

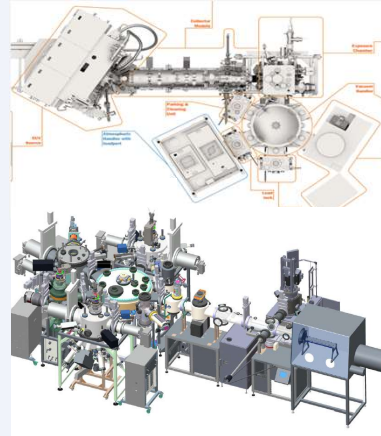
RGA developments at TNO

EVC 2024

Drs. R. Koops | Harrogate

Introducing me / TNO

- Research Scientist at TNO
 - EUVL development (customer support first EUVL systems)
 - Contamination Control / Plasma / Vacuum (UCV, RGA, ...)
 - Molecular Beam Epitaxy for Quantum devices
- A not for profit organization, bridging the gap between university and (high tech) industry
- TNO was established by law in 1932 to support companies and governments with innovative, practicable knowledge. As a statutory organisation, TNO has an independent position that allows to give objective, scientifically founded judgements



- › Nano Instrumentation
- › Contamination control
- › Vacuum
- › Materials
- › Plasma
- › Semiconductor & Quantum
- › Space & Scientific instrumentation
- › Smart Industry
- › Flexible & Free-form products

Acknowledgements



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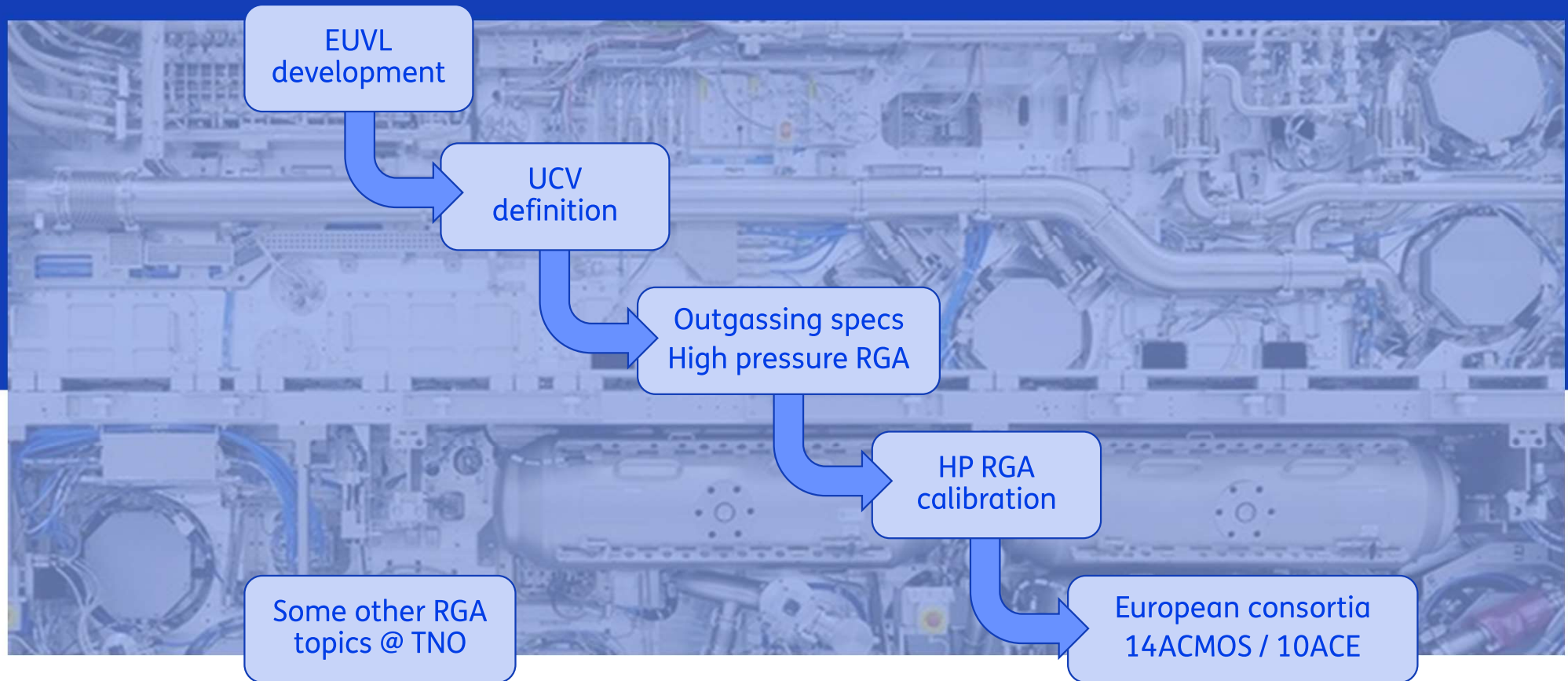
Arnold Storm

Marina Gomes Rachid

Norbert Koster

ASML

Outline



EUV Lithography and Ultra Clean Vacuum

ASML's transition from DUV to EUV systems introduced big changes and huge technological challenges.

TNO was heavily involved in the early development of EUVL technology on many topics.

One such topic: Contamination Control and Vacuum Quality (to maximize optics lifetime).

Together with ASML and Carl Zeiss, TNO defined a brand new vacuum regime: **Ultra Clean Vacuum (UCV)**

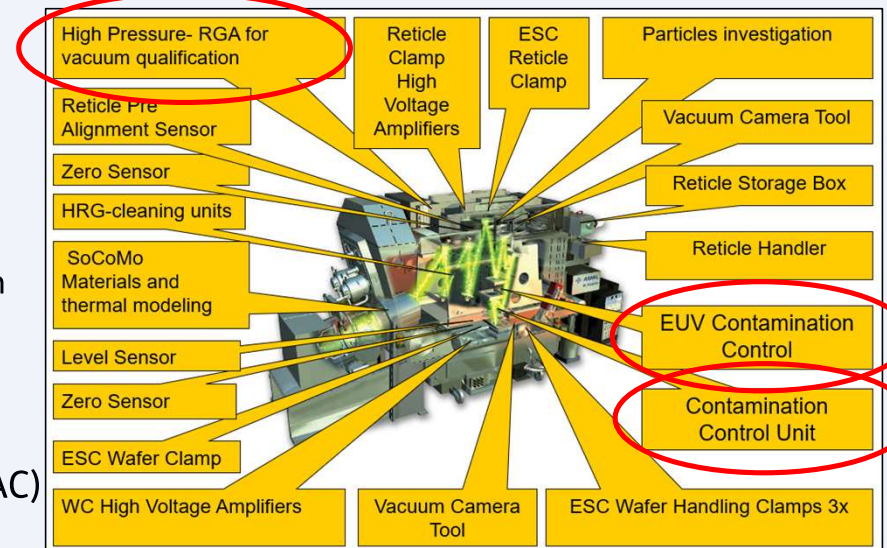
What is an UCV system?

