IMEC UPDATE ON RESIST OUTGASSING

I. Pollentier

OUTLINE

NXE outgas qualification at imec

Correlation of outgassing (RGA) to contamination growth (CG) in NXE outgas qualification

EUV vs. electron induced resist outgassing and contamination

Contamination behavior and H-cleaning

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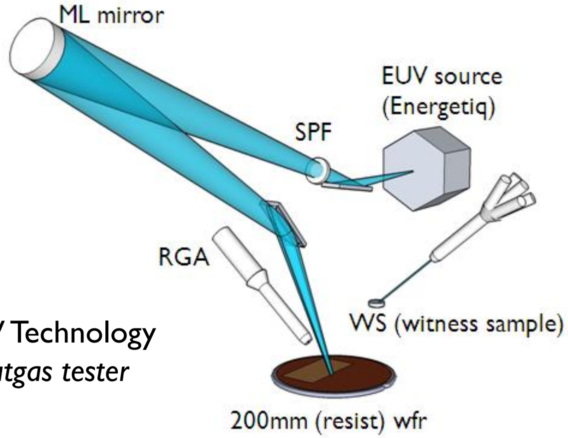
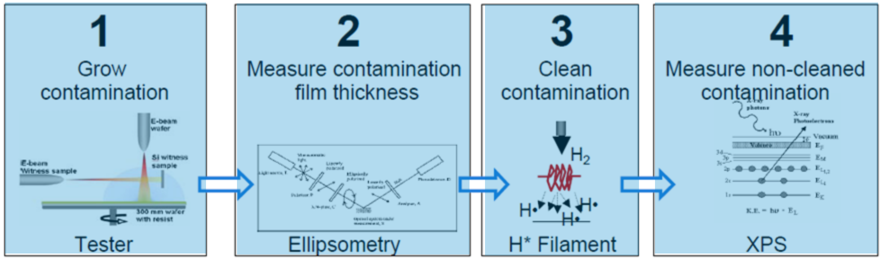
RESIST OUTGASSING QUALIFICATION PROCEDURE FOR NXE3x00



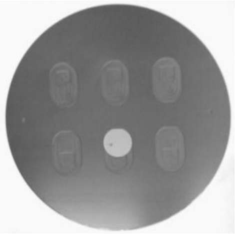
EUV Technology
outgas tester



1. Grow contamination — Tester
2. Measure contamination film thickness — Ellipsometry
3. Clean contamination — H* Filament
4. Measure non-cleaned contamination — XPS

NXE outgas qualification certified end H1'2012
107 materials were tested so far (69 customer samples)
Throughput : ~20 samples/month (XPS limited)

KLA-tencor UV1280 *ellipsometer*



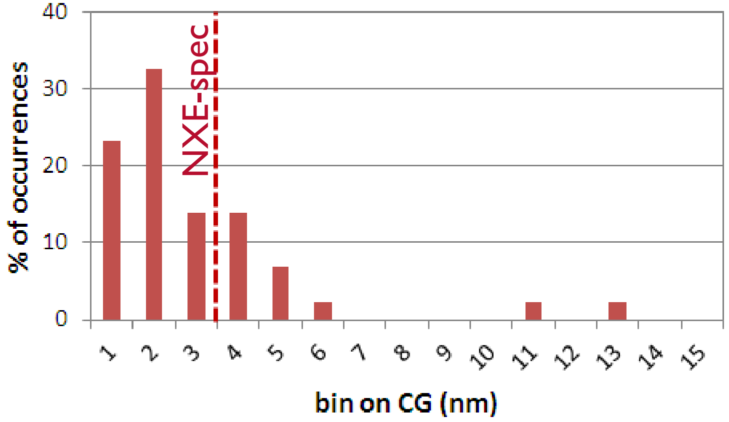
200mm Pocket-wafer
with 6 available
positions for 1" WS

EUV Technology
H-filament cleaner

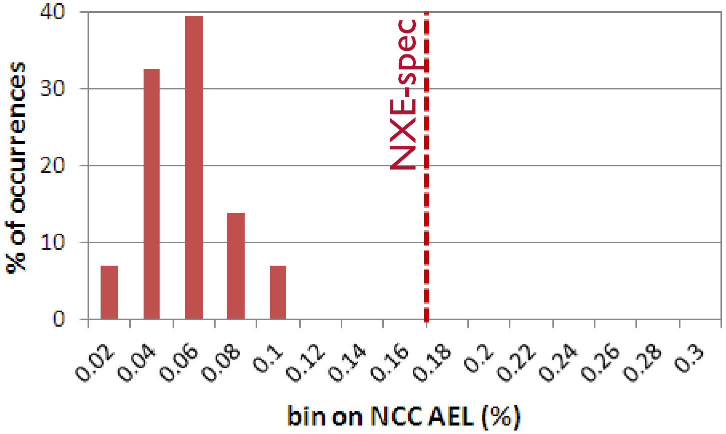
Thermo Instruments Theta 300
XPS

NXE OUTGAS QUALIFICATION AT IMEC

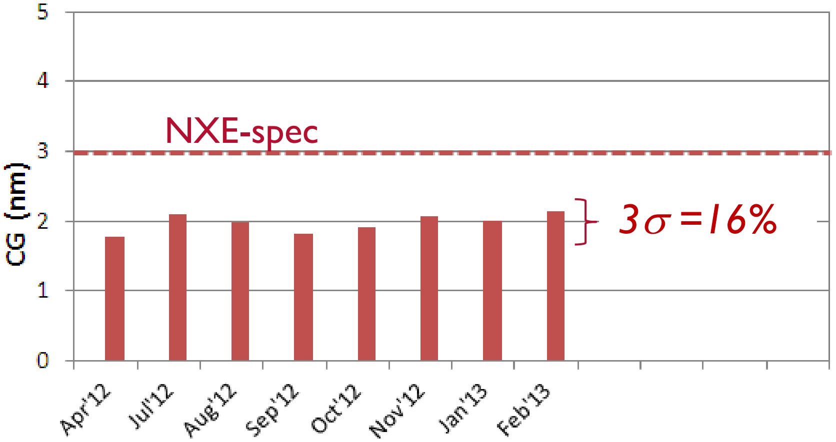
Analysis of qualification results : cleanables



