EBL2: GAS CONDITIONS

Timo Huijser, Michel van Putten, Marco van der Lans

OUTLINE

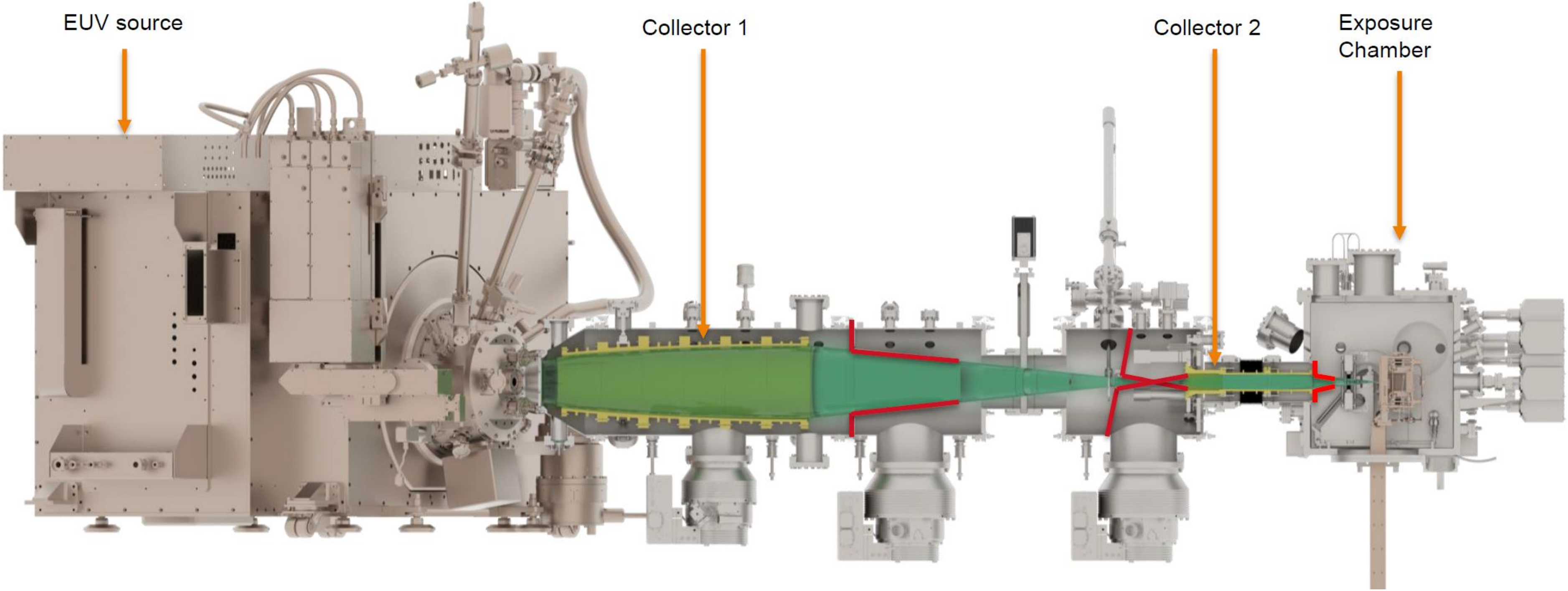
- Gas conditions in EUV lithography
- EBL2 layout
- Control gas environment:
  - Based on Residual Gas Analysis (RGA)
  - Based on pump speed measurements

