Characterization of EUV resist related outgassing and contamination

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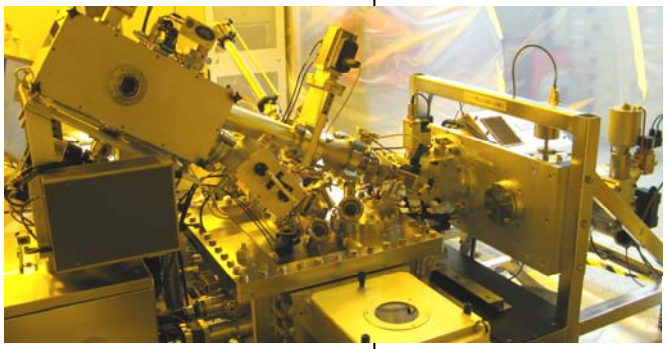
* on internship from INSA, Univ. Lyon (Fr)
** on assignment from Intel Corp. (US)

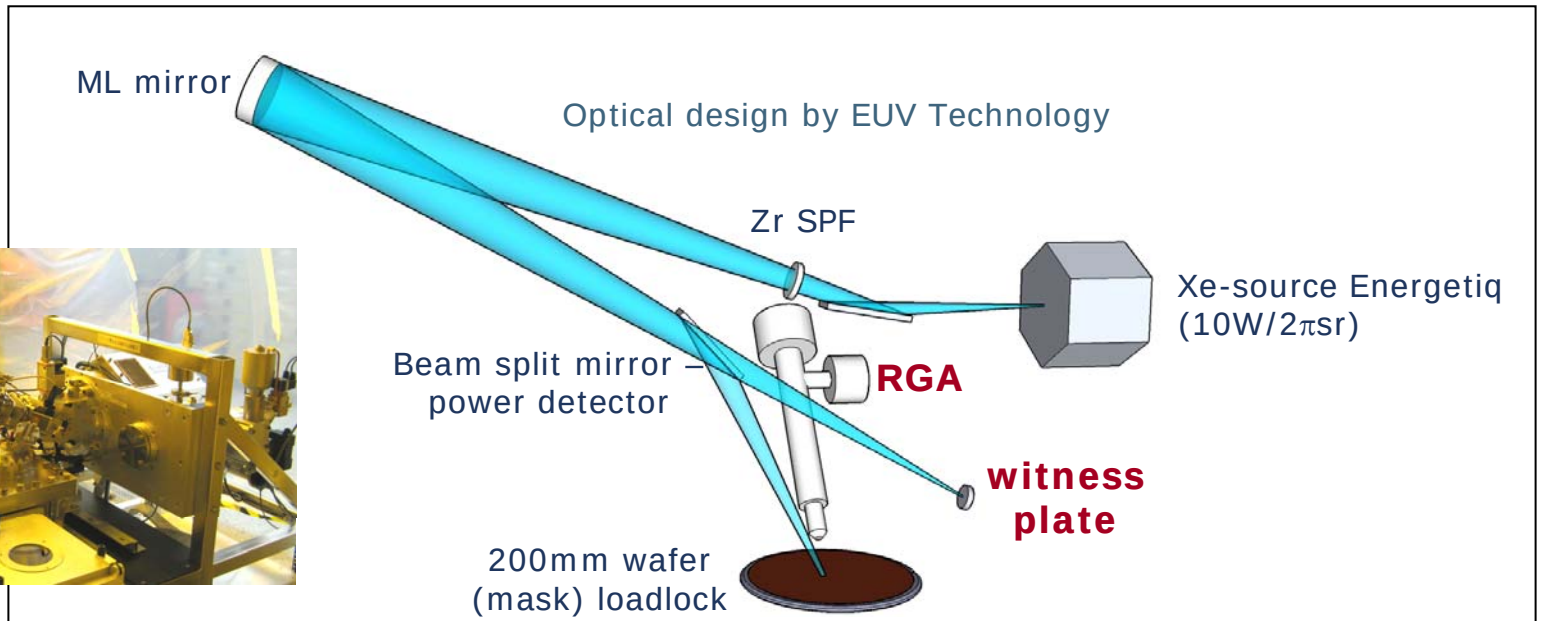
Outline

- Introduction
- Time dependency and post-exposure outgassing
- Identification of outgassing species and implication on outgassing quantification
- Impact of processing on outgassing
- Comparison of outgassing and witness sample testing
- Summary

Introduction

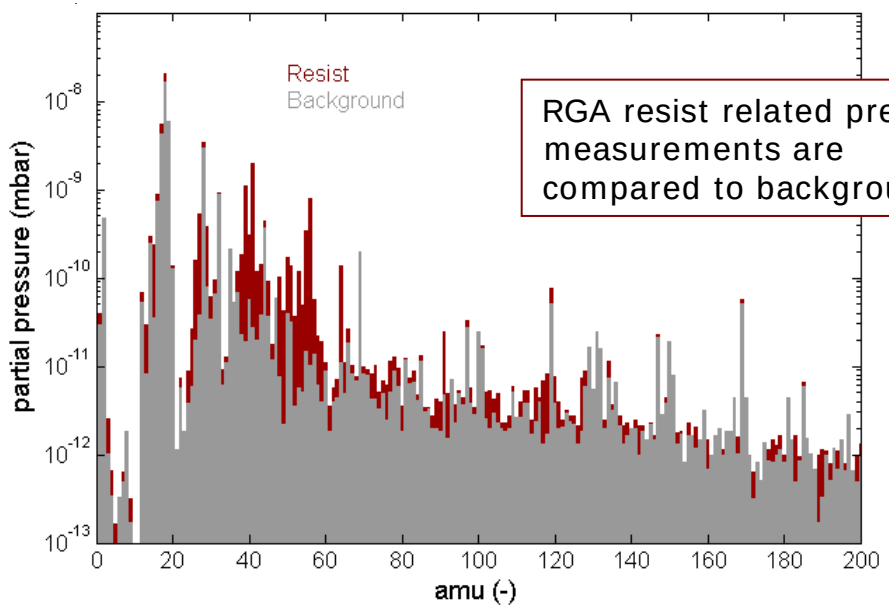
- Set-up from EUV Technology has been introduced in IMEC in Nov'08
  - Investigation of outgassing by Residual Gas Analysis (RGA)
  - Investigation of mirror contamination by witness plate testing



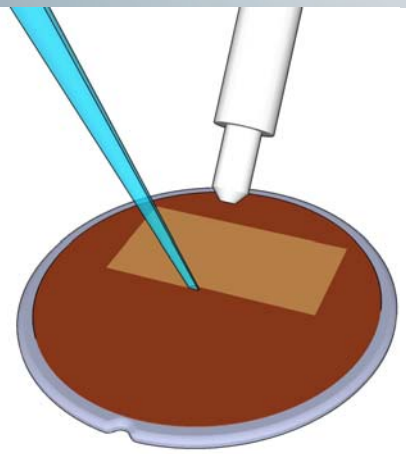


[See also poster 26 R. Perera et al. (EUV Technology)]

RGA for resist outgassing measurement
(Residual Gas Analysis)



RGA resist related pressure measurements are compared to background

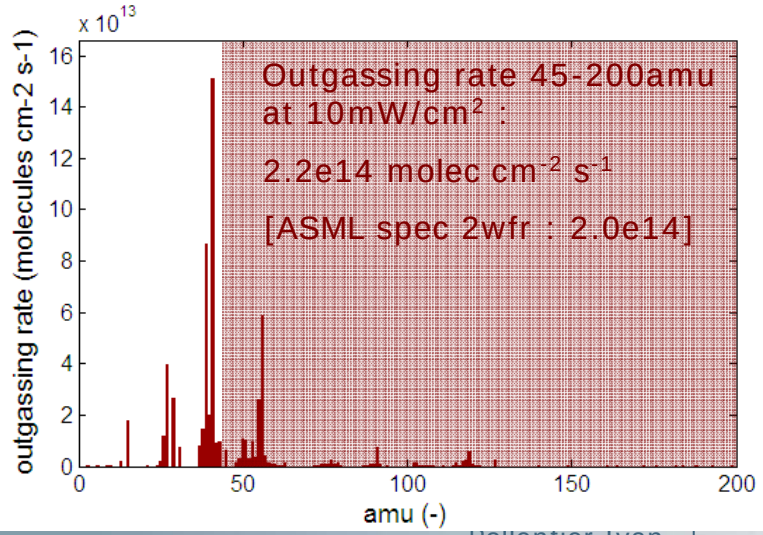


The outgassing rate can be calculated out of partial pressure difference and pumping speed (using calibrated leak with test gas)

Is outgassing measurement result affected by measurement procedure or processing ?

How to identify the outgassing species ?

Is outgassing correlated with witness sample contamination ?



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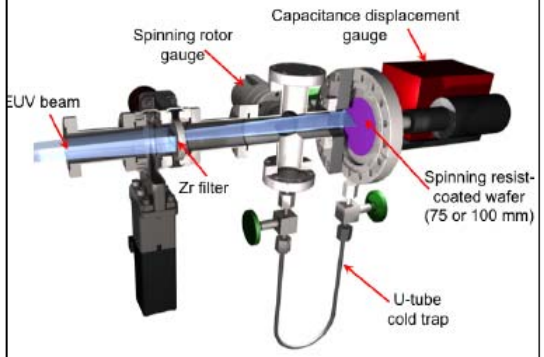
CNSE-NIST-IMEC outgassing comparison

See EUVI Resist TWG Feb2009 :
http://ieuvi.org/TWG/Resist/2009/022609/8-Mbanaso_OS1_outgassing.pdf

Methods adapted to measure outgassing

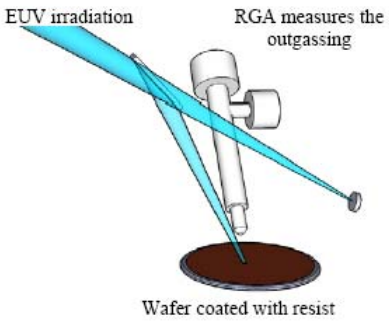
NIST



- CW (synchrotron) source,13.3+/-0.5 nm
- Expose 100 mm wafer to 2.5 x E_o for 10 – 20 minutes.
- Sample Analysis - GCMS with Cryo-focus

~2.5e14

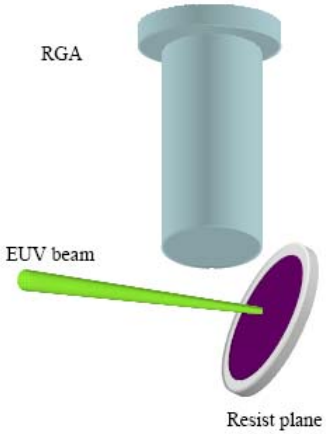
IMEC



- Energetiq EUV source, 13.5 nm ± 1% bandwidth in 2π
- Expose 200 mm wafer at 2.5 x E_o for 1 hour
- Sample Analysis - RGA

~7.3e14

CNSE



- Energetiq EUV source, 13.5 nm ± 1% bandwidth in 2π
- Expose a strip of wafer at 2.5 x E_o for 30 seconds
- Sample Analysis - RGA

~2.5e14

[using R. Brainards' OS1 open source resist]

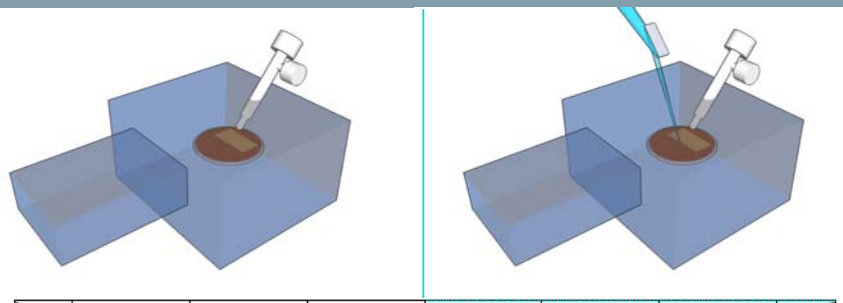
Limited difference between different R&D sites !

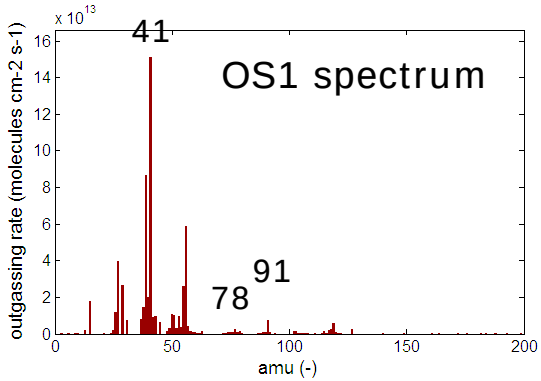
...but can the