Inverted and thin NEG, where we are

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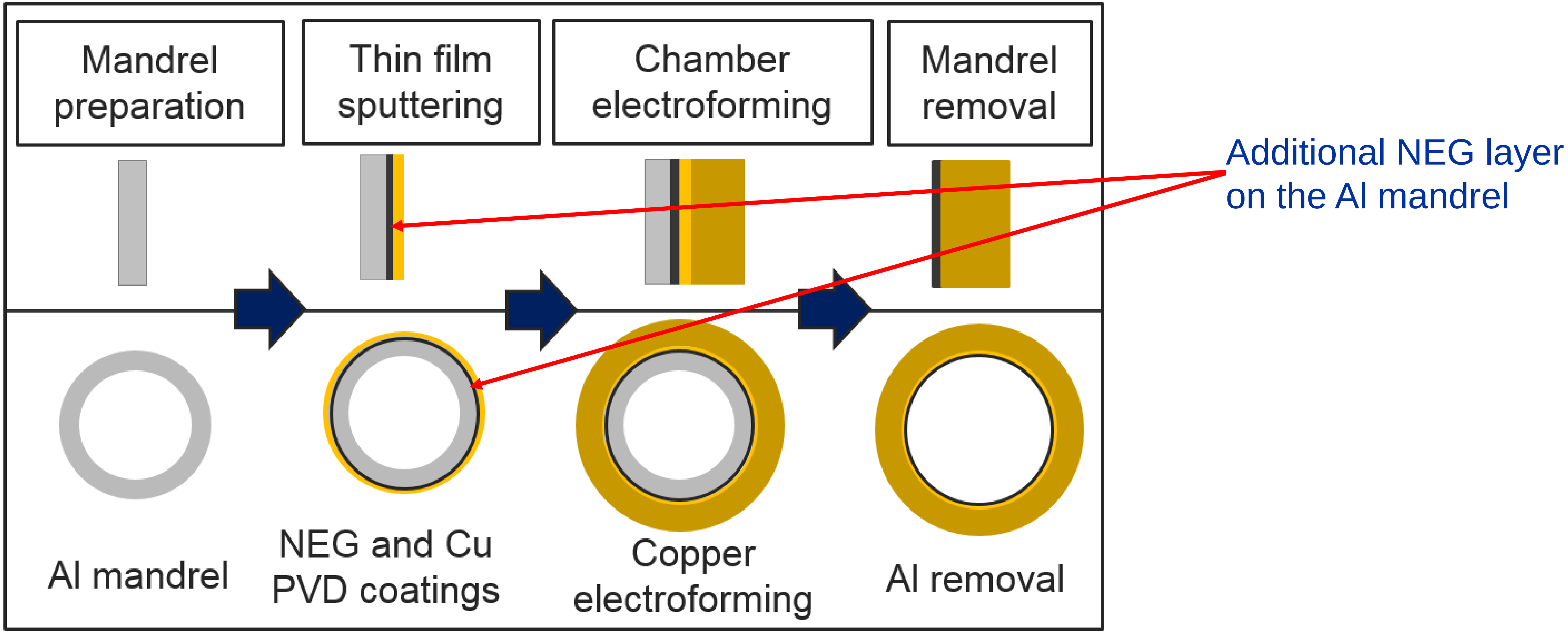
TE-VSC

Summary

- Inverted NEG scheme
- Performance of inverted NEG
- Performance of thin NEG < 1µm

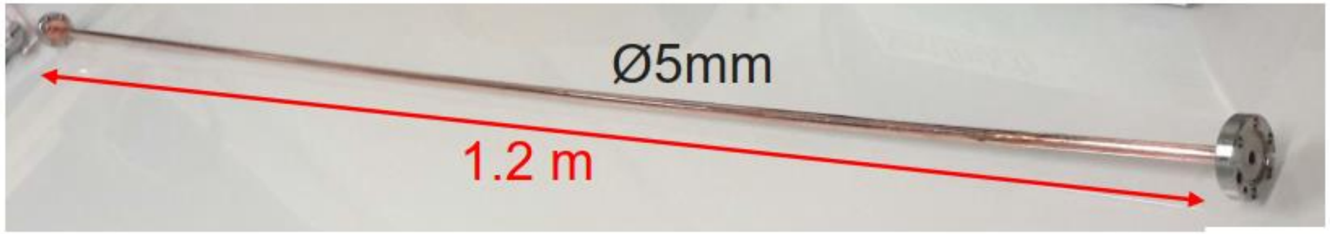
Inverted NEG (Non Evaporable Getter) scheme

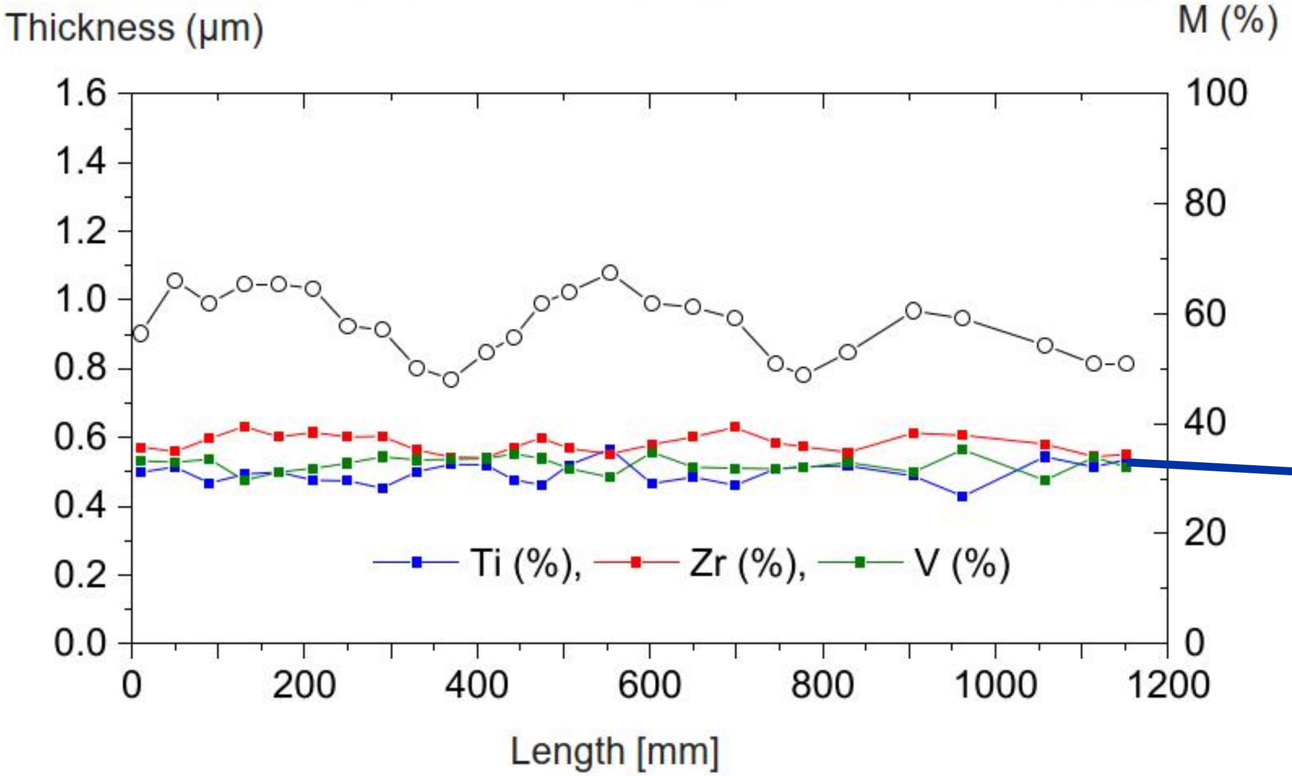


Additional NEG layer on the Al mandrel

Control of the NEG thickness

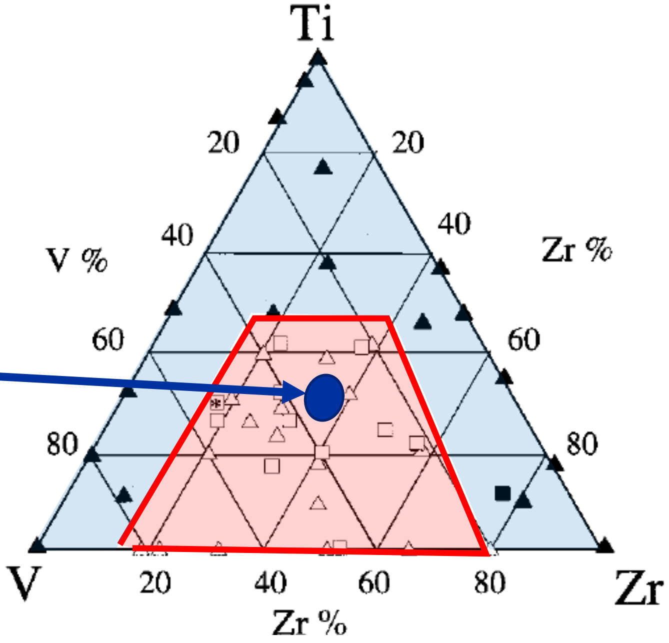
5mm internal diameter, 1.2 m length, TiZrV coated chamber





Analysis in XRF after cutting the chamber:

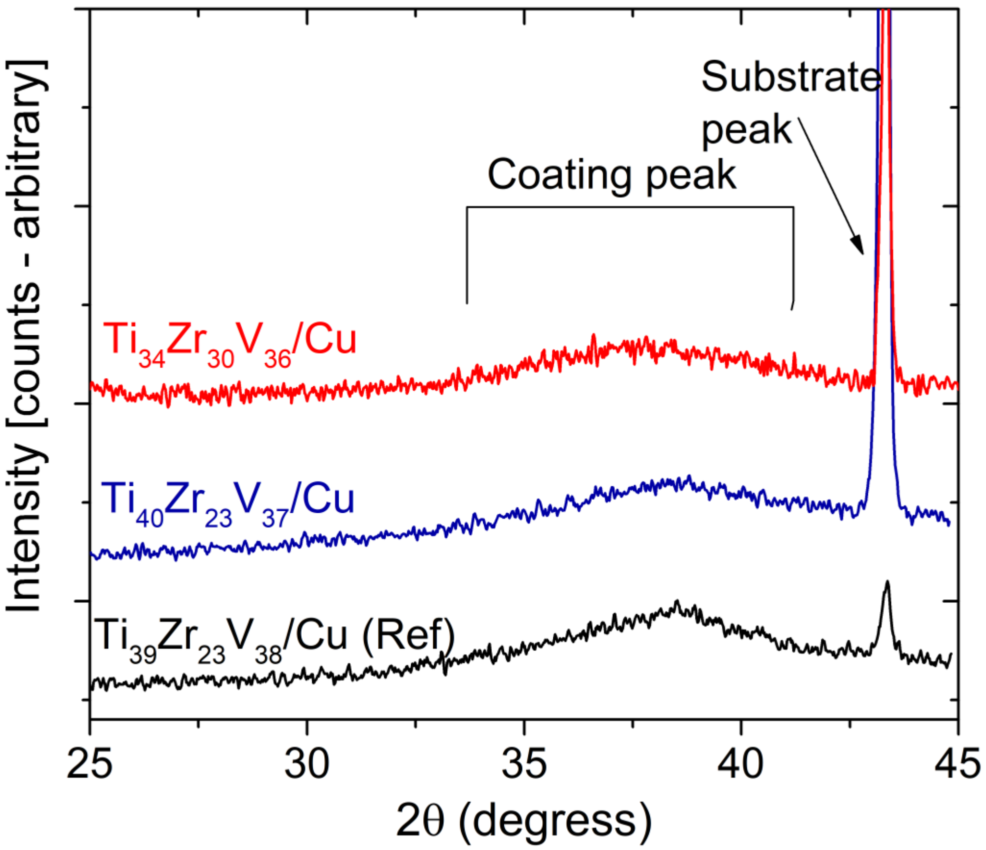
- The thickness is uniform
- Composition is uniform and correct



A. E. Prodromides et al. Vacuum 60 (2001) 35, 41

Crystalline Structure

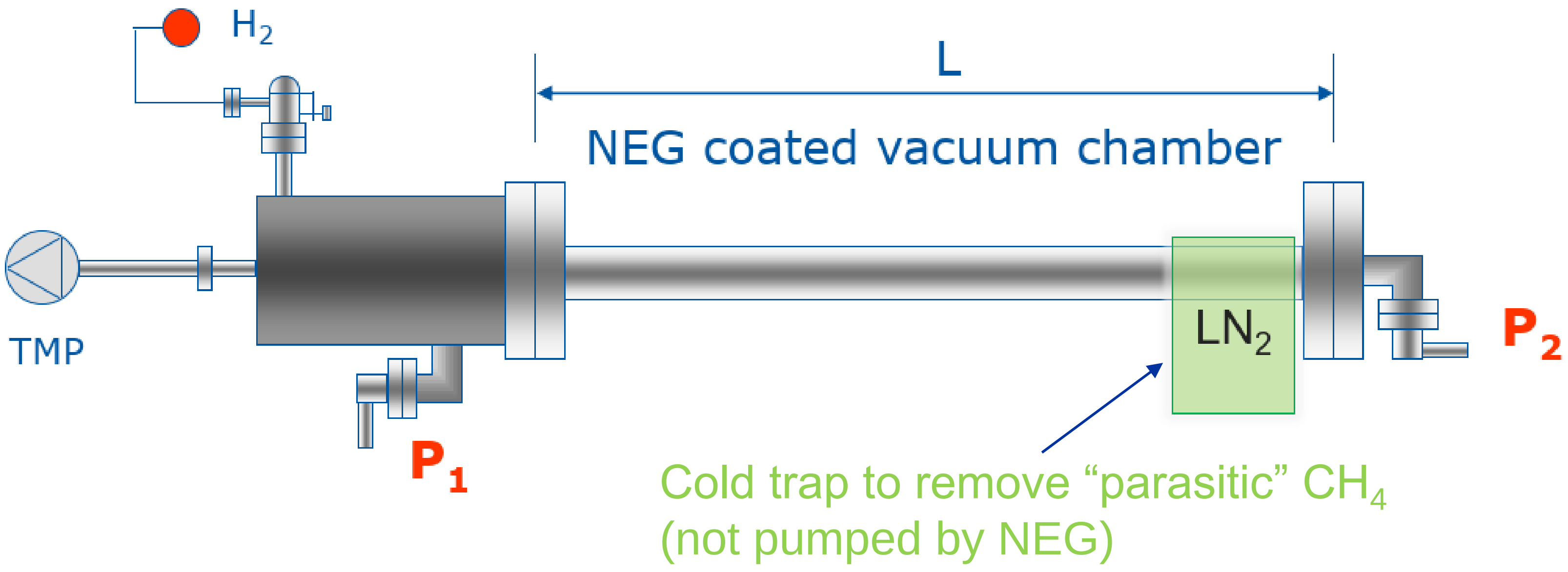
XRD analysis



All samples show the small crystal size (estimated around 3 nm)

Ref. prepared by the conventional coating process

Pumping performance: transmission method



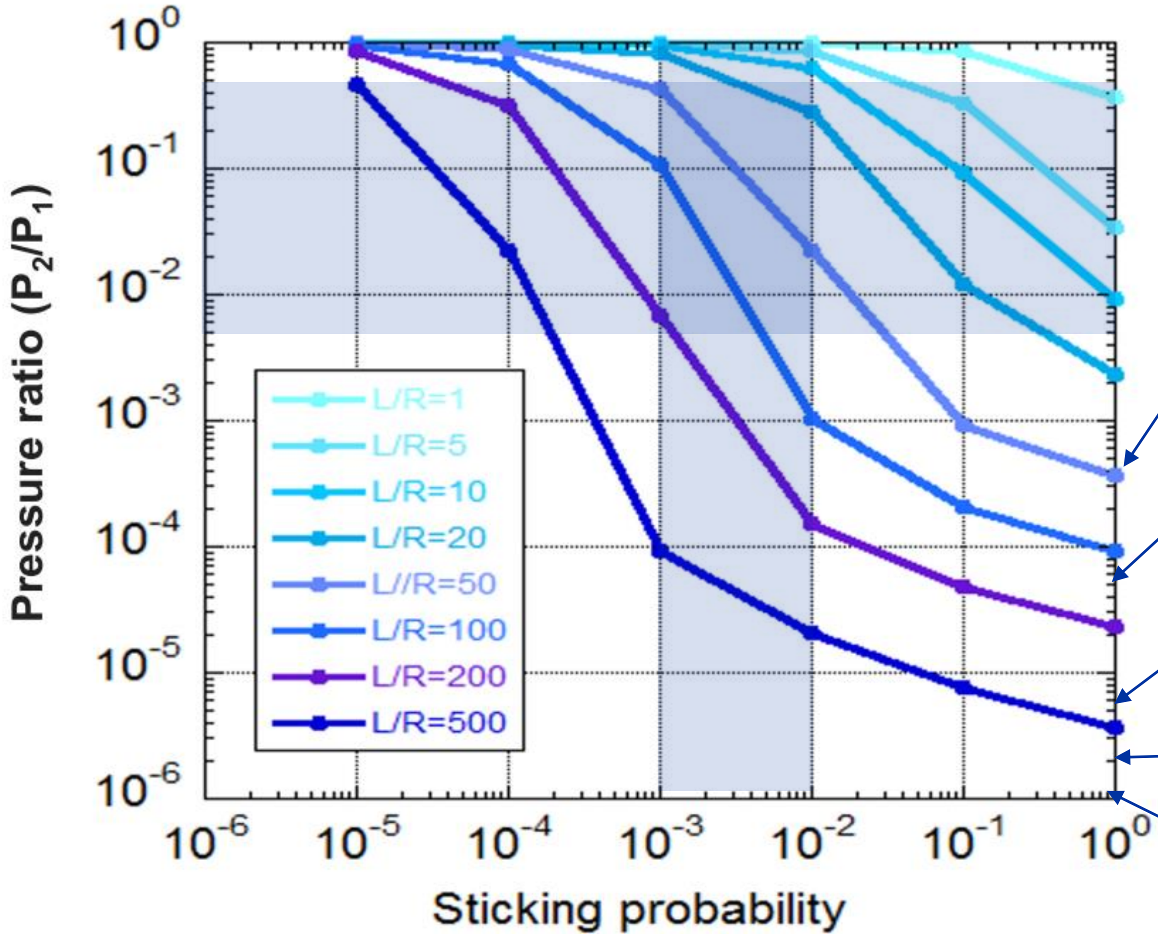
Cold trap to remove “parasitic” CH_4 (not pumped by NEG)

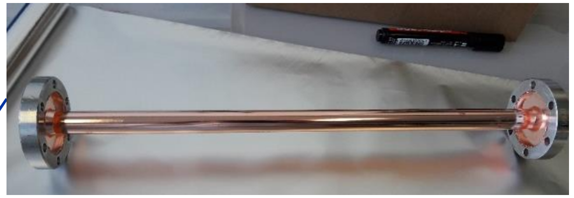
Steady state upon H2 injection:

P_2/P_1 + Monte Carlo calculation (Molflow) : enable to get the sticking coefficient for hydrogen

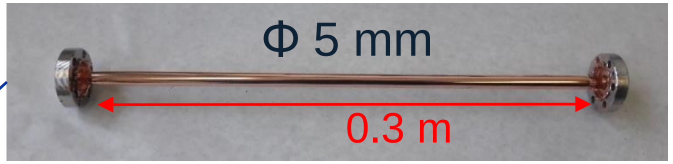
Pumping performance: what can be measured

We expect a sticking of 10^{-3} 10^{-2} and can easily measure a pressure ratio of 0.5-0.005: **not for too slim chambers!**