Analysis of qualification results : non- cleanables



Monitoring of cleanable contamination (incl. dose to clear)



~70% of materials meet the spec for cleanable contamination (CG<3nm)

Good control on cleanable contamination CG result

100% of materials meet the spec for non-cleanable contamination (AEL<0.16% for NXE:3300) (even materials out-of-spec for CG)

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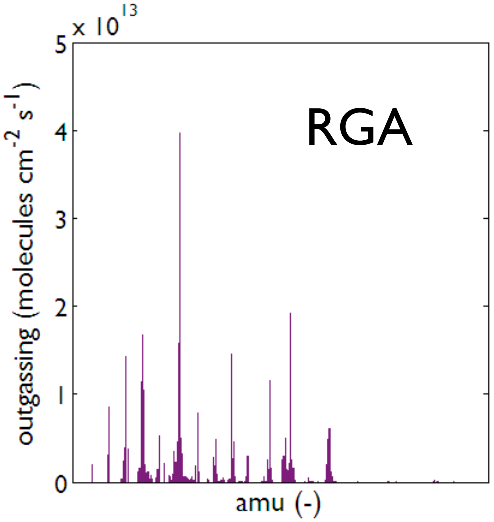
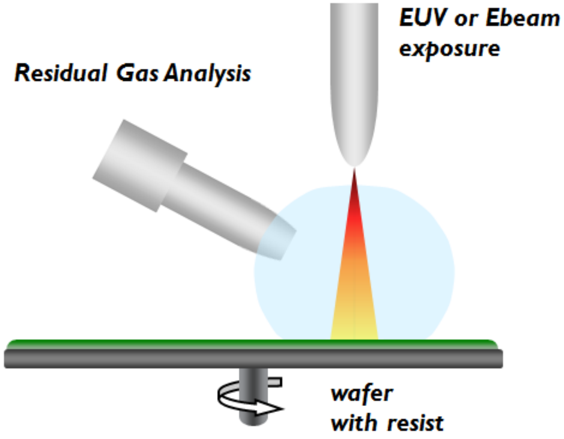
RGA APPROACH FOR CONTAMINATION QUALIFICATION



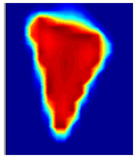
☺ Gives detailed information on outgassing species and their molecular structure (amu)

😐 Information is rather complex

☹ No direct output towards contamination



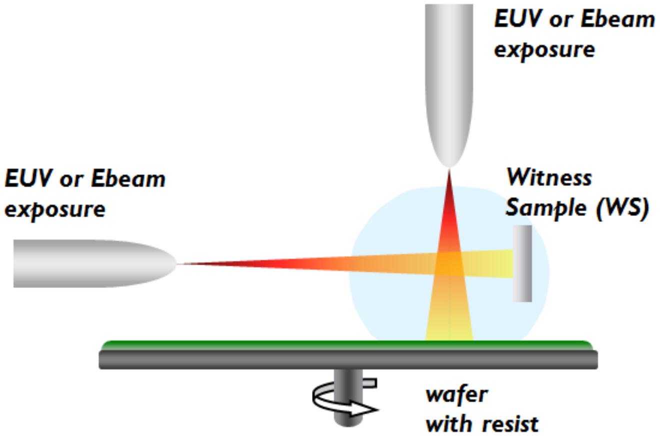
NXE WS test



☺ Direct relation to NXE contamination, e.g. contamination growth thickness (CG) and non cleanables

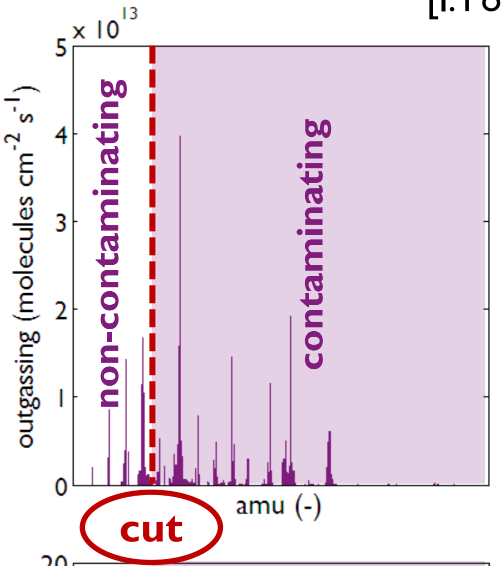
😐 More lengthy test

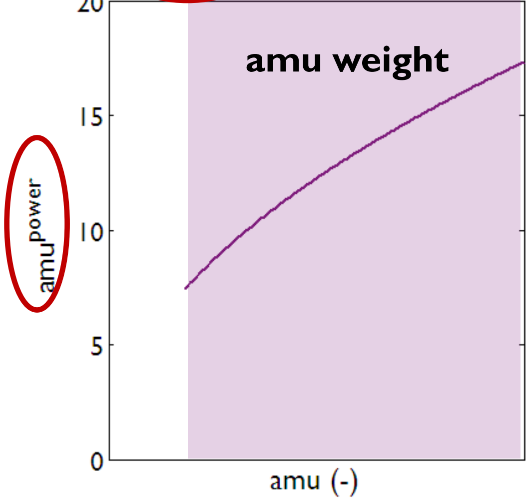
☹ No direct information of which resist species are involved, … but should be a result of what is outgassing from the resist !



