VARIABILITY OF EUV RESIST OUTGAS TEST RESULTS : COMPARISON OF OUTGAS VERSUS CONTAMINATION BEHAVIOR AT MULTIPLE TEST SITES USING MODEL EUV RESISTS

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EIDEC

NIST National Institute of Standards and Technology

imec

OUTLINE

Introduction : round robin variability

RGA outgas metric for contamination

Within-site relationship of outgas/contamination

Site-to-site relationship of outgas/contamination

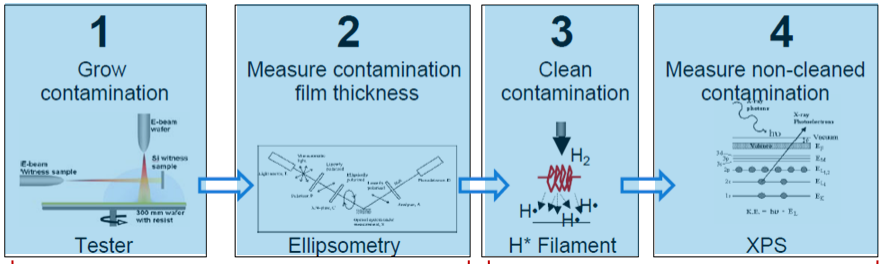
How to use outgas contamination relationship towards 'round robin' variability ?

Summary

OUTGAS TESTING

Resist outgassing is potential risk for NXE:3x00 and needs to be tested according to a procedure

[N. Harned, IEUVI ResistTWG, Feb'2014]



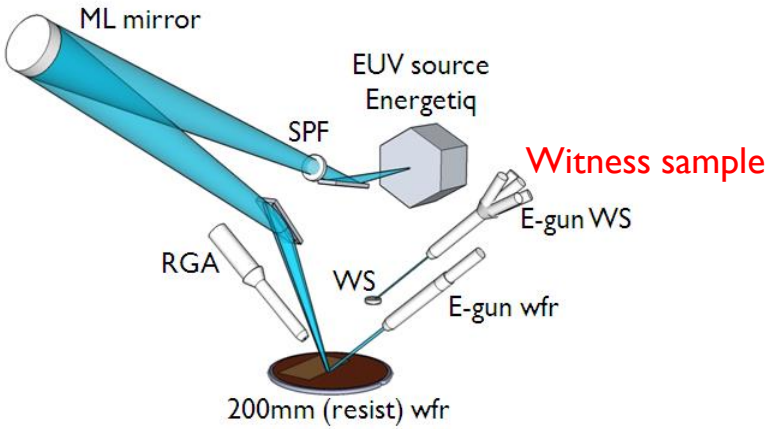
'cleanable contamination'

CC ≤ 3nm→10nm (NXE3100)
CC ≤ 3nm→10nm (NXE3300)

'non-cleanable contamination'

NCC ≤ 0.23% (NXE3100)
NCC ≤ 0.16% (NXE3300)

Example of Contamination Growth (CG) tester (imec)



['Round Robin 2' reported at IEUVI Resist TWG meeting, Feb' 2014]

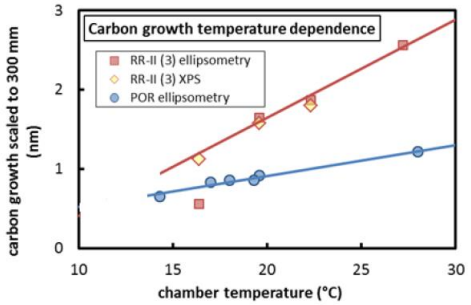
Different outgas test qualification sites have different test infrastructure, resulting in variability ('round robin' testing) despite the well-defined procedure.

ROUND ROBIN VARIABILITY

In order to reduce the gap of inter-site CG variability, collaborative work is done in between EIDEC, NIST, Sematech, and imec under advice of ASML (reported in detail on recent IEUVI resist TWG meeting), and 3 main root causes of variability have been identified.

Temperature

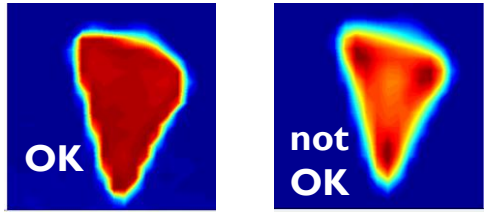
Stability in time is key, and site-to-site matching needs to be checked.



T. Lucatorto (NIST), IEUVI Resist TWG, Feb' 2014]

Contamination limited regime (CLR)

CG spot on witness sample



Intensity of WS exposure needs to be sufficiently high. Non-CLR can underestimate the contamination.

A/PS ratio (A :wafer area; PS : pumping speed)

Different outgas test sites expose different wafer areas, and the pumping speed of testers are different. ASML proposed to use common A/PS ratio