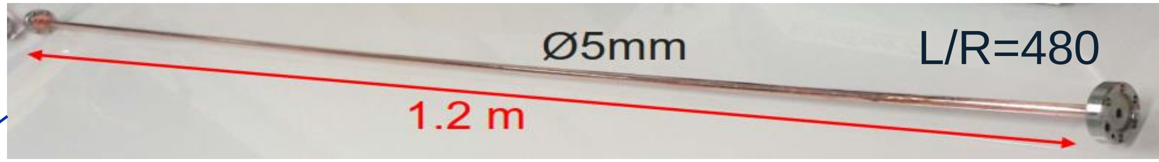




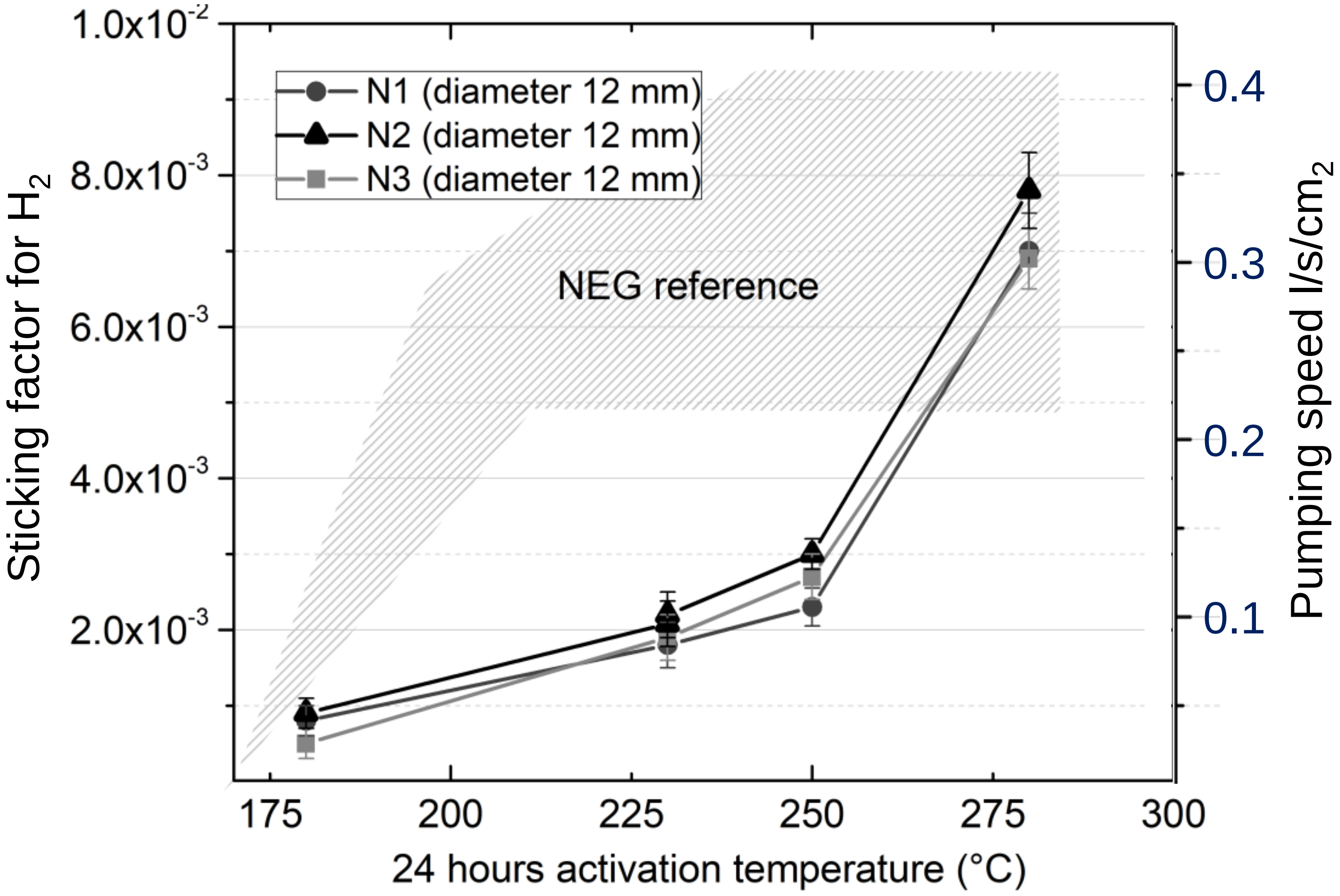
Φ 16 mm x 0.4 m
Φ 12 mm x 0.3 m
L/R=50



L/R=120



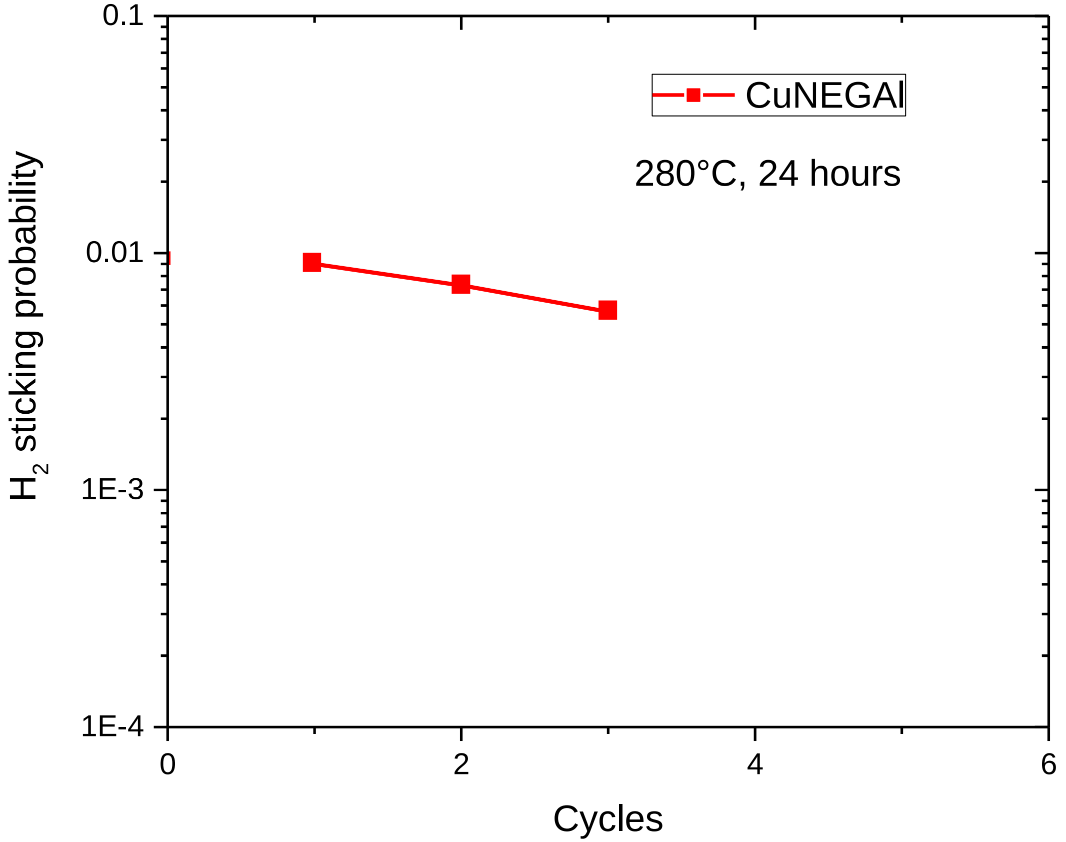
Pumping performance: sticking factor and speed



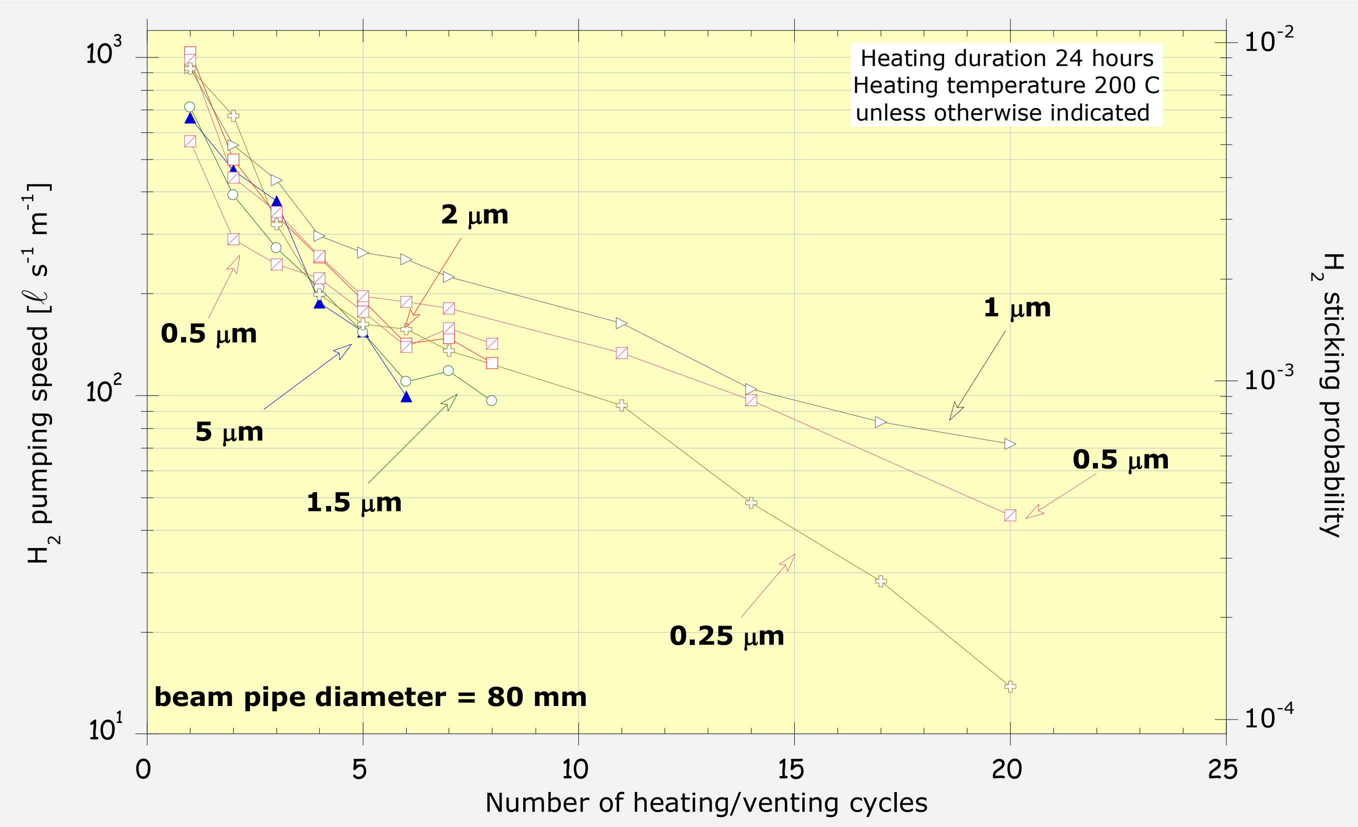
- Reproducible
- Reaches reference sticking and pumping speed (Ex: For a chamber of 6 mm diam. the pumping speed for H_2 will be 5.6 l/s/m)
- Activation is delayed in temperature compared to standard reference

