LITHOGRAPHY VACUUM SYSTEM HYDROGEN SAFETY WHILE MAXIMIZING PROCESS PRODUCTIVITY

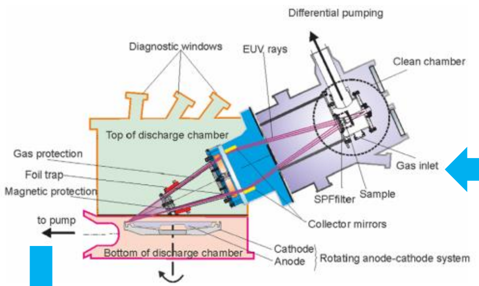
Dec 2021 Ma Zhen

EDWARDS

Confidentiality Statement

This presentation has been prepared exclusively for the benefit and use of Edwards and does not carry any right of publication or disclosure, in whole or in part, to any other party. This presentation is the property of Edwards. Neither this presentation nor any of its contents may be used for any purpose without the prior written consent of Edwards. This presentation includes certain statements, estimates, targets and projections as to anticipated future business performance. Such may reflect significant assumptions and subjective judgements by Edwards which may or may not prove to be correct. Edwards makes no representations as to the accuracy, completeness or fairness of this presentation and so far as is permitted by law, no responsibility or liability whatsoever is accepted by Edwards for the accuracy or sufficiency thereof or for any errors, omissions, or misstatements relating thereto.

EUV source and exposure requires hydrogen flow

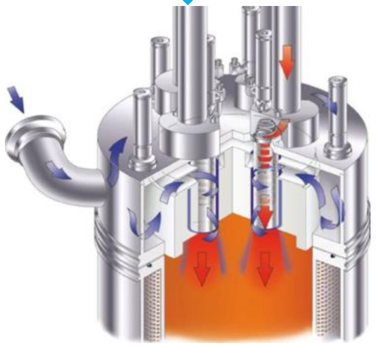


H_2 flow

Plasma Sources Science & Technology, 2015, 24(3).

EUV Source tester

Vacuum pump system



Hydrogen treatment

H_2 must flow all time, due to:

- Reduce surface reaction, minimize secondary electrons
- Protection of source and optics from contamination
- Cooling of reflectors and reticle stage
- Minimize partial pressure of photoresist

Vacuum system challenge:

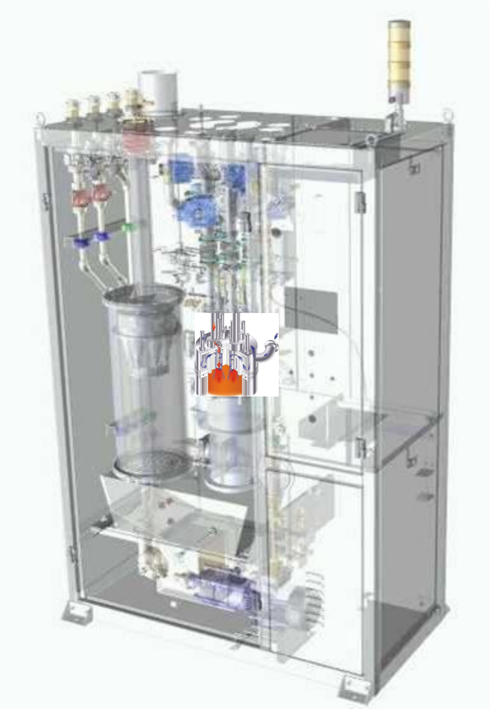
- Pumping of flammable gas
- Ultra high vacuum of small molecule gas
- Safe handling of flammable H_2 mixture
- Reliability and repeatability