RGA APPROACH FOR CONTAMINATION QUALIFICATION

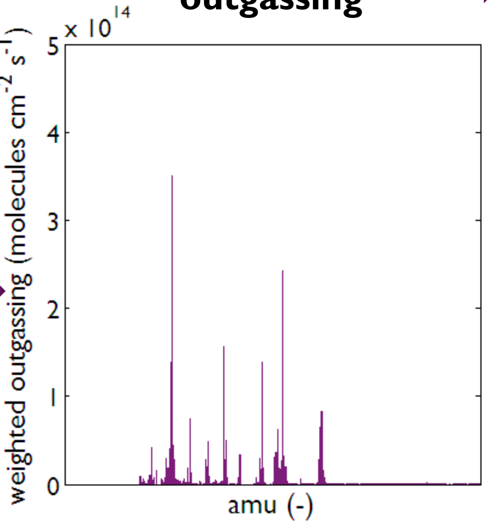
[I. Pollentier, EUVL symposium, Brussels (2012)]

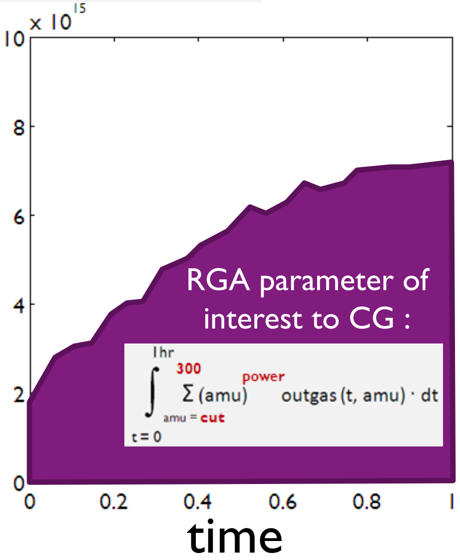




amu weighted contaminating outgassing

$$\sum_{amu\,=\,cut}^{300} (amu)^{power}\ outgas(t, amu)$$





RGA parameter of interest to CG :

$$\int_{t=0}^{1hr} \sum_{amu\,=\,cut}^{300} (amu)^{power}\ outgas(t, amu) \cdot dt$$

Key in the correlation is :

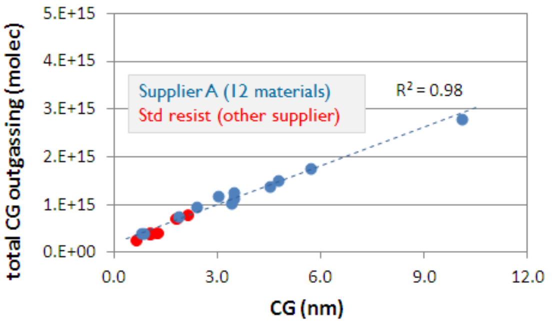
1. Use resist related outgassing rate (background subtracted)
2. Remove the lower amu outgassing in the spectrum, since this is not contributing to contamination (e.g. amu cut at 55amu)
3. Apply a weight to the outgassing rate proportional to the amu (e.g. $(amu)^{1/2}$)
4. Measure and integrate this weighted outgassing during the time the WS is exposed

RGA APPROACH FOR CONTAMINATION QUALIFICATION

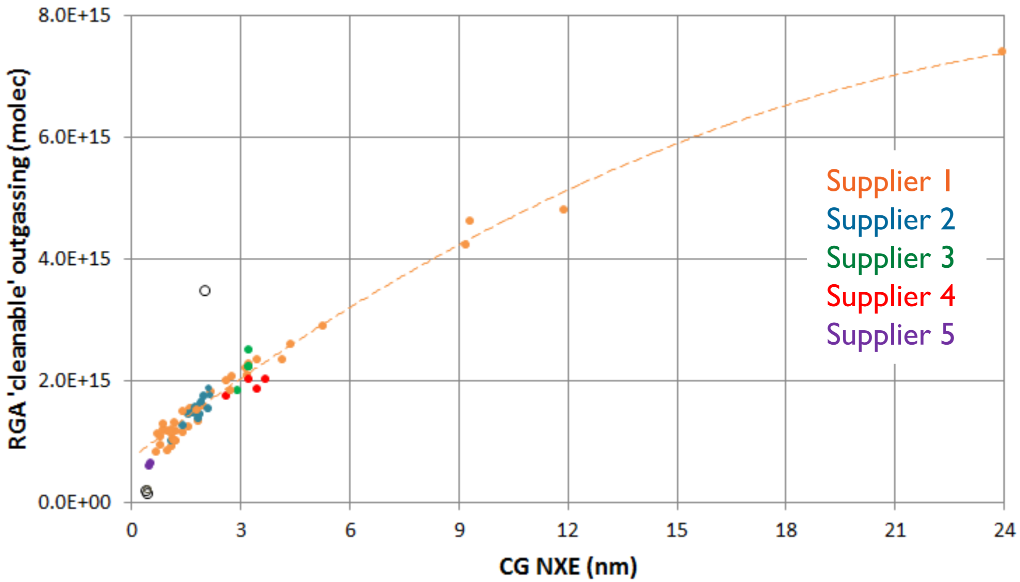
Optimized RGA parameter for CG :
(based on regression on 22 materials)

$$\int_{t=0}^{1\,hr} \sum_{amu=55}^{300} (amu)^{1/2} \; outgas(t, amu) \cdot dt$$

Proof of principle demonstrated using 13 resist materials
[I. Pollentier, EUVL symposium, Brussels (2012)]



Check of correlation in 72 resist tests so far :



Resist materials from 5 suppliers follow correlation fairly well.