Pumping performance: aging

Aluminium mandrel 0.5 mm

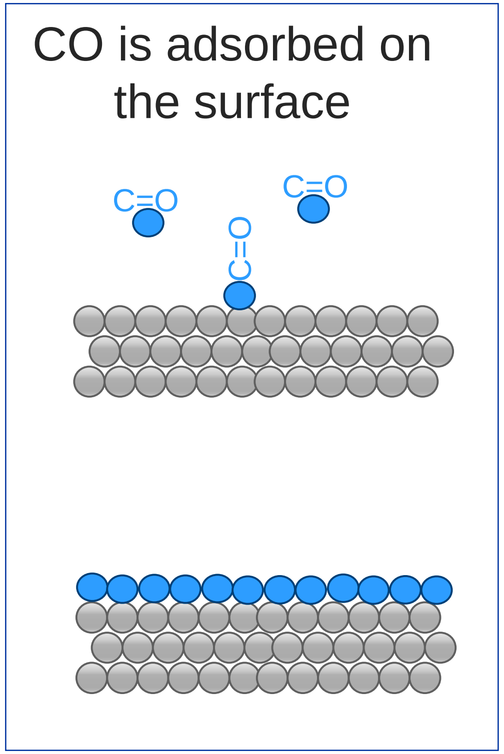


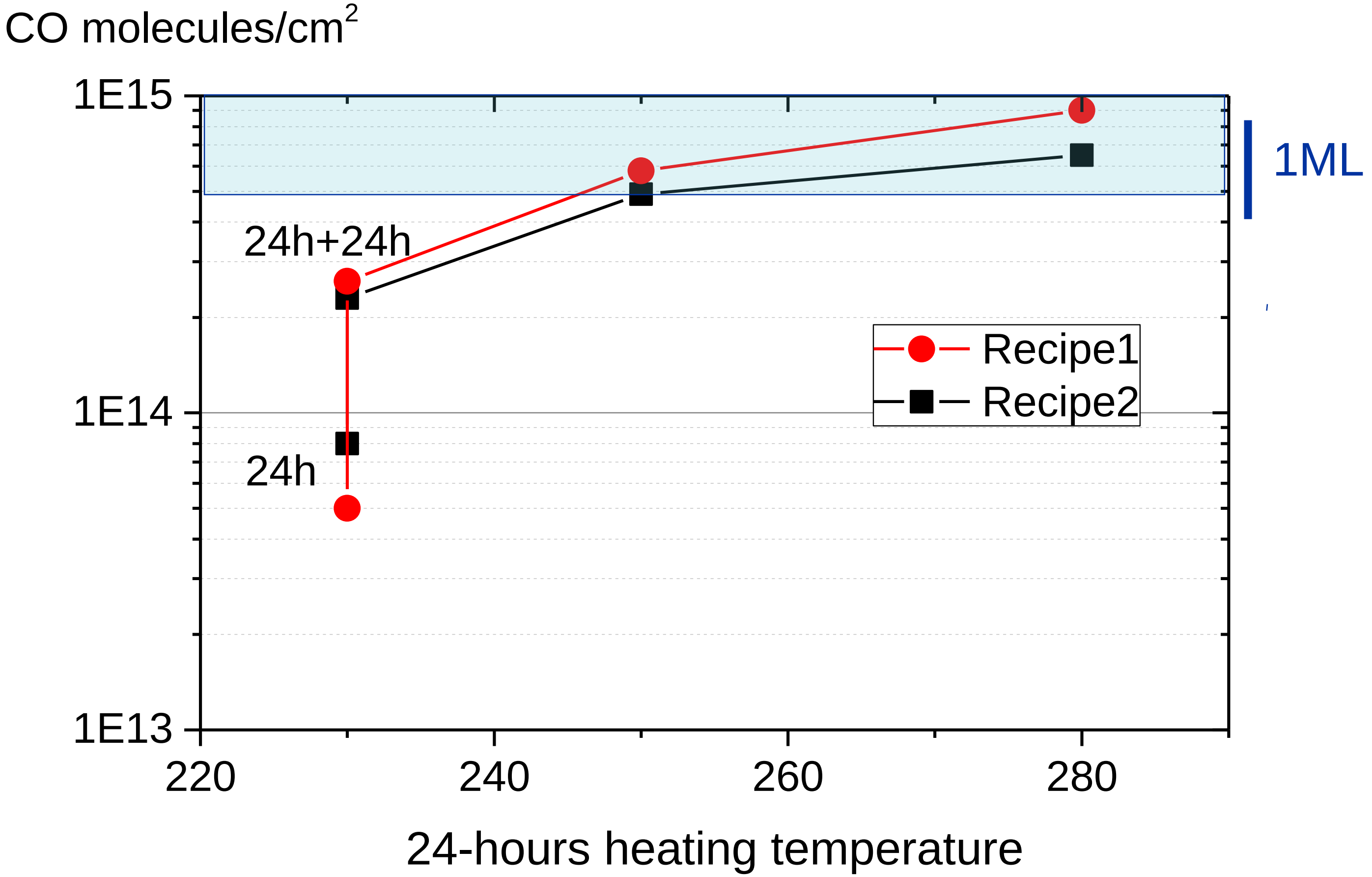
Expected for standard NEG



Pumping performance: CO capacity

Saturated surface: 1 Monolayer ML
CO (defined as 5×10^{14} -1×10^{15})


CO is adsorbed on the surface



- The expected capacity(as reference) is reached
- Also in this case there is a delay in the temperature

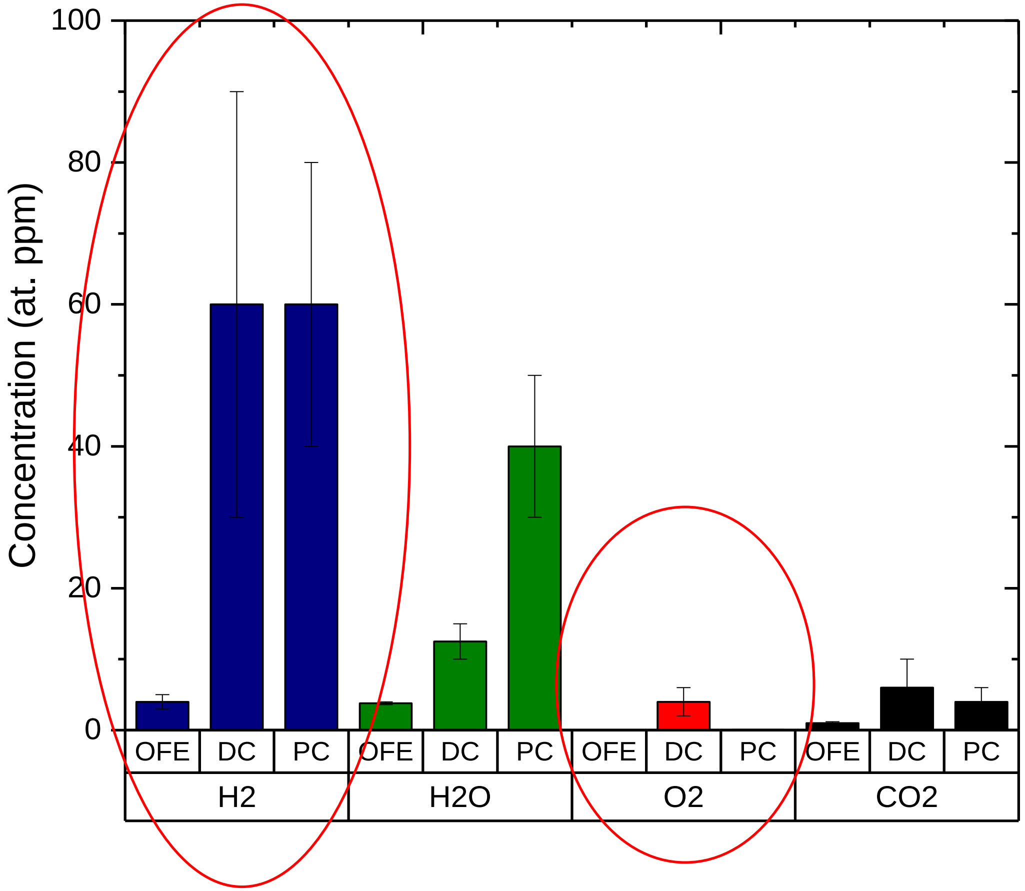
Hypotheses for the origin of delay

Impurities incorporated during the process?

- transferred to the NEG from the electroplated copper substrate
- coming from the chemical baths

Origin of delay: comparison of substrates

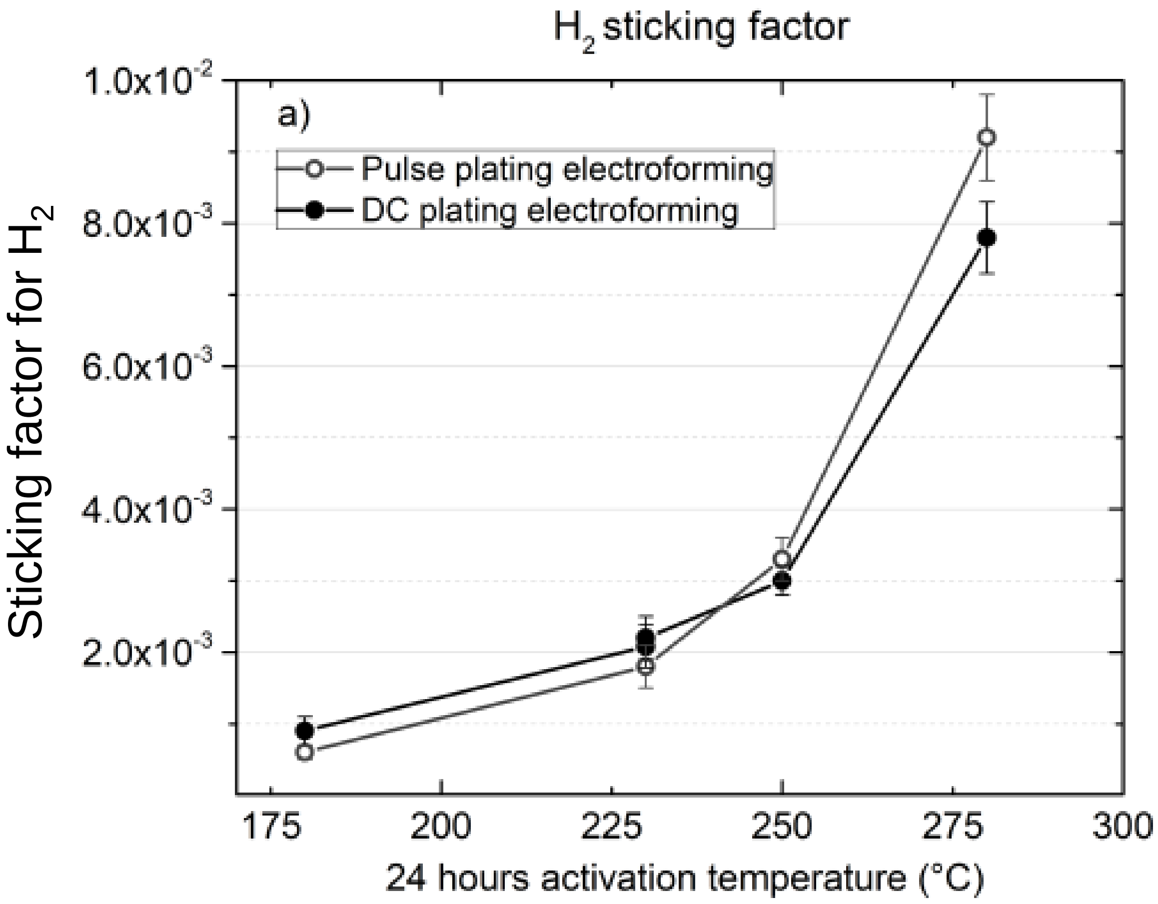
Electroformed copper has in general few more impurities than OFE:



Measured in Thermal Desorption Spectroscopy on 10x10x1 mm samples

Still there is no evidence that O related impurities those play a role for the activation

Orgin of delay: different plating recipes?



