MOLECULAIRE OPPERVLAKTEREINHEID VAN PRODUCTEN

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TNO innovation for life

INHOUDSOPGAVE

MOLECULAIRE OPPERVLAKTEREINHEID VAN PRODUCTEN

- Waarom is het nodig?
  - Voorbeelden van moleculaire vervuiling
    - EUV
      - Proces van deze vervuiling
    - TEM
- En wat is de aanpak?
  - Voorbeeld aan de hand van EBL2
  - Nieuwe reinheid richtlijn (VCCN richtlijn 12)
- Conclusie

EUV LITHOGRAFIE

- Steeds kleinere microchips, met nieuwe lithografiemethode

Foto: ASML

- EUV lithografie
- Golflengte:13,5 nm
- In ultra-clean vacuüm
- Spiegels in plaats van lenzen

Foto: Carl Zeiss SMT

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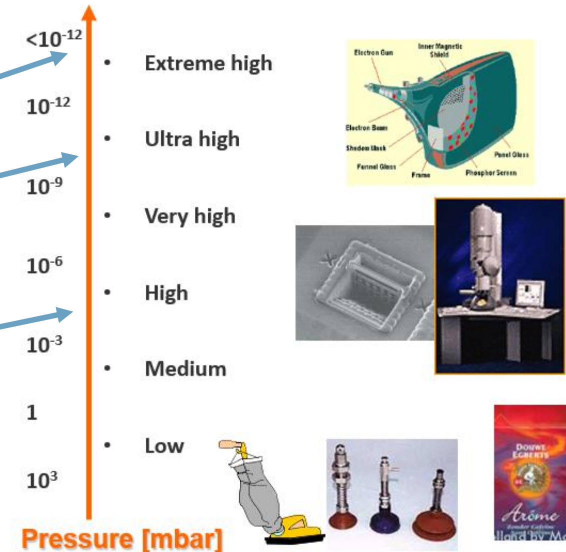
Foto: Carl Zeiss SMT

VACUÜM

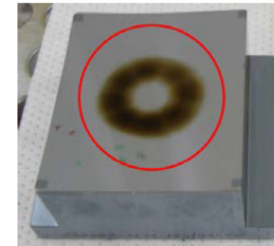
- Een vacuüm is een ruimte zonder materie en zonder druk [wikipedia]
  - In praktijk is een ruimte zonder druk en materie niet haalbaar
  - 10^{-12} mbar heeft nog steeds 10^5 moleculen per cm^3
  - 10^{-6} mbar geeft 1 monolaag aangroei per seconde

- Vacuüm heeft vele toepassingsgebieden
  - CERN en op de maan
  - SEM
  - TL lamp

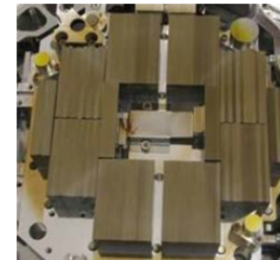


Carbon contamination

- ‘Vacuum’ contains residual (hydrocarbon) contaminants
- Hydrocarbons adsorb on (mirror) surfaces
- EUV photons and secondary electrons cause
  - Transformation of C_xH_y chains to aC:H
  - Reduction of H-content with irradiation dose
  - Radiation-induced outgassing of fragments
- EUV lifetime issue
  - How fast does carbon grow under actual tool conditions?

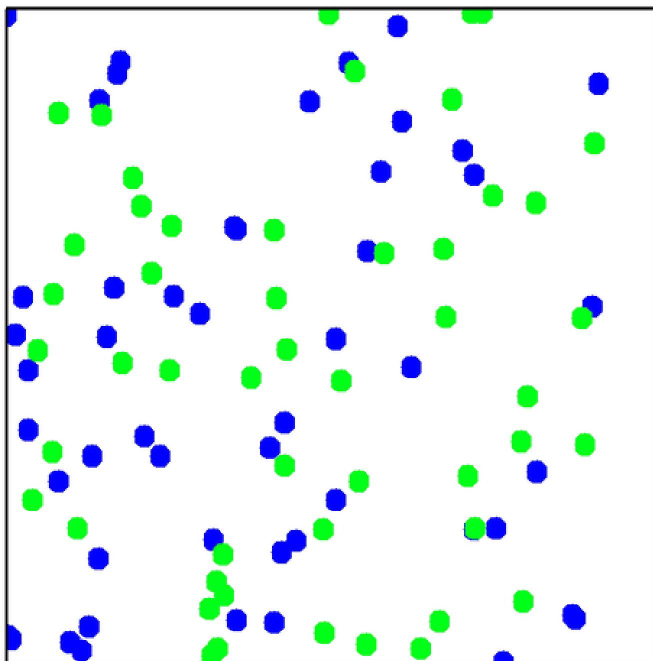


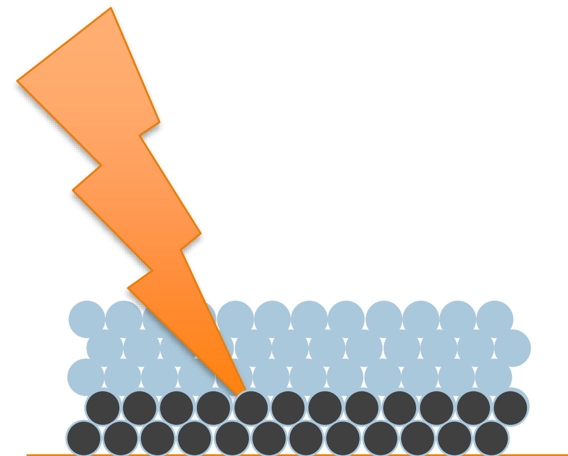
SEMATECH MET, 2007



ADT mirror, 2007

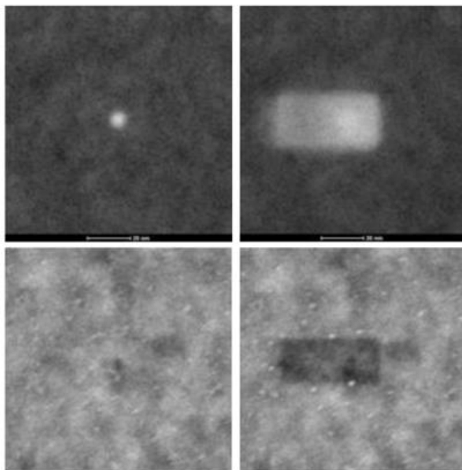
EUV optics lifetime, Radiation damage, contamination, and oxidation; M van Kampen (ASML); PXRNM workshop 2016