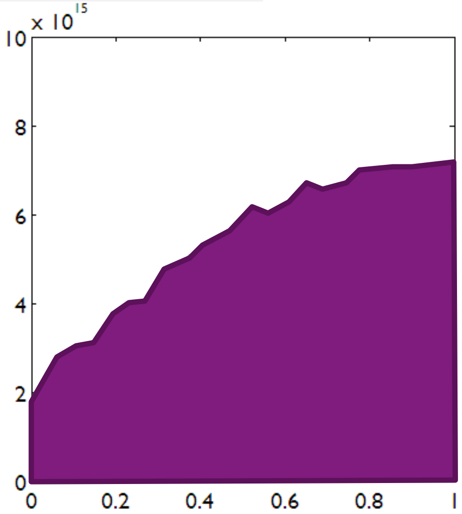
So far only one TC is significantly away from the curve.

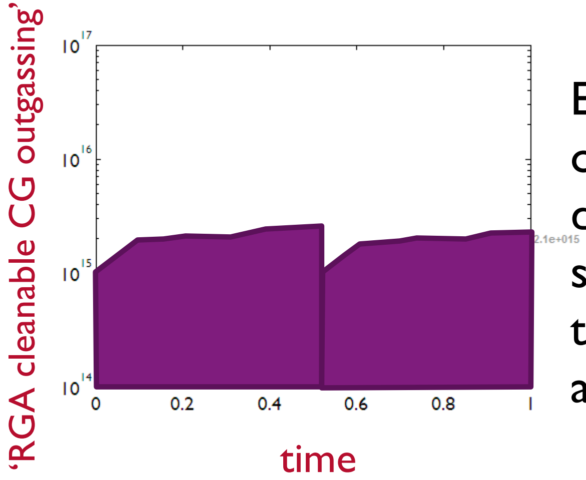
RGA APPROACH FOR OUTGAS QUALIFICATION

RGA metric might provide additional learning on contamination mechanisms; since its measurement is continuous during testing, it can be considered almost as ‘in situ’ measurement of the contamination.

- Compare different procedures, e.g. single wafer test vs. 2wfr test; area scaling, impact of residual outgassing, …
- Differences in contamination between Egun vs. EUV resist exposure

$$\sum_{amu\,=\,\mathbf{cut}}^{\mathbf{300}} (amu)^{\mathbf{power}}\ outgas\,(t,\ amu)$$





Example : RGA cleanable outgassing as function of time during imec’s 2wfr test; it should be possible to predict the contamination thickness at any intermediate time.

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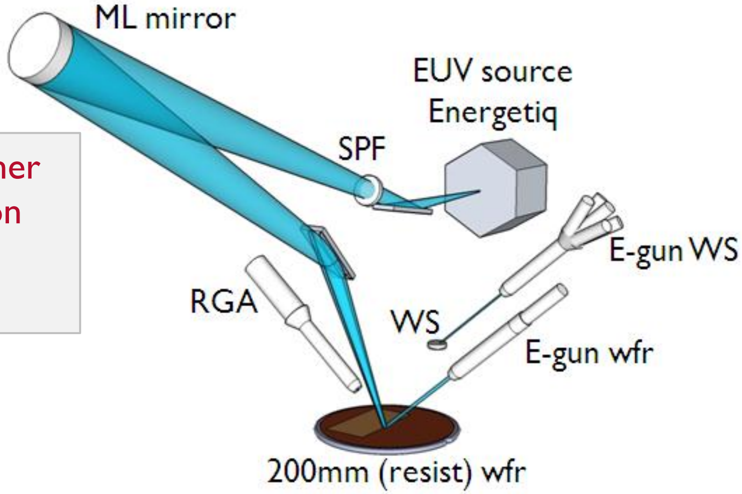
EUV VS EGUN EXPOSURE ON WAFER

Comparison of beam intensity, E0 determination and CG

EUV

☺ Similar as in NXE:3x00 scanner with respect to resist absorption
☹ Limitations in source power
😐 Higher operational cost



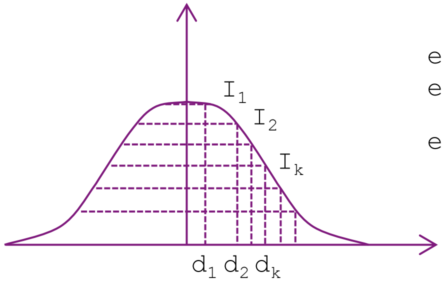
Electron gun

☺ Low operational cost
😐 Various settings are possible, e.g. electron energy
☹ Still debate on its equivalence to EUV