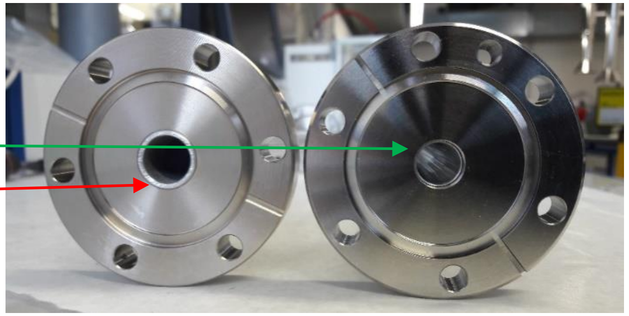
Not much statistics, but ...no marked difference with electroforming in pulse mode or DC (with brightener)

In spite of the different purity of the copper the performance of NEG is similar and delayed with respect to the reference NEG

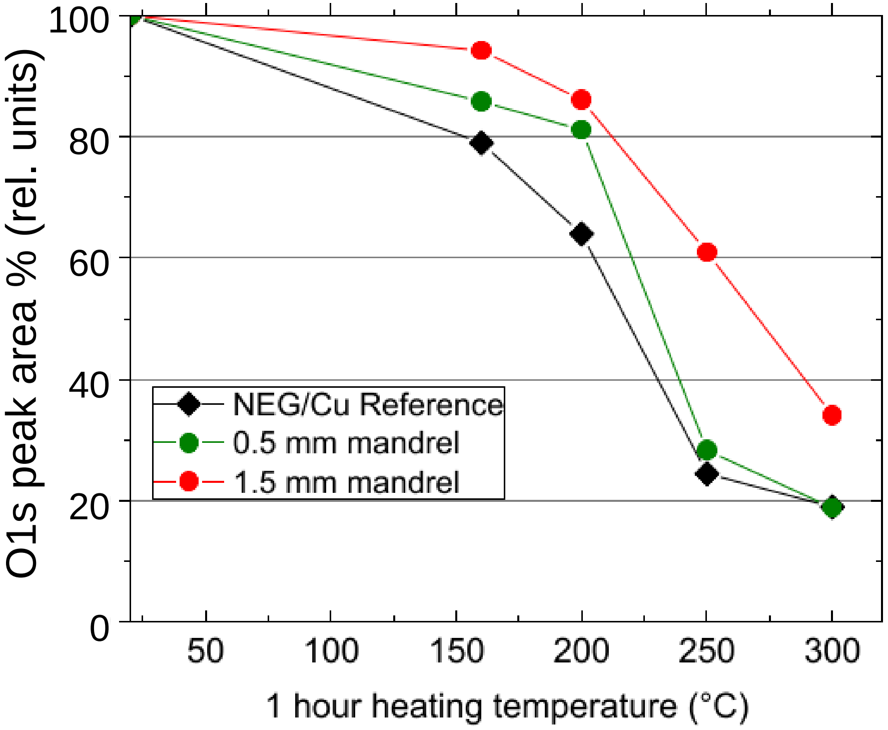
Origin of delay: etching and mandrel thickness

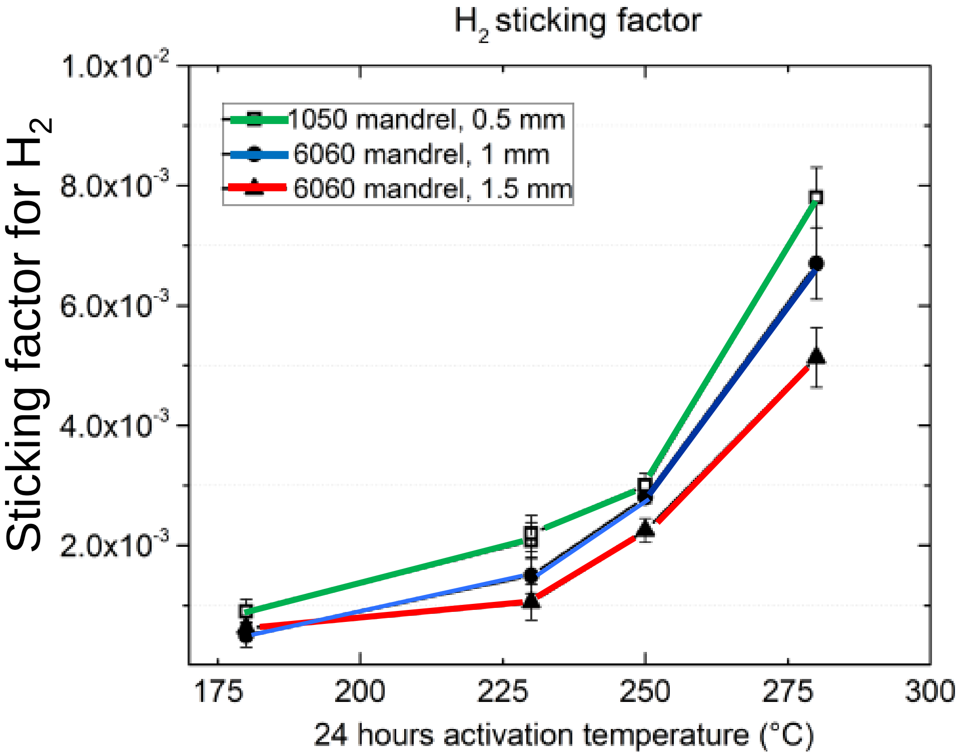
Thickness of aluminium mandrel
0.5 mm, 7h etching
1.5 mm, 24 h etching

$2\,Al(s) + 2\,NaOH(aq) + 2\,H_2O(aq) \rightarrow 2\,NaAlO_2(aq) + 3\,H_2(g)$



Decrease of O in XPS





Better activation with **thin** mandrel

Making the NEG thin (if necessary for impedance)

For a film with much lower conductivity (σ_f NEG) than the substrate (σ_s Cu) the impedance is only governed by film thickness *d*

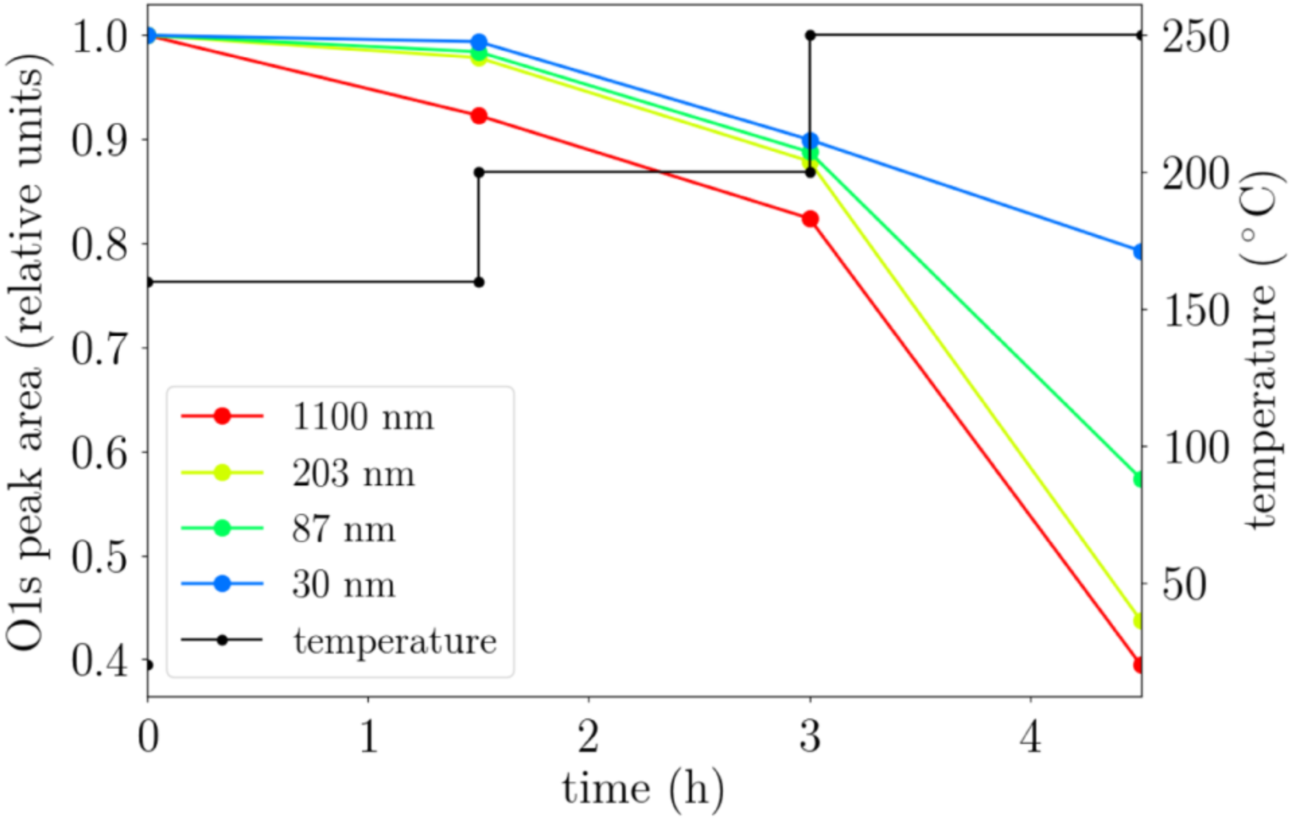
$$\frac{Z_{\parallel}(\omega)}{C} \simeq \frac{Z_0 \omega}{4\pi c b}\left\{[\mathrm{sgn}(\omega) - i]\delta_s - 2 i d \left(1 - \frac{\sigma_f}{\sigma_s}\right)\right\} \qquad (3)$$

$$\frac{Z_{\perp}(\omega)}{C} \simeq \frac{Z_0}{2\pi b^3}\left\{[1 - i\,\mathrm{sgn}(\omega)]\delta_s - 2 i d\,\mathrm{sgn}(\omega)\left(1 - \frac{\sigma_f}{\sigma_s}\right)\right\} \qquad (4)$$