GAS CONDITIONS IN EUV LITHOGRAPHY

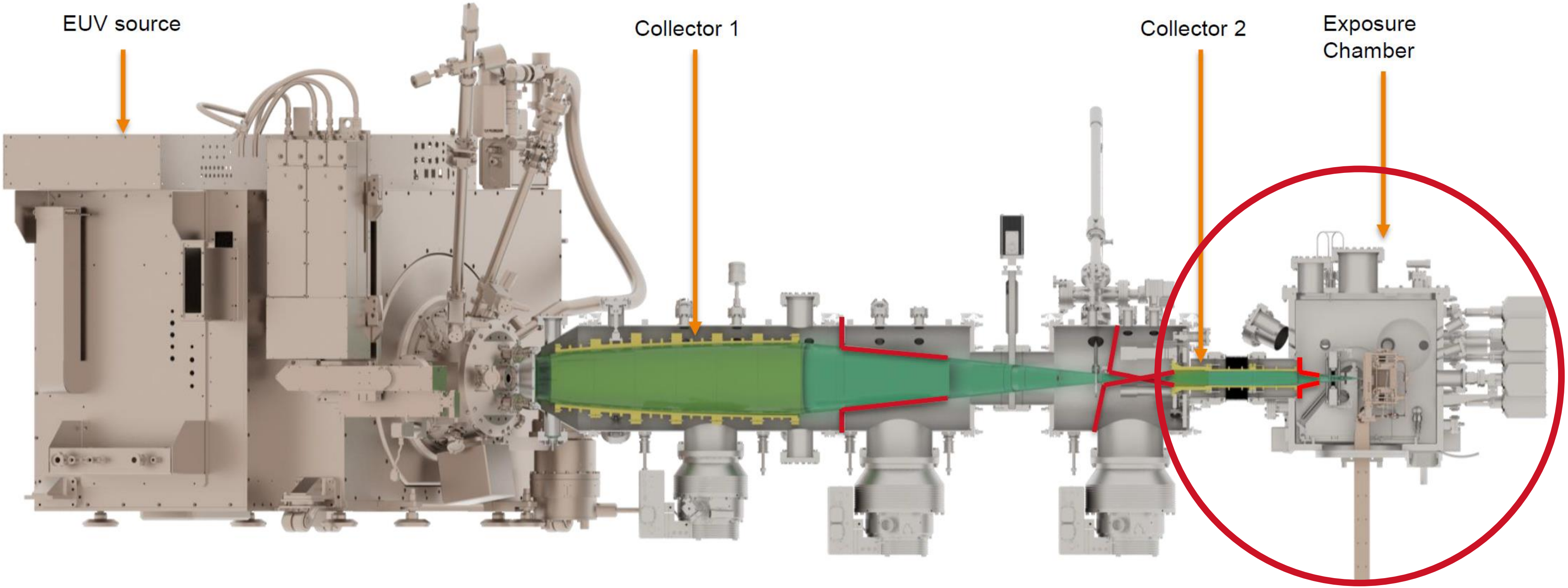
- Gases in EUV lithography machines
  - Hydrogen (purge gas, cleaning effect)
  - Contaminants (H_2O, O_2, N_2, H_xC_y)

- Research with EBL2 exposure tool focuses on studying degradation mechanisms of optics, reticles, pellicles and materials
- Well controlled gas environment is essential