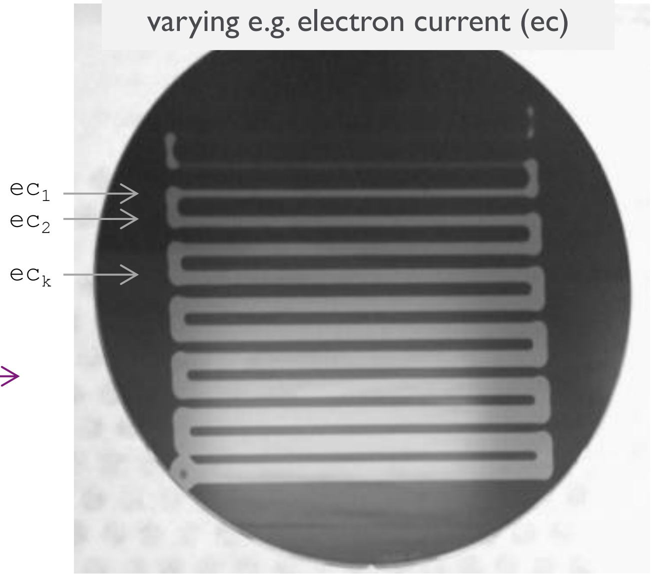
E-gun 2keV, 3keV, and 5keV are investigated and compared to EUV for three resists

EUV VS EGUN EXPOSURE ON WAFER

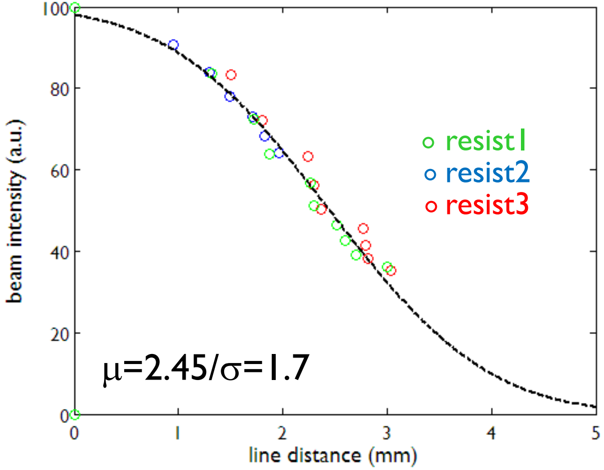
Experimental determination of beam intensity distribution



Dose to clear exposure based on varying e.g. electron current (ec)



E-gun 2keV



d_k can be determined from line scan by ellipsometer scan measurement of track width.

At track edge the dose is constant (E_0)

⇨ I_k = const / ec_k

Beam intensity is fitted to the function :