E.Belli et al
PR Accel Beams
21 111002 (2018)

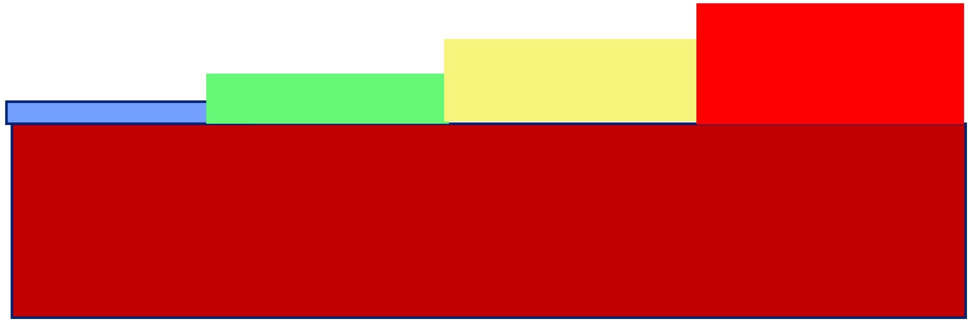
How much cycles for thin NEG?

The expected effect is a higher sentitivity to venting/activation cycles for thin NEG: indeed……



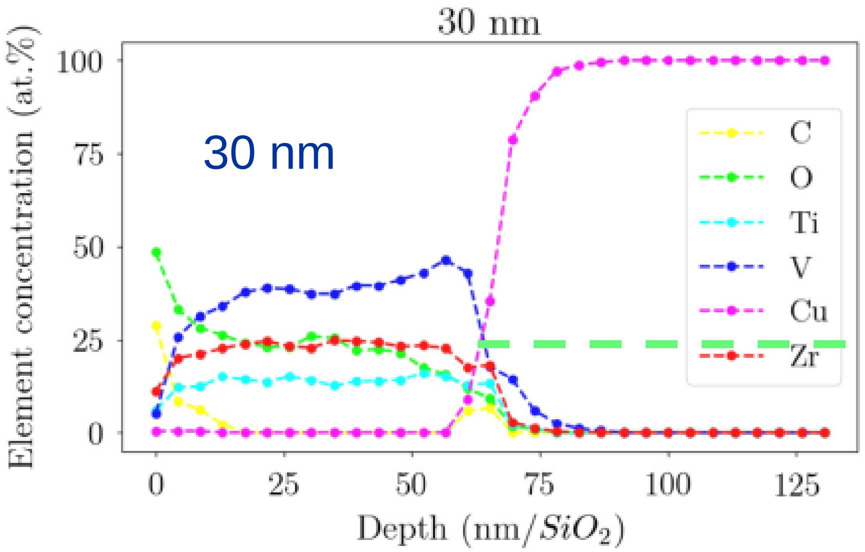
After **4 cylces** of venting /activation the activation of thinner films requires more time

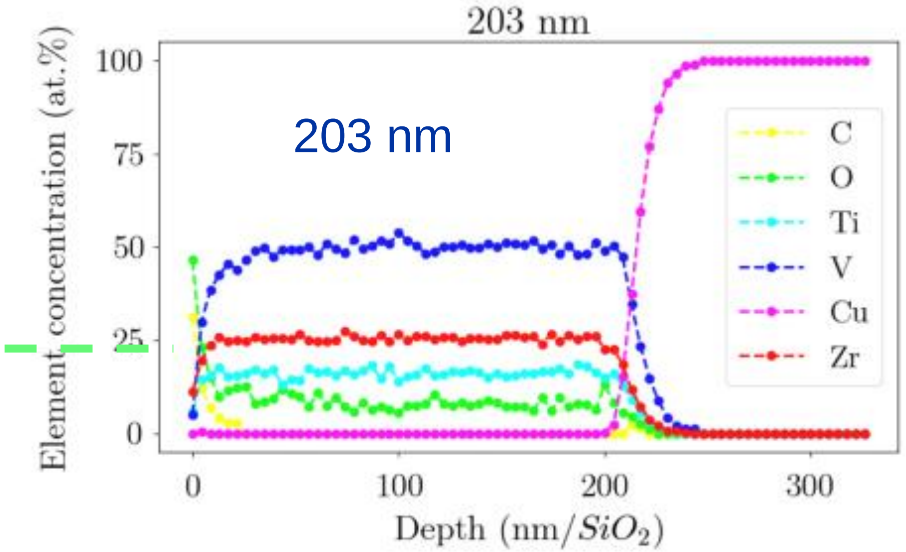
→It is more difficult for the surface oxygen to diffuse into the film



How much cycles for thin NEG?

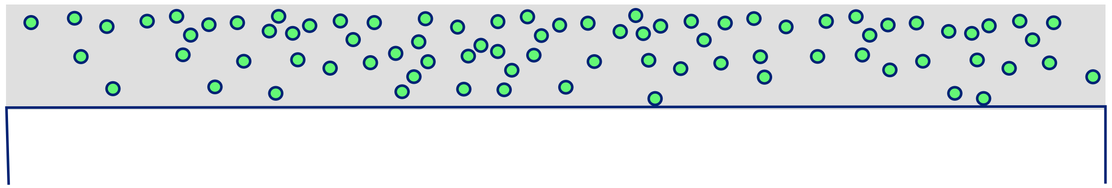
XPS
depth profiles

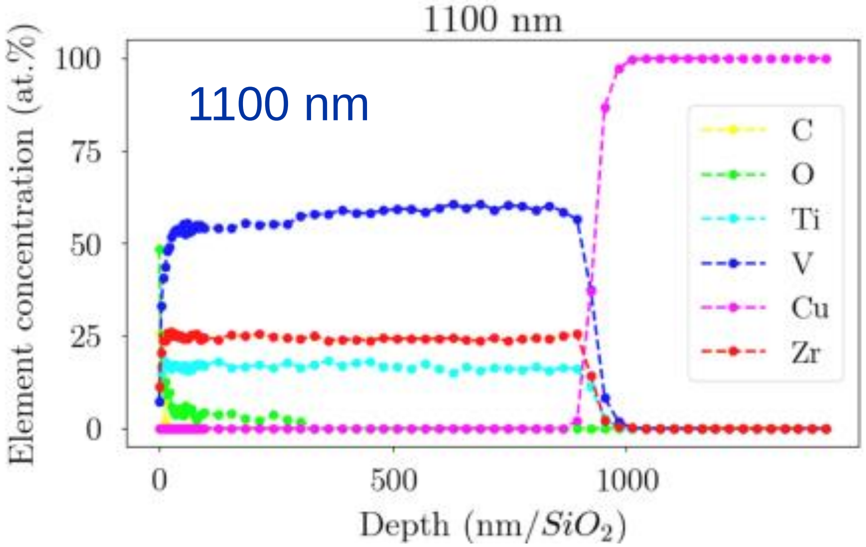




As expected after some cycles the concentration of dissolved **oxygen** is higher in thinner films

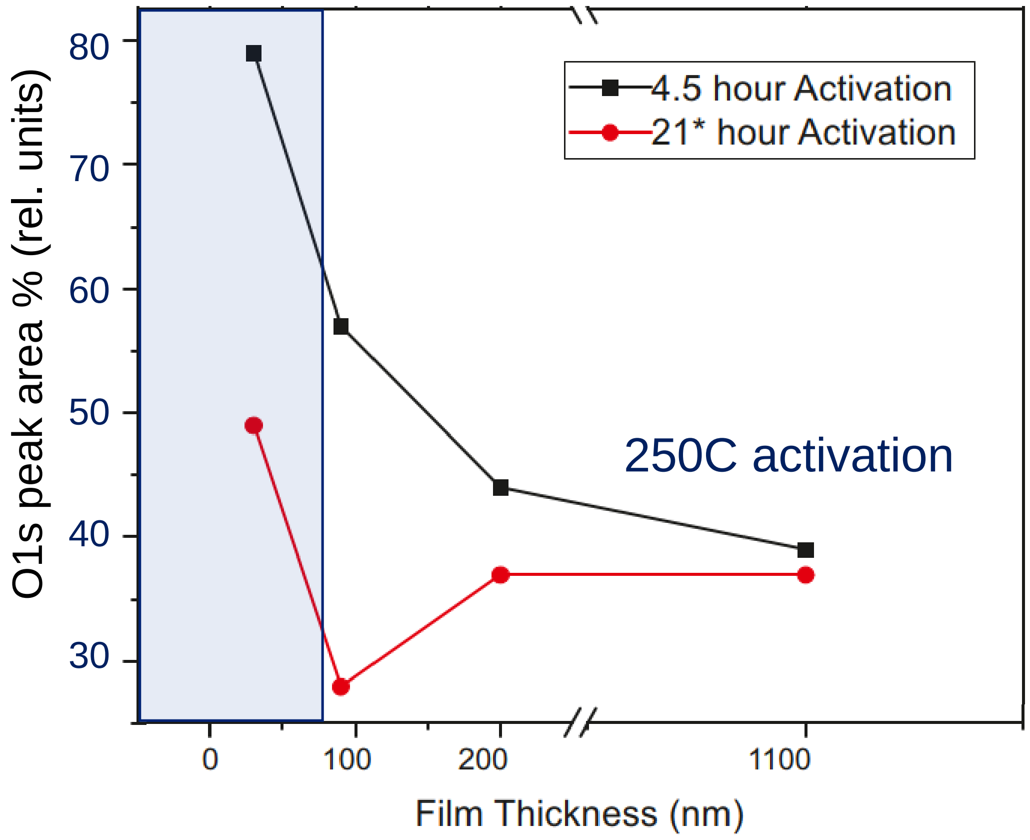
The lower concentration gradient slows down the further diffusion and activation