BEAM LINE LAYOUT

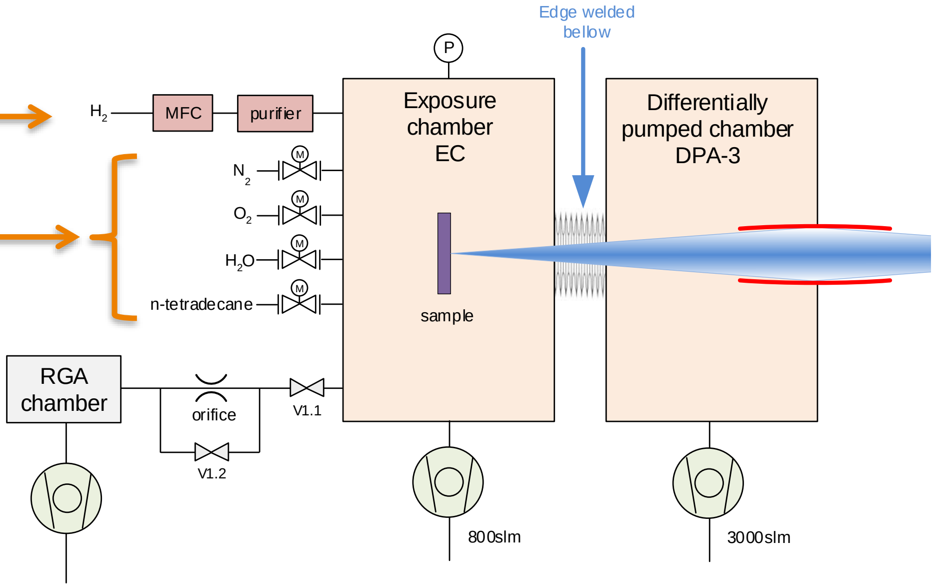


BEAM LINE LAYOUT



GAS ENVIRONMENT

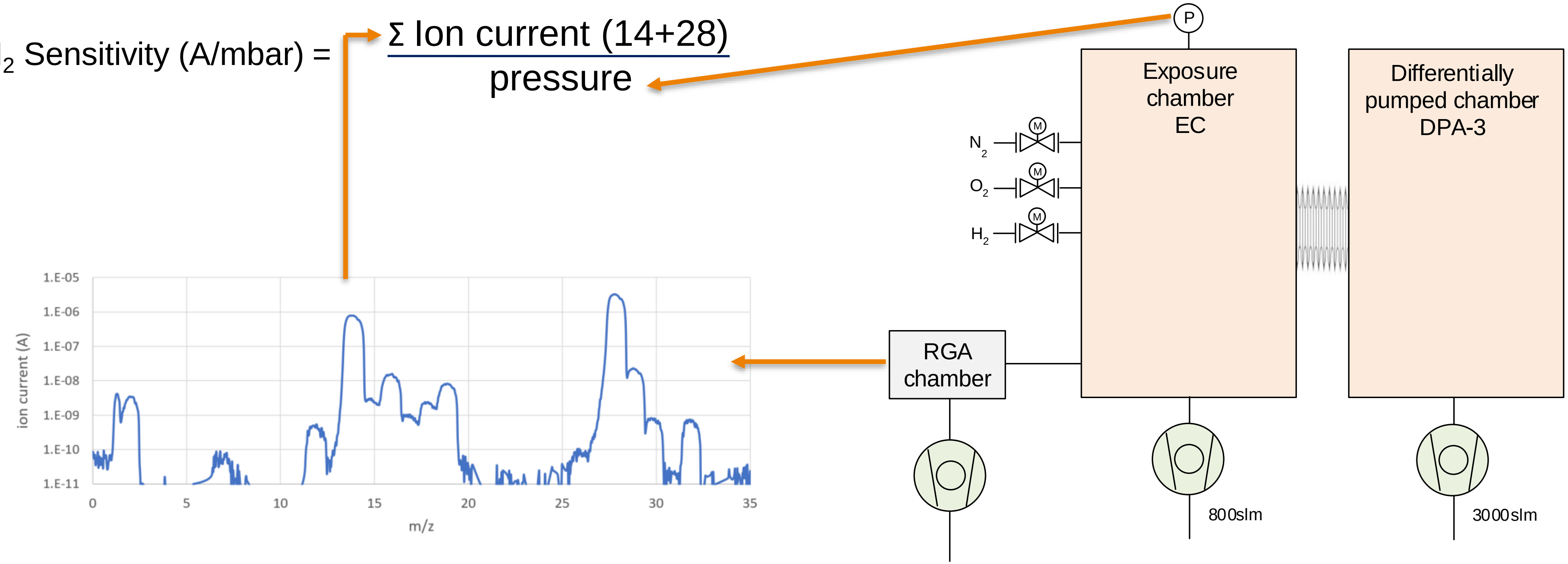
- Process gas: H_2 up to 50 Pa
- Contamination gasses: H_2O, O_2, N_2, C_xH_y, etc. typically 1E-7 to 1E-4mbar
- Differentially pumped RGA