This article mainly discuses about H_2 mixture handling

Methods of hydrogen treatment

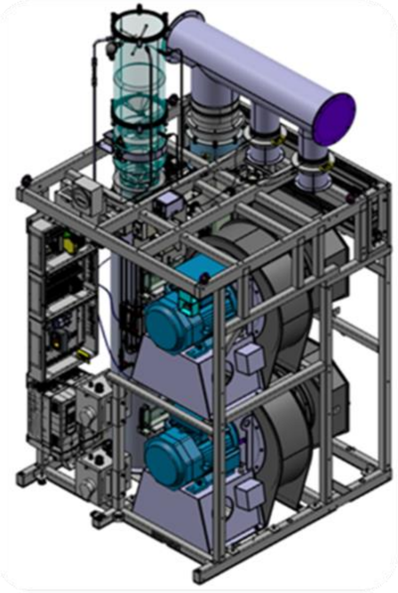
Controlled burning:

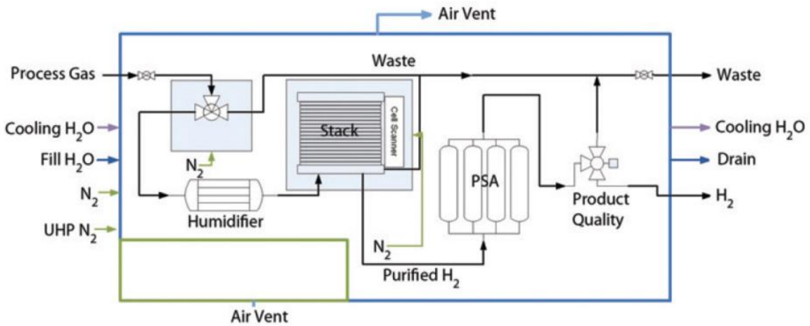
- Oxidization of H_2 by "Inward combustor"
- Large installed base, over 12,000 tracked record
- *carbon unfriendly*



Dilution with air:

- Not beyond 4%
- Carbon friendly
- *Prevent H_2 aggregation*
- *back up solution*





Solid state technology, 2018, 61(9):17-20

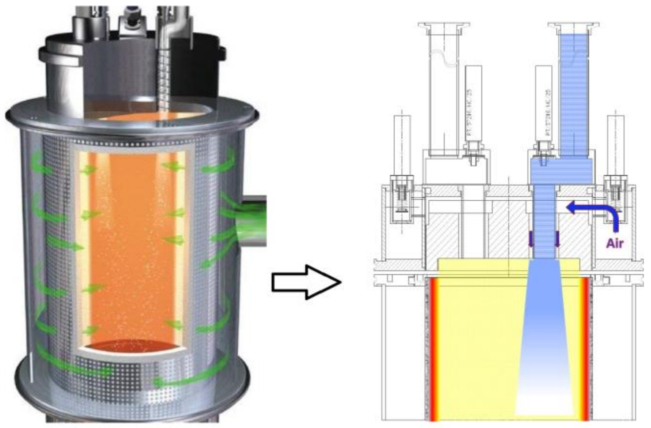
Recycle:

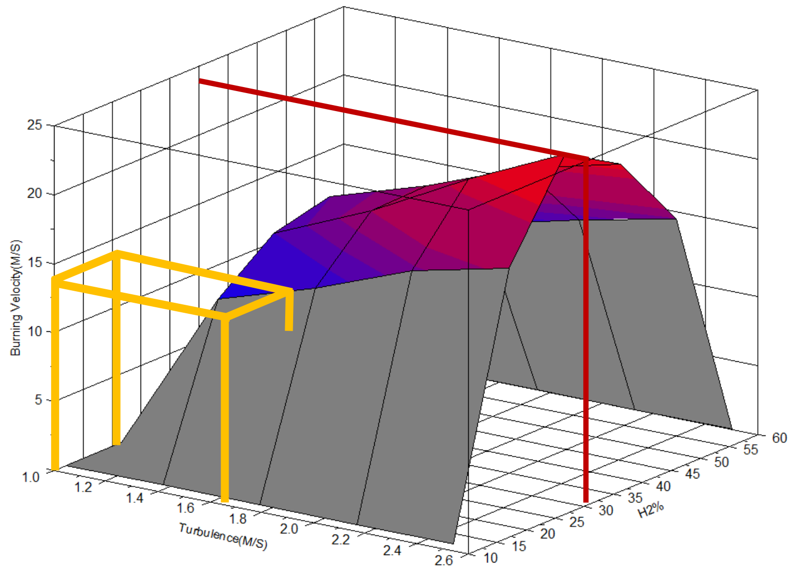
- Separate H_2 from N_2 and other contaminations
- Reduce H_2 usage thus reduce carbon emission
- Leading technology