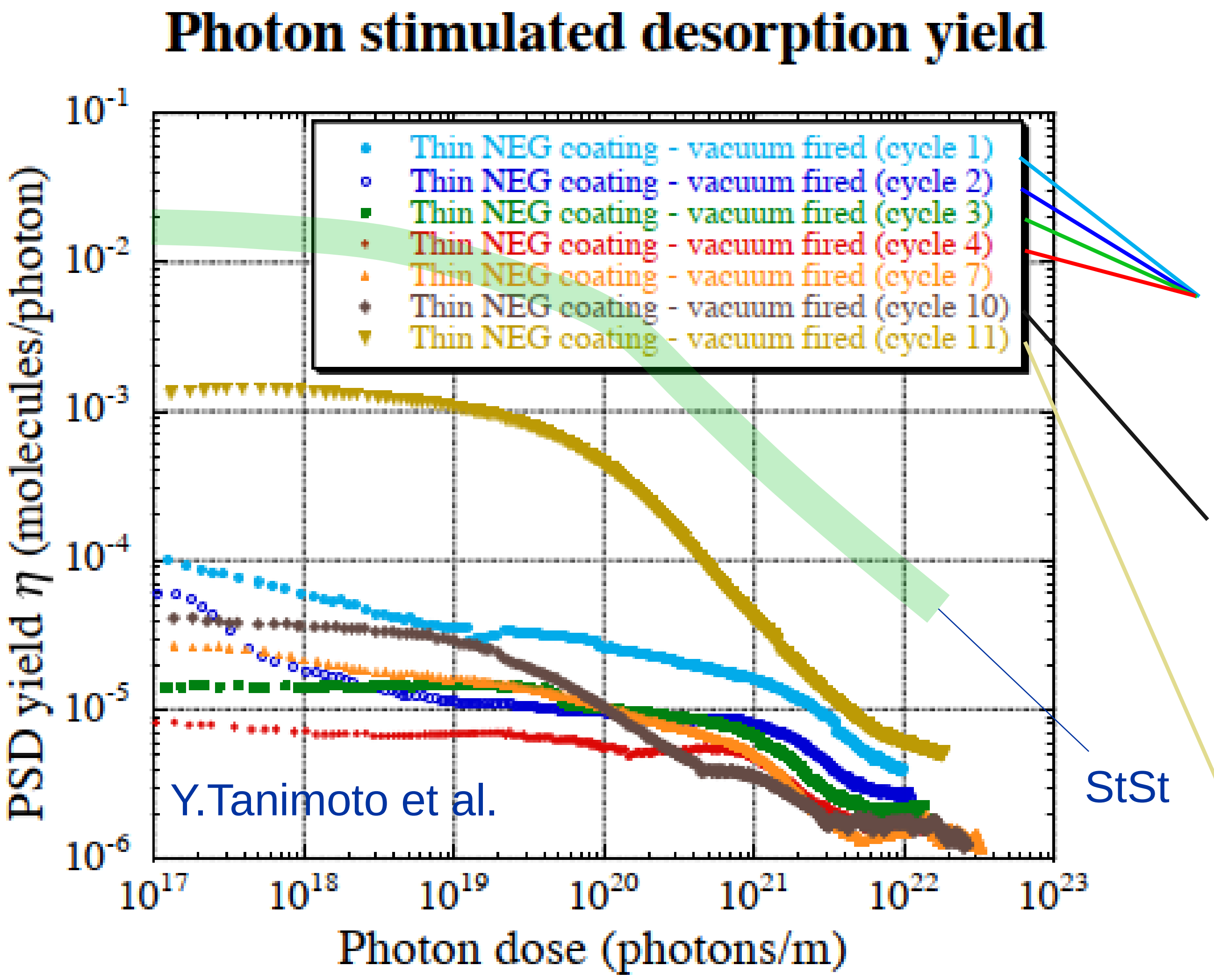
How much cycles for thin NEG?

Reduction of the surface oxides
(X-ray Photoelectron Spectroscopy)



- ➢ For film thickness ≥100 nm the activation after few (4) cycles can be recovered for 21h of activation at 250C

Photon stimulated Desorption on thin NEG



Y.Tanimoto et al.

Critical energy:4keV
Incidentangle:10mrad
Powerdensity:20W/m
150 nm thick NEG

Cycles 1-4: PSD decrease with venting/activation(250C x 4h)/irradiation cycles

Cycle 10: slight increase when venting/activating without further irradiationn, but conditions quickly (irradiation helps to reduce H content)

Cycle 11: venting without activation

For PSD the thin NEG is robust upon cycling

What do we know on thin and inverted NEG

Property/NEG	Standard NEG	Thin NEG	Inverted NEG
1st activation O decrease	250C x 1h	Lowest thickness 30nm	250C x 1h
N cycles: O decrease	(see pumping)	>100 nm 250C x 24h N ≤ 4	?
1st activation pumping speed	180-200C x 24h	Reduced for 200 nm	275C x 24h
pumping speed: N cycles	Sticking 1/N , N≤ 20 200C x 24h	?	Sticking as expected 1/N, N≤ 3 , 275Cx24h
PSD	Ec = 20keV, 250C x 24h	150 nm, Ec=4KeV, 250C x 4h, N=10	?
SEY	1.1 for 250 C x 1h	>30 nm 1.2, 250C x 24h	1.2 for 250C x 1h
SEY, N cycles	1.2 , 250C x 1h for N=3 recovers at 300 x 1h for N=10	≥200 nm 1.2, 250C x 24h , N = 4	?

Thank you!

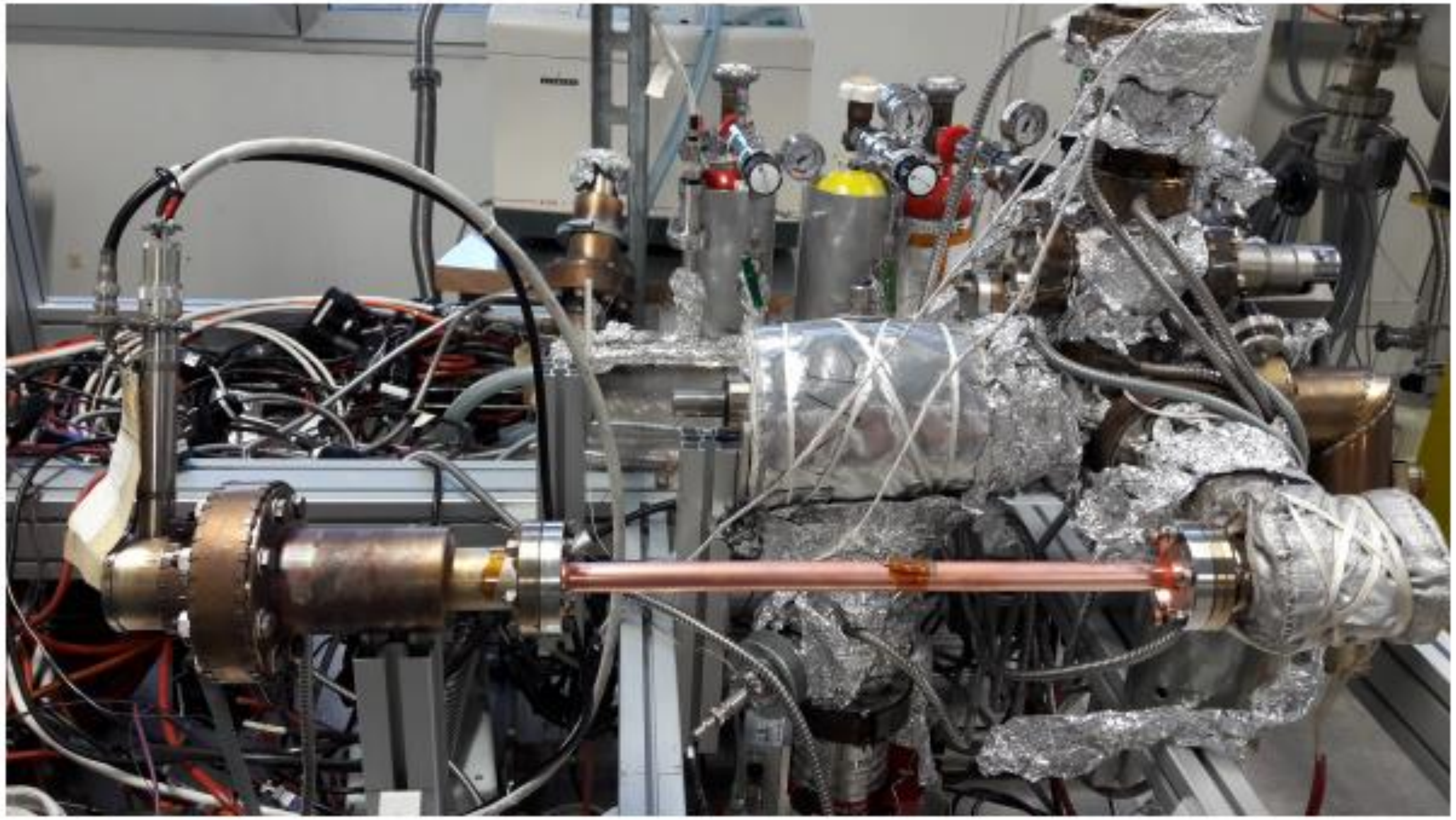
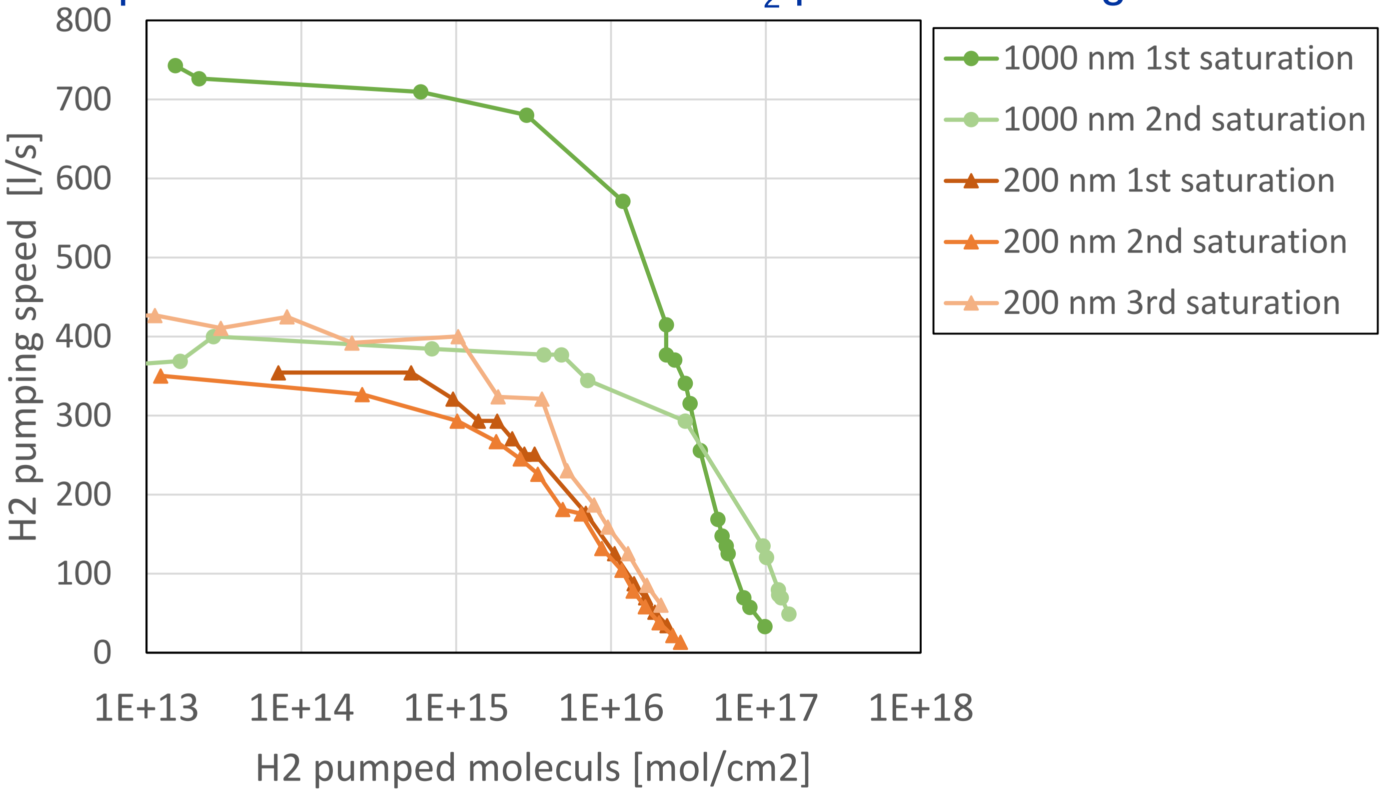
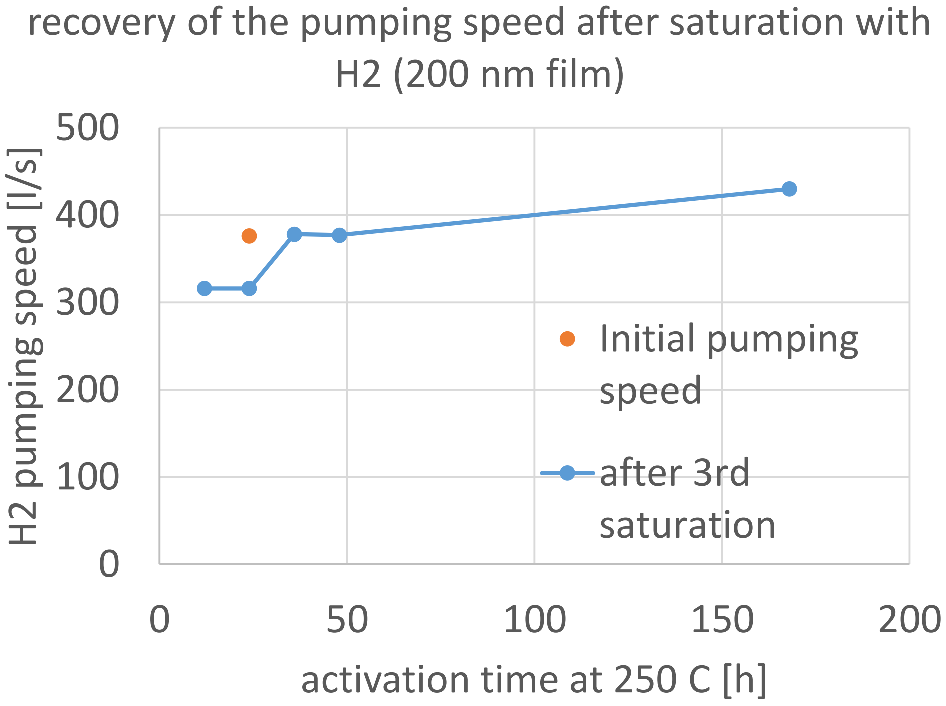