ROUND ROBIN VARIABILITY

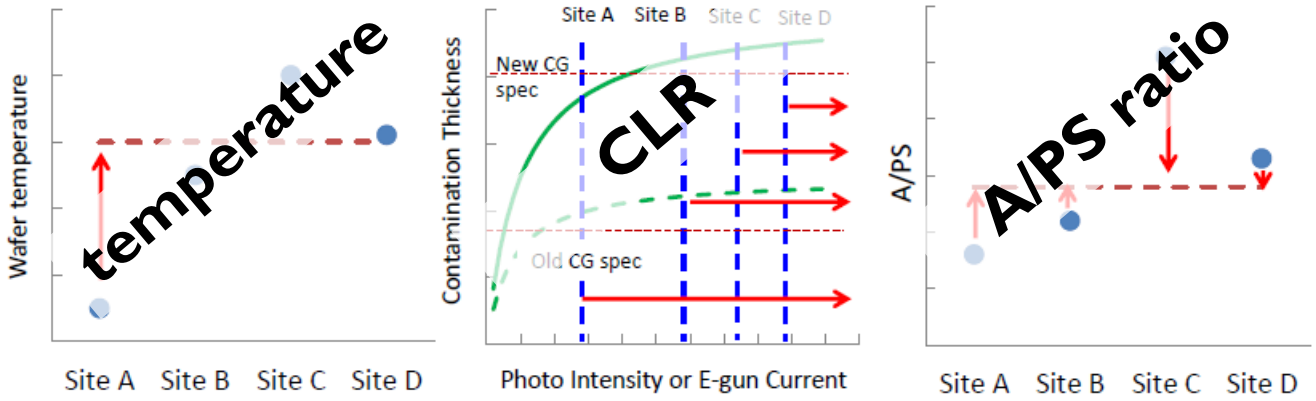
Presented by S. Inoue (EIDEC), IEUVI Resist TWG meeting, Washington, Oct'2014

Strategy for Reducing CG Gaps among Test Sites

Step 1: Set compromised wafer temperature for all test sites

Step 2: Establish contamination-limited regime for 10nm criteria

Step 3: Set common ratio between exposed Area and Pumping Speed (A/PS)



Step 4: Confirmation of tester reproducibility
Step 5: Re-calibration at all test sites

EIDEC IEUVI Resist TWG, Washington D.C., Oct. 26, 2014 imec NIST SEMATECH 2

The goal of this presentation is to validate and show progress, but also to include RGA as complementary information

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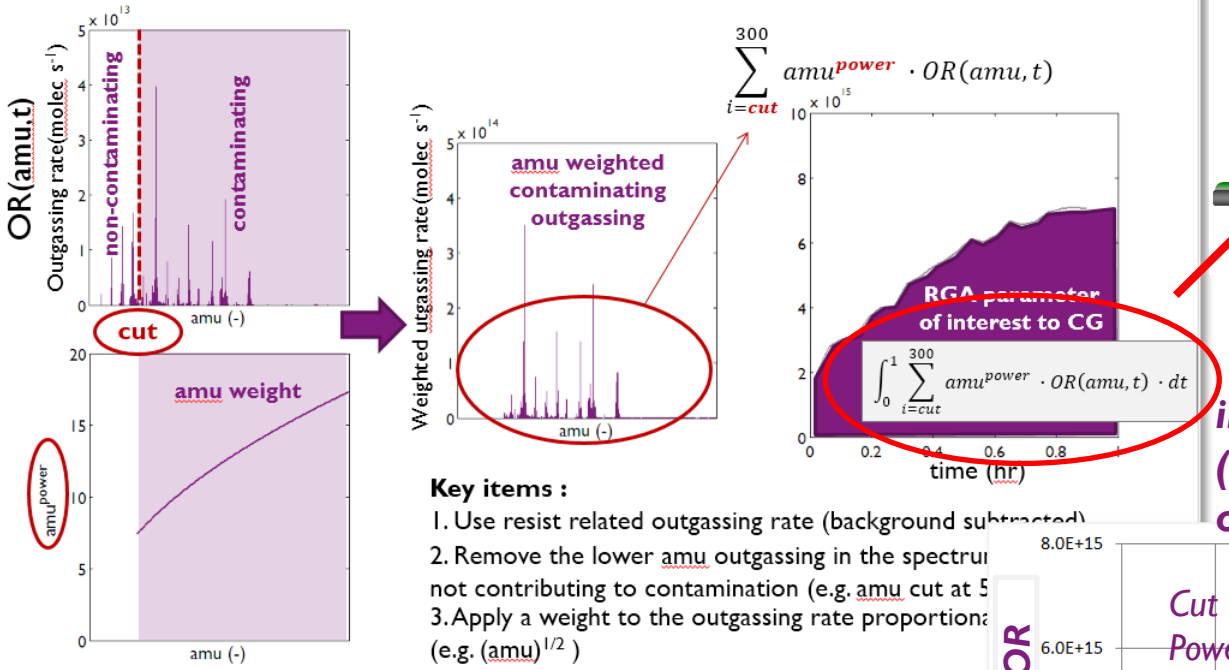
PRIOR WORK ON RGA CG CORRELATION TO CG

I. Pollentier et al, SPIE 2013

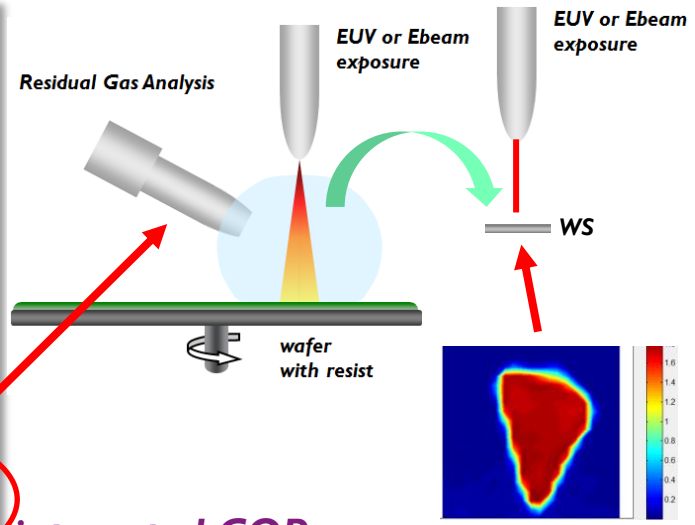
RGA FOR CONTAMINATION QUALIFICATION



Key items :

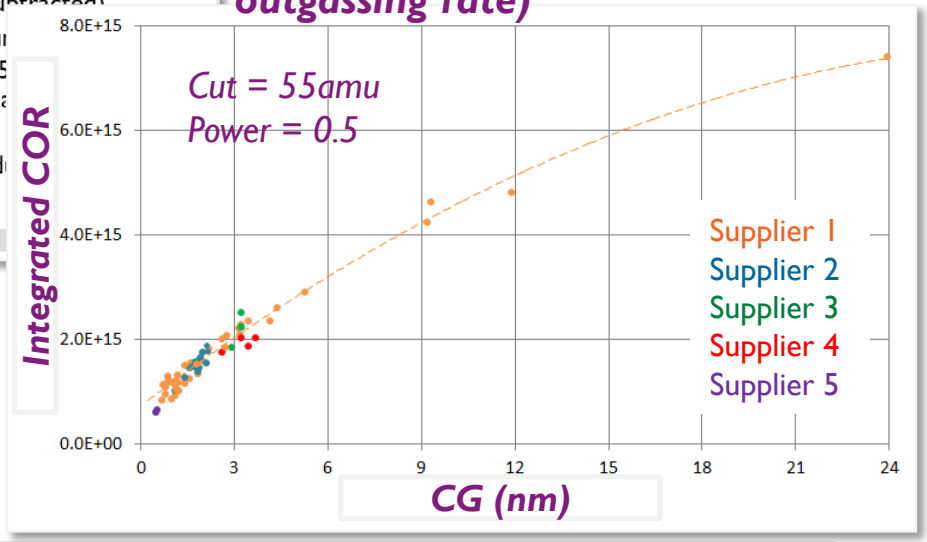
1. Use resist related outgassing rate (background subtracted)
2. Remove the lower amu outgassing in the spectrum not contributing to contamination (e.g. amu cut at 5
3. Apply a weight to the outgassing rate proportional (e.g. $(amu)^{1/2}$)
4. Measure and integrate this weighted outgassing during the WS is exposed

imec © IMEC 2013 Ivan Pollentier SPIE 8679-19, San Jose (2013)



integrated COR (contaminating outgassing rate)

contamination growth (CG)



Integrated COR can be considered as independent & complementary measurement to the CG

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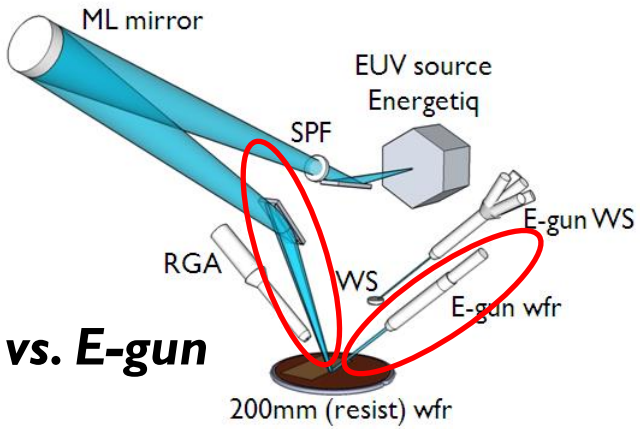
WITHIN-SITE OUTGAS/CONTAMINATION

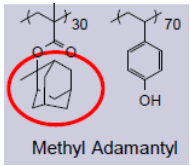
CG testing at imec

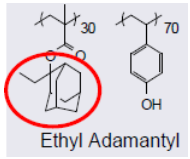


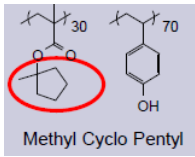
EUV vs. E-gun

Model resists provided by EIDEC

EIDEC distributed 5 model resists amongst the qualification sites for next step round robin; Two resists are expected to be high contaminating (CG = 7-10nm)







Contamination limited regime (CLR)

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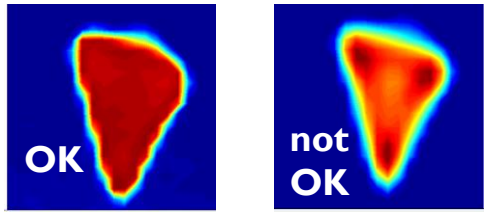

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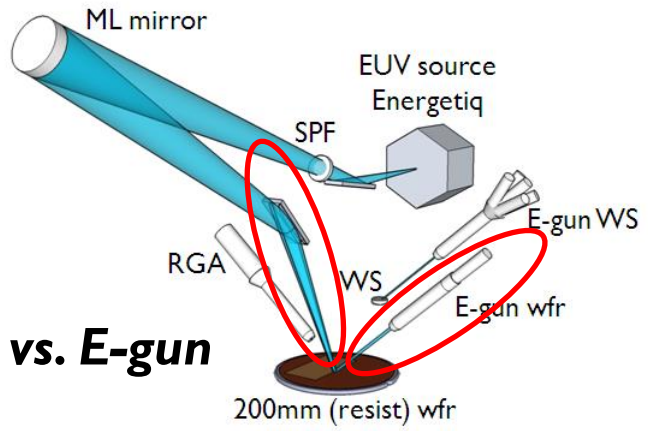

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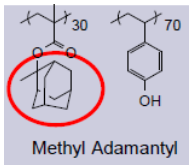
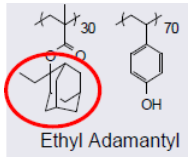
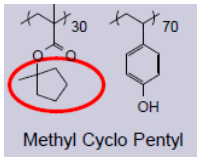
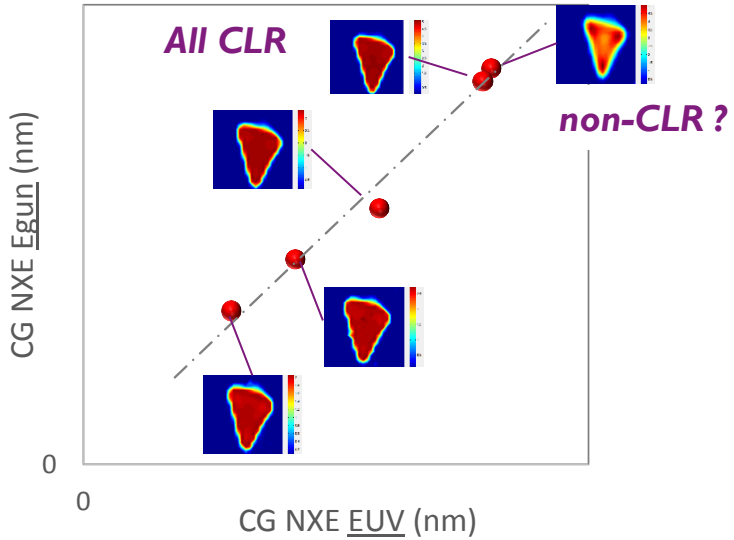
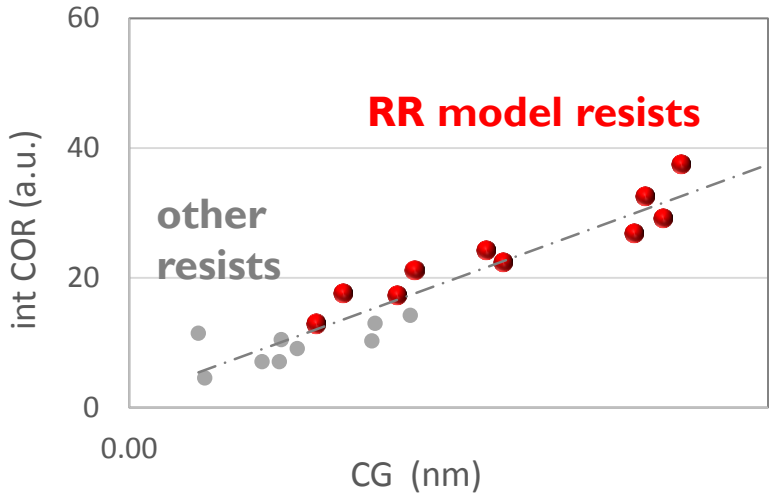






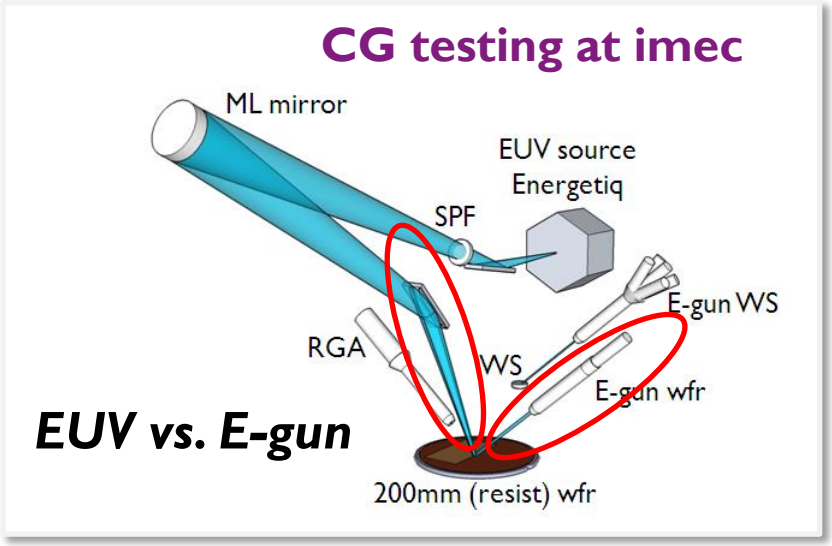


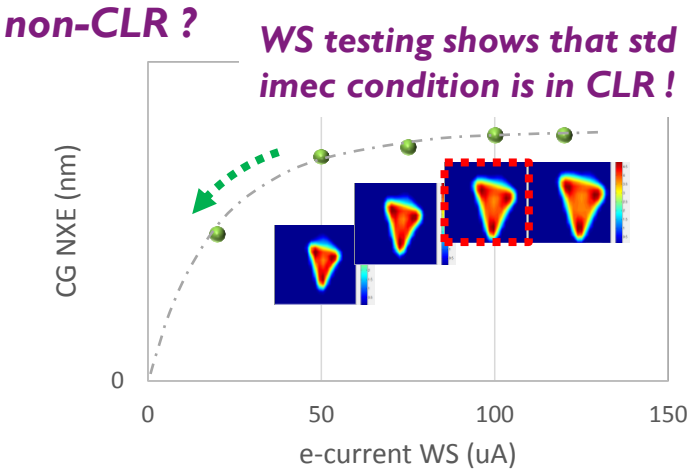
Good correlation between EUV exposed and Egun exposed CG results.

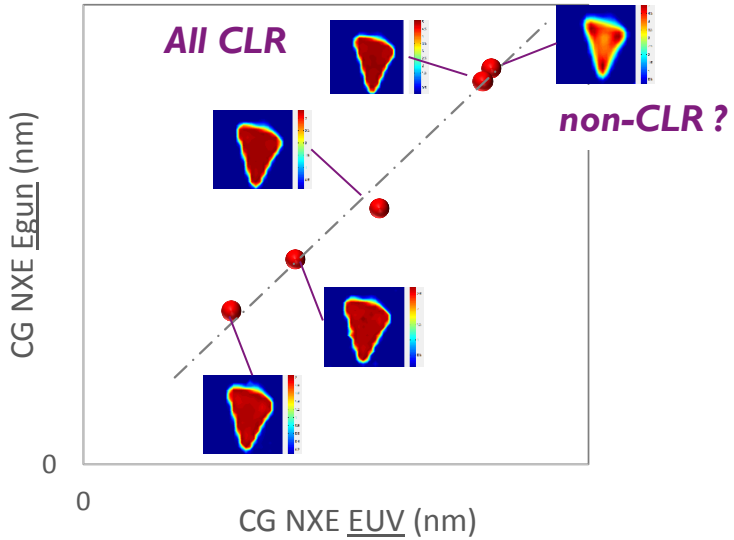


Good correlation between outgassing and contamination.

WITHIN-SITE OUTGAS/CONTAMINATION







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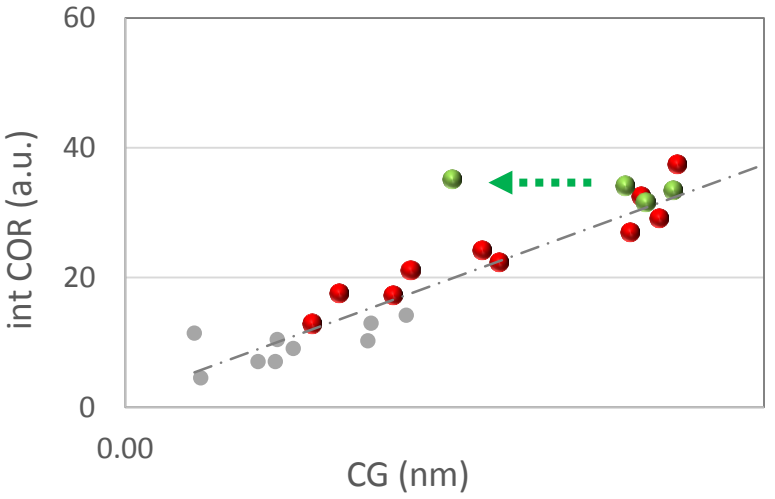
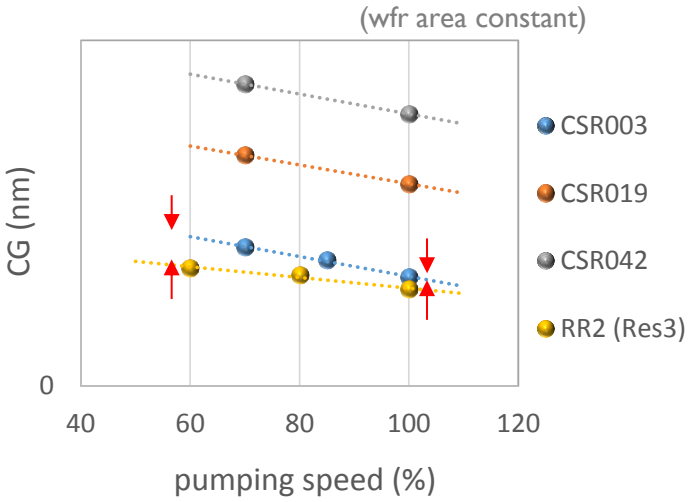
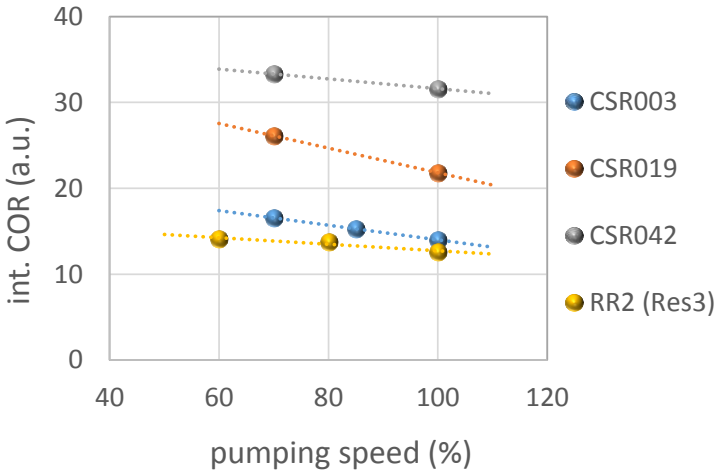


RGA confirms that max CG of std condition meets CLR and even can predict CRL violations !

RR TESTING AT IMEC : A/PS

Area / Pumping Speed





Differences in CG vs. PS slope could be responsible for different CG behavior. Agreement with integrated COR.

Sources of variability (CLR and PS/A) are confirmed to be important !

The integrated COR (RGA) can help in the investigation !

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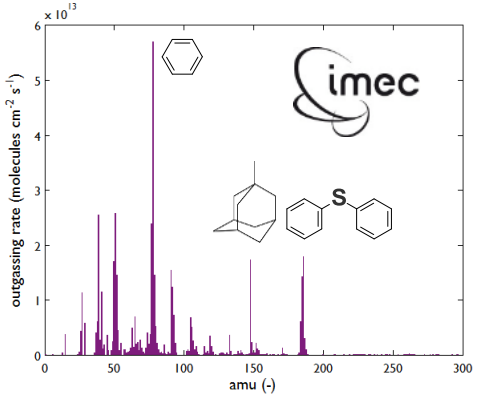
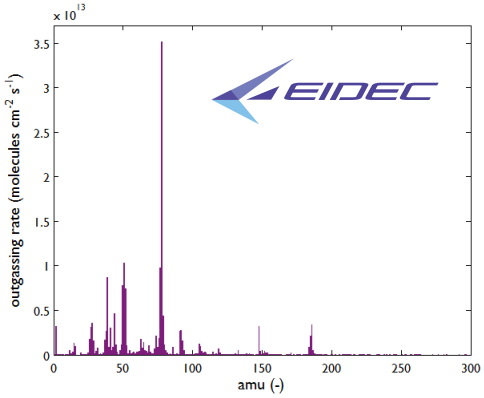
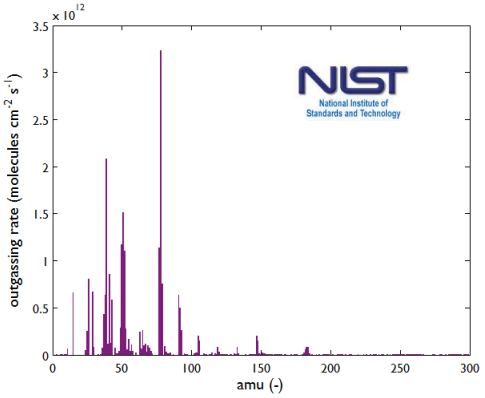
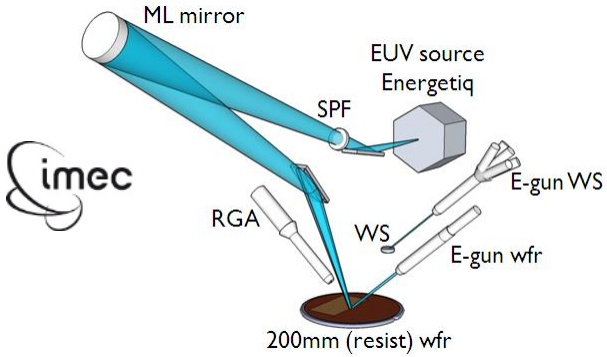
RGA-CG CORRELATION SITE-TO-SITE







One material evaluated by RGA at 3 different sites.
Similar peak masses are found, however with different relative magnitude.

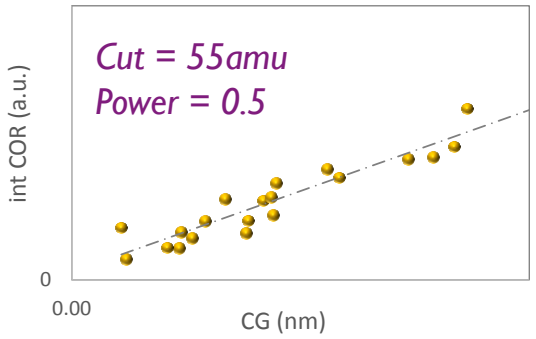


RGA peak differences can be due to many reasons :

- RGA hardware and measurement setting
- Distance and/or line-of-sight between RGA and wfr

RGA CG CORRELATION AT DIFFERENT SITES ?

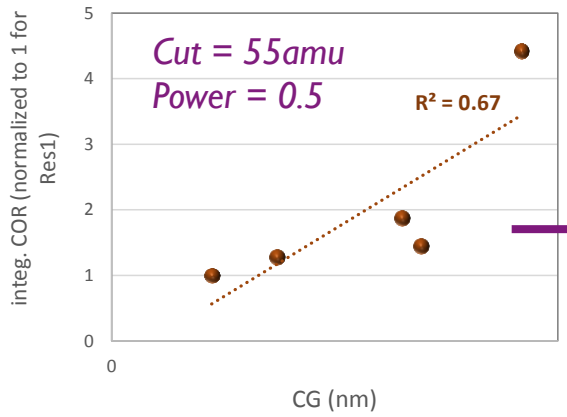
imec

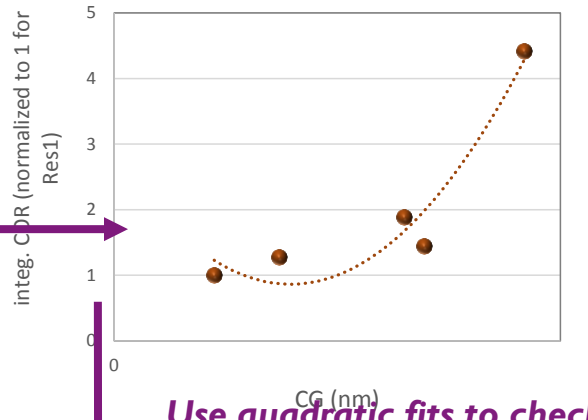


Good correlation both for commercial resists and model resist in EUV and Egun

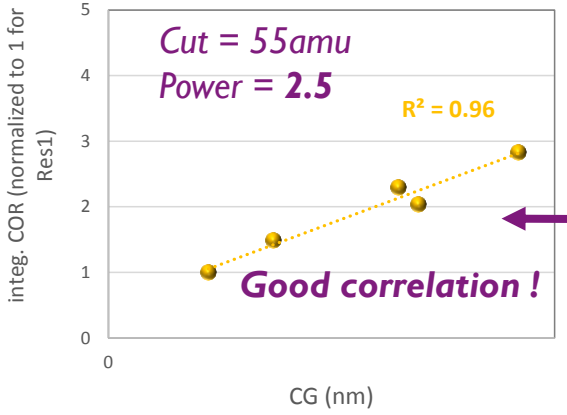
EIDEC

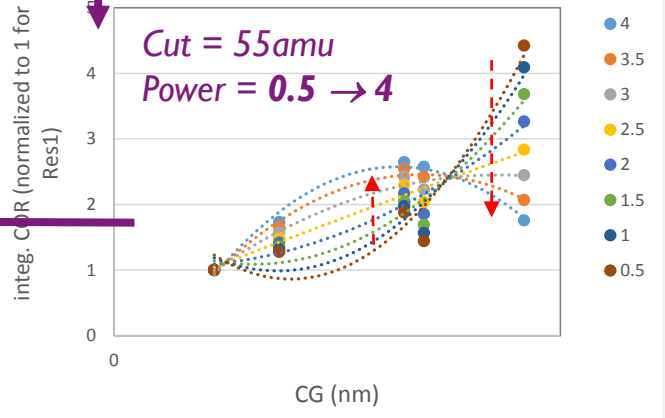
Bad correlation !





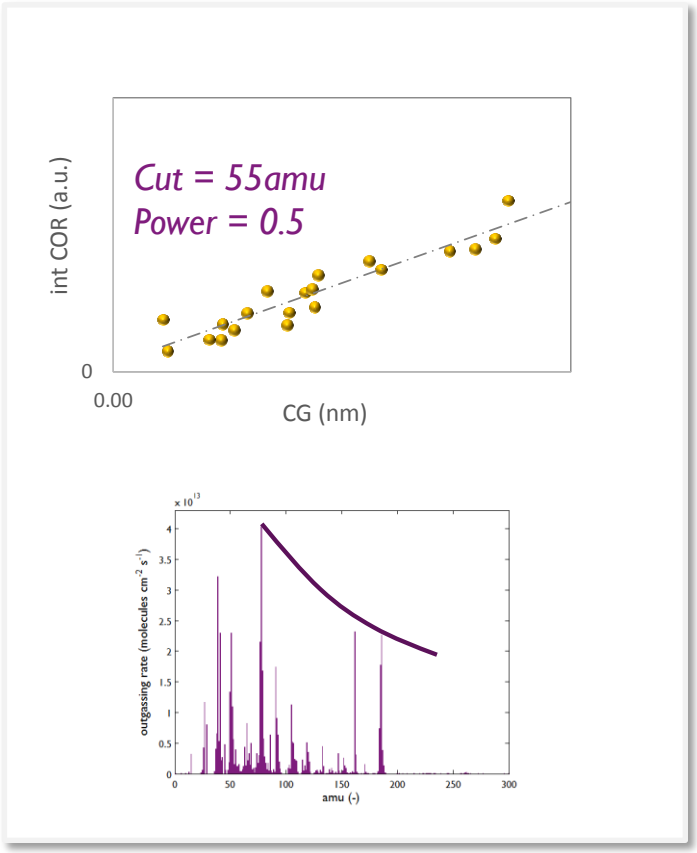
Use quadratic fits to check correlation as function of 'power'



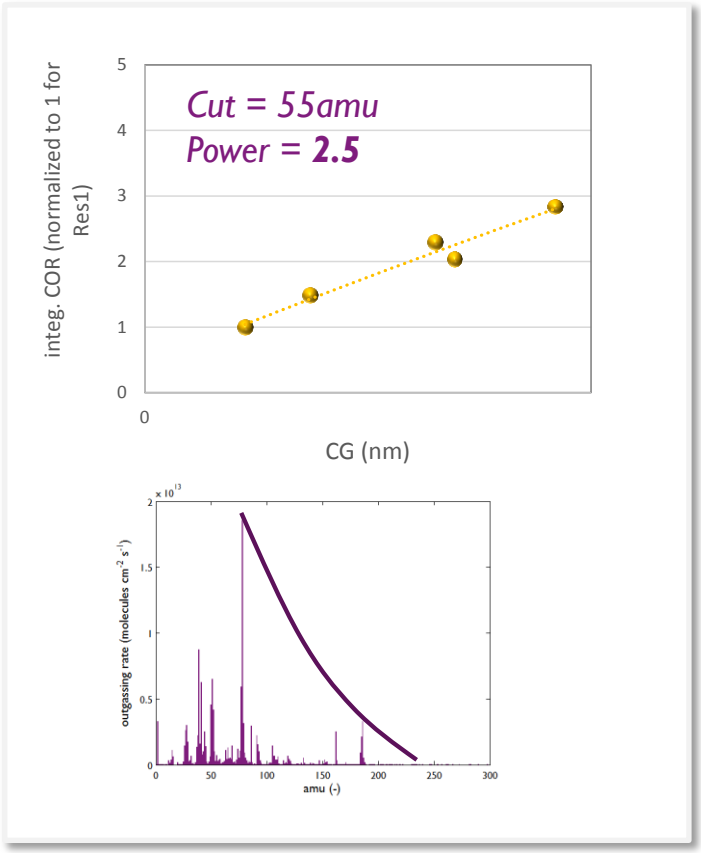


RGA CG CORRELATION AT DIFFERENT SITES ?

imec



EIDEC



Power weight needs to be tuned to compensate the lower detection of peaks at higher amu's

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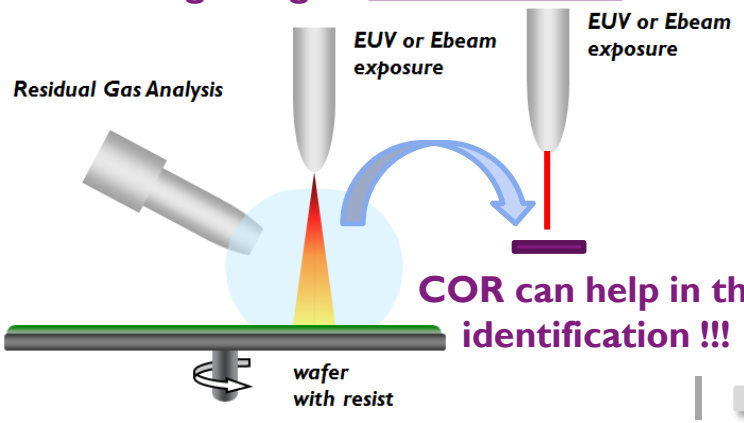
USE OF RGA-CG CORRELATION TO (RR) CG VARIABILITY INVESTIGATION

Is round-robin variability related to variability in outgassing or contamination ???

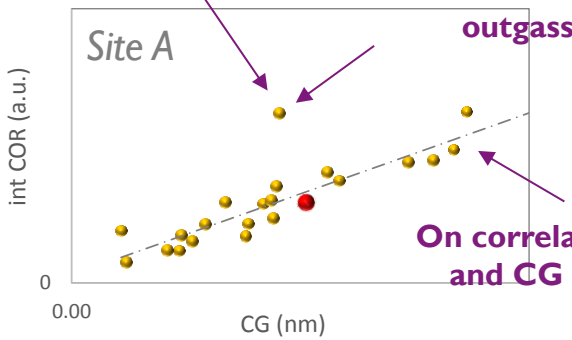


COR can help in this identification !!!

1

Root cause is (very likely) contamination ! (e.g. CLR)

Away from correlation : 'mismatch' between outgassing and CG

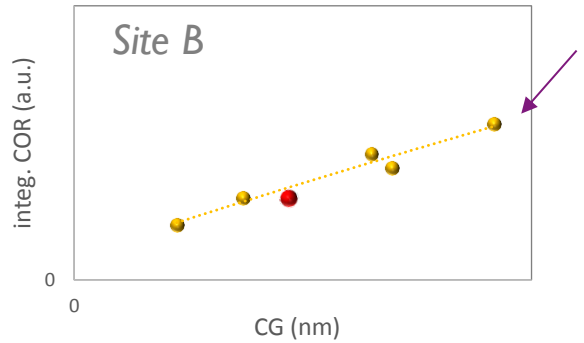


On correlation : outgassing and CG are 'matching'

2

3

On correlation : outgassing and CG are 'matching'

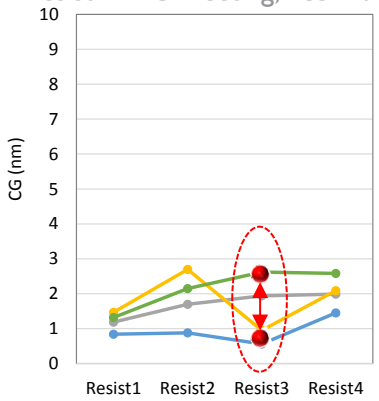


● Example of resist

4

['Round Robin 2' reported at IEUVI Resist TWG meeting, Feb' 2014]

Site-to-site variability



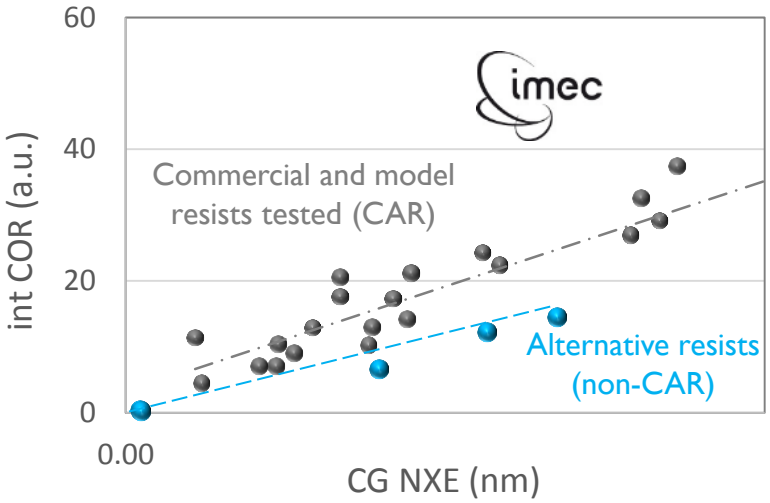
if RGA/CG correlation is observed at both sites :

Root cause is outgassing !

[can still have many sources : dose, PS/A, ...]

USE OF RGA-CG CORRELATION FOR ALTERNATIVE RESIST MATERIALS

Novel inorganic materials have been explored at imec towards outgassing



Outgassing vs. contamination relationship is slightly different compared to CAR.

Low 'cleanable' contamination is feasible.

More investigation is required to check if current outgas test procedure needs to be revised for the alternative materials.

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SUMMARY

In order to decrease the round robin variability between outgas sites, collaborative work is done between the outgas qualification sites in close cooperation with ASML. Control on key parameters such as temperature, CLR, and PS/A has found to be important.

In addition to the contamination growth (CG) from the witness sample testing, benefit has been found in the RGA outgas measurement, where simple analysis can provide complementary information (integrated COR). This RGA parameter is typically correlating very well with CG, and this correlation has been demonstrated on multiple sites.

It is expected that this approach is helpful in identification of within-site and site-to-site excursions of contamination results and help in understanding of contamination processes of advanced photoresists.

ACKNOWLEDGEMENTS

ASML : S. van Pham, G. Rispens, and N. Harned

D. De Simone, and E. Hendrickx (imec) and Resist suppliers for providing resist samples and helpful discussions.

EUV Tech : C. Perera and D. Houser

ASPIRE
INVENT
ACHIEVE

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GLOBALFOUNDRIES intel Micron Panasonic ideas for life SAMSUNG tsmc

SK hynix SONY FUJITSU QUALCOMM