- System under vacuum
- Very low partial pressures of specific contaminants
- (Often) in a matrix of a specific ultrapure gas at a relatively high pressure
- (Often) to be realized without the option of baking the fully assembled system

UCV is also becoming popular and important beyond EUVL technology

→ IUVSTA workshop UCV, February 3-6, 2025 (organized by TNO & NEVAC)

TNO development for ASML EUVL demonstrator: Alpha-Demo Tool

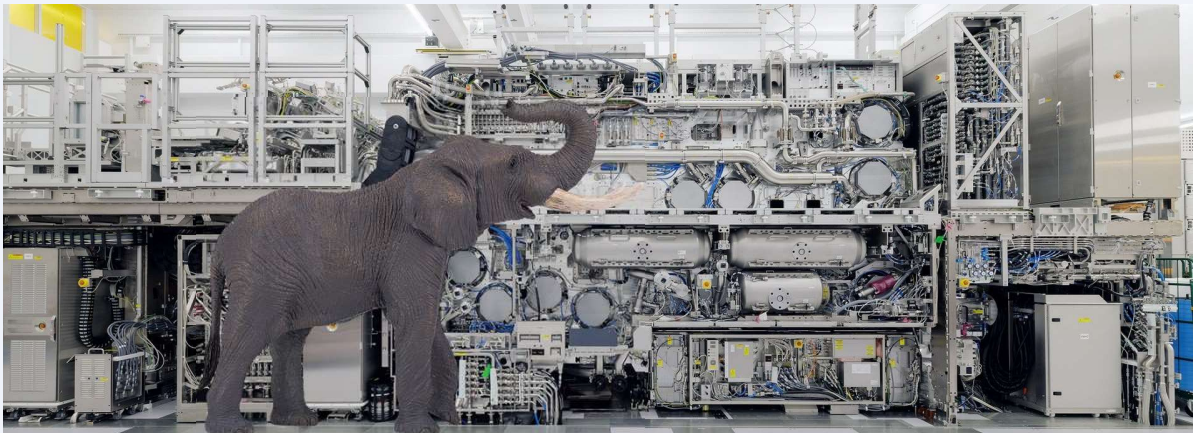


EUV Lithography and Ultra Clean Vacuum

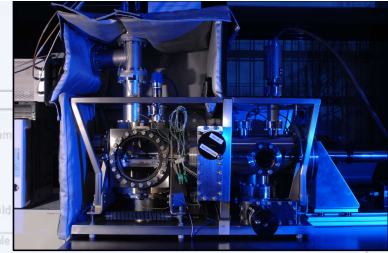
How to achieve UCV in a complex system like an EUVL waferstepper?

- Define strategy: outgas budgeting (top-down and bottom-up of mono-parts towards full assembly)
- Define specs in grades for EUVL systems (maximum allowed outgassing wrt material and surface area)
- Define a standard for outgassing measurements to validate (ISO/TS 20177)

ASML's EUVL wafersteppers are UCV systems and need to remain Ultra Clean during operation

TNO Outgassing Test Report

Test details	
Sample Id:	Thorlabs mirror and holder
Description:	aluminum holder and mirror, vacuum seal spec feb-22 20209_1a 20204_1a
Filename:	2022.02.09 Thorlabs mirror and holder
Operator:	René Koops
Comments:	Sample holder was packed in double plastic box



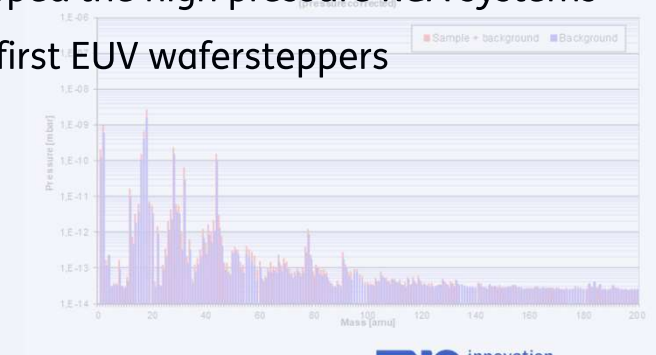
Outgassing rate at 1h:		Outgassing rate at 10h:	
Sample (background subtracted)		Sample (background subtracted)	
Q _{gas} [mbar·s]	(background)	Q _{gas} [mbar·s]	(background)
Q _{gas} [mbar·s]	3.33E-07	5.10E-08	7.75E-08
Q _{gas} [mbar·s]	2.74E-07	2.74E-08	3.90E-08
Q _{gas} [mbar·s]	2.03E-10	2.03E-10	1.87E-10
Q _{gas} [mbar·s]	7.68E-11	8.21E-11	7.71E-11
Q _{gas} [mbar·s]	5.10E-09	5.85E-10	2.64E-10
Q _{gas} [mbar·s]	6.23E-10	5.14E-09	3.10E-09

Comments: Background subtracted values over entire range, only below LOD, no apparent compounds added above BG



Constant monitoring is needed!

- TNO developed the high pressure RGA systems for ASML's first EUV wafersteppers



High pressure RGA

An RGA cannot be used at EUVL waferstepper pressures

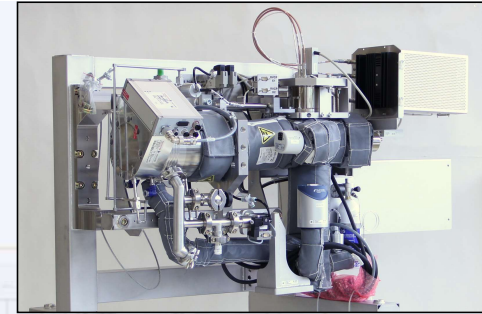
- The gas mixture to be measured needs to be diluted 10-1000 times
- The RGA analyser at lower pressures is sampling the gasmixture through a restriction
- A high pressure RGA is a vacuum system on it's own!

A high pressure RGA opposes new challenges:

- The LDL (lowest detection level) for trace gasses is limited (dynamic range vs. relatively high total pressure)
- Chemistry in the ion source increases with ion source pressure
- Mass separation through the restriction causing the heavier trace gasses to dilute

For ASML, TNO performs calibrations of the current high pressure RGA's used in the field on EUVL wafersteppers and investigates the effect of the above challenges on these calibrations

In European funded consortia, TNO is also researching ways to improve dynamic range of measurement, lower LDL's and investigate mass separation effects and ion source chemistry



High pressure RGA calibration

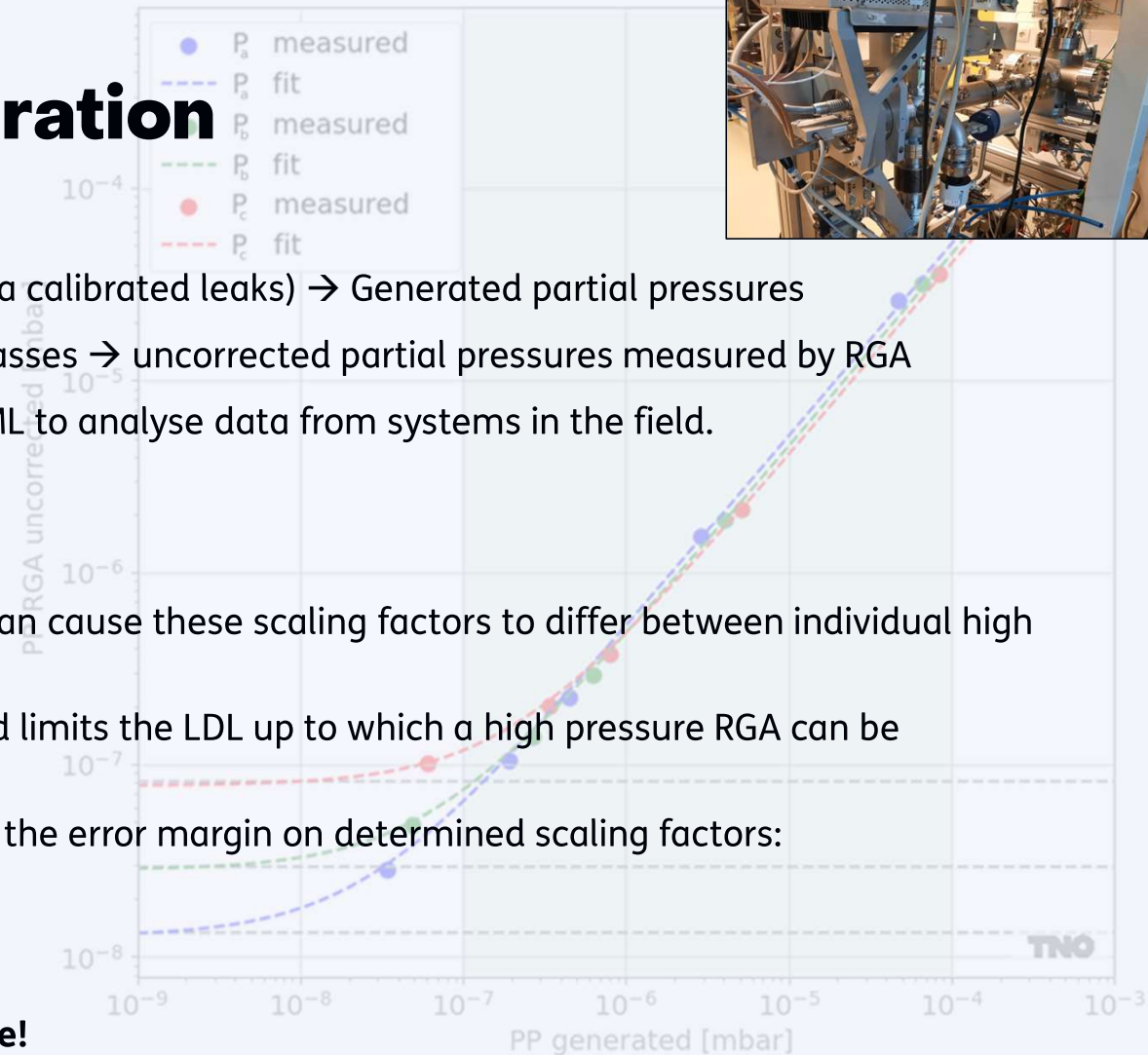
Calibration method:

- Mimic scanner conditions (matrix gas + trace gas via calibrated leaks) → Generated partial pressures
- Measure ion currents of the matrix gas and trace gasses → uncorrected partial pressures measured by RGA
- Determine trace gas specific scaling factors for ASML to analyse data from systems in the field.

Sounds straightforward, but:

- Mass separation effects and ion source chemistry can cause these scaling factors to differ between individual high pressure RGA's considerably.
- The dynamic range of the whole measuring method limits the LDL up to which a high pressure RGA can be calibrated and used in the field.
- Uncertainties and errors contribute considerably to the error margin on determined scaling factors:
 - pump speed for trace gasses in a matrix gas
 - leak calibration (also temperature dependent)

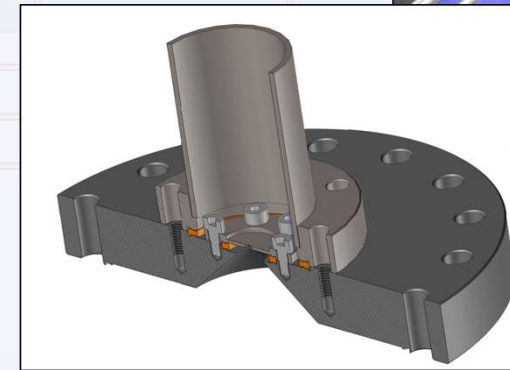
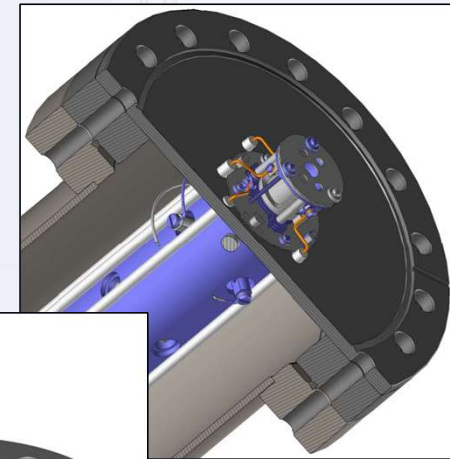
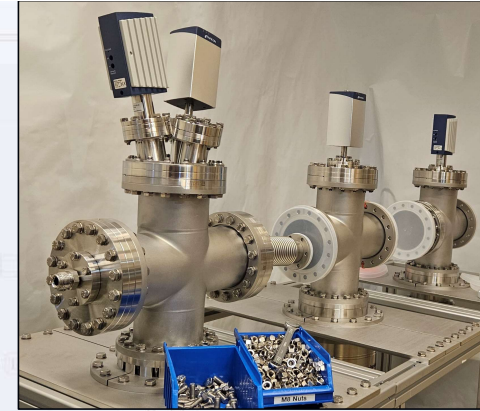
→ Many interesting topics to investigate and improve!



Running project (European consortium)

Within the European consortium 14ACMOS, TNO is currently building a system to:

- More accurately produce partial pressures of trace gasses
 - More accurately calibrate trace gas leaks
 - Better temperature control
- Improve the dynamic range of measurement to lower the LDL of trace gasses
 - Reduce trace gas dilution by mass separation effects
 - Tune settings individually for matrix gas and trace gasses



The 14ACMOS project is supported by the Chips Joint Undertaking (under grant agreement No 101096772) and its members, including the top-up funding by The Netherlands, Germany, France, Sweden, Romania, Belgium, Israel.

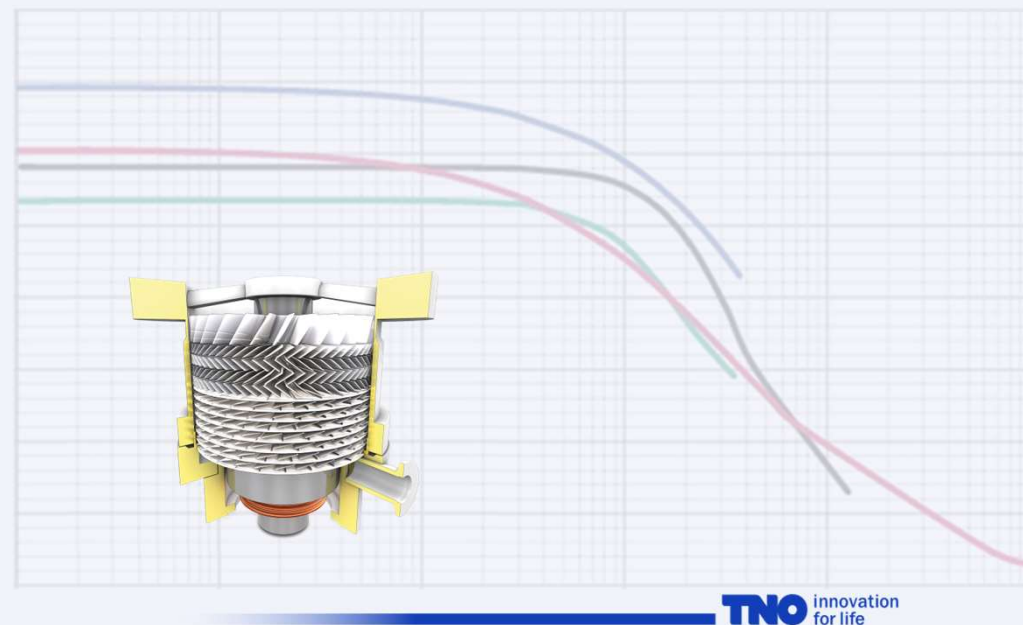
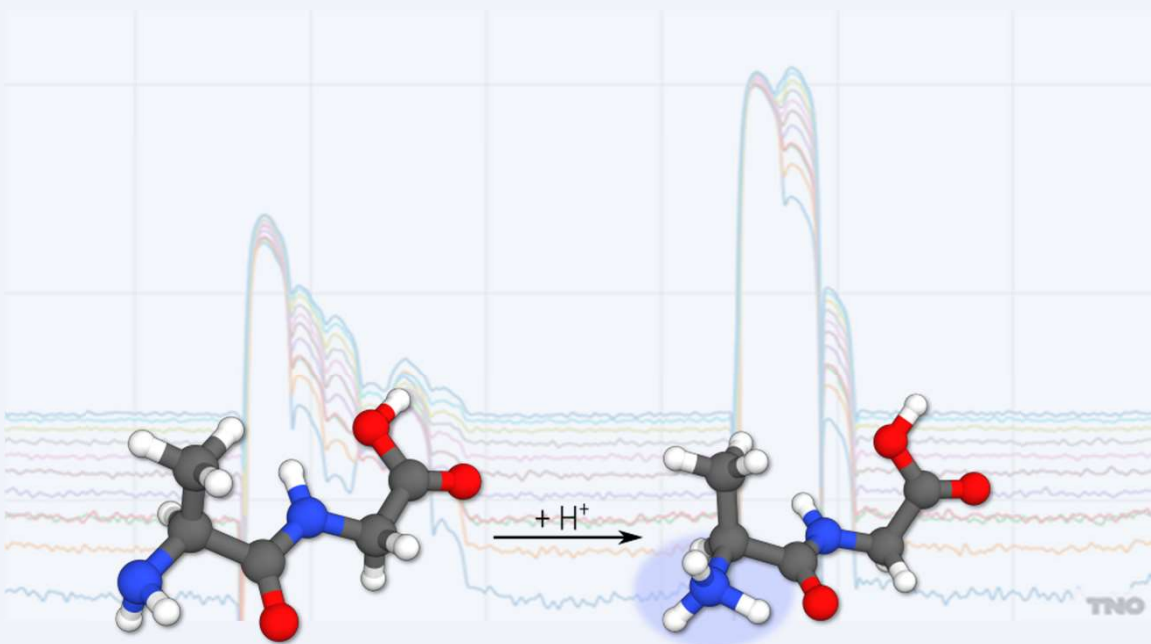
TNO innovation for life

Starting project (European consortium)



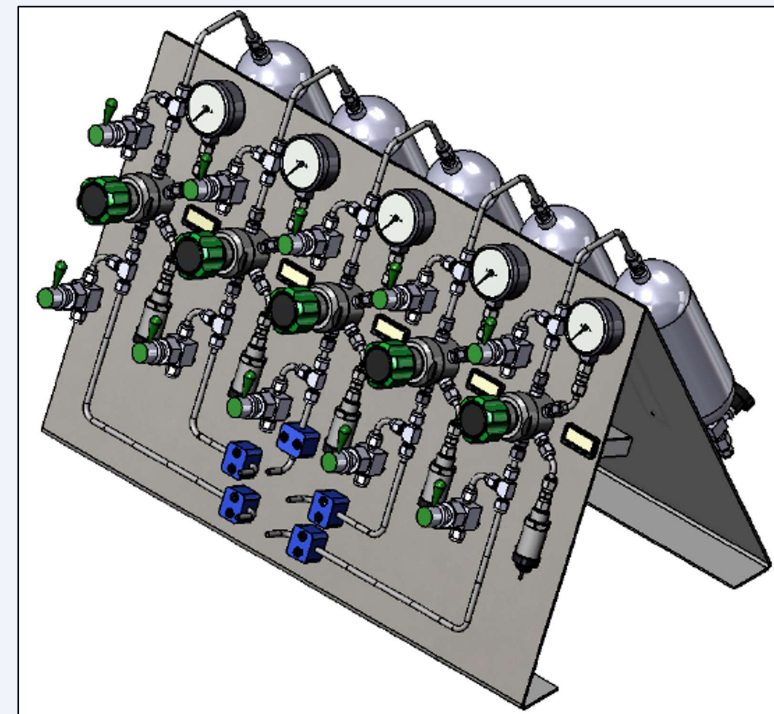
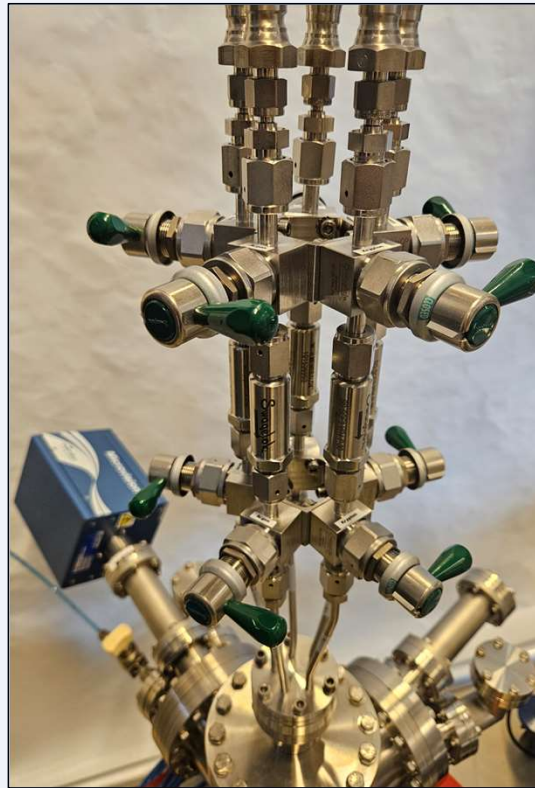
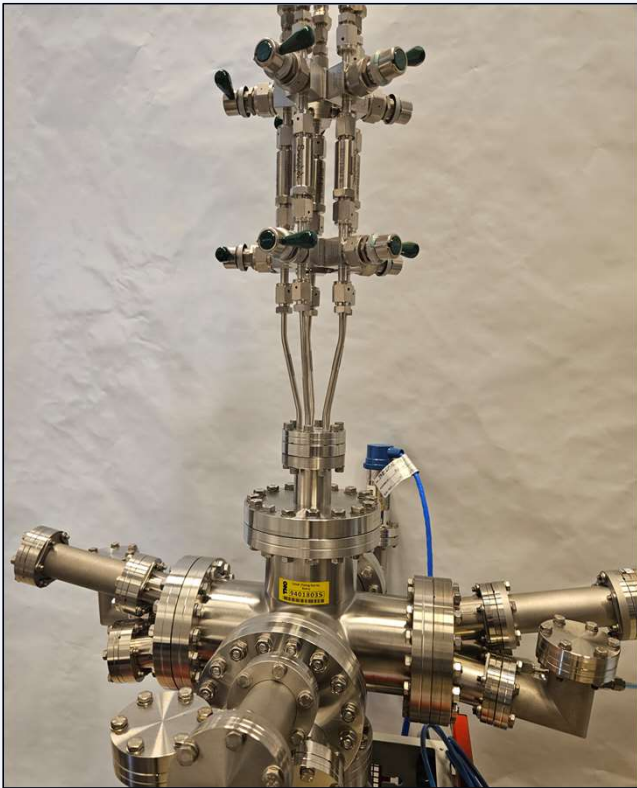
Within the European consortium 10ACE, TNO will investigate:

- Ion source chemistry and its dependency on ion source settings:
 - Protonation (The addition of a hydrogen ion to a molecule, changing its mass)
 - O₂ conversion to H₂O (changing the measured values for both species)
- Trace gas pump speed dependency on gas mixture (mixing ratio of matrix and trace gas)



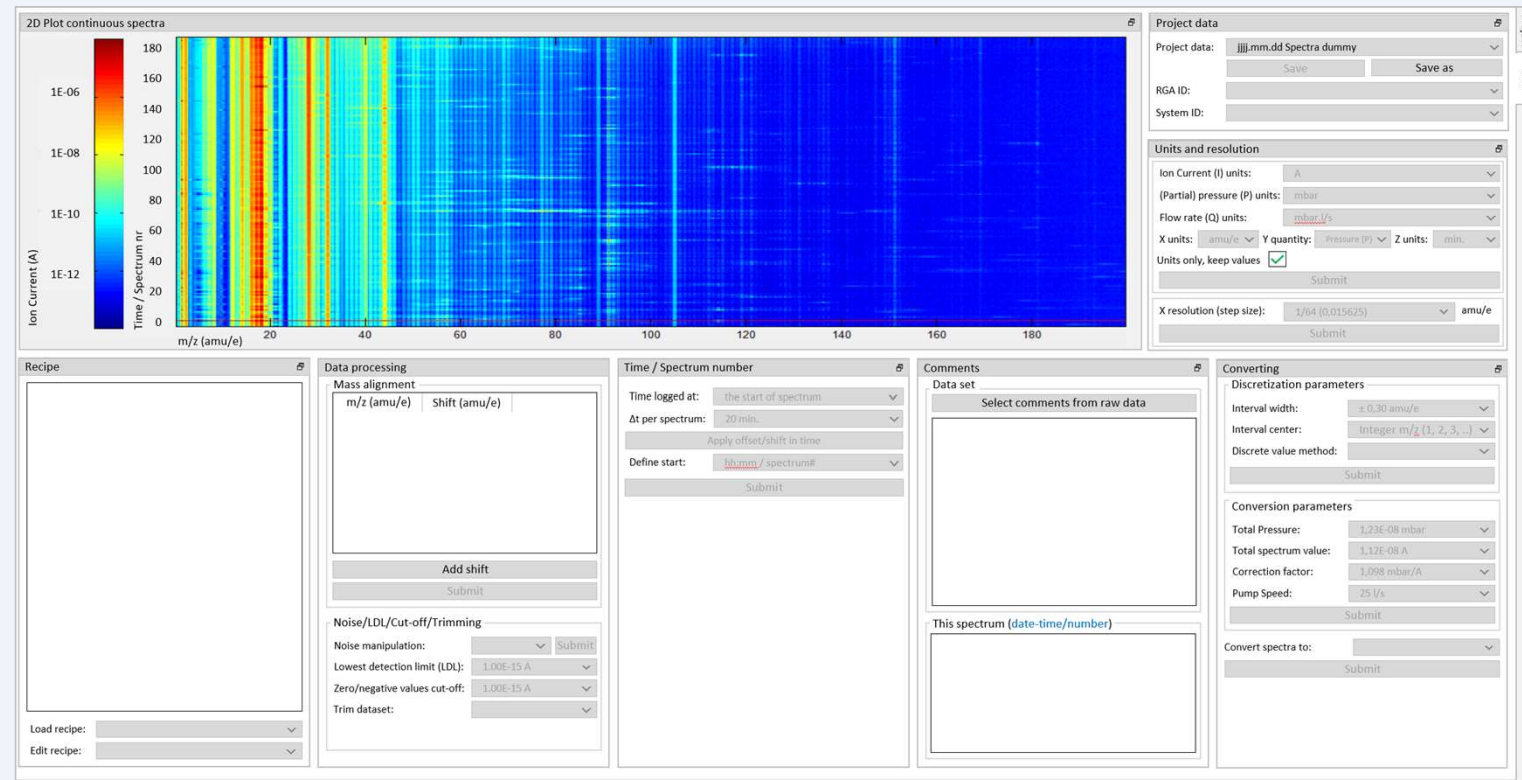
More fun with RGA's at TNO

→ Tuning Tool for RGA's (TuToR)



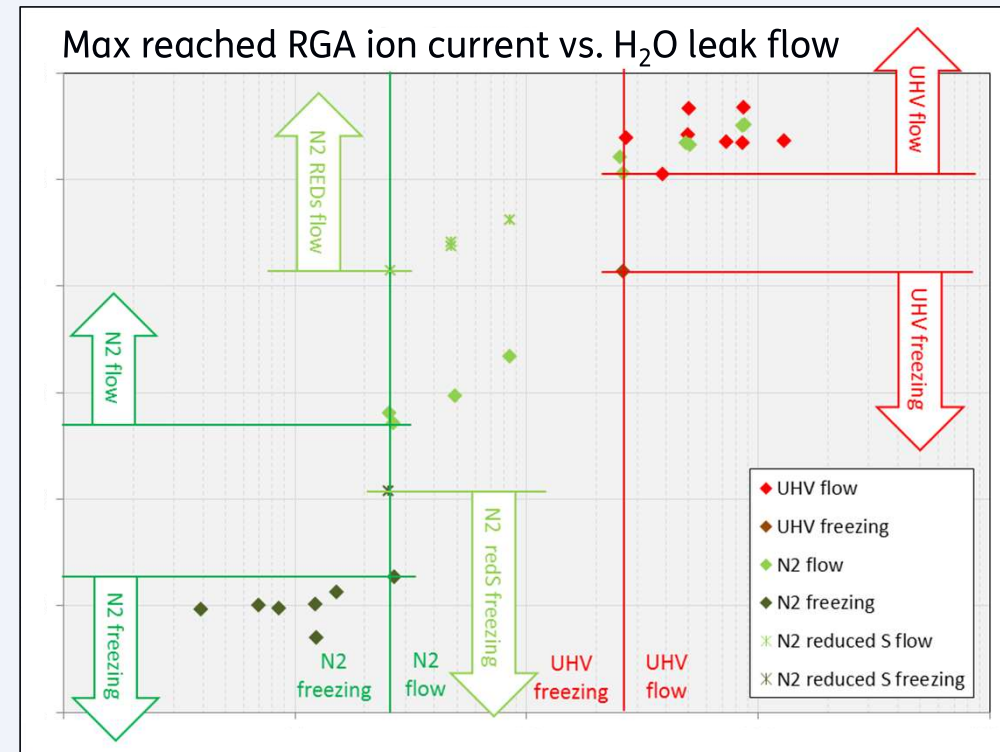
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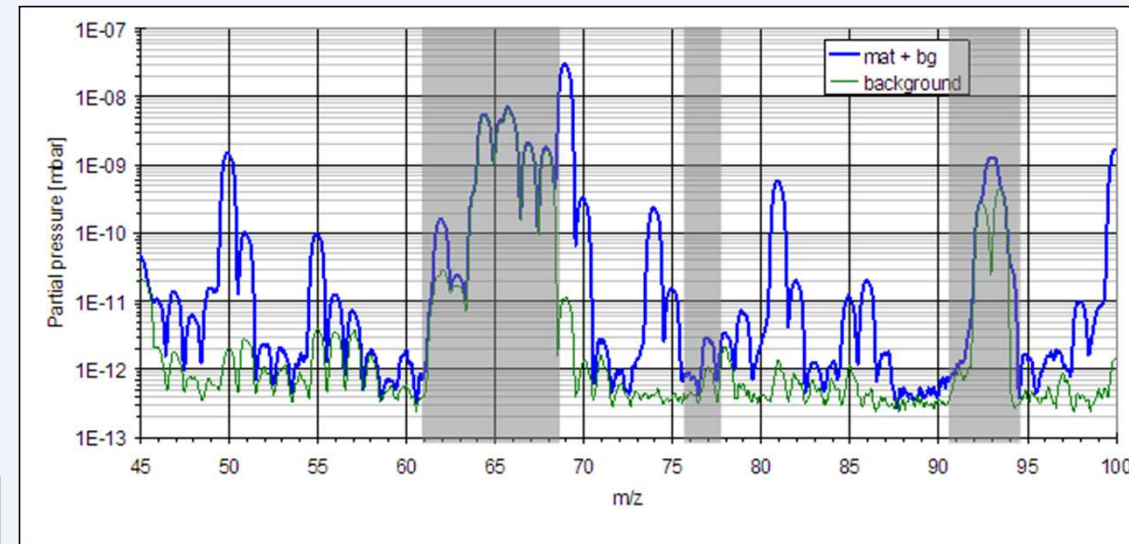
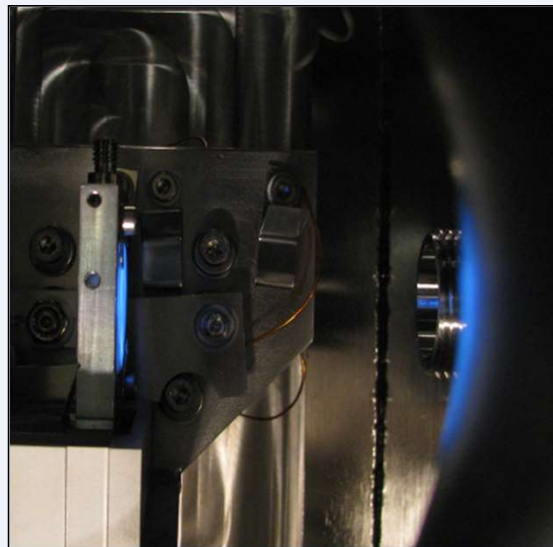
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- Investigate behaviour of aborning waterleaks in UCV



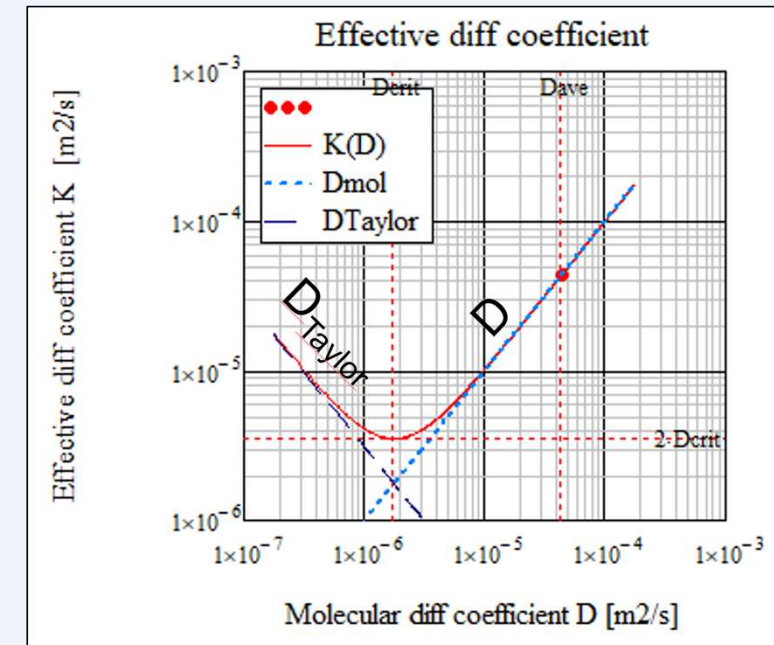
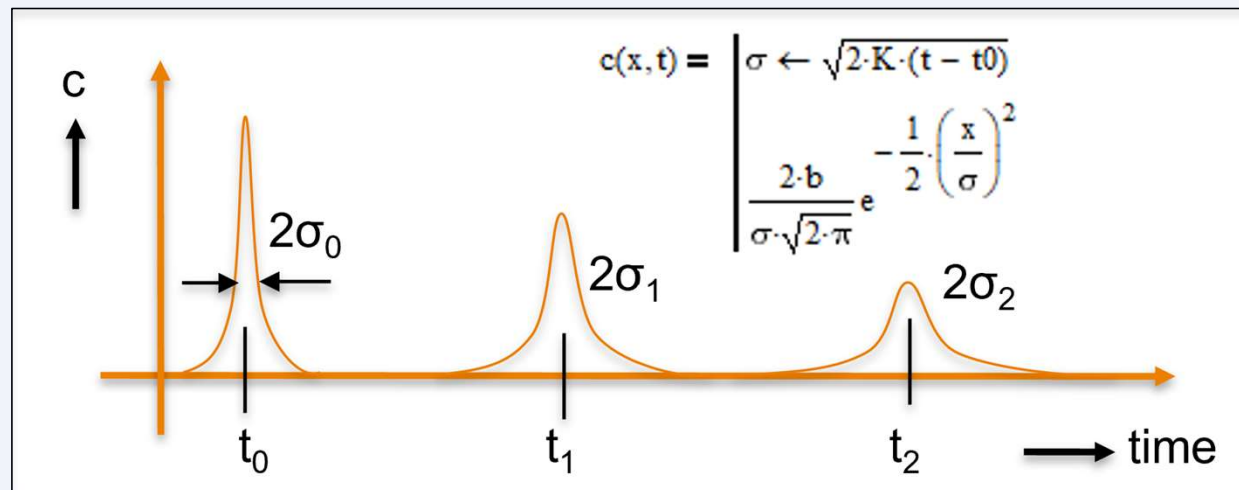
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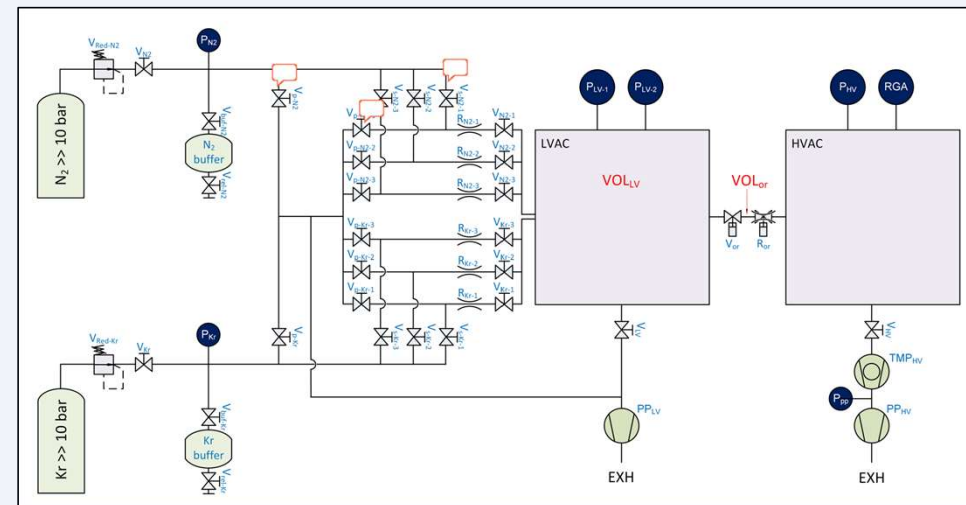
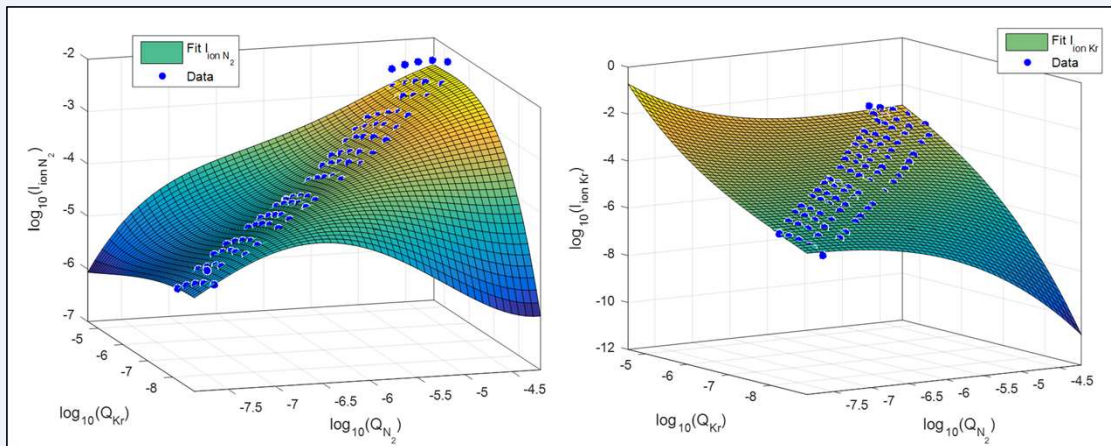
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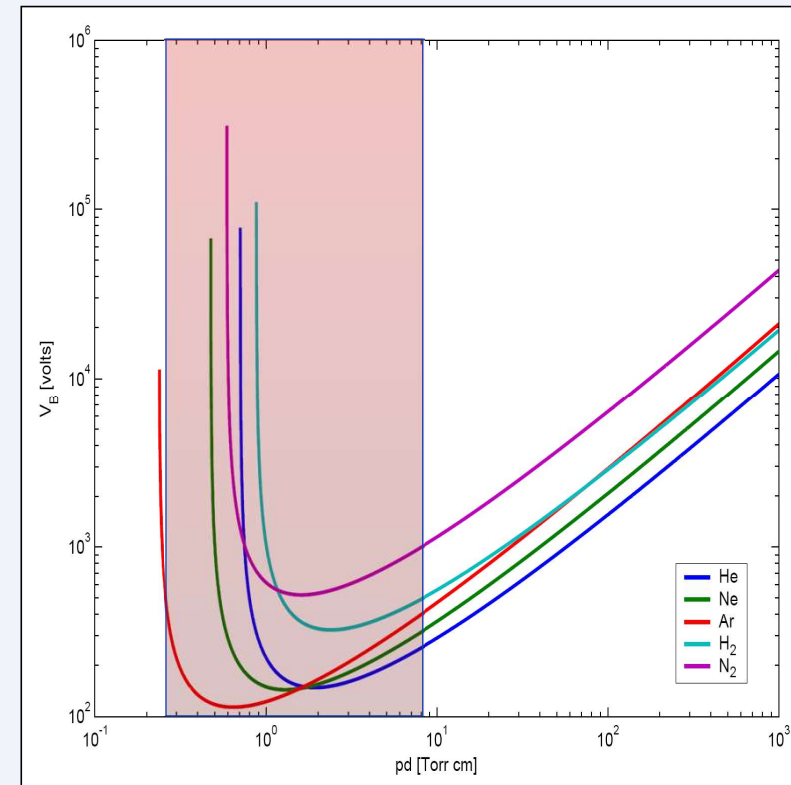
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- Mass separation in rarified flow modelling and experimental verification
- RGA-on-a-chip
-



The background of the slide is a dark blue field filled with numerous light blue, three-dimensional question marks. These question marks are scattered across the entire area, creating a dense, textured effect. They vary slightly in size and orientation, giving the impression of floating or stacked. The lighting on the question marks creates subtle highlights and shadows, enhancing their 3D appearance.

Thank you for your attention!

IUVSTA workshop 102



- ◎ Ultra-clean vacuum: why, how, and how to measure
- ◎ Organized by TNO the Dutch vacuum society (NEVAC)
 - ◎ Partners; DSPE, Mikrocentrum and VCCN
- ◎ 3-6 Februari 2025
- ◎ Delft, the Netherlands
- ◎ Key goal is knowledge sharing;
 - ◎ Science and industry
 - ◎ And between technology domains
 - ◎ Semicon, Space, Quantum, big science
- ◎ www.tno.to/ucv