Figure 4.24. Chamber installed in transmission system.

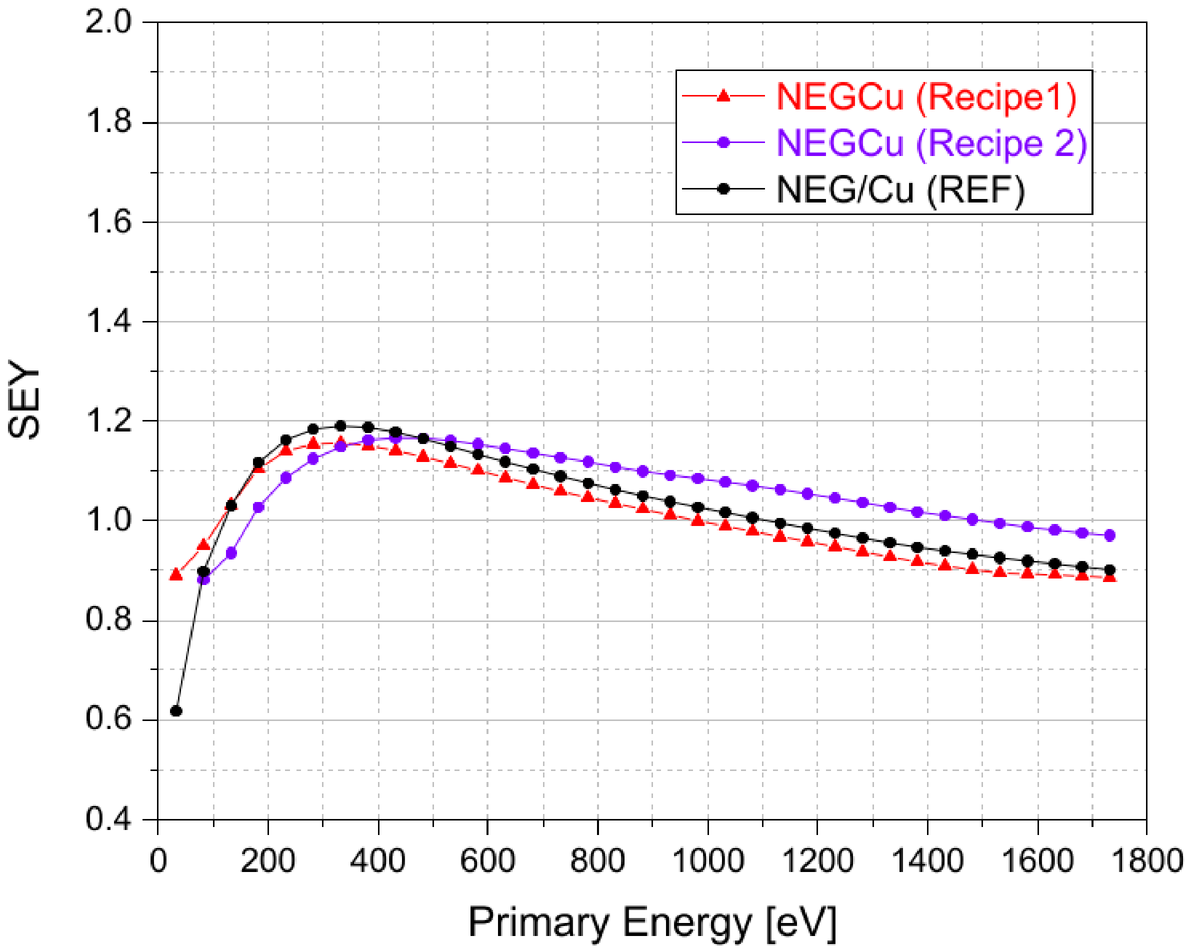
Pumping speed and H2 saturation of NEG

- For 1000 nm the pumping speed is as expected: after saturation a regeneration (no venting) of 24h x 250C, recovers only **half** of the initial pumping speed.
- For 200 nm the pumping speed is about half of reference: after saturation and regeneration (no venting) it recovers the same value for several saturation (no venting) cycles
- Atomic concentration of H in the film is similar for both thicknesses (~4% at. H in the film): did we reach equilibrium of H dissolved and H_2 pressure during activation?





SEY after activation 1h at 250°C

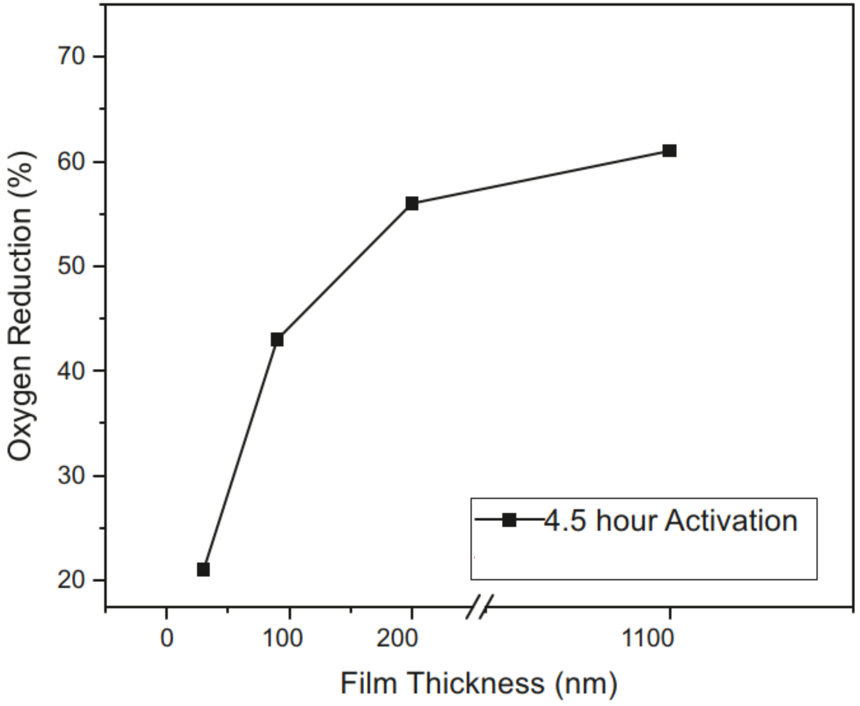


Inverted NEG:
Shows a decrease of SEY which is not delayed

3 – Studies on “very thin” NEG films

4^{th} activation cycle at 250 °C

Reduction of the surface oxides
(X-ray Photoelectron Spectroscopy)



Maximal secondary electron yield