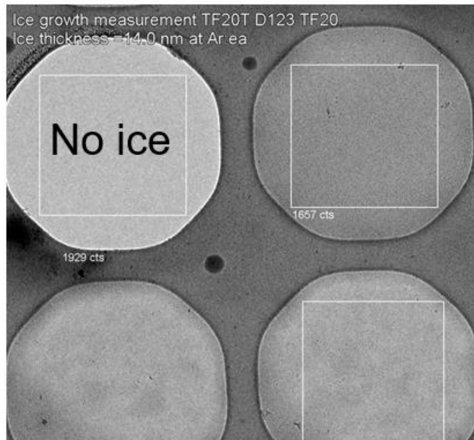
Contamination measurement on TEM

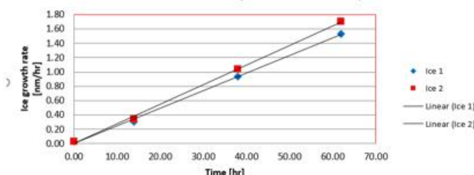
Example:
C_xH_y contamination level via Carbon Grown in STEM mode on sample

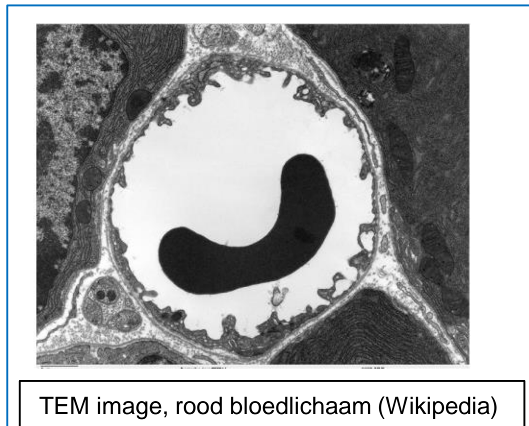


Measurement examples, contrast difference on SiN window of measuring sample @950 kx.
Upper contaminated, lower clean (sample etching)
Left reference image, right image after focus window.

Example:
H_20 contamination via Ice Grow on TEM Cryo sample, Transmission loss in time



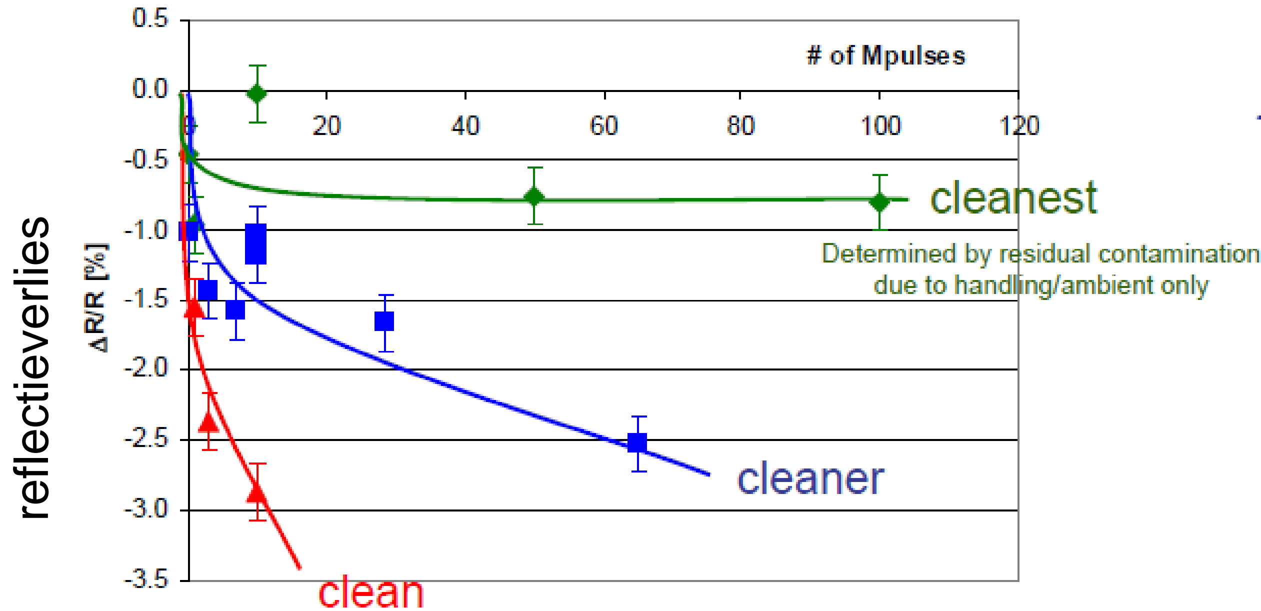




TEM image, rood bloedlichaam (Wikipedia)

ThermoFisher SCIENTIFIC

Contamination Control in the Electron Microscopy Supply Chain; Rients de Groot. (Thermo Fisher scientific); VCCN mini symposium 7 nov 2019



2008

Ultra clean vacuüm

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VOORBEELD VAN AANPAK: EBL2

- EBL2 is een onderzoeksfaciliteit van TNO die gebruikt wordt voor het onderzoeken van levensduur van onderdelen die aan EUV blootgesteld worden, dit door samples met EUV licht bloot te stellen