- Scope: focus on H_2 + N_2 + O_2

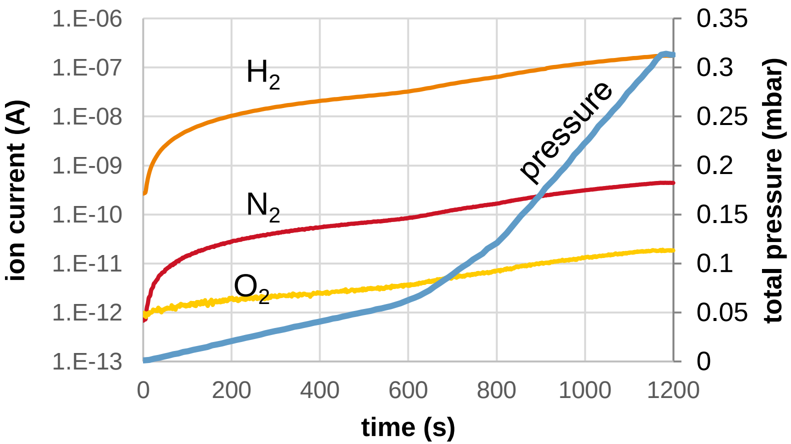
RGA CALIBRATION IN HIGH VACUUM

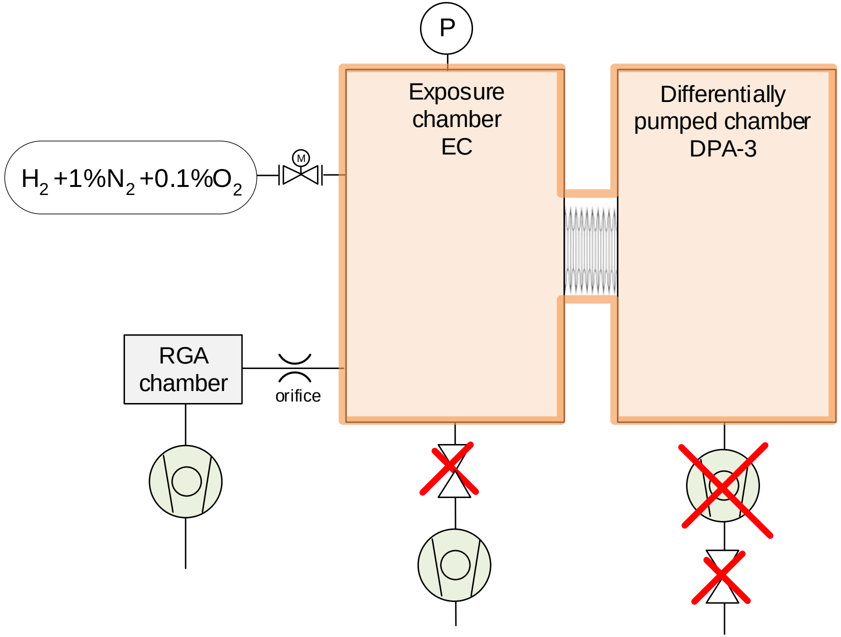
$$N_2 \text{ Sensitivity (A/mbar)} = \frac{\Sigma \text{ Ion current } (14+28)}{\text{pressure}}$$



RGA CALIBRATION IN ROUGH VACUUM

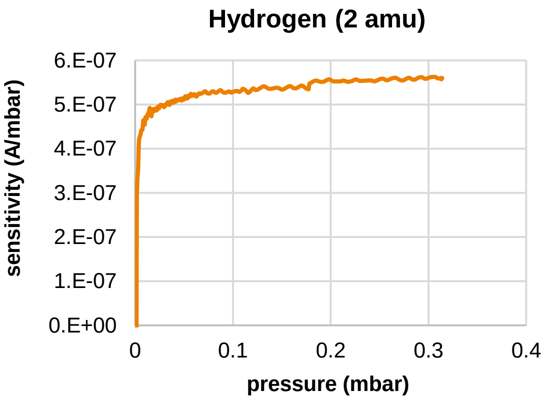
- Main gas is hydrogen
- RGA is connected through an orifice
- A mixture of H_2(98.9%), N_2(1%) and O_2(0.1%) is introduced in the closed EC + DPA3 vessel, disconnected from pre pump
- Total pressure and RGA signals are monitored

