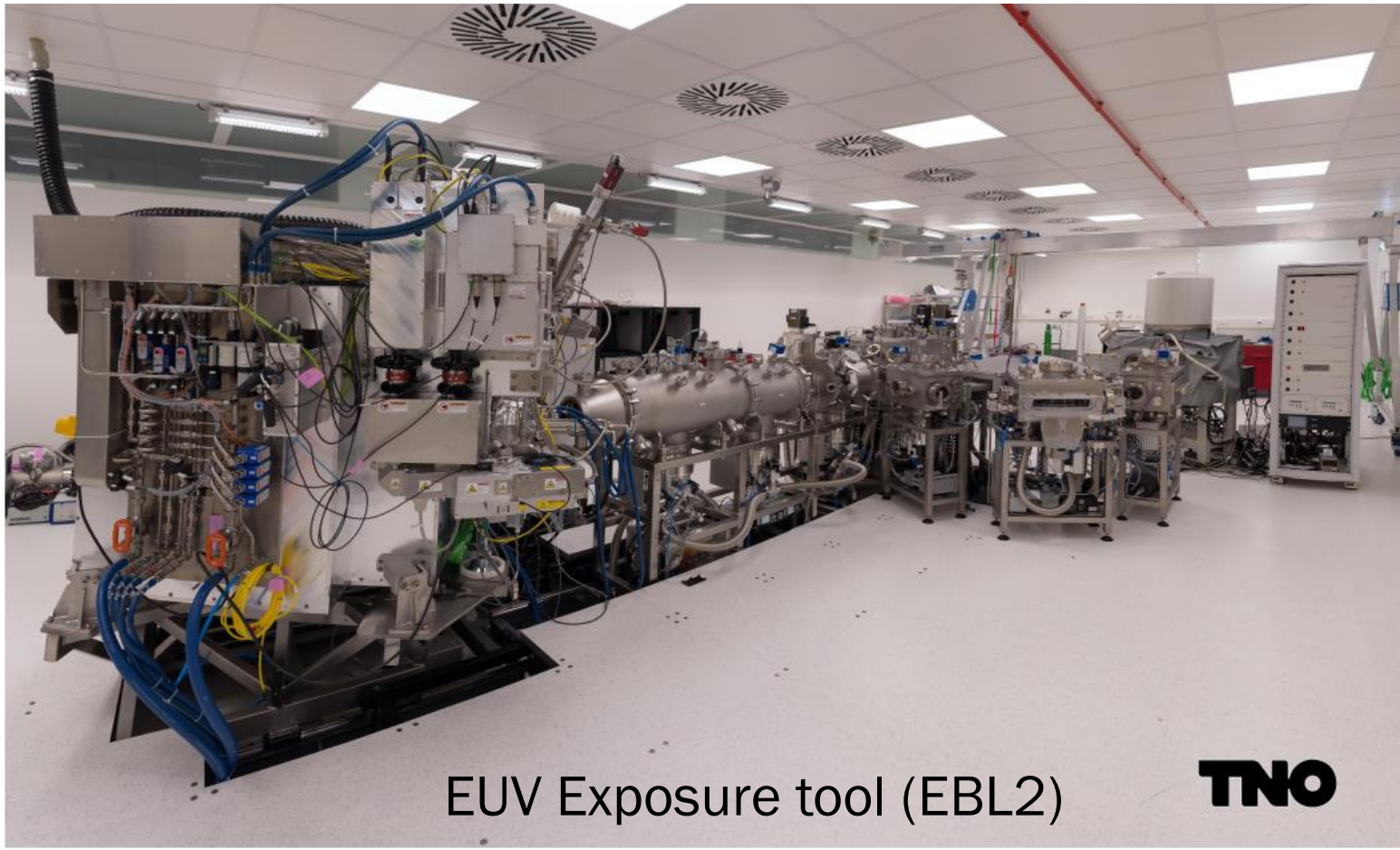
- EBL2 is an EUV research facility, designed/owned and operated by TNO
- Used by customers for lifetime research on mirrors and other materials under EUV conditions (www.tno.nl/EBL2)
- Question: Enable (accelerated) test conditions for materials under EUVL conditions with increased sample temperature

EUV Exposure tool (EBL2)



ACCELERATED LIFE TIME TESTING OF SURFACE EUV EXPOSURE TOOL (EBL2)

- Some characteristics
  - Sn-fuelled EUV source (Ushio)
  - Typical 4W @ 3kHz (spot 1-30mm dia)
  - Size sample: up till full masks 6inx6in with/without pellicle
  - Cleanliness 10^{-10} mbar
  - Typical partial pressures
    - 10^{-11} mbar CxHy (45 – 100 amu)
    - 10^{-12} mbar CxHy (101 – 200 amu)
  - <0.03 particle per reticle pass
  - NXE compatibility
  - In-situ analysis (XPS, ellipsometry)
  - Heated chuck –15°C to +150°C with BFG
  - Controlled gas atmosphere (RGA)
  - T-sample with i-button / pyrometer



EUV Exposure tool (EBL2)

ACCELERATED LIFE TIME TESTING OF SURFACE
EUV EXPOSURE TOOL (EBL2)

EUV dual pod consists of an inner and an outer pod

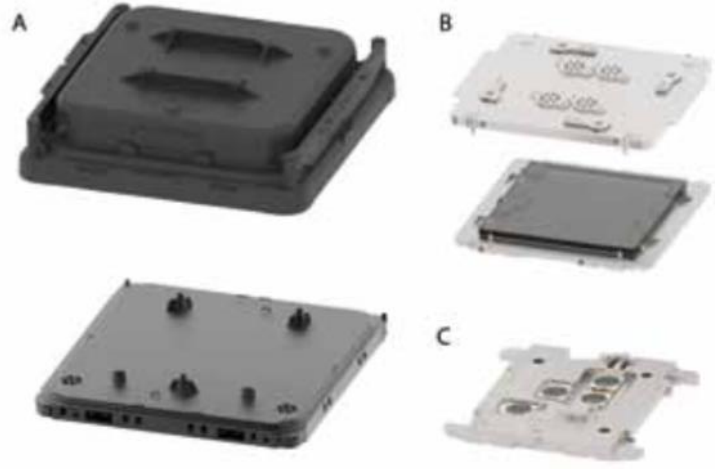
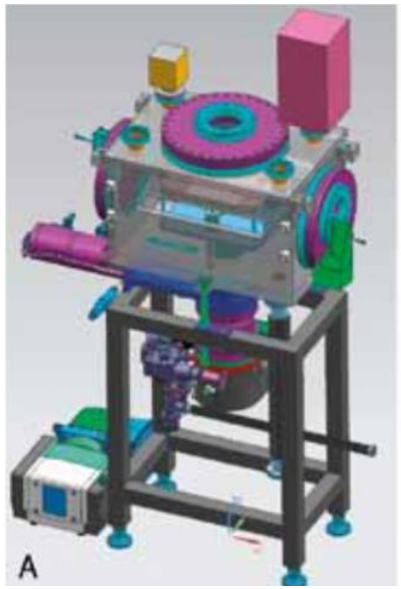
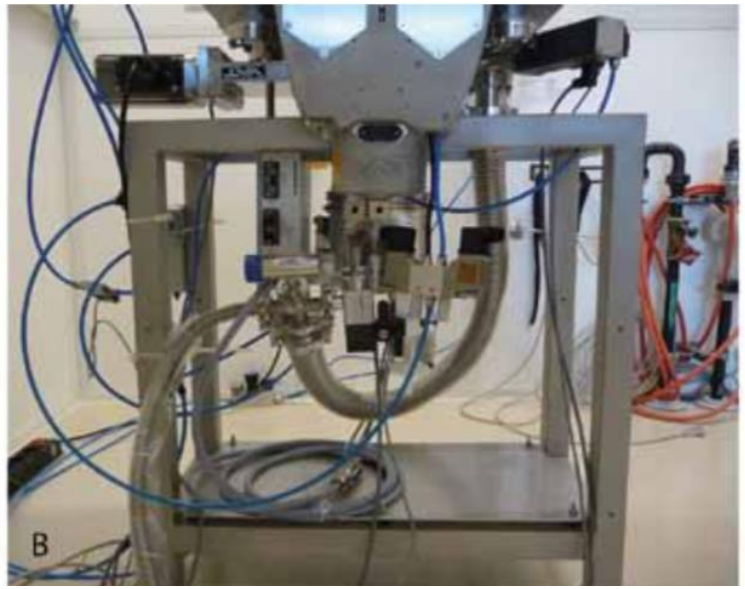


Figure 2 (a) EUV outer pod; (b) EUV reticle on inner base plate with inner cover; (c) Sample holder (200 mm by 200 mm).