Controlled burning of hydrogen

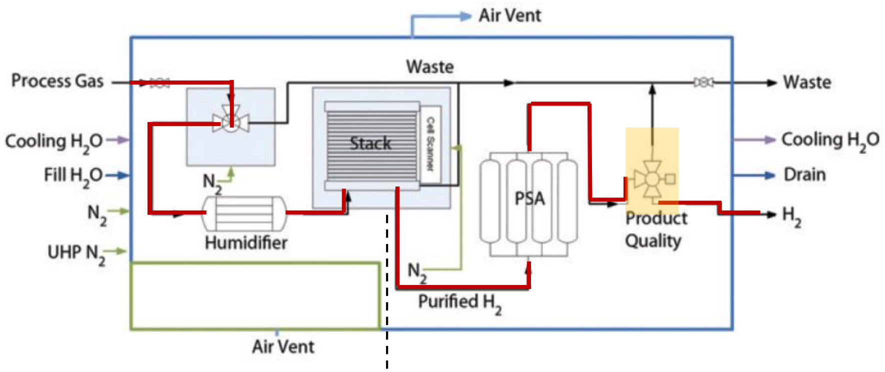
- H_2/air ratio must be controlled between 4% to 20%
- Inlet turbulence minimize through orifice
- Inlet nozzle speed must be higher then H_2 burning velocity
- Inlet nozzles keep scarped by mechanical actuator

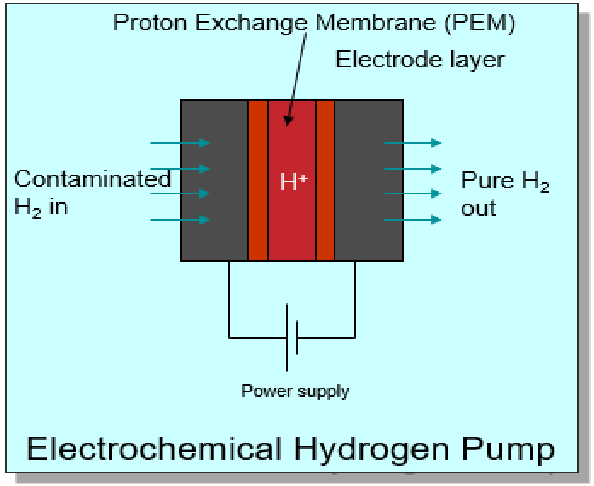
>12,000 Controlled burning combustor are running in leading fabs





Recycle of hydrogen





- Wet H_2 converted into proton and electron by apply voltage
- Proton pulled to Cathode in “Ion exchanger”
- H_2 generated at cathode by getting electron from current
- PSA(Pressure Swing Adsorption) used further separation
- Impurities not good enough for EUV reuse yet

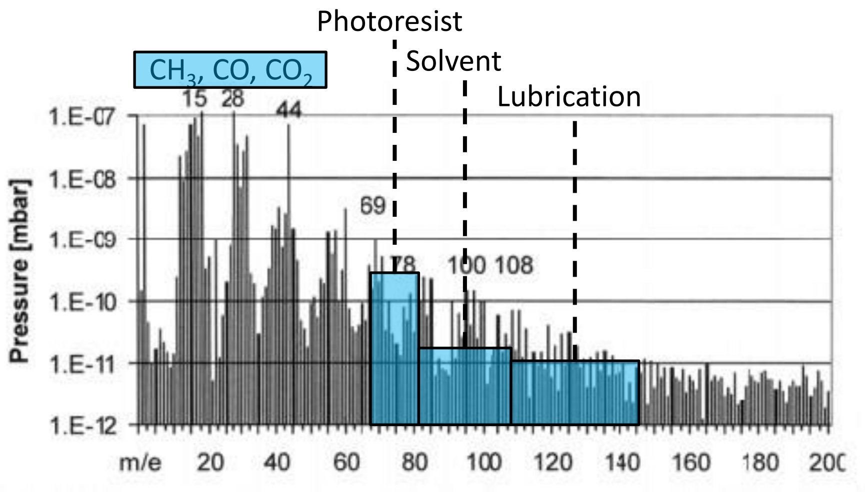
Evaluation units are running at US and EU site, with **90%** recover rate

Quality check will be discussed in next slide

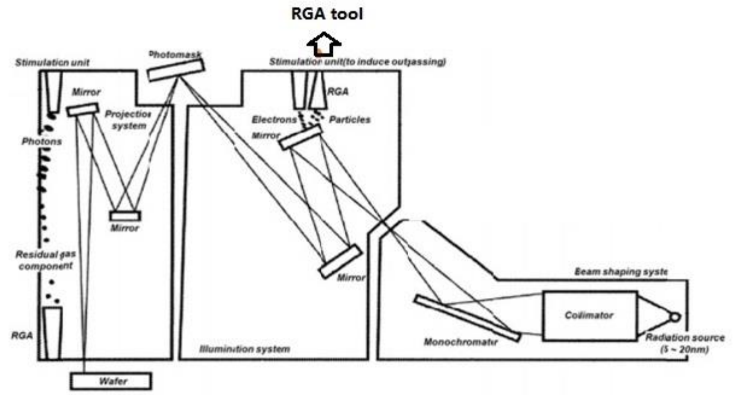
Impurities study

- Hydrocarbon fragments from plasma bombardment
- Outgassing of photoresist
- Solvent carrier
- Back diffused vacuum system lubrication oil (Fomblin®)

Trap needed to mitigate impurities before iron exchanger

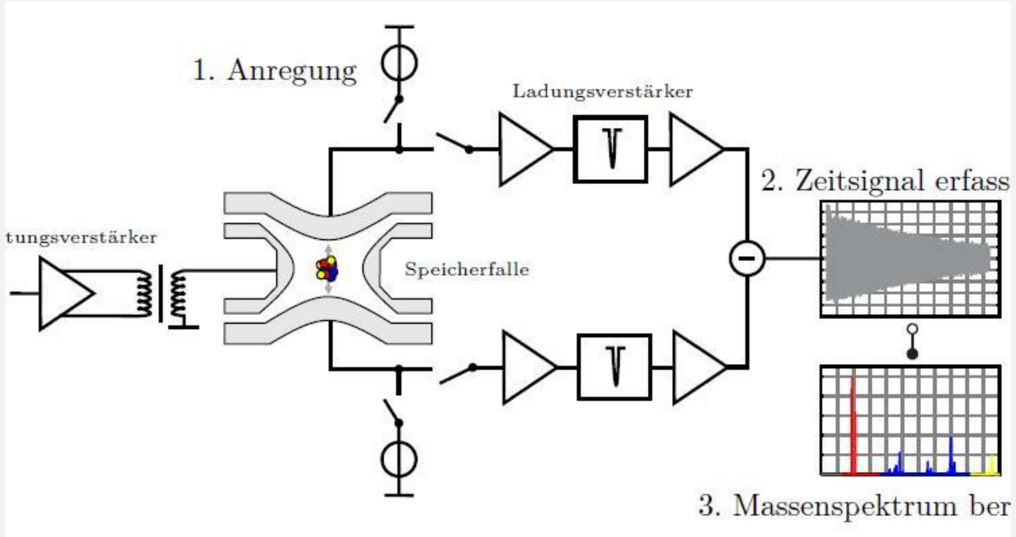


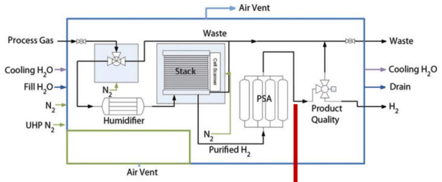
International Society for Optics and Photonics, 2001, 4343:342-346.



Future work (impurity check)

- "Deep learning" of recycled impurity data
- Differentiation based learning with RGA
- Introduce clarification gas to low down baseline
- Not to measure impurity but to compare impurity across time





start

1s…

2s…

3s…

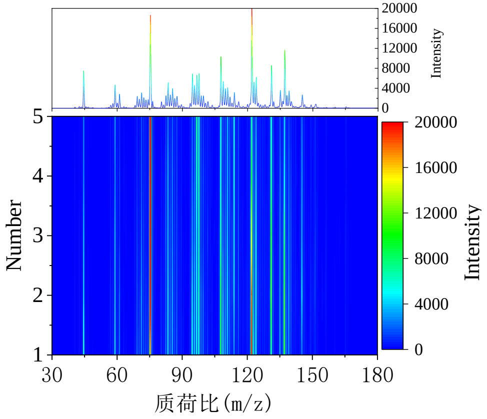
Next cycle

H_2 calibration

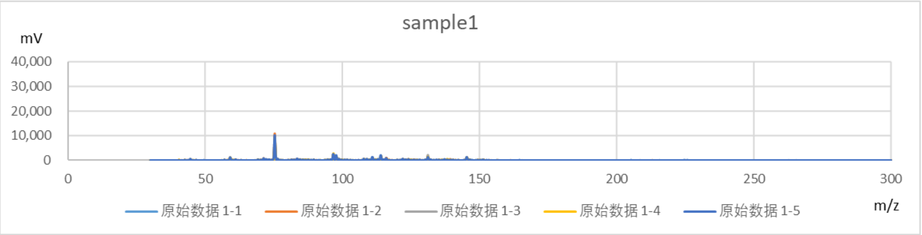
Reuse

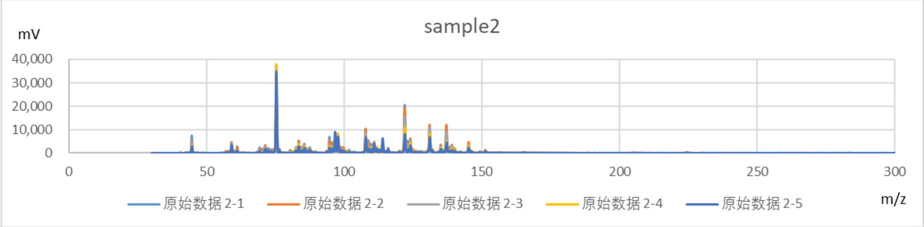
Purifier

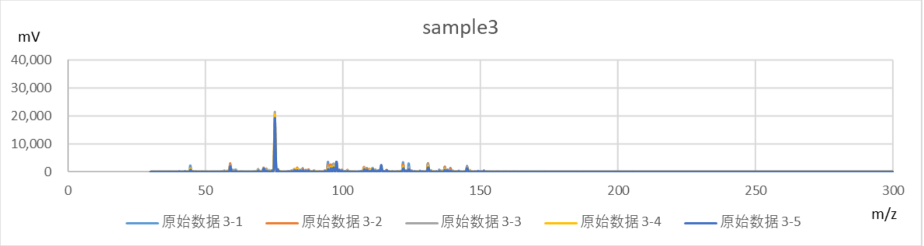
Reject

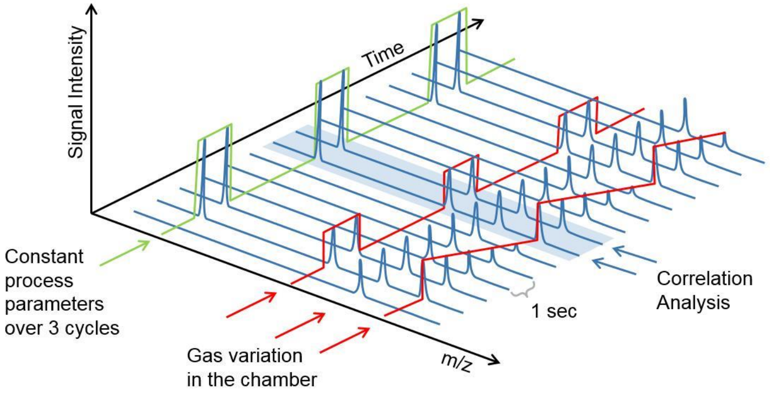


RGA sampled data









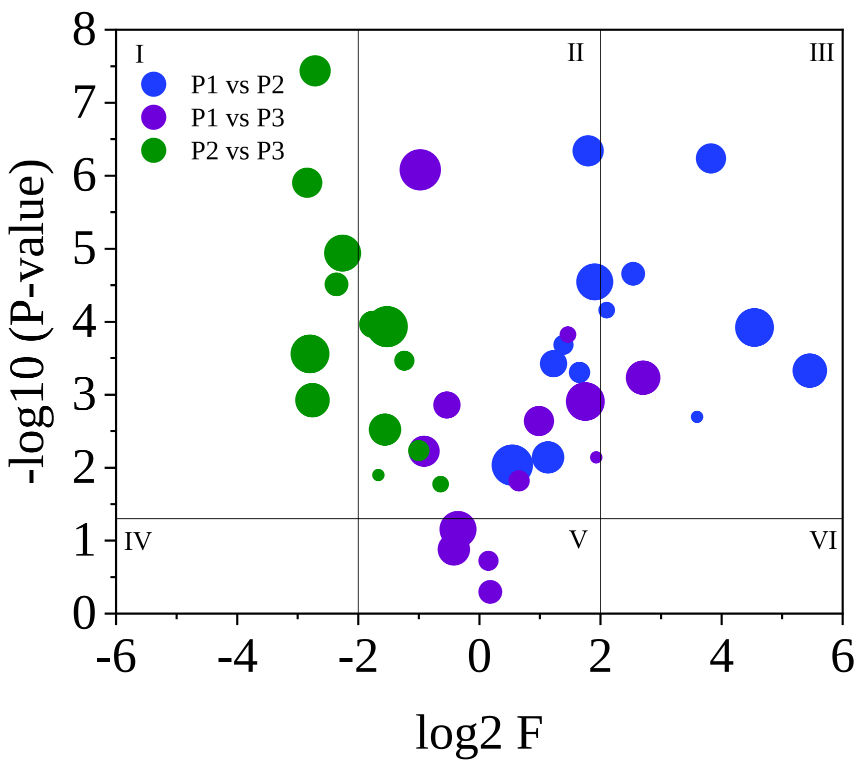
单因素方差分析	1#和2#对比		1#和3#		2#和3#		1#和2#对比		1#和3#		2#和3#	
质荷比(m/z)	F	P-value	F	P-value	F	P-value	log2 F	log P	log2 F	log P	log2 F	log P
44.5	12.1	0.0020	3.8	0.0073	3.2	0.0127	3.6	2.7	1.9	2.1	-1.7	1.9
59.0	4.3	0.0001	2.8	0.0002	1.6	0.0169	2.1	4.2	1.5	3.8	-0.6	1.8
71.4	2.6	0.0002	1.1	0.1900	2.4	0.0003	1.4	3.7	0.2	0.7	-1.2	3.5
75.4	3.2	0.0005	1.6	0.0152	2.0	0.0059	1.7	3.3	0.7	1.8	-1.0	2.2
83.6	5.8	0.0000	1.1	0.5050	5.1	0.0000	2.5	4.7	0.2	0.3	-2.4	4.5
96.8	2.3	0.0004	1.4	0.0014	3.4	0.0001	1.2	3.4	-0.5	2.9	-1.8	4.0
107.9	14.2	0.0000	2.0	0.0023	7.2	0.0000	3.8	6.2	1.0	2.6	-2.8	5.9
111.0	3.5	0.0000	1.9	0.0060	6.6	0.0000	1.8	6.3	-0.9	2.2	-2.7	7.4
114.1	2.2	0.0073	1.3	0.1319	2.9	0.0030	1.1	2.1	-0.4	0.9	-1.6	2.5
122.0	43.9	0.0005	6.5	0.0006	6.7	0.0012	5.5	3.3	2.7	3.2	-2.8	2.9
131.2	3.7	0.0000	1.3	0.0703	4.8	0.0000	1.9	4.5	-0.4	1.2	-2.3	4.9
137.2	23.4	0.0001	3.4	0.0012	6.9	0.0003	4.5	3.9	1.8	2.9	-2.8	3.6
145.4	1.5	0.0093	2.0	0.0000	2.9	0.0001	0.5	2.0	-1.0	6.1	-1.5	3.9

- “STDEV.P” function to get “**P value**” in each group
- Compare peak values between 2 samples to get “**F**”
- Chose the “F” which all 3 group is larger than “1”
- Convert data into logarithmic scale
- Annotate data into “volcano chart”

$$P = \sqrt{\sum_{i=1}^{n} \frac{(x_i - \bar{x})^2}{n}}$$

(n=5)

Data process of RGA

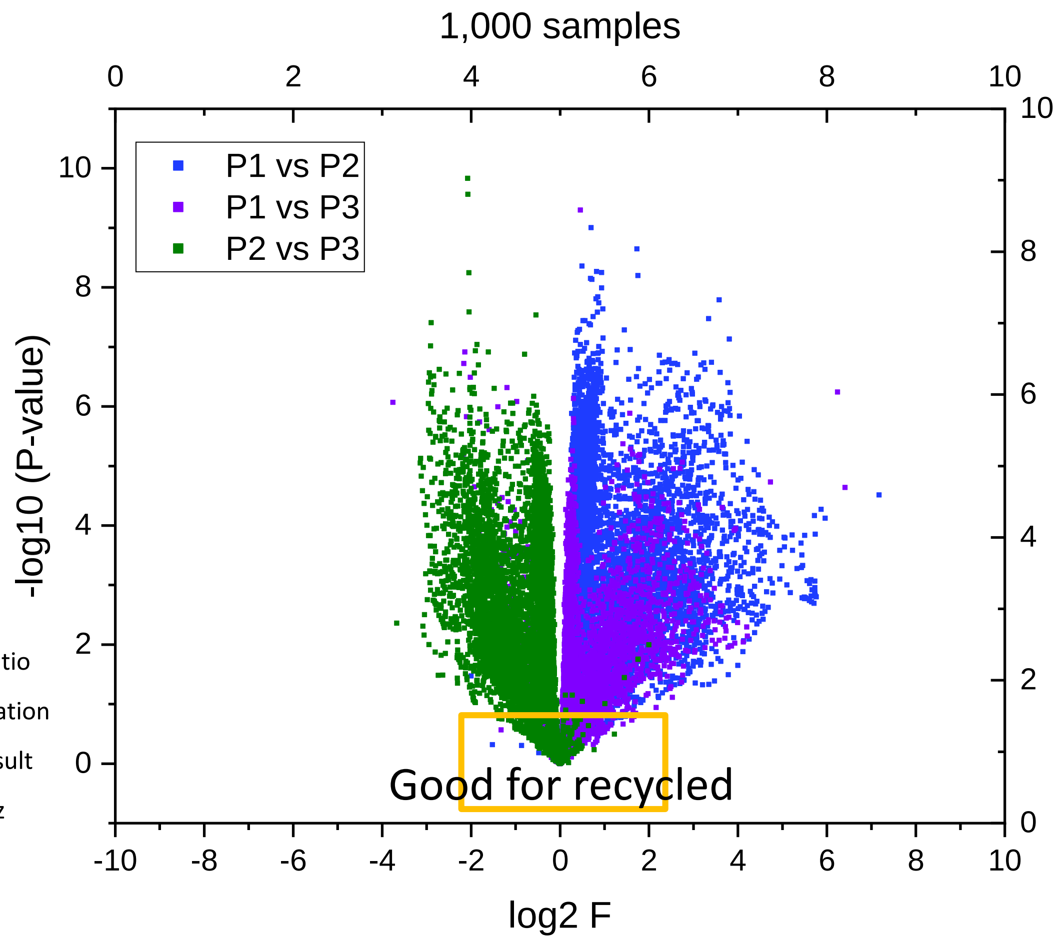


F: peak impurity ratio

P: group STD deviation

Color: compare result

Size of bubble: m/z



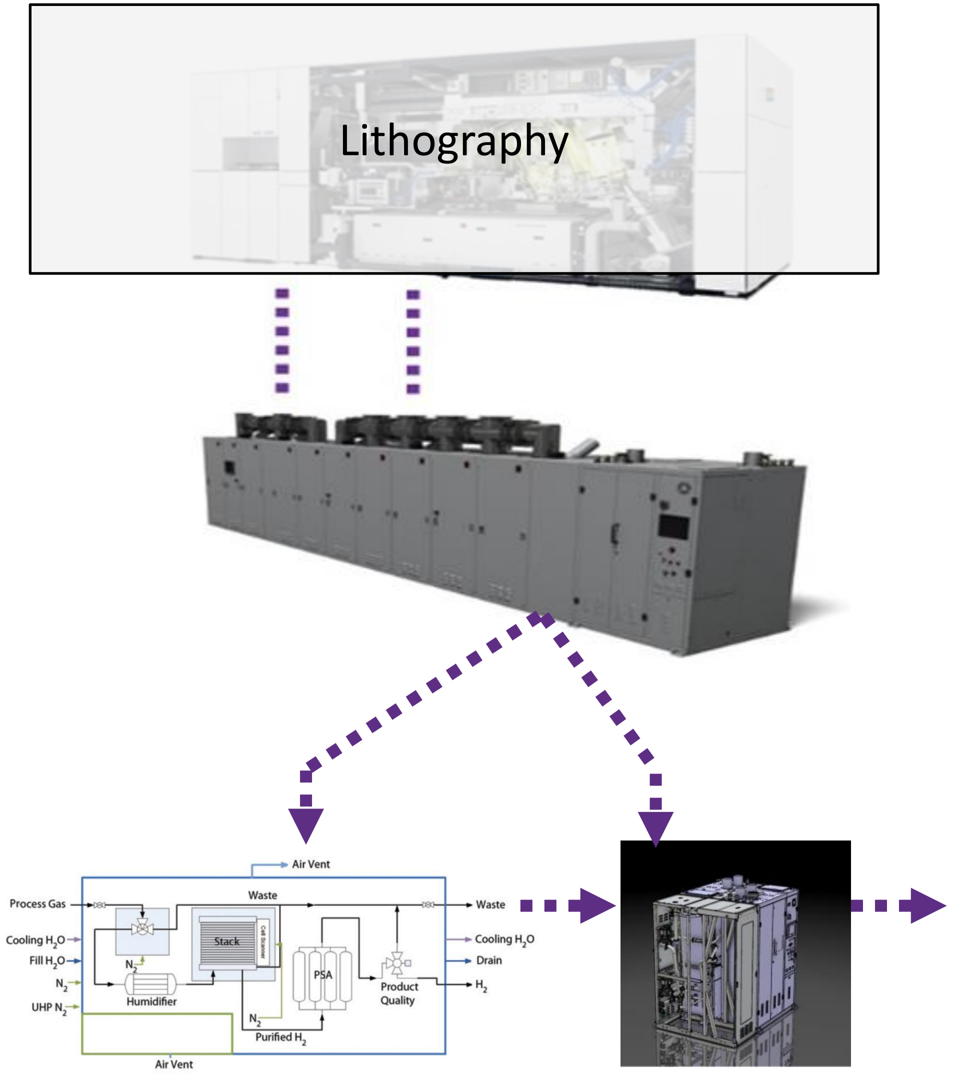
- “Zone V” is good data and good uniformity
- “Zone I and III” are worst data which can’t be use
- “Zone II” can be saved for further measurement
- “Zone IV and VI” do not contain any useful data

Introducing calibration gas can make the data more reliable

EDWARDS

Summary

- 3 options for EUV Lithography H_2 treatment
  - “Controlled Burning“
  - "Dilution”
  - “Recycle”
- Availability is required for all method, up to 99.9%
- Above 95% user choose “Controlled burning”
- “Dilution” started to commercialize
- “Recycle” is under evaluation and improving purity



edwardsvacuum.com