$$\mathrm{erfc}((x-\mu)/\sigma)$$

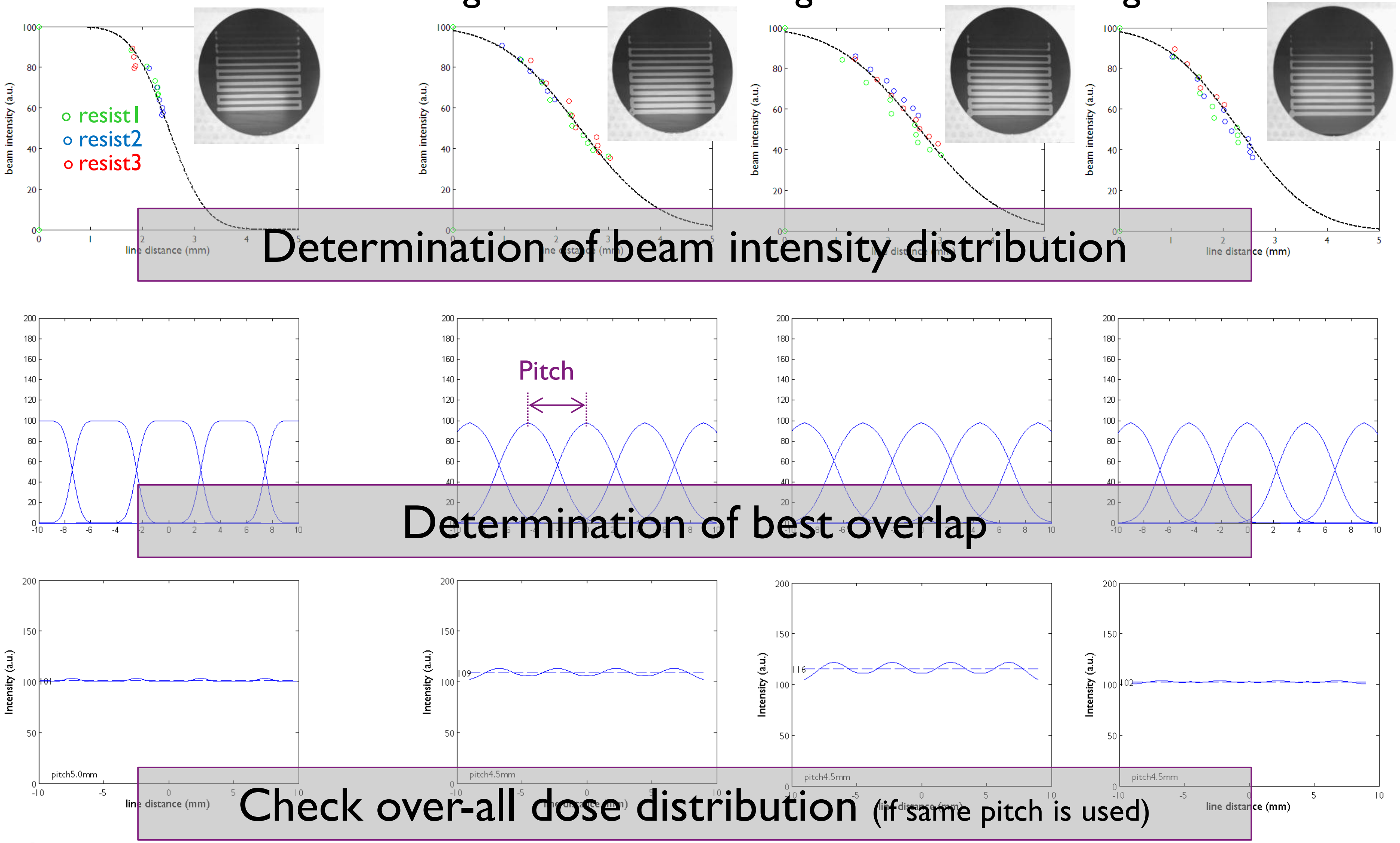
EUV VS EGUN EXPOSURE ON WAFER

EUV

E-gun 2keV

E-gun 3keV

E-gun 5keV



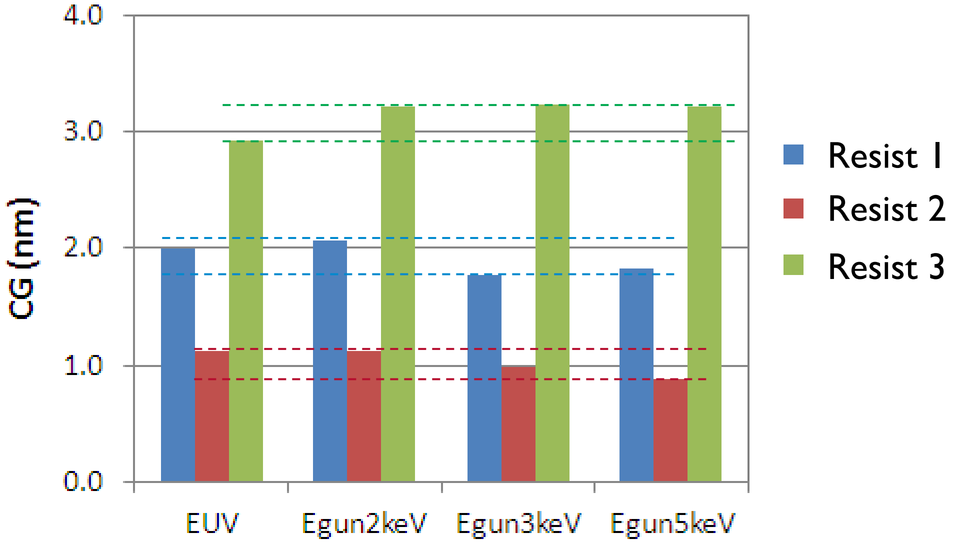
Determination of beam intensity distribution

Determination of best overlap

Check over-all dose distribution (if same pitch is used)

EUV VS EGUN EXPOSURE ON WAFER

Taking into account an optimized dose matching, the (absolute) difference between CG in EUV and different E-gun settings is very limited !



Variability on CG amongst different exposure modes is comparable to the variability in the (EUV based) monitoring.

No significant differences observed in non-cleanables

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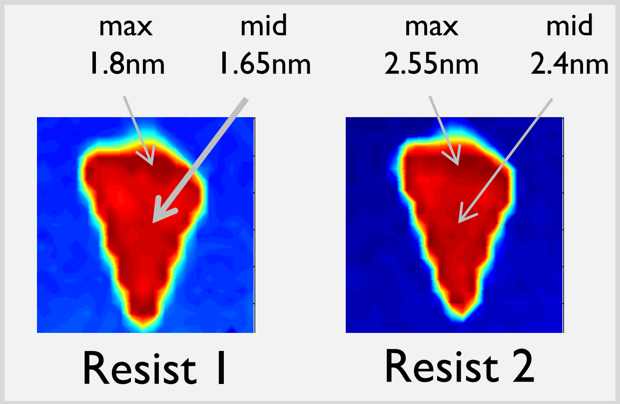
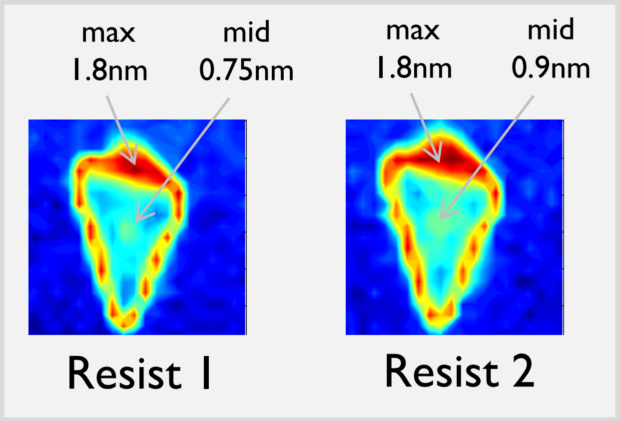
CONTAMINATION ON WS

Ru/Si WS

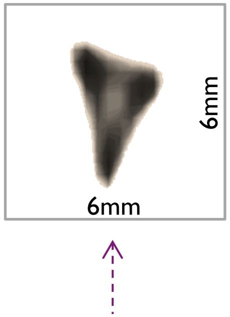


Typically the contaminated area is larger than the e-gun exposed area with slightly higher thickness in the border.