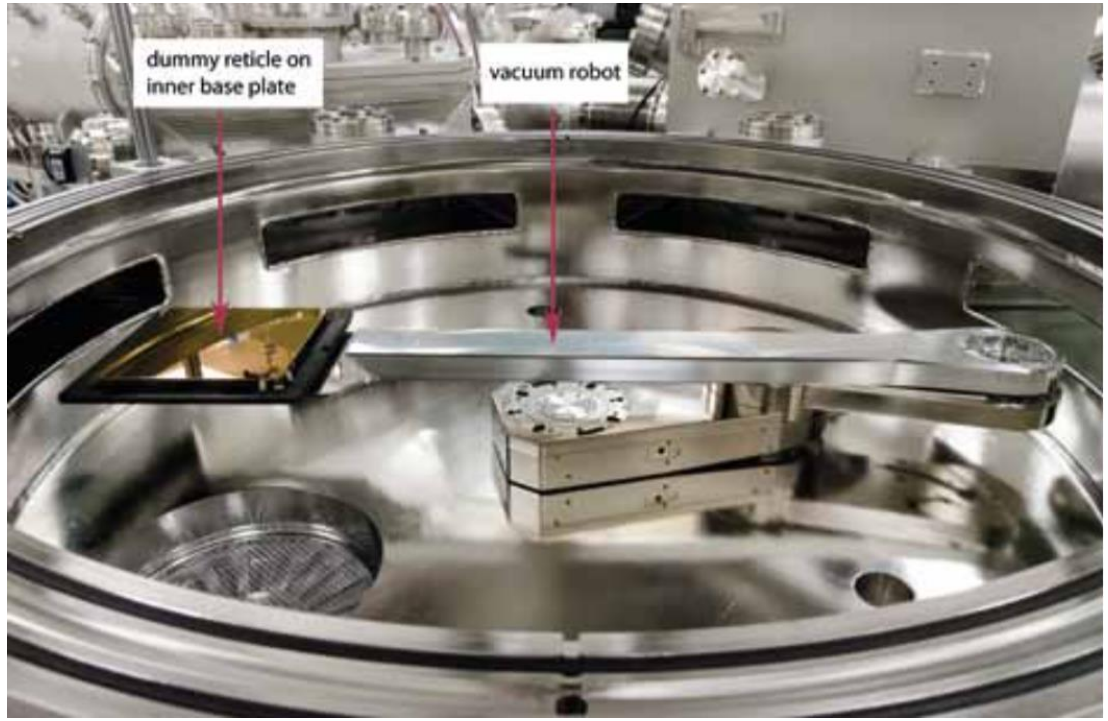
Loadlock (joint TNO-ASYS), ≈20mm slot





ACCELERATED LIFE TIME TESTING OF SURFACE
EUV EXPOSURE TOOL (EBL2)

Vacuum handler (joint TNO-ASYS)



ACCELERATED LIFE TIME TESTING OF SURFACE
EUV EXPOSURE TOOL (EBL2)

Vacuum handler → Exposure chamber

Sample gripper flipper" (SGF)

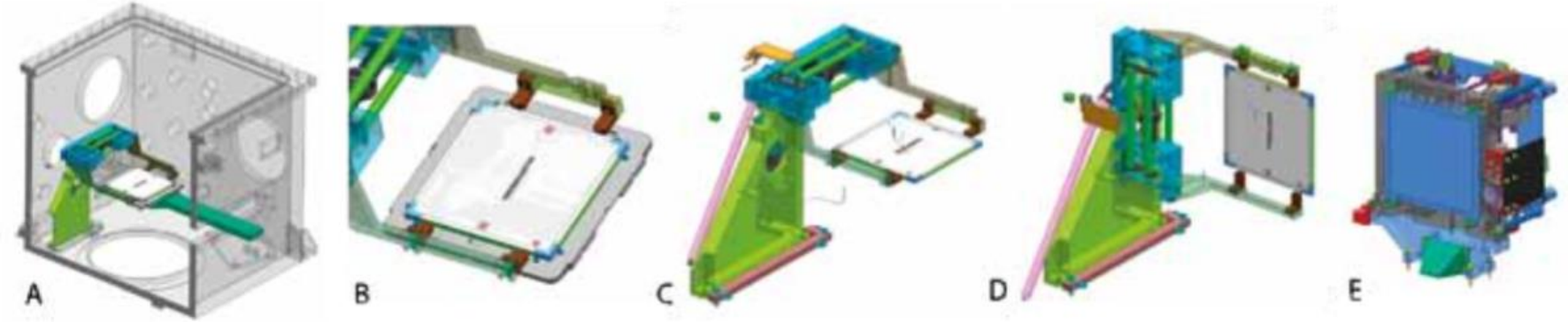


Figure 5 (a) Vacuum handler robot in exposure chamber; (b) Take-over reticle from inner base plate; (c) Vacuum handler robot retracted; (d) SGF has flipped the reticle vertically; (e) Reticle is mounted to sample chuck.

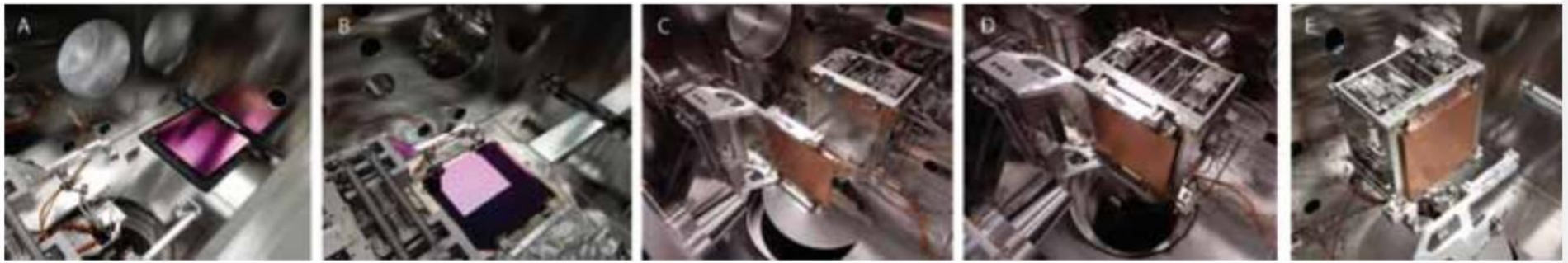
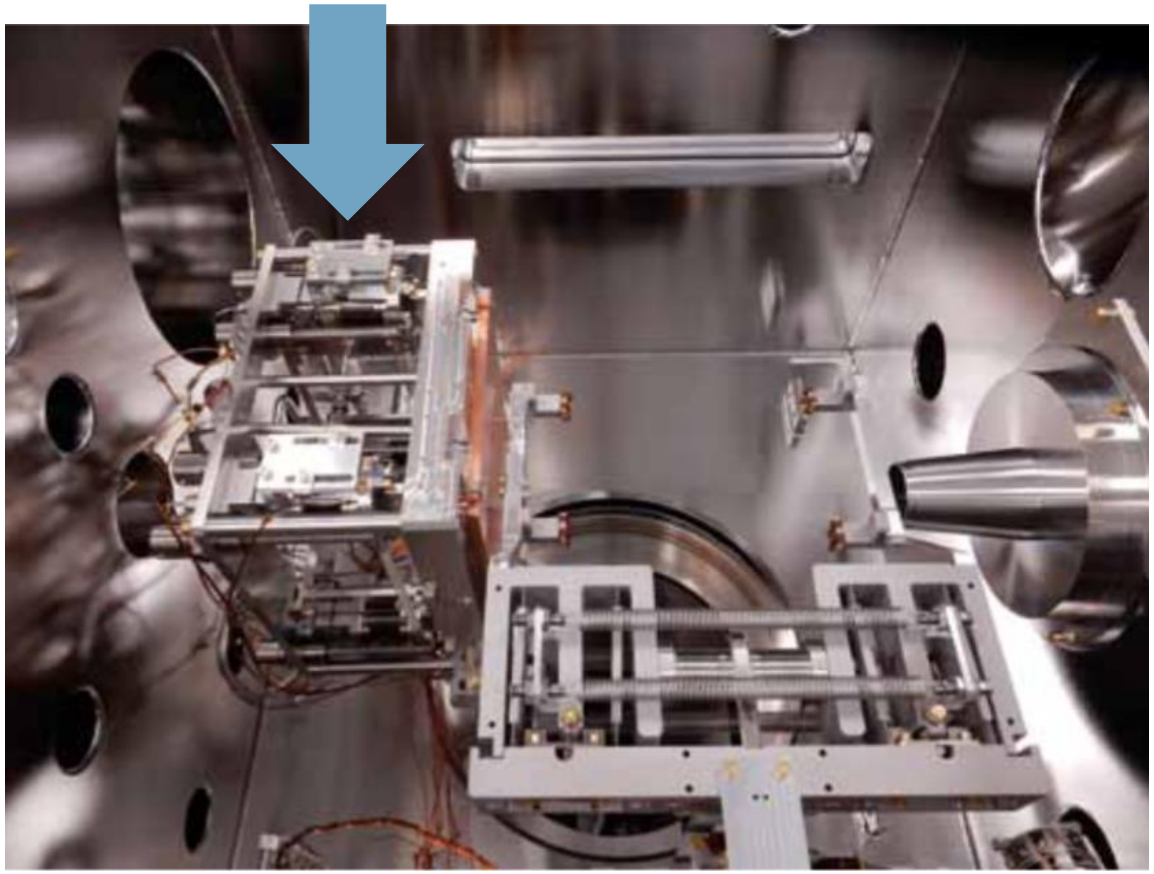


Figure 6 (a) Vacuum handler robot in exposure chamber; (b) Take-over reticle from inner base plate; (c) SFG has rotated the copper plate sample; (d) The sample chuck has moved to pick-over position; (e) Copper sample mounted on sample chuck.