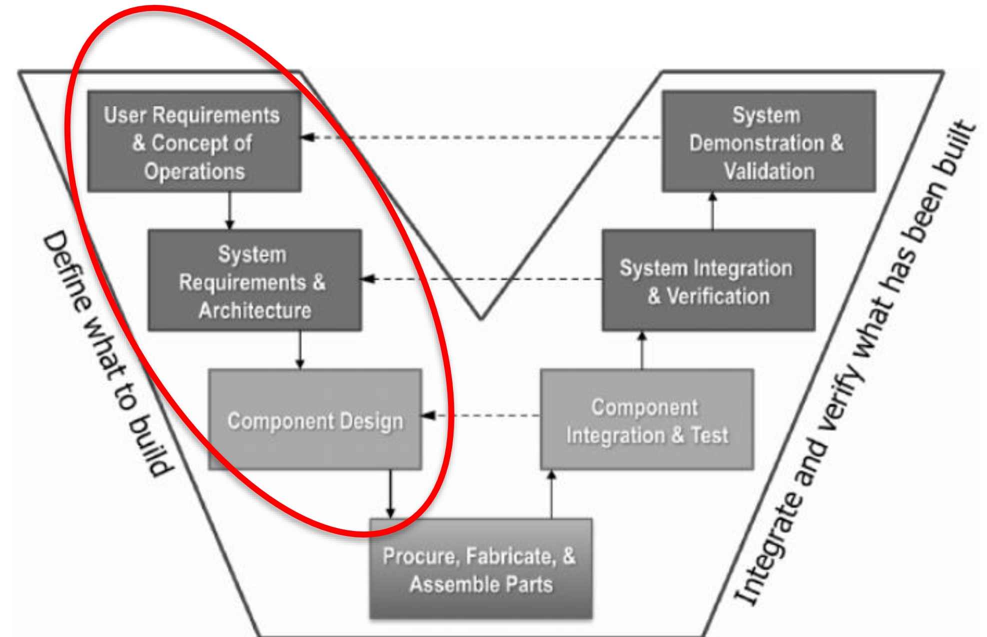
- Hiervoor is een deeltjes arm, en ultra-schoon vacuüm systeem nodig

www.tno.nl/ebl2

innovation for life

VERVUILINGSBUDGET

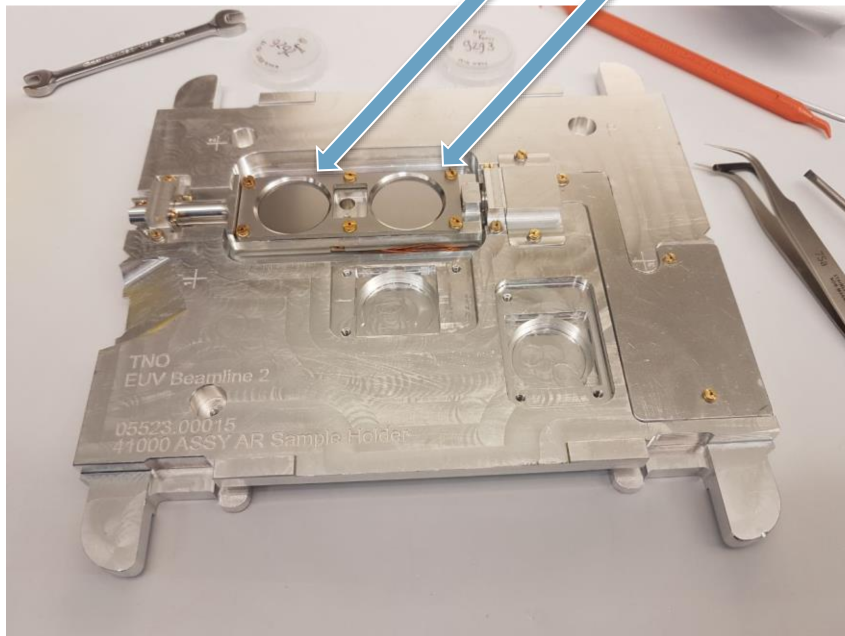
- Systeemaanpak
  - Vervuilingsbudget
    - Waar, hoe schoon
- Sample route door EBL2



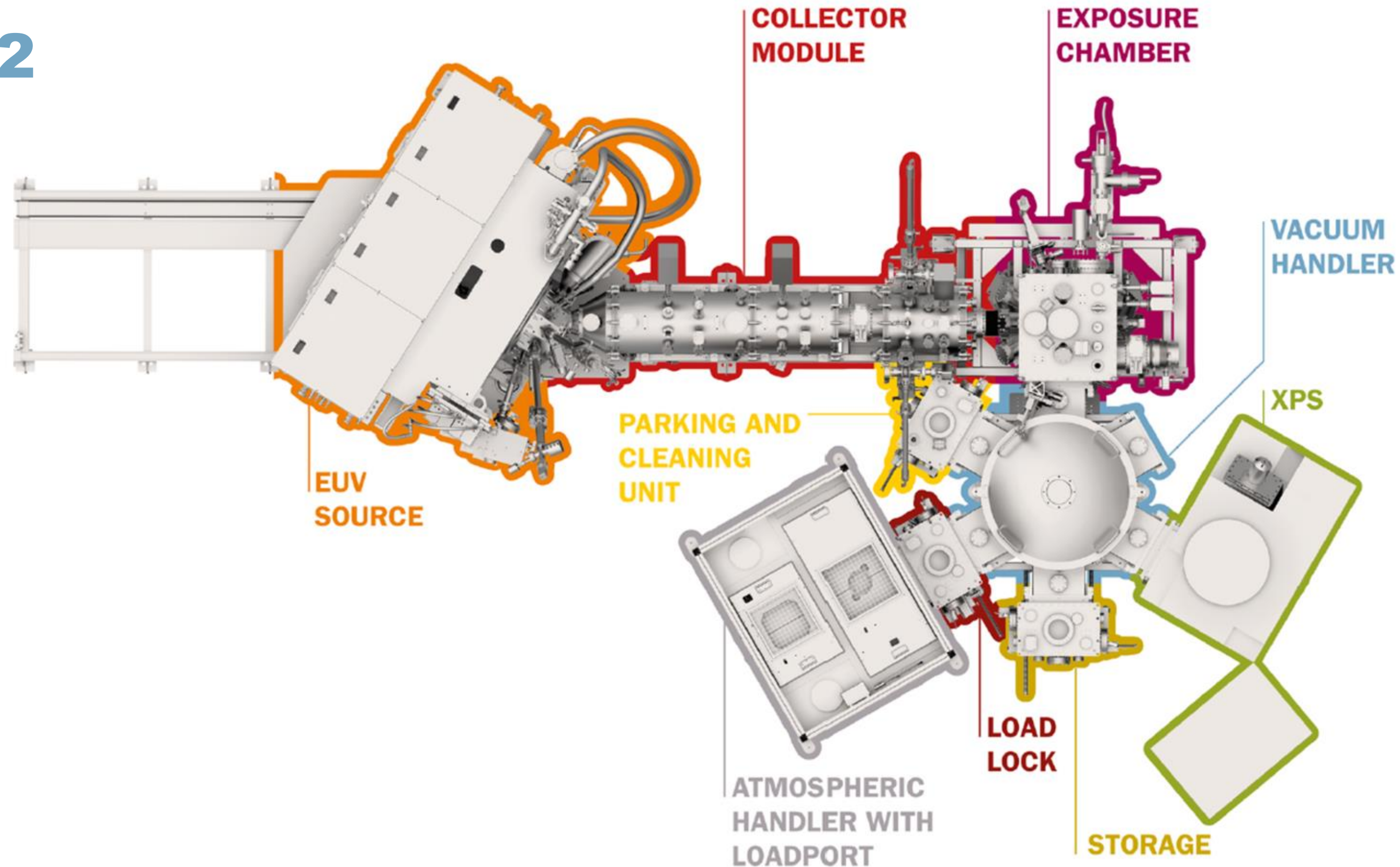
Sauser, Brian & Gove, Ryan & Forbes, Eric & Ramirez-Marquez, Jose. (2010). Integration maturity metrics: Development of an integration readiness level. Information Knowledge Systems Management. 9. 17-46.

EBL2

Samples



EBL2



EBL2

COLLECTOR MODULE

EXPOSURE CHAMBER

VACUUM HANDLER

XPS

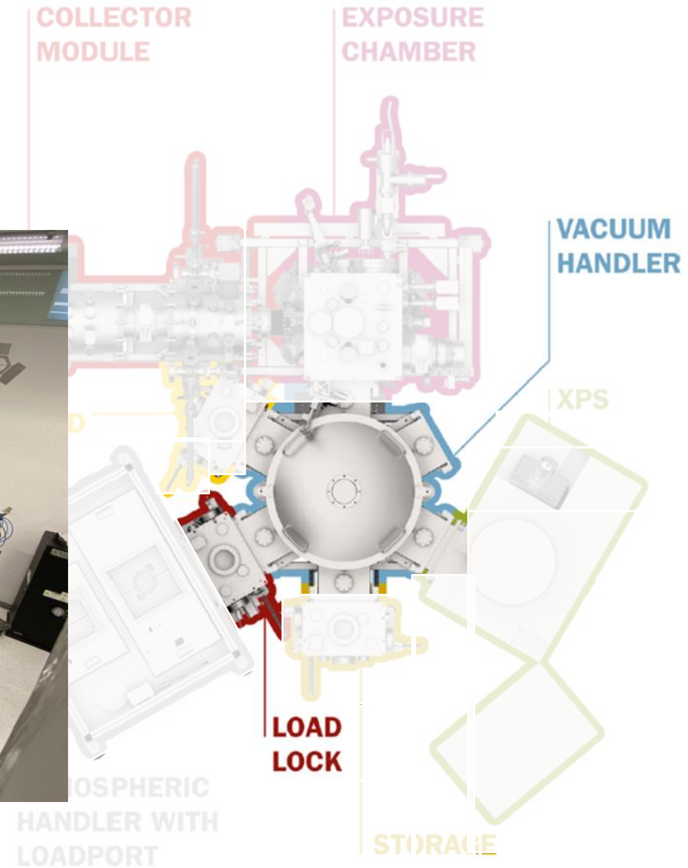
PARKING AND CLEANING UNIT

LOAD LOCK

ATMOSPHERIC HANDLER WITH LOADPORT

STORAGE

EBL2



EBL2

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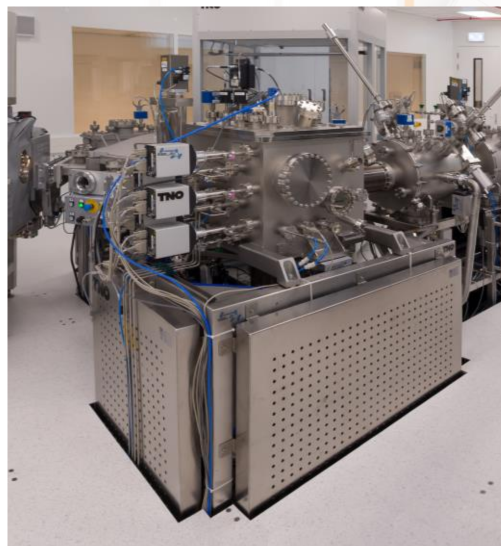
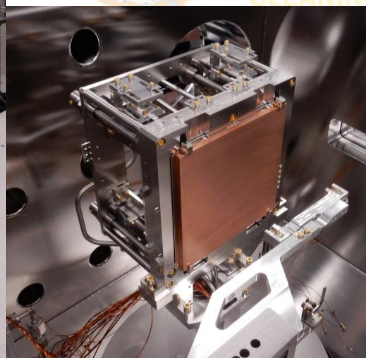




EBL2 VACUÜM

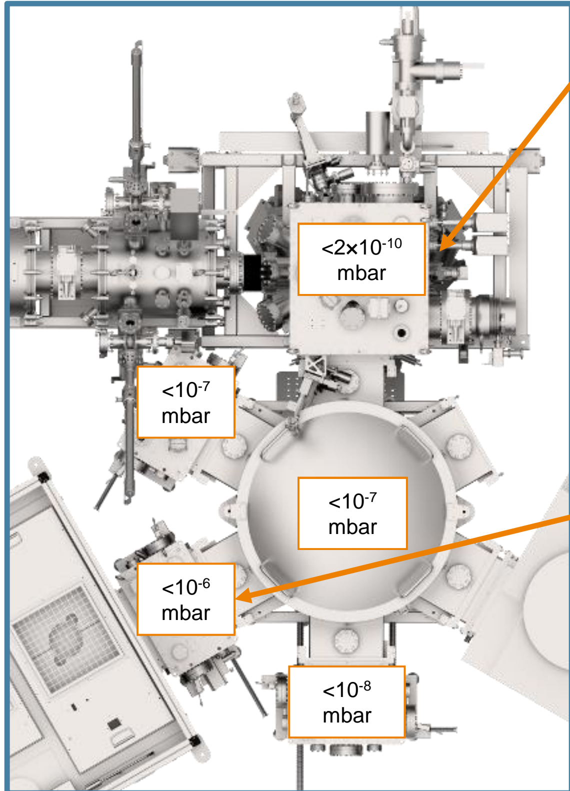
Table 4-9 Exposure Chamber qualification requirements

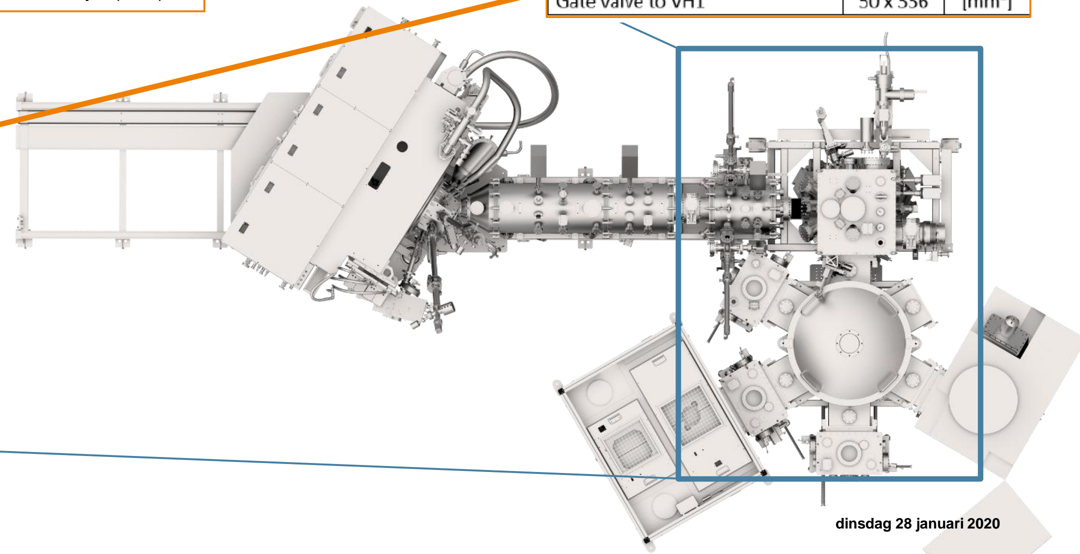
Requirement	Value	Unit
Total end pressure	<1 - $2 \cdot 10^{-10}$	[mbar]
Partial pressure H_2	$<10^{-10}$	[mbar]
Partial pressure H_2O	$<10^{-10}$	[mbar]
Partial pressure N_2	$<10^{-12}$ (integrated)	[mbar]
Partial pressure O_2		
Partial pressure C_xH_y 45-100		
Partial pressure – C_xH_y 101-200		
He leak rate	$<1*10^{-10}$	[mbar.l/s]

Grade 1 cleaning,(extra schoon)
Verboden materialen lijst (HIO)

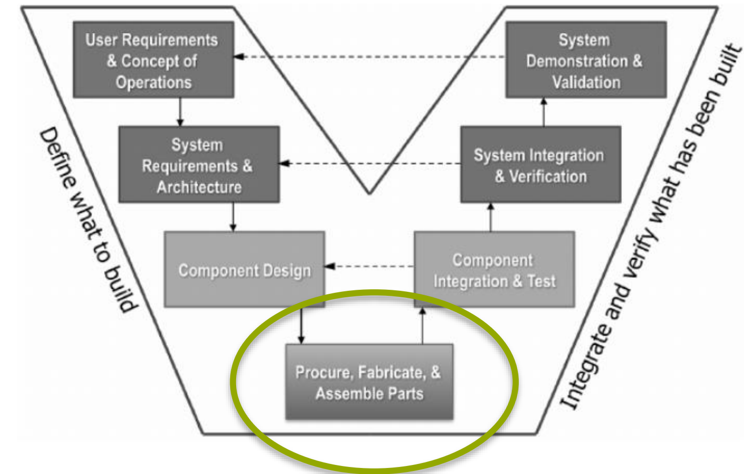
Table 4-2 Load Lock process requirements

Requirement	Value	Unit
Total pressure	$<10^{-6}$	[mbar]
Partial pressure H_2	NA	
Partial pressure H_2O	NA	
Partial pressure N_2	$<10^{-7}$	[mbar]
Partial pressure O_2	$<10^{-8}$	[mbar]
Partial pressure C_xH_y 45-100	$<10^{-9}$	[mbar]
Partial pressure – C_xH_y 101-200	$<10^{-10}$	[mbar]
Partial pressure Ar	NA	
Partial pressure Xe	NA	
Evacuation (pump down) time	15-20	[min]
Gate valve to VH1	50 x 336	[mm²]





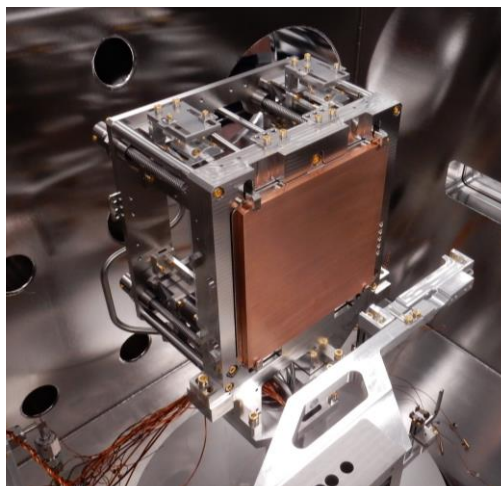
PRODUCTIE

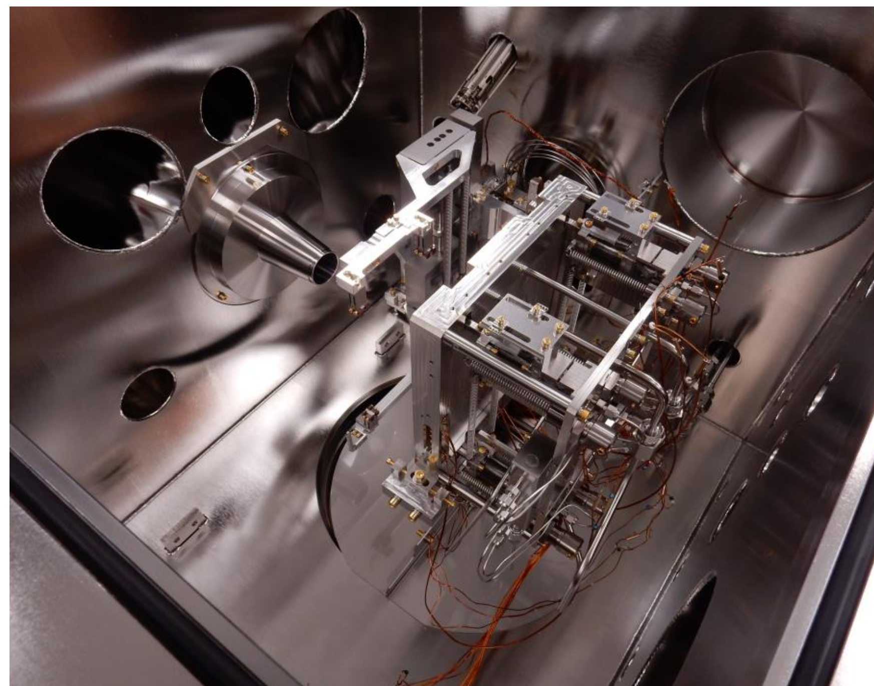


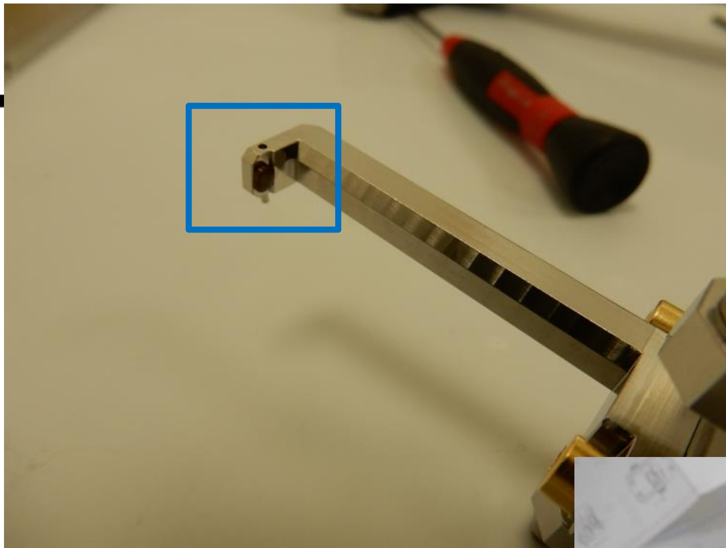
- Materiaal en ontwerp moet reinigbaar zijn
  - Bestendig tegen nat-chemisch reinigen
  - Temperatuur bestendig
  - Oppervlakken moeten bereikbaar zijn
- Verspaningsmachines moeten schoon zijn
  - Juiste koel- en smeermiddelen
  - Geen tools gebruiken die in aanraking zijn geweest met materialen die niet toepasbaar zijn in vacuüm
- Tijdens assemblage moet product schoon blijven
  - Duidelijke instructie van personeel

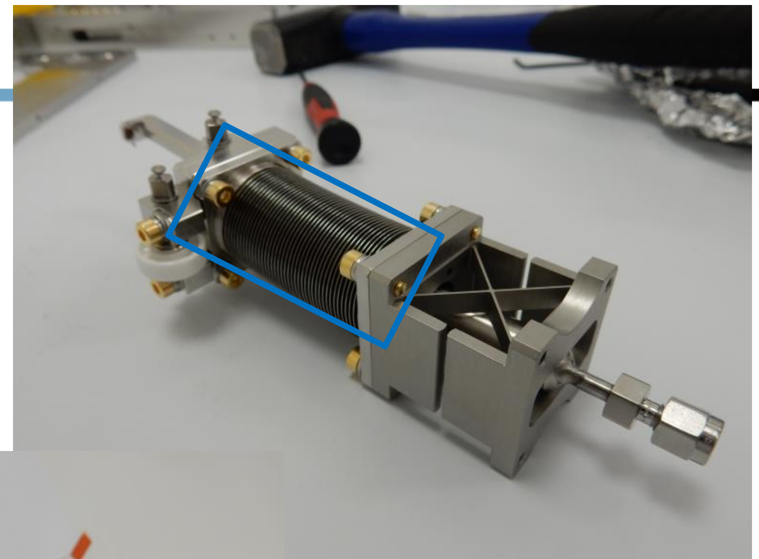
PRODUCTIE / ONTWERP VOORBEELDEN

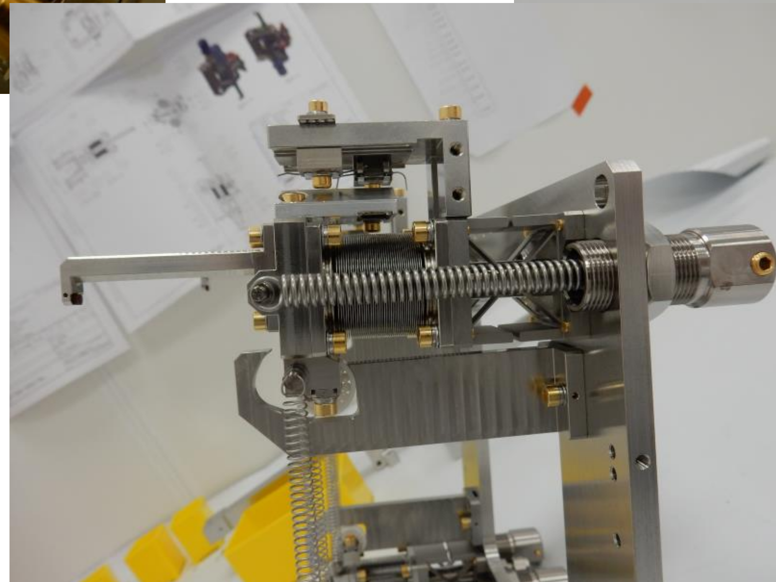
- Sample handling in de exposurekamer
- Strenge eisen op toegestane materialen
- Onderdelen moeten reinigbaar zijn



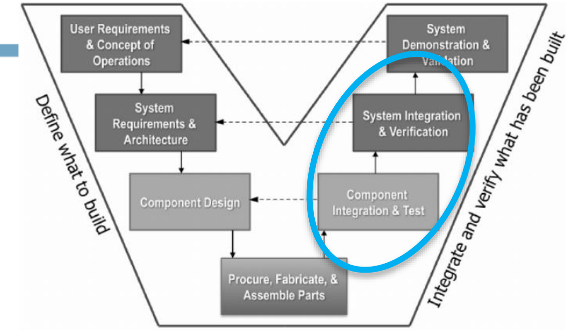


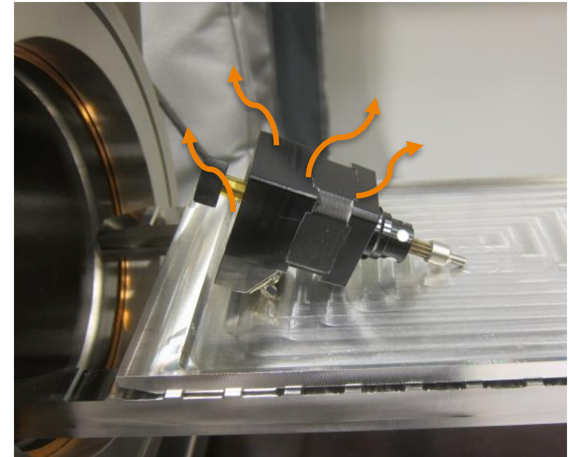




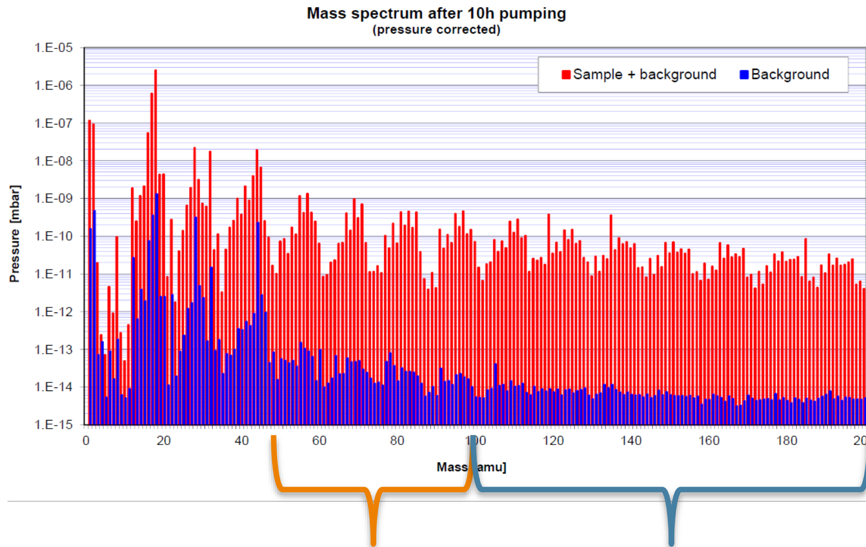


VALIDATIE REINHEID; UITGAS MEETOPSTELLING;





VALIDATIE UITGASSING



Test details			
Sample Id:		Pump speed [l.s^{-1}]:	25
Description:		System:	ATOM
Date:	20-Nov-15	Ratio: IG/RGA	0.6
Data filename:		RGA Id:	QMA 422: SN 44248116
Background file:		Ion gauge Id:	IG (YEA07221)
Filename:			
Operator:			Sample Outgassing 200amu v7
Comments:	Black coated stepper motor with sub-D connector, no vents to prevent for virtual leakage, no appearant (visible) lubricationon outside		

Outgassing rate at 1h:		
	Sample (background subtracted)	(background)
Q_{total} [mbar.l.s^{-1}]	NA	7.50E-07
Q_{H2O} [mbar.l.s^{-1}]	NA	4.69E-07
$Q_{CxHy<101amu}$ [mbar.l.s^{-1}]	NA	6.41E-10
$Q_{CxHy>100amu}$ [mbar.l.s^{-1}]	NA	2.75E-11
Q_{CxHy} [mbar.l.s^{-1}]	NA	6.68E-10
$P_{ion\ gauge}$ [mbar]	NA	3.00E-08

Outgassing rate at 10h:		
	Sample (background subtracted)	(background)
Q_{total} [mbar.l.s^{-1}]	8.79E-05	7.50E-08
Q_{H2O} [mbar.l.s^{-1}]	6.33E-05	3.30E-08
$Q_{CxHy<101amu}$ [mbar.l.s^{-1}]	4.51E-07	1.40E-10
$Q_{CxHy>100amu}$ [mbar.l.s^{-1}]	1.15E-07	1.72E-11
Q_{CxHy} [mbar.l.s^{-1}]	5.66E-07	1.57E-10
$P_{ion\ gauge}$ [mbar]	3.52E-06	3.00E-09

Comments: High outgassing of H2O and CxHy, traces of CxFy/fluorocarbons (119, 135, 185 amu), high O2 traces probably be due to virtual leakage

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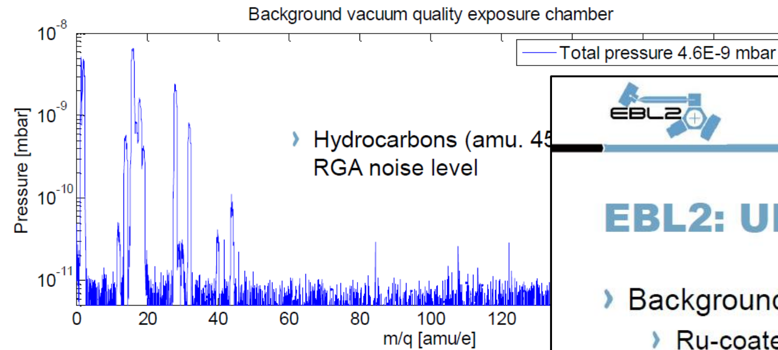
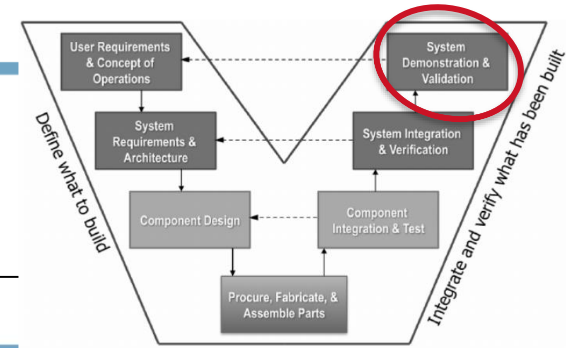
EBL2: HIGH VACUUM QUALITY

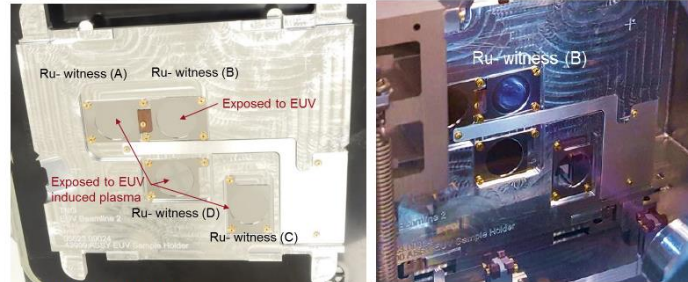


- Hydrocarbons (amu. 45
  RGA noise level



EBL2: ULTRA CLEAN SYSTEM

- Background screening of EBL2 exposure chamber
  - Ru-coated witness plates
  - 3kHz, 18 MShots, 15 mW/mm² in standard H_2 condition
  - XPS analysis without breaking vacuum



XPS results (at %) ; wide scan, without breaking vacuum

Sample code	O	Ru / C	S	Sn
Ru-witness (A)	7.3	91.1	1.5	<
Ru-witness (B)	7.3	91.0	1.7	<
Ru-witness (C)	10.3	88.8	1.0	<
Ru-witness (D)	8.0	90.6	1.4	<

EUV mask lifetime testing using EBL2; Chien-Ching Wu et.al. (TNO); 2018 SPIE Advanced Lithography

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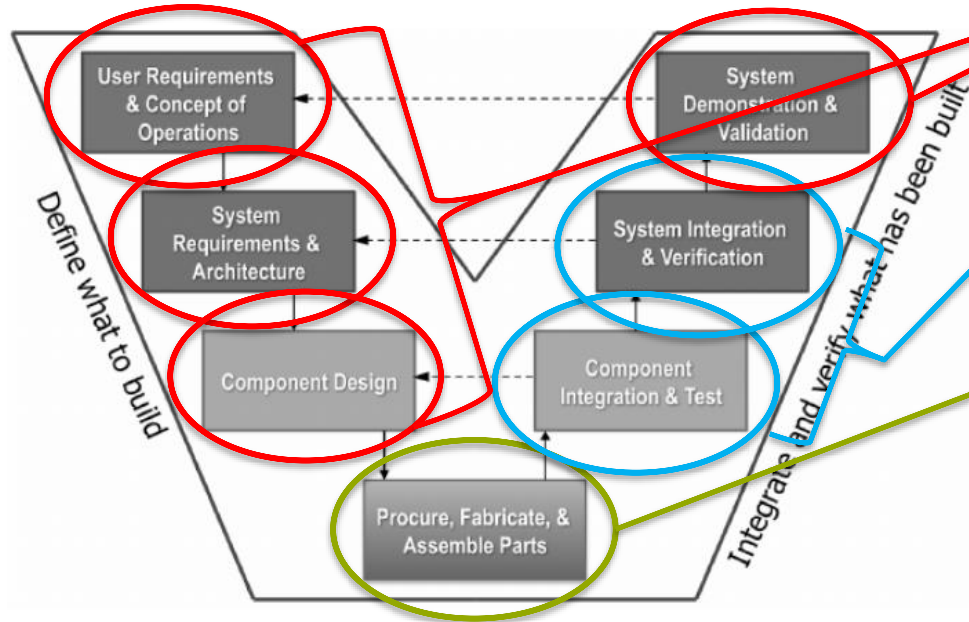
VCCN RICHTLIJN 12

Product/part cleanliness
with respect to particles and chemicals

specification, manufacturing, cleaning, contamination control and qualification

VCCN RICHTLIJN 12



0 Introduction
1 Scope
2 Normative references
3 Terms and definitions
4 General outline of this guideline
5 Surface cleanliness specification
  5.1 General
  5.2 Surface cleanliness levels with respect to particles
  5.3 Surface cleanliness levels with respect to chemicals
  5.4 Surface cleanliness with respect to trace elements
6 Measurement methods
  6.1 General
  6.2 Surface cleanliness with respect to particles
  6.3 Cleanliness with respect to chemicals
7 Machining
  7.1 Raw materials
  7.2 Machine conditions
  7.3 Product handling
  7.4 Transport
  7.5 Surface treatment
8 Cleaning
  8.1 Cleaning methods
  8.2 Cleaning agents
  8.3 Evaluation of cleaning methods
9 Assembly
10 Clean controlled environment
  10.1 Contamination mechanisms
  10.2 Clean controlled environment
  10.3 Contamination control solutions
11 Packaging
12 Applications (best practises)
  12.1 Product cleanliness with respect to particles
  12.2 Product cleanliness with respect to chemicals
  12.3 Product cleanliness with respect to particles and chemicals

CONCLUSIE

- In de toekomst zal er om steeds schonere producten gevraagd worden

- Het is van groot belang om samen te werken om haalbare eisen op te stellen tegen reële kosten

- **Acknowledgement**
  - "If I have seen further it is by standing on the shoulders of Giants.“ - **Isaac Newton**
  - “Great things in business are never done by one person. They’re done by a team of people” **– Steve Jobs**

BEDANKT VOOR UW AANDACHT

Voor meer inspiratie:
TNO.NL/TNO-INSIGHTS

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