Si WS

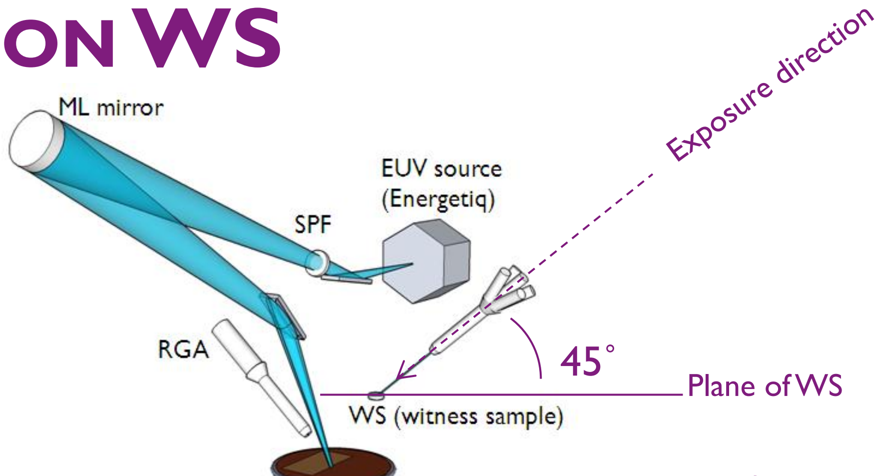


In absence of Ru the inner spot and border behavior is significantly different.



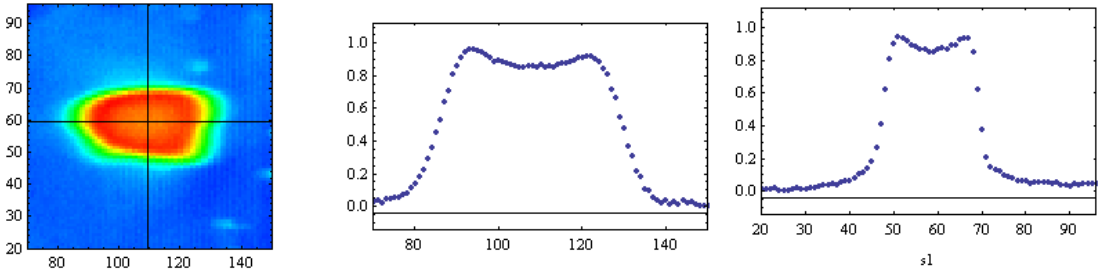
Exposure direction

Intensity profile of egun primary electrons



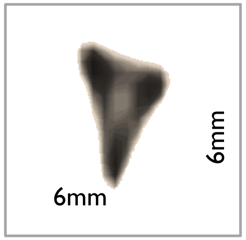
Due to the E-gun focus and deflection settings the spot shape in the imec system is triangular.

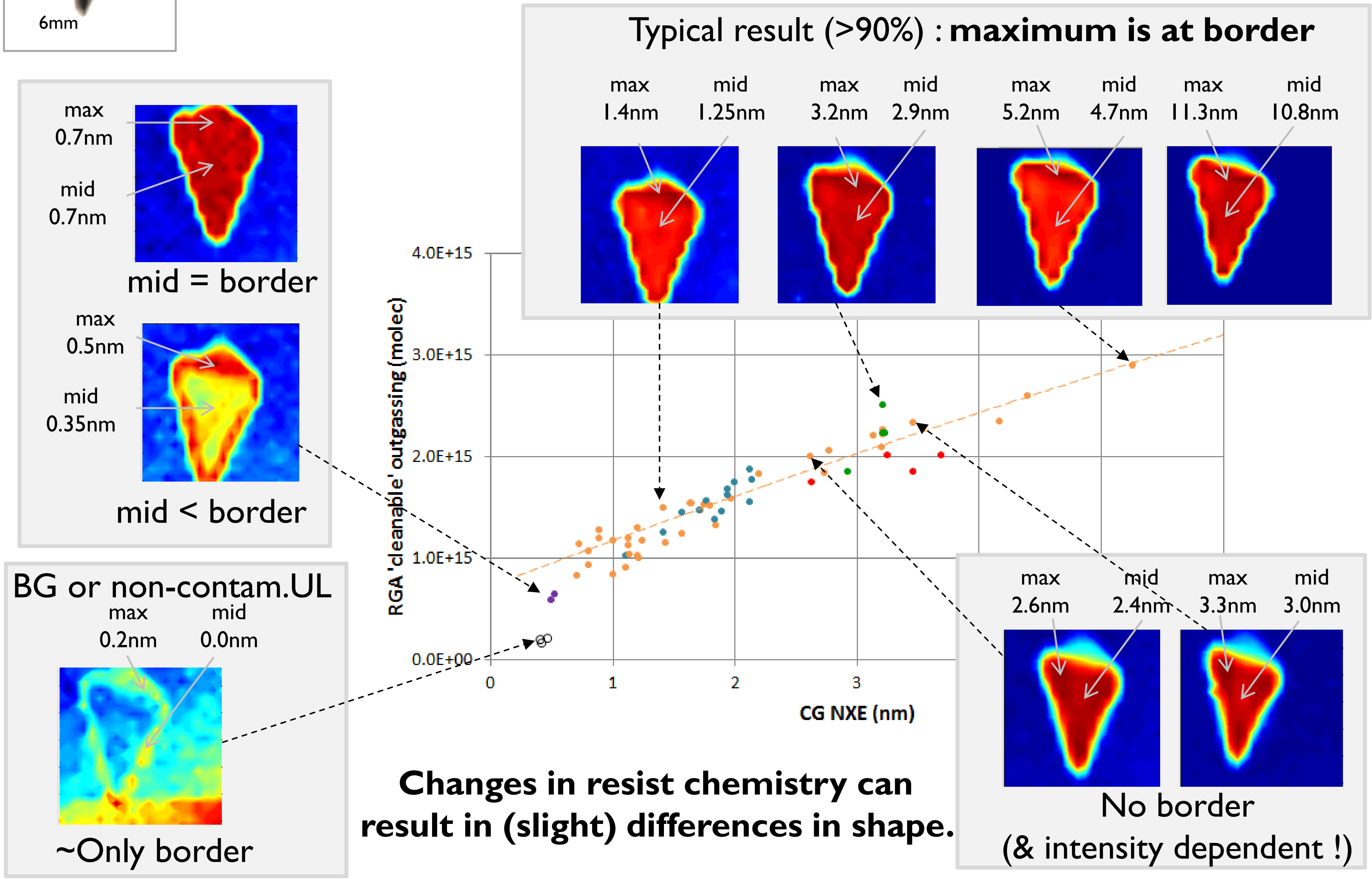
Border (or vulcano shape) also seen at other test sites [Courtesy of S. Hill (NIST)]