ACCELERATED LIFE TIME TESTING OF SURFACE
EUV EXPOSURE TOOL (EBL2)

Sample gripper flipper" (SGF)

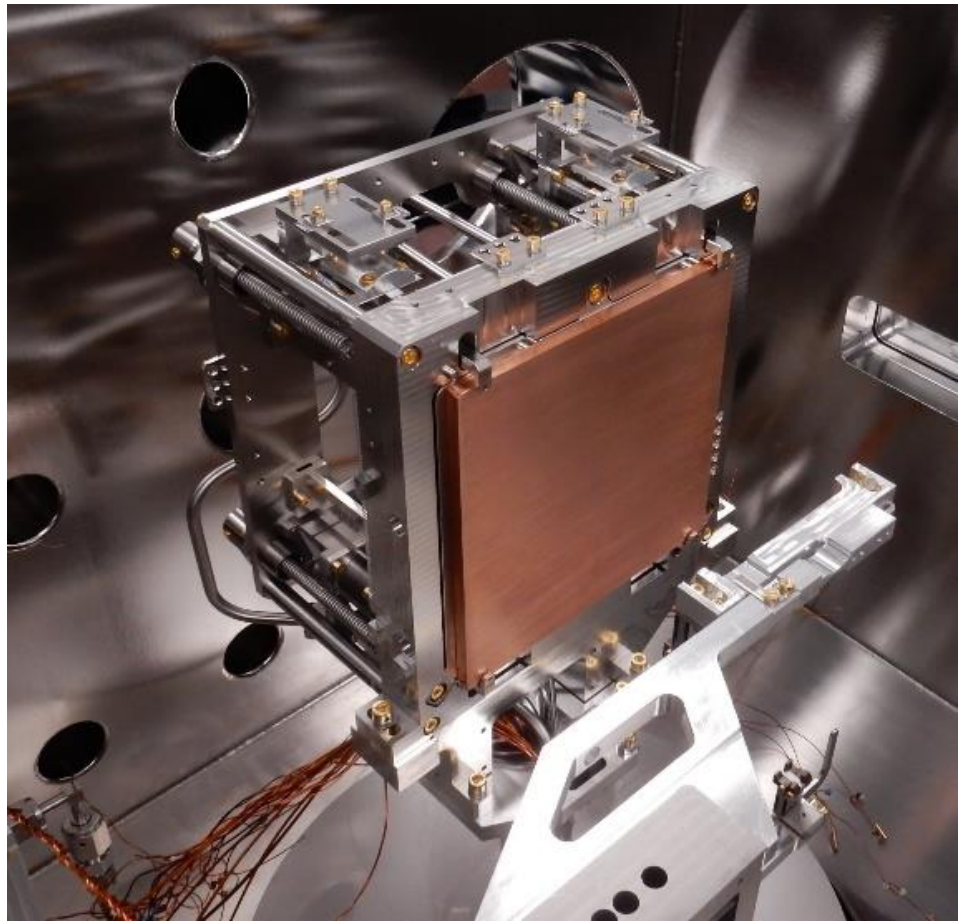


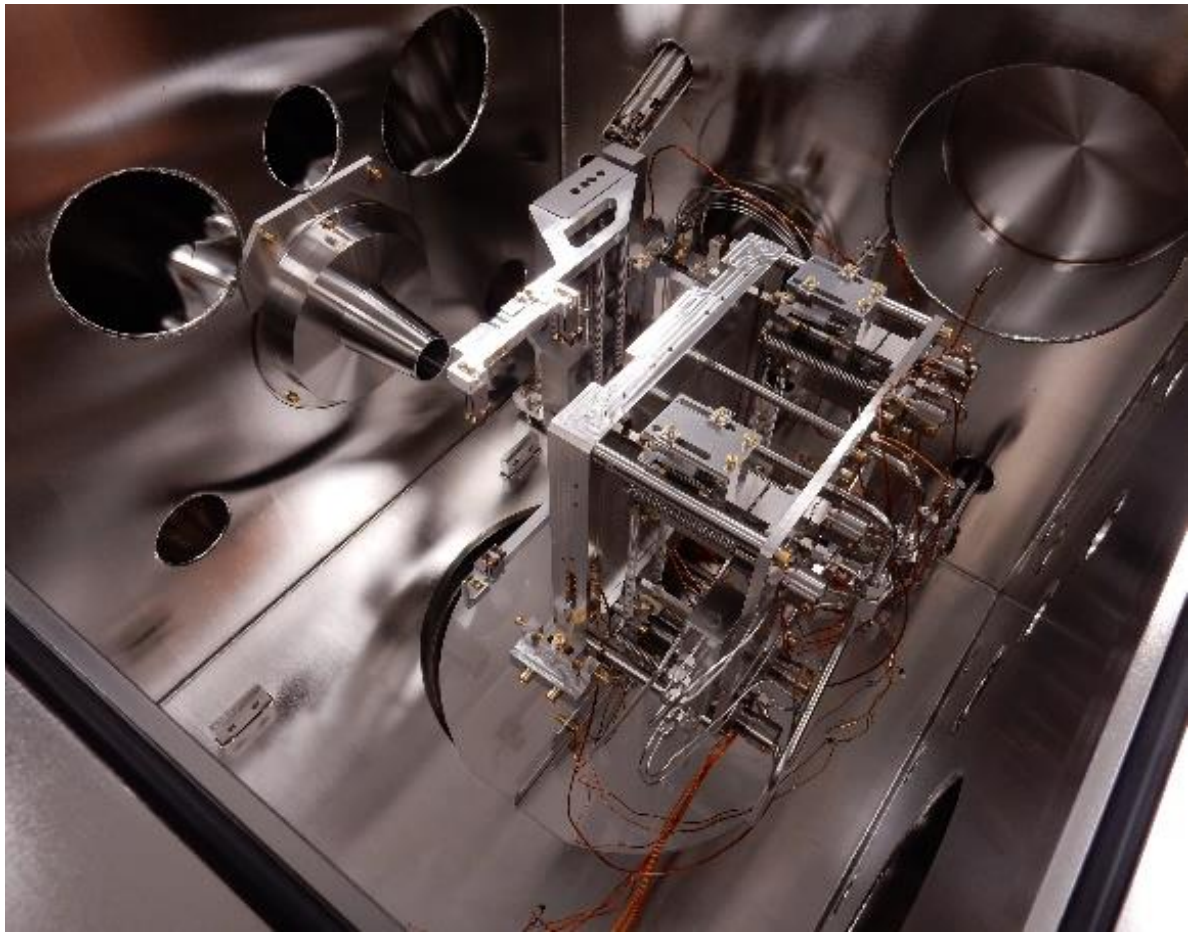
Chuck on hexapod (air-side view)

Figure 7 Hexapod and bellow installed underneath the exposure chamber.

ACCELERATED LIFE TIME TESTING OF SURFACES

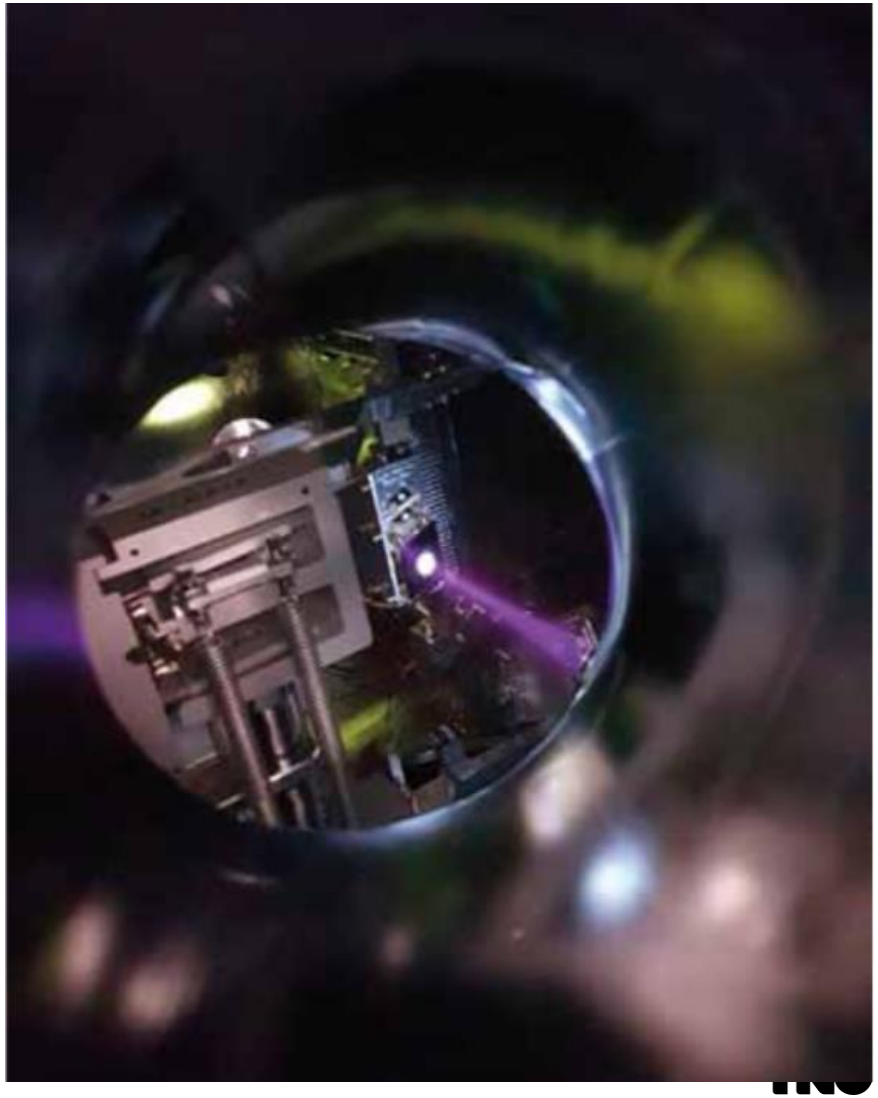
EUV EXPOSURE TOOL (EBL2)





ACCELERATED LIFE TIME TESTING OF SURFACES

EUV EXPOSURE TOOL (EBL2)



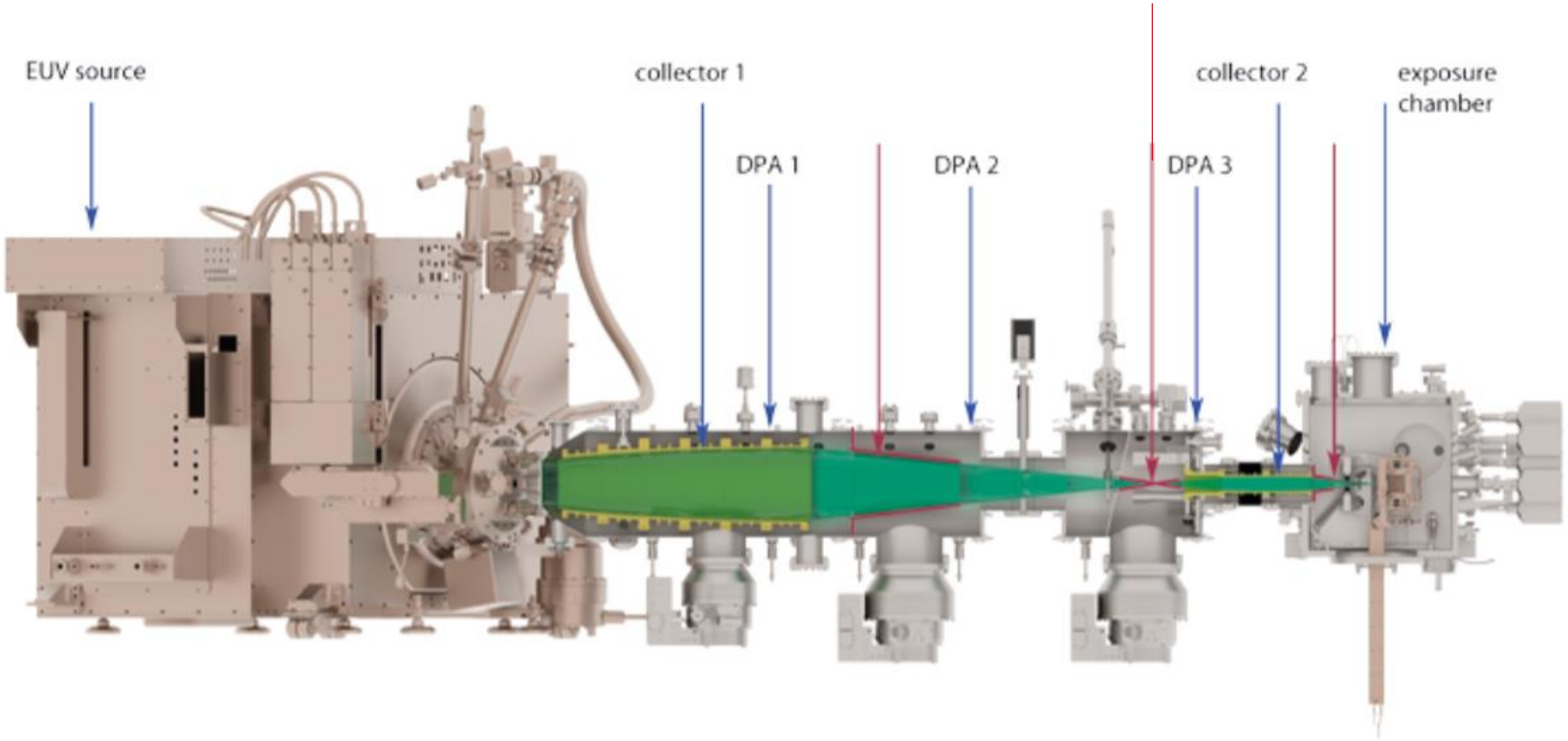
ACCELERATED LIFE TIME TESTING OF SURFACES
EUV EXPOSURE TOOL (EBL2)

- Cleanliness
  - Exposure chamber is lined with Mini-Environment (“ME”)
  - Exchangeable box like structure / witness plates
  - When ME dirty → exchange ME and send for cleaning
  - Three pieces ME available

ACCELERATED LIFE TIME TESTING OF SURFACES
EUV EXPOSURE TOOL (EBL2)

- DPA = differential pumping assembly

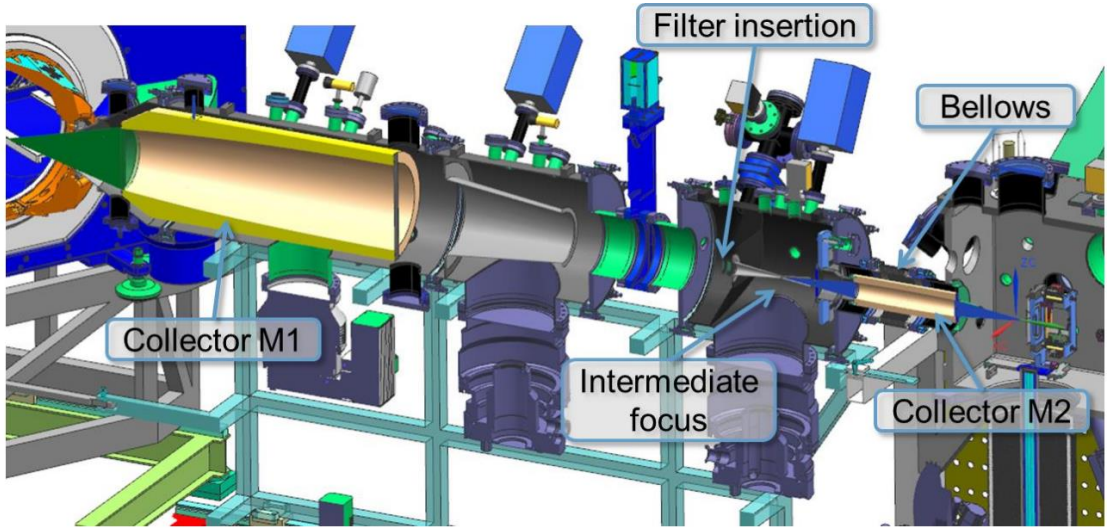
Intermediate focus



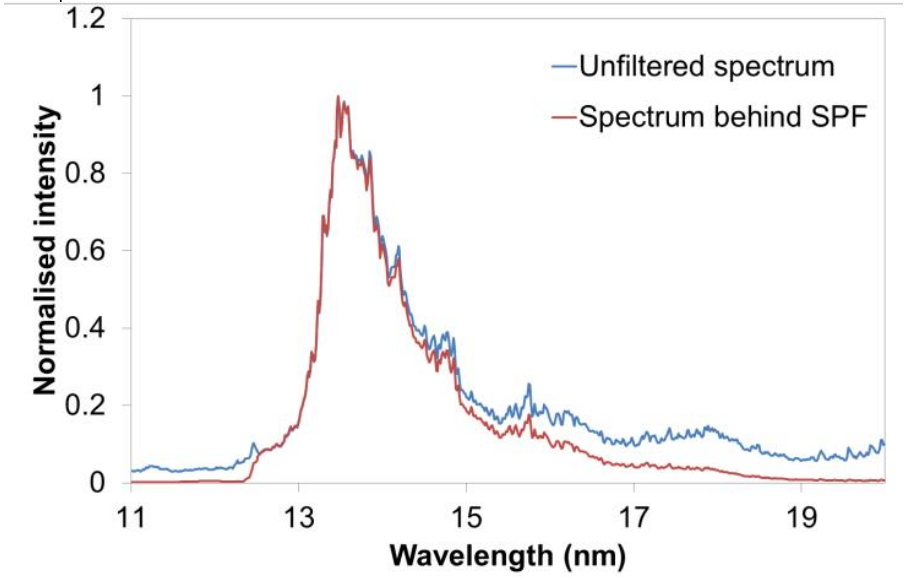
DPA-cones

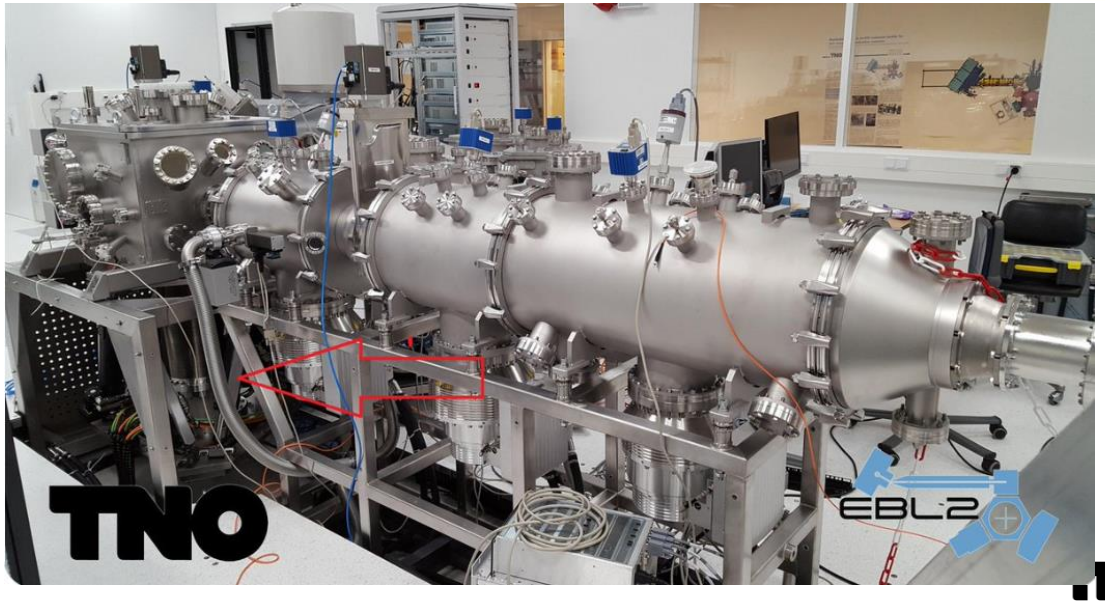
ACCELERATED LIFE TIME TESTING OF SURFACES

EUV EXPOSURE TOOL (EBL2)



Spectral purity filter (OoB)



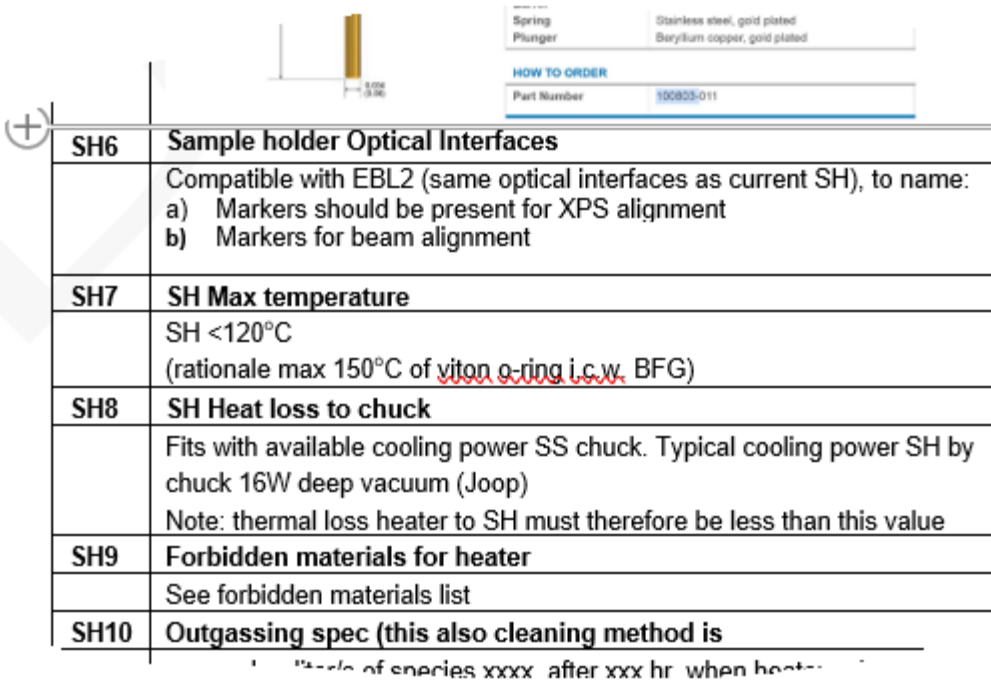


USE-CASE/HIGH LEVEL REQUIREMENT
TEST SAMPLE AT ELEVATED TEMPERATURES

- Enable (accelerated) test conditions for materials under EUVL conditions with increased sample temperature
- Sample dia <1inch, 0.5mm-6mm thick
- Sample temperature < 400 °C (wish <600 °C)
- Read-out and control of sample temperature
- Do not contaminate the ultra-clean vacuum chambers
  - Forbidden material list
  - Strict outgassing requirements
  - Experimental proof off cleanliness required before usage in EBL2
- No irreversible changes to EBL2 setup, use current:
  - Sample holder loading and unloading method

    Vacuum robot / load lock (22mm) / vacuum-valves
  - Sample chuck (limited cooling power ≈16W)
  - Electric connections (4 spring loaded push pins, limited power, 1 bias/ground pin)

Specification document



	Spring: Stainless steel, gold plated Plunger: Beryllium copper, gold plated
	HOW TO ORDER Part Number: 100803-011
SH6	**Sample holder Optical Interfaces**
	Compatible with EBL2 (same optical interfaces as current SH), to name: a) Markers should be present for XPS alignment b) Markers for beam alignment
SH7	**SH Max temperature**
	SH <120°C (rationale max 150°C of viton o-ring i.c.w. BFG)
SH8	**SH Heat loss to chuck**
	Fits with available cooling power SS chuck. Typical cooling power SH by chuck 16W deep vacuum (Joop) Note: thermal loss heater to SH must therefore be less than this value
SH9	**Forbidden materials for heater**
	See forbidden materials list
SH10	**Outgassing spec (this also cleaning method is**
	[illegible] of species xxxx after xxx hr when heat[illegible]

ARCHITECTURE
SOLUTION

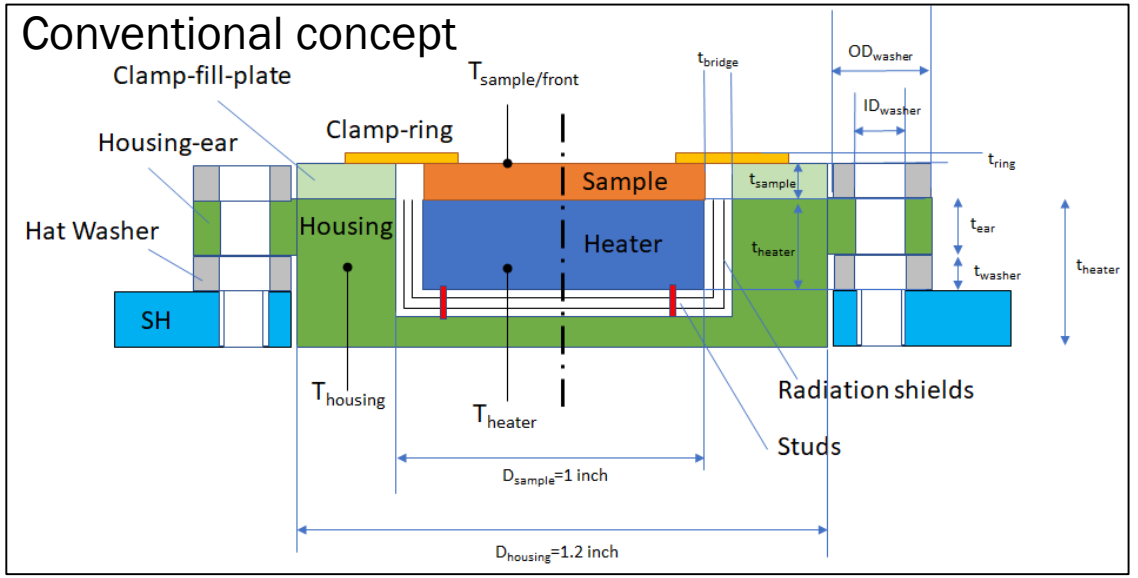
- Solution to be realized onto Sample Holder, travelling in and out vacuum
- Two Sample Holders to cover EUV powers

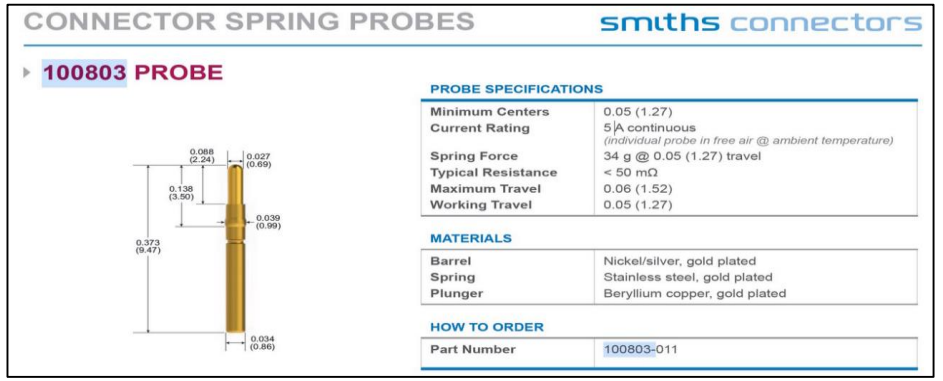
- (SH1) “Heated Sample Holder”
  - At low EUV powers (< ≈2W) heater assist required

- (SH2) “BFG Sample Holder” (SSH2)
  - At high EUV powers
  - Vacuum is a very good isolator
  - Insufficient cooling from chuck → T_{sample} runaway
  - Variable cooling required
  - Pressure controlled Backfill Gas (BFG)

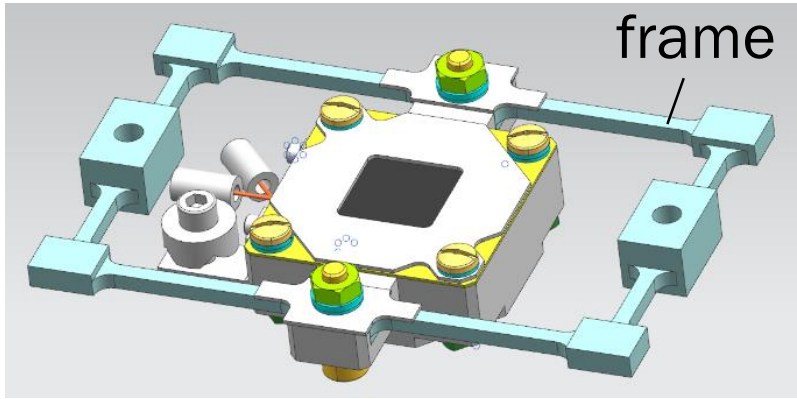
“HEATED SAMPLE HOLDER” (SH1) AT LOW EUV POWERS

- Typical expected power consumption
- Heater @ 400°C:
  - Loss radiative: ≈ 7W
  - Gas: ≈ 6W
  - Heater support: ≈ 110W ☹
- Compare
  - Cooling power chuck, typical 16W
  - Current carrying capacity pin in vacuum ≈ 1.7A → U_{power_supply}=36V → 60W
- Challenge: Reduce power consumption





“HEATED SAMPLE HOLDER” (SH1) AT LOW EUV POWER



- Challenge: Minimal power consumption

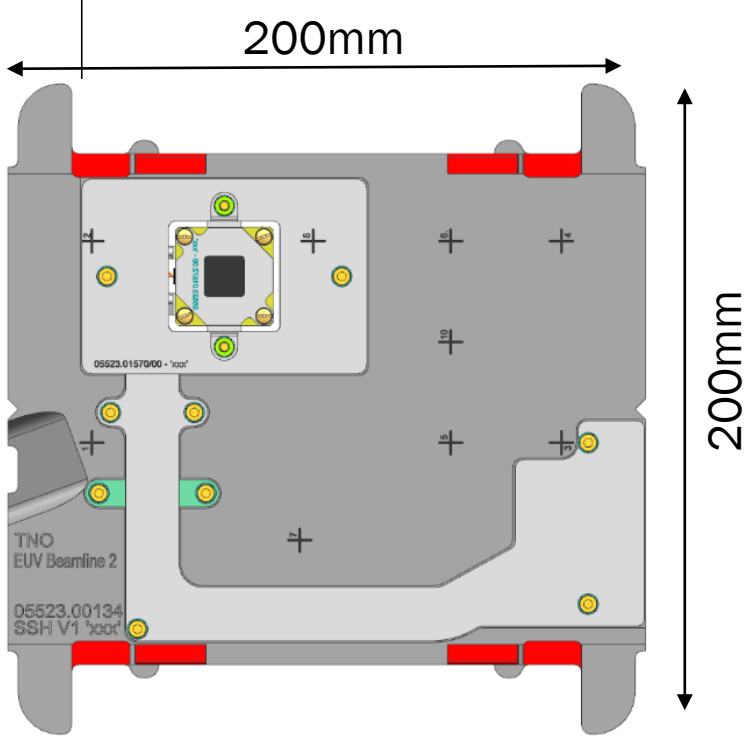
- Solution
  - Create local hot region on Sample Holder
    - > Sample Holder with integrated Moly heater, sample clamped to heater surface
  - Hot region is thermal isolated from rest Sample Holder
    - > Heater support frame with long and slender “legs” to break thermal path
    - > Frame made of thermal non-conducting TiAlV alloy frame
      - > Heat loss support (≈110W→ ≈ 4W)
    - > Moly Radiation screens
    - > Heater resistance must be matched to current carrying capacity pins and supply voltage

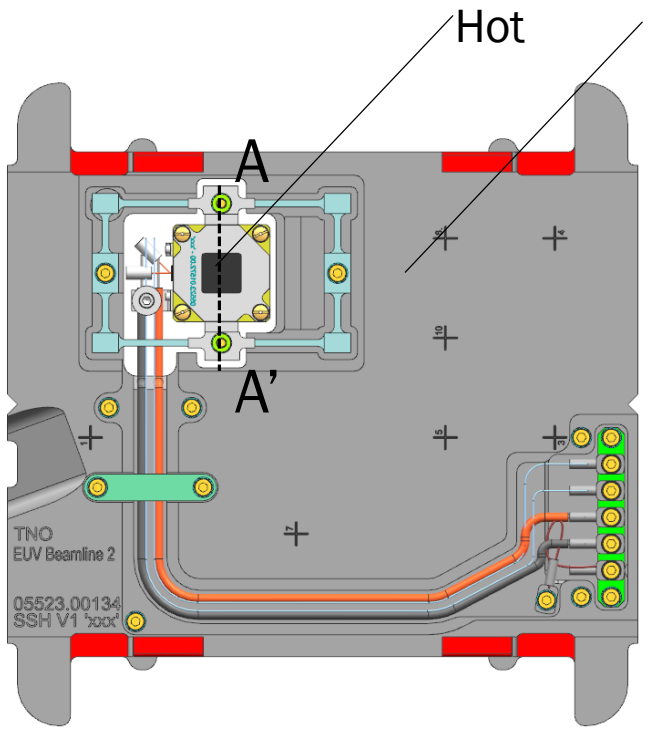
$$k \approx 10 \frac{W}{m \cdot K}$$

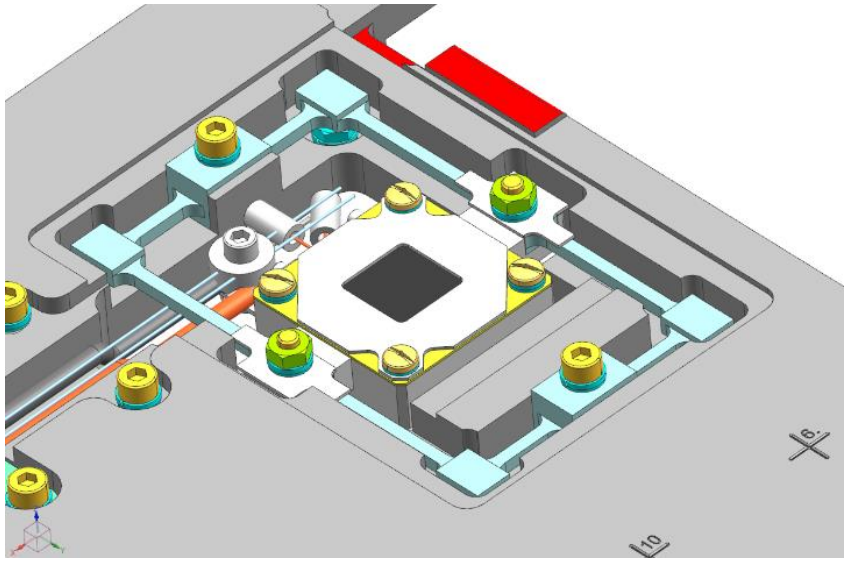
- To improve (radiative) sample thermal contact
  - Grooved Mo heater surface for enhanced effective emissivity (ε≈0.1→0.3) [1]

[1] A. Alekseev et al. Fusion Engineering and Design 146 (2019) 144–148

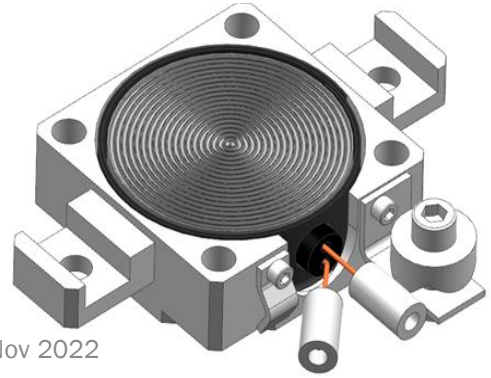
“HEATED SAMPLE HOLDER” (SH1)



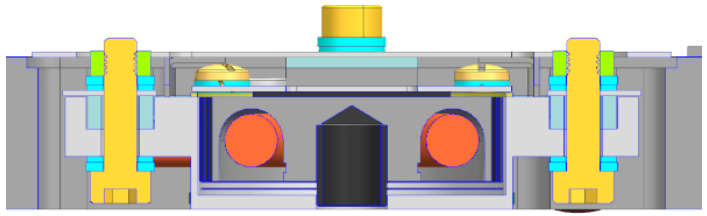


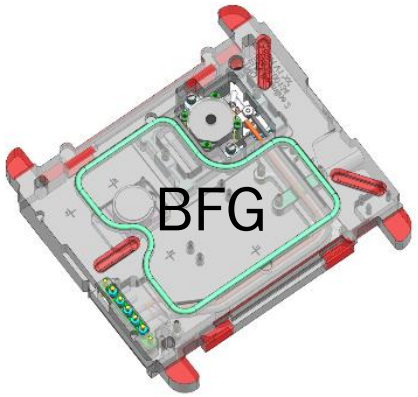


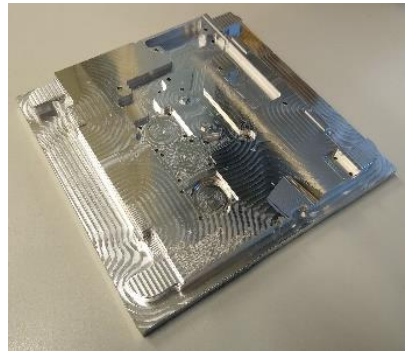
10.2mm



Cut A’-A’

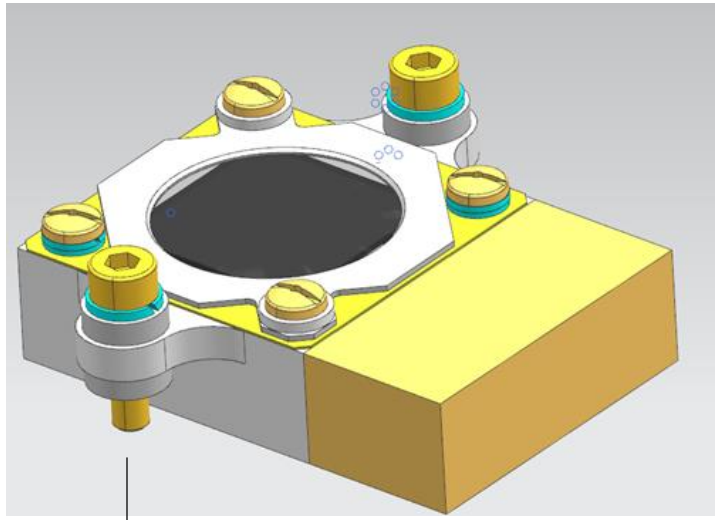




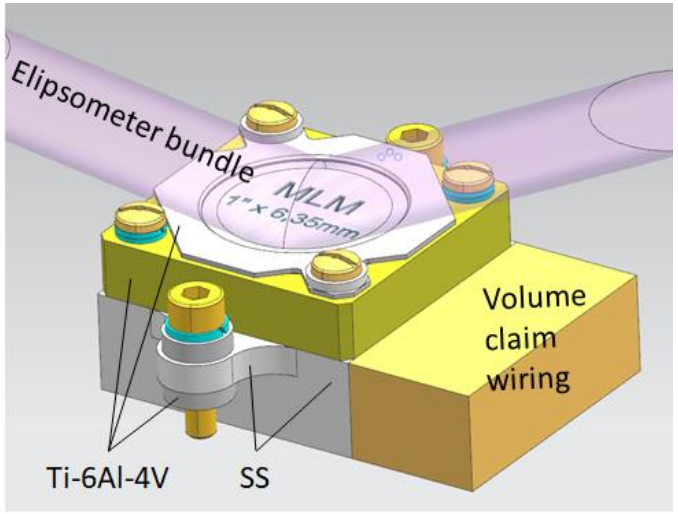


“HEATED SAMPLE HOLDER” (SH1)

- Samples thickness varies between 0.5mm to 6 mm

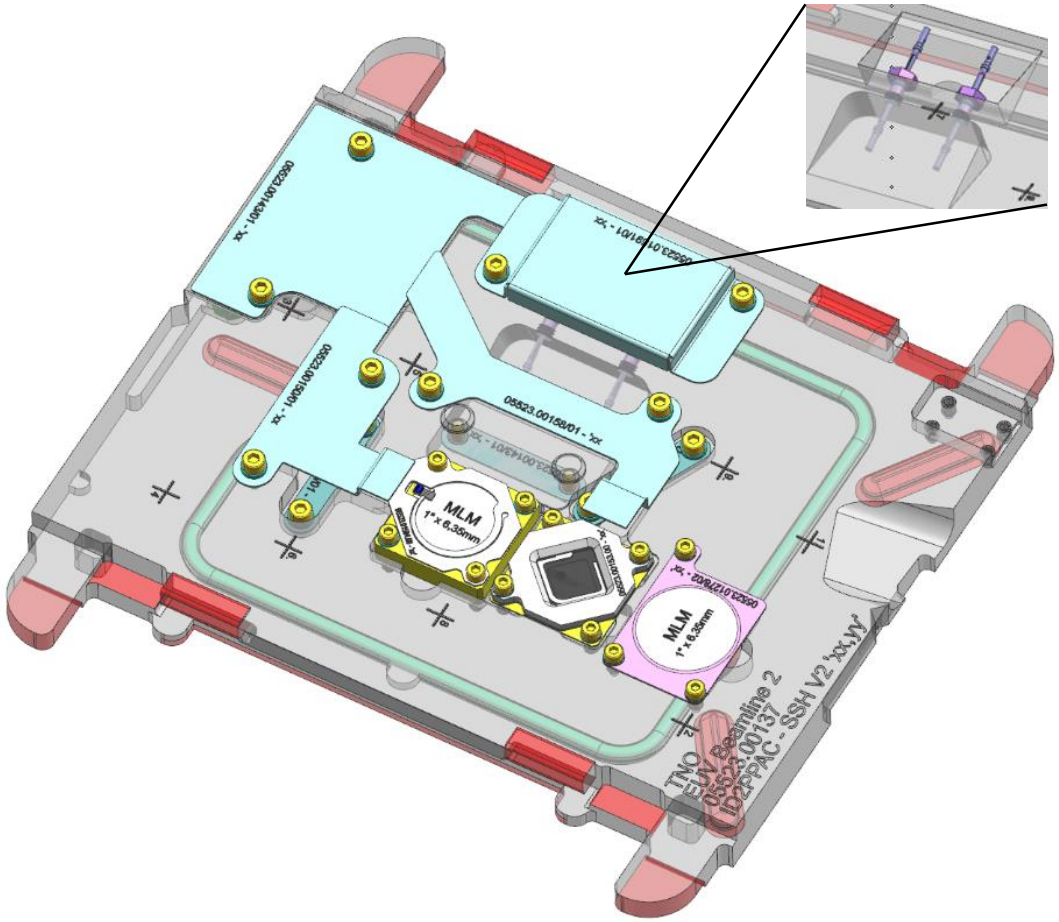


(Rejected interface)

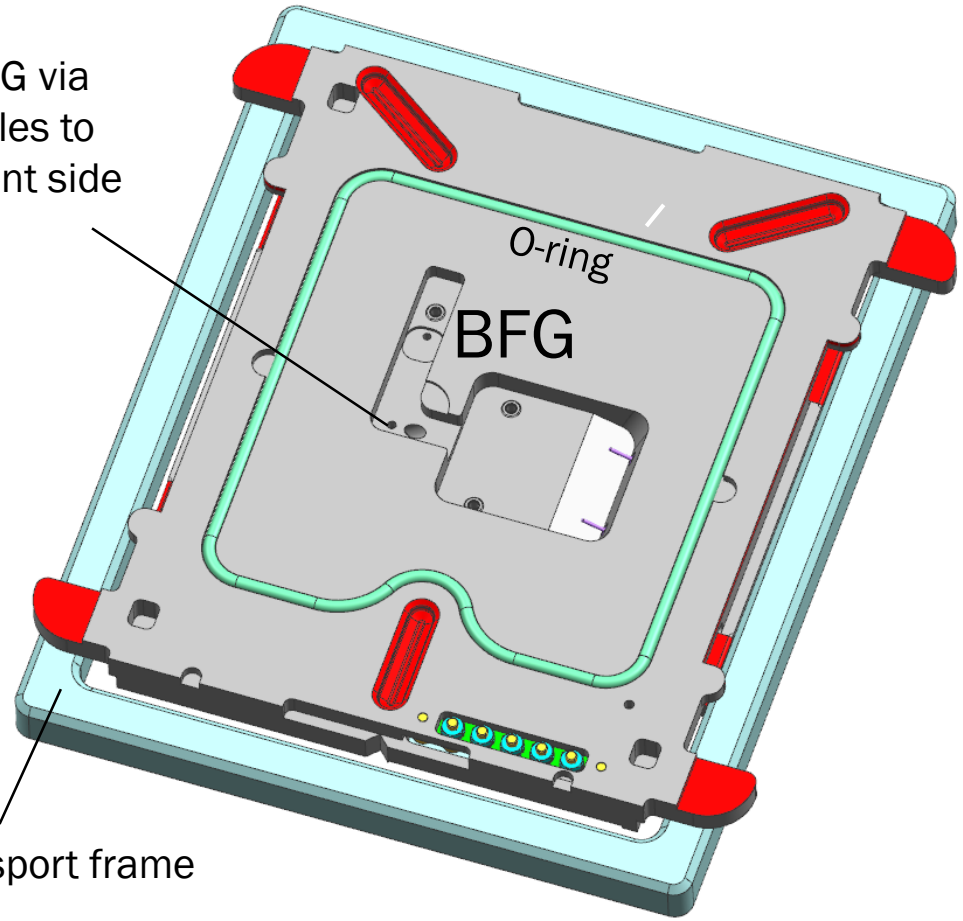


“BFG SAMPLE HOLDER” (SH2) AT HIGH EUV POWERS

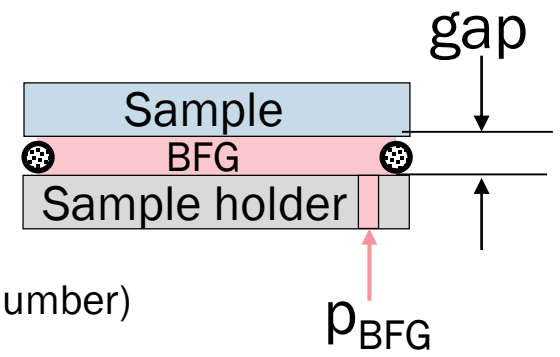
Front-side (exposed to EUV)



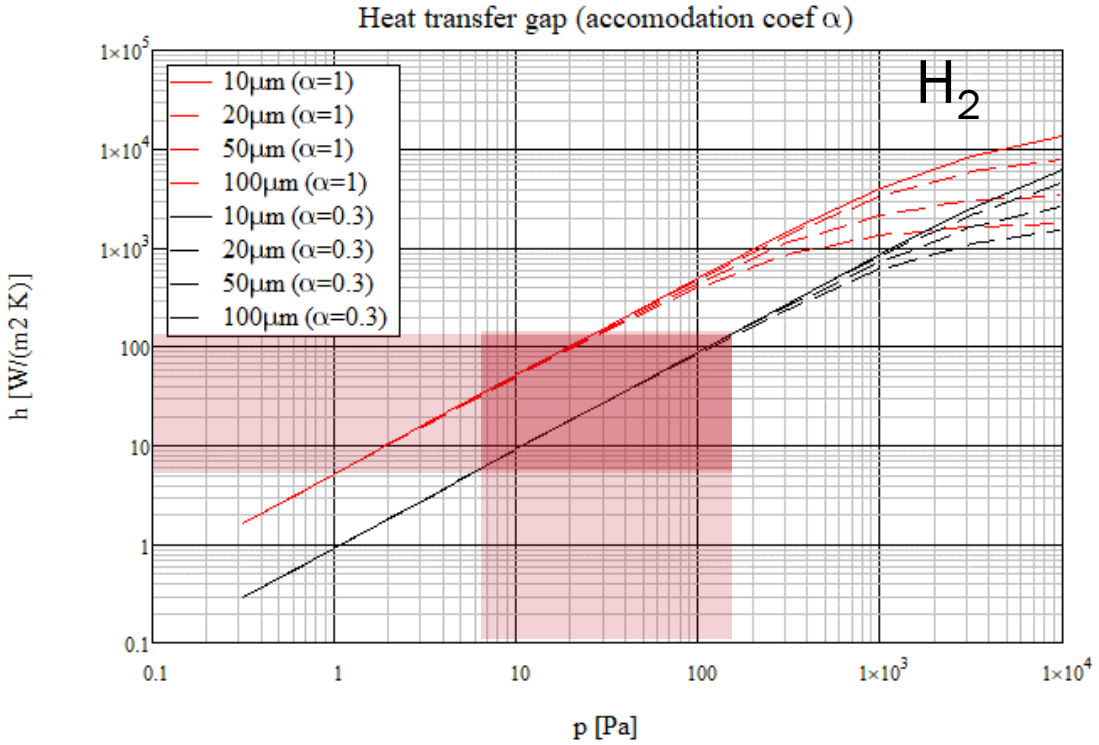
Backside contacting chuck



"BFG SAMPLE HOLDER" (SSH2) AT HIGH EUV POWERS

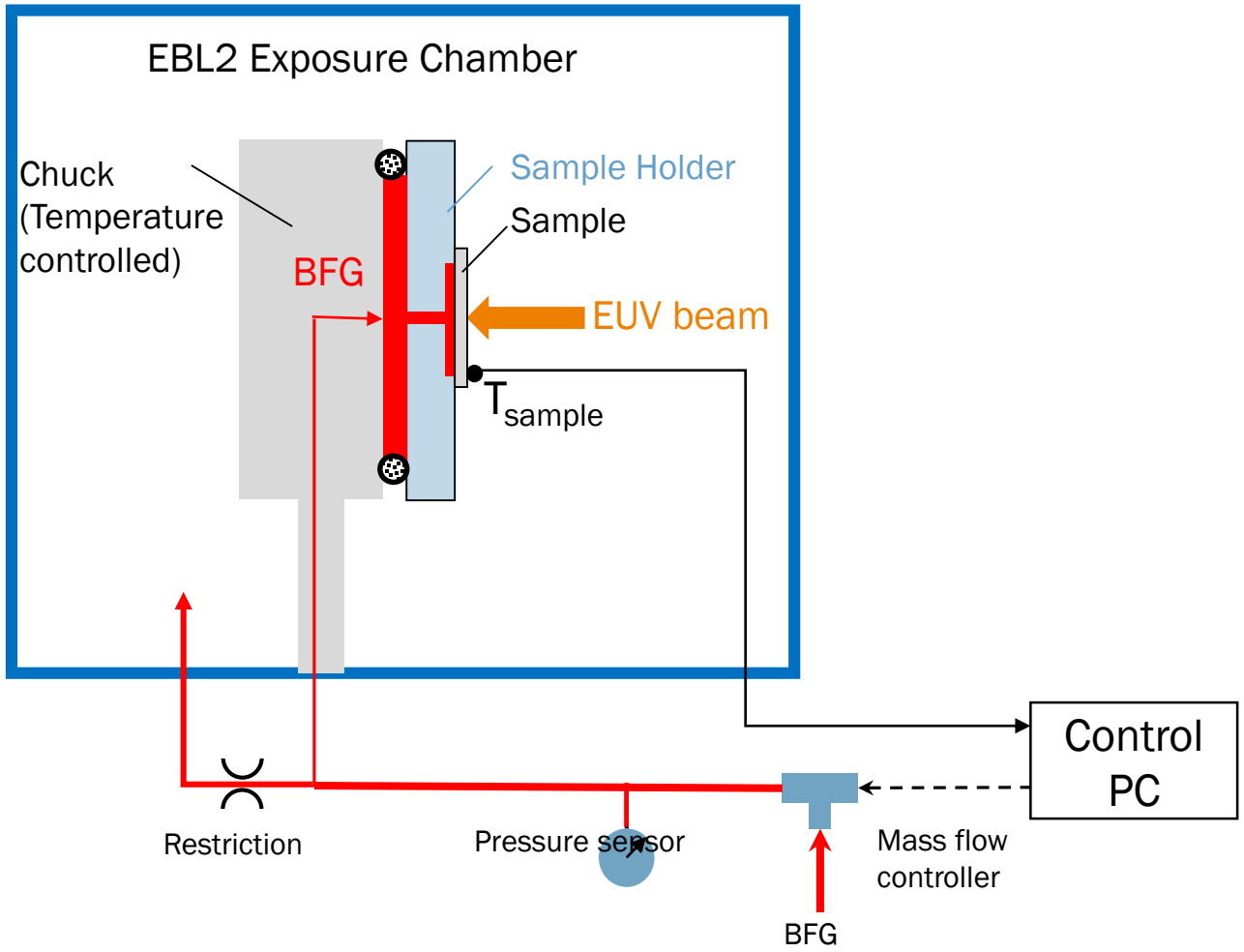


- Backfill gas is a commonly used method of cooling samples / objects
  - Thermal contact depends on length scales: ratio mean free path / gap distance (Knudsen number)
  - Mean free path inversely scales with pressure
  - Most cases with static pressure → static cooling capacity
  - Smart Sample Solder will have controlled BFG pressure
  - Controlled heat transfer between the sample and cooled medium



"BFG SAMPLE HOLDER" (SSH2) AT HIGH EUV POWERS

- Backfill gas implementation (simplified)



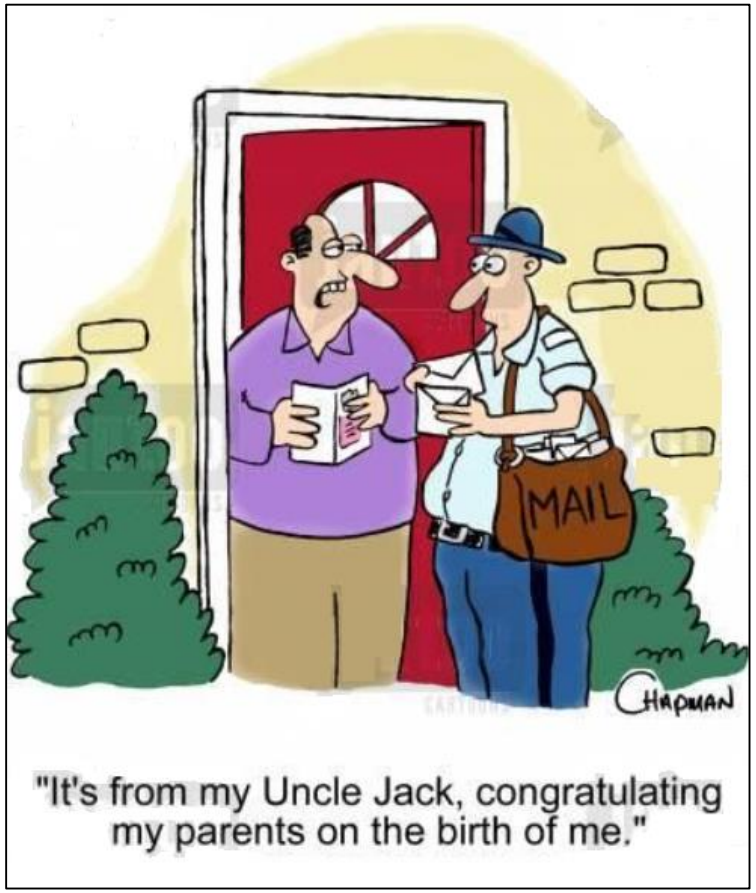
SAMPLE TEMPERATURE

- Sensor types
  - Thermocouple TC not possible (wiring/feedthroughs not TC compatible)
  - RTD (Resistance Temperature Detector)
    E.g. PT1000 (PT100 inaccurate due to added (variable) resistance circuit & push pins)
  - Non-contact, Infrared

- Available options
  - Clamp sensor to sample surface (front-side and/or backside (outgassing / volume conflict)
    Con: bad thermal contact vacuum, clamping act as thermal shortcut and disturbs measurement
    Pro: simple
  - Cement sensor to sample surface
    Con: requires bake / outgassing cement (→ move to backside sample)
    Pro: good thermal contact sensor – sample, no thermal shortcut
  - Pyrometer
    Con: line of sight, not accurate (calibrate for unknown/varying emissivity → high emissivity dots),
    Pro: non-contact

CONCLUSION

- Heating a sample, how hard can it be….
- Parts ordered / machining started…delivery times…
- Perform qualifying experiments on sample holders before use in EBL2 (TPS)
  - Outgassing (external of EBL2)
  - Used materials (external of EBL2)
  - Loading into EBL2 (in EBL2, no EUV)
- Hand over to EBL2 operation team and scientist 23Q1



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THANK YOU FOR YOUR ATTENTION


THANK YOU FOR
YOUR TIME
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