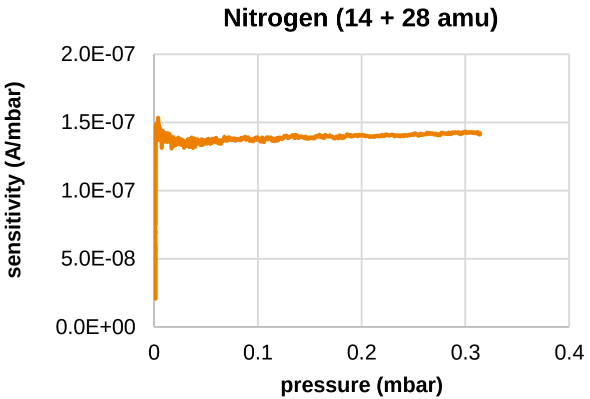


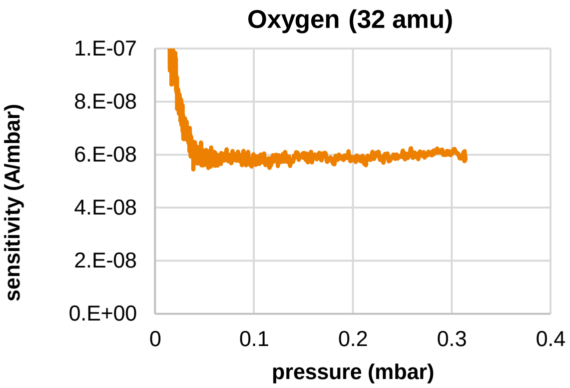


RGA SENSITIVITIES HYDROGEN, NITROGEN, OXYGEN

amu	1Pa	5Pa	10Pa
2	4.92E-07	5.18E-07	5.32E-07 A/mbar
14+28	1.40E-07	1.36E-07	1.38E-07 A/mbar
32	1.40E-07	5.91E-08	5.87E-08 A/mbar

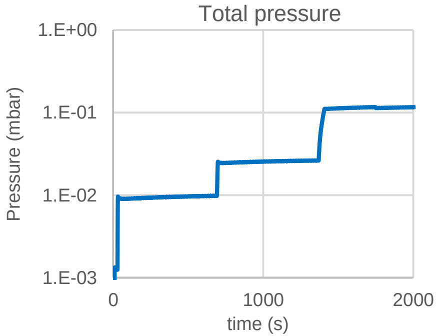






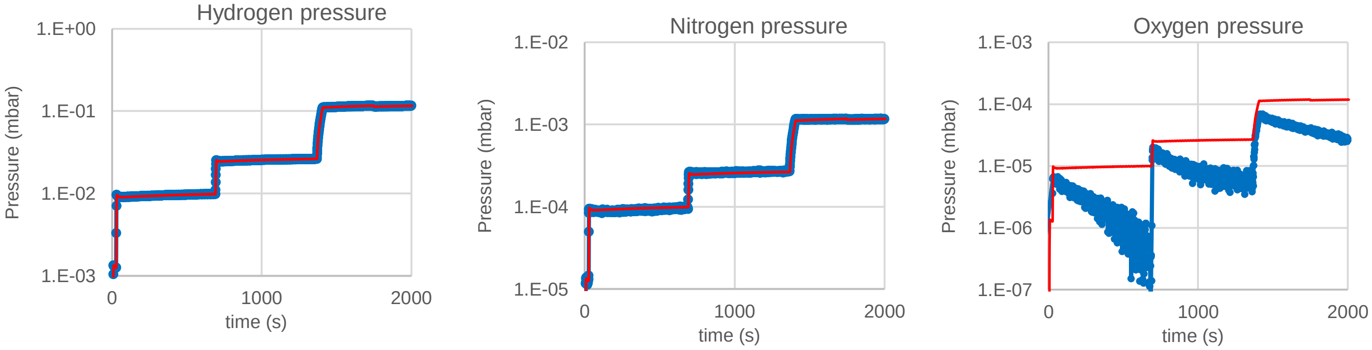
TEST: GAS MIXTURE INTRODUCED IN STEPS

- EC evacuated and filled with gas mix without pumping
- Three pressure levels (0,01; 0,03 and 0,1 mbar) set by briefly letting in the gas mix (1% N_2, 0.1% O_2, balance H_2)
- Oxygen concentration not constant and does not follow hydrogen pressure trend.
- Increasing water level suggest oxygen/hydrogen to water conversion
- Other explanation: adsorption of O_2 on walls of the exposure chamber and/or RGA chamber



Expected detection limits:

- Nitrogen: ~ 2E-6 mbar
- Water: ~ 1E-5 mbar
- Oxygen: ~ 3E-4 mbar



PLAN B: PUMP SPEED MEASUREMENTS

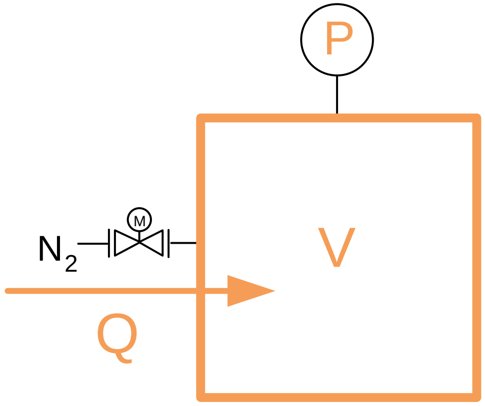
Determine pump speed of individual species with and without added hydrogen

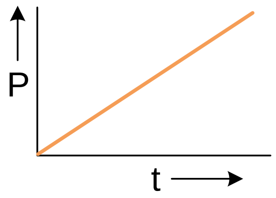
Set contaminant pressure prior to adding hydrogen, taking the pump speed change into account:

$$P_{set} = P_{required} \cdot \frac{S(with\ hydrogen)}{S(without\ hydrogen)}$$

DETERMINE PUMP SPEED AT HIGH VACUUM

- Mass flow controllers not suited (minimal flow too high): automatic leak valves need to be used
- Leak valves need to be calibrated to determine the flow rate. This is done by introducing the flow into the closed vessel.
- The volume *V* of the vessel is determined using a mass flow controller: 308 ± 4 liter





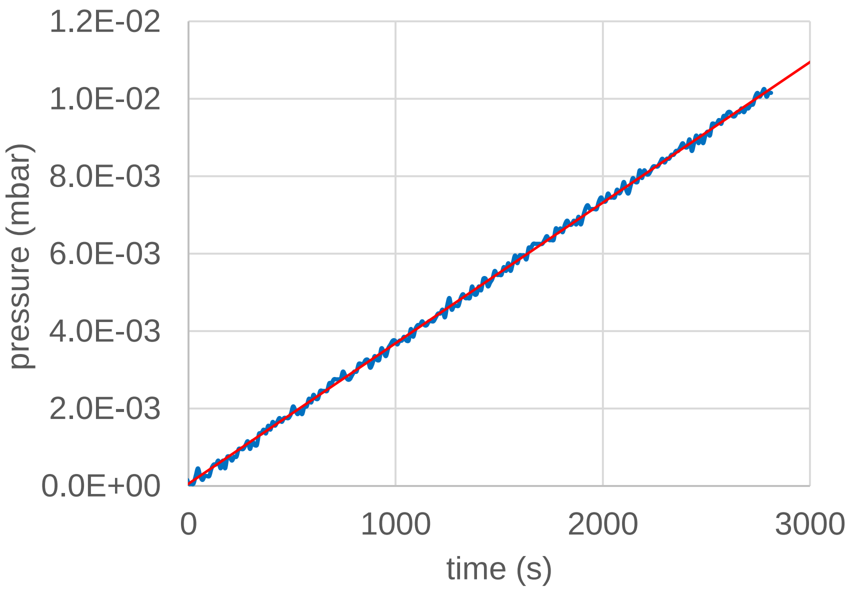
$$Q = V \cdot \frac{\Delta P}{\Delta t}$$

PUMP SPEED AT HIGH VACUUM - NITROGEN

- $Q = V \cdot \frac{\Delta P}{\Delta t}$
- V = 308 l
- $\frac{\Delta P}{\Delta t}$ = 3.63E-6 mbar/s
- Q = 1.12E-3 mbarl/s

- With pumps running at the same flow:
- P = 1.95E-6mbar

S = Q/P = 574 l/s

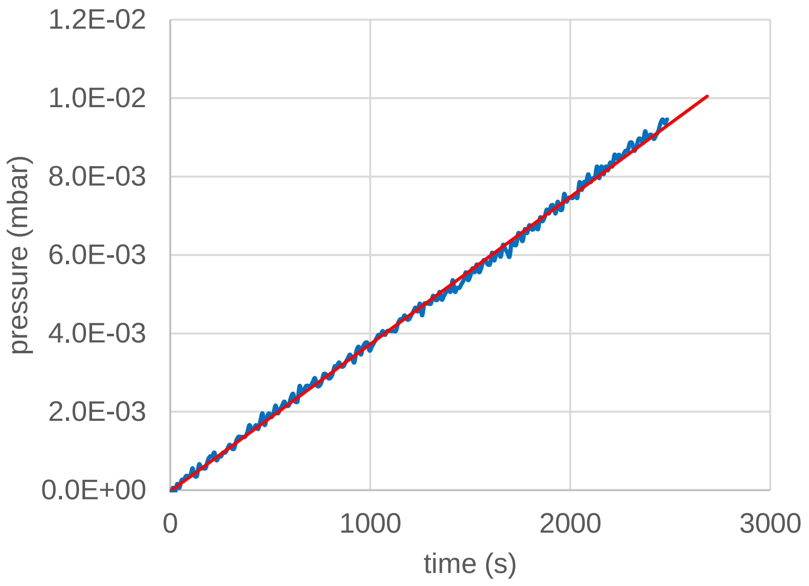


PUMP SPEED AT HIGH VACUUM - OXYGEN

- $Q = V \cdot \frac{\Delta P}{\Delta t}$
- V = 308 l
- $\frac{\Delta P}{\Delta t}$ = 3.76E-6 mbar/s
- Q = 1.16E-3 mbarl/s

- With pumps running at the same flow:
- P = 2.01E-6mbar

S = Q/P = 576 l/s

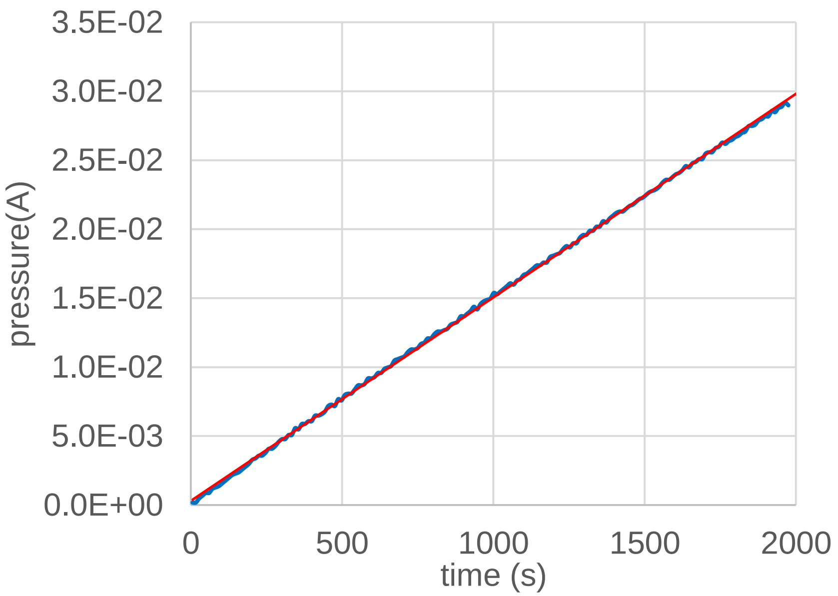


PUMP SPEED AT HIGH VACUUM - HYDROGEN

- $Q = V \cdot \frac{\Delta P}{\Delta t}$
- V = 308 l
- $\frac{\Delta P}{\Delta t}$ = 1.475E-5 mbar/s
- Q = 4.54E-3 mbarl/s

- With pumps running at the same flow:
- P = 4.93E-6mbar

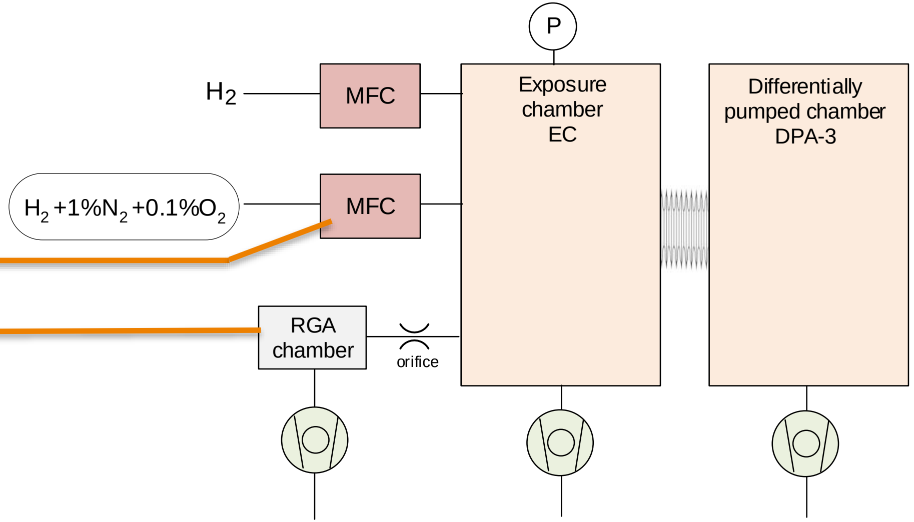
S = Q/P = 922 l/s



PUMP SPEED AT ROUGH VACUUM - METHOD

With the known sensitivities the partial pressures are calculated. Pump speed is calculated with:

$$S_x = \frac{Q_x}{P_x}$$

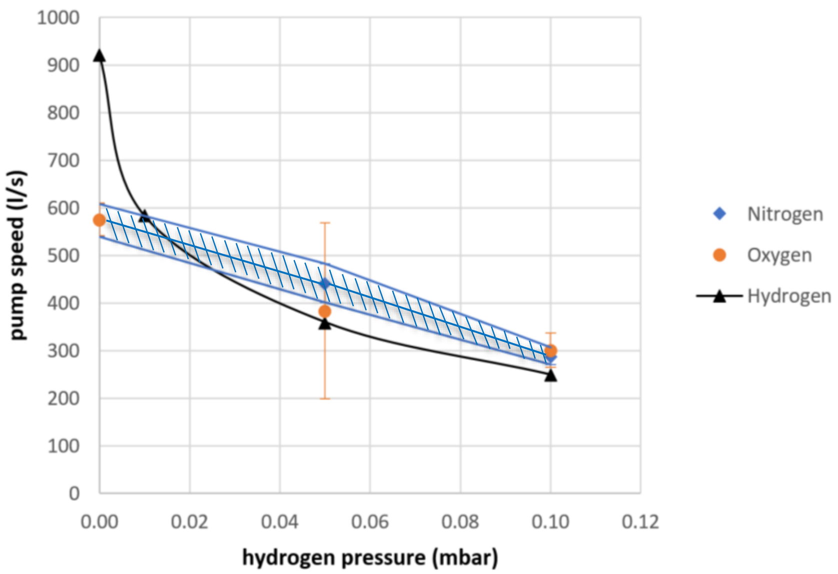


PUMP SPEED AT ROUGH VACUUM - RESULTS

Measurements N_2 give best results (hatched area). Partial pressure setpoint uncertainty for N_2 appr. 12% (target 10% for all contaminant gases)

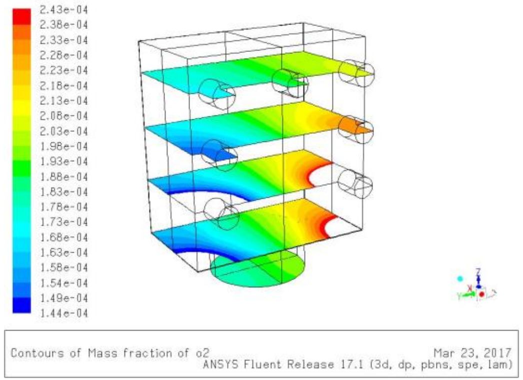
More data for O_2 and H_2O needed

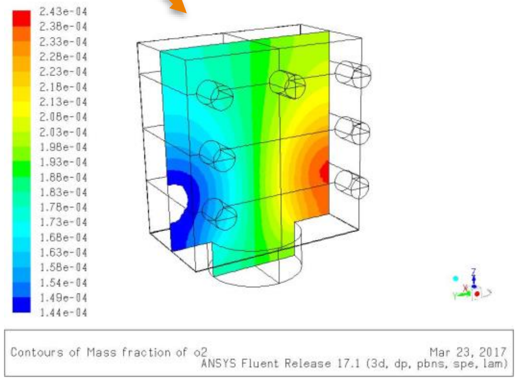
For now assume S(contaminants) = S(N_2)



CONCLUSIONS AND RECOMMENDATIONS

- Optimize dynamic range of the RGA → increase relative pump speed for H_2, install multiple orifices, bake-out, closed ion source
- Use dedicated gas mixtures + mass flow controllers
- CFD modelling to verify proper mixing of gases






THANK YOU FOR YOUR ATTENTION
Take a look:
TNO.NL/TNO-INSIGHTS
TNO innovation for life