Parameters that are expected to play a role : densification by exposure, balanced contamination/cleaning, charging, … ?

CONTAMINATION ON WS





Typical result (>90%) : **maximum is at border**

mid = border

mid < border

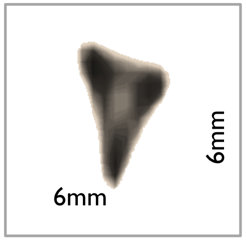
BG or non-contam.UL

~Only border

No border

(& intensity dependent !)

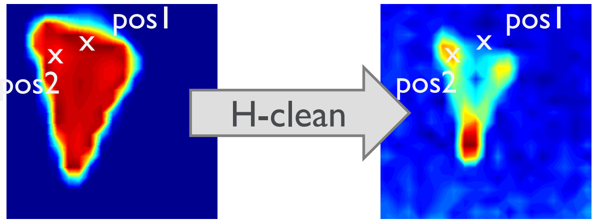
Changes in resist chemistry can result in (slight) differences in shape.

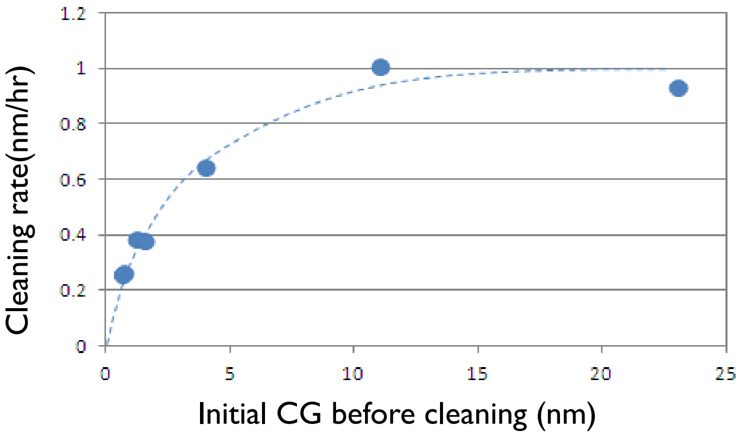


CONTAMINATION ON WS : CLEANING

Contamination thickness ~10nm

Contamination thickness ~0.5nm





Border and spot area related to lower emission current are cleaned faster (~20%) than spot area with highest emission current

Thin contamination is harder to clean than thick contamination (both exposed for 1hr in WS test).

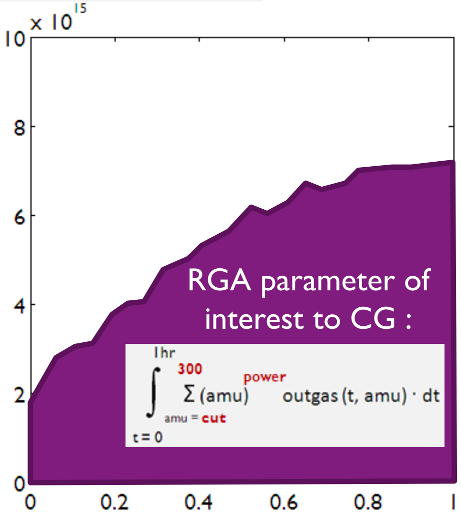
SUMMARY

$$\sum_{\text{amu} = \textbf{cut}}^{\textbf{300}} (\text{amu})^{\textbf{power}} \ \text{outgas}(t, \text{amu})$$

The RGA contamination parameter has been optimized. Good correlation is found for all resists so far coming from 5 suppliers.

Moreover this RGA parameter seems to be an interesting ('in situ) help for understanding contamination mechanisms.

Differences between EUV and E-gun exposed resist outgassing and contamination are small. Also different E-gun settings 2-5keV give minor changes. Dose matching and control is key to get close results.



RGA parameter of interest to CG :

$$\int_{t=0}^{1\text{hr}} \sum_{\text{amu} = \textbf{cut}}^{\textbf{300}} (\text{amu})^{\textbf{power}} \ \text{outgas}(t, \text{amu}) \cdot dt$$

ACKNOWLEDGEMENTS

Imec : R. Gronheid, R. Lokasani, E. Hendrickx, T. Conard and J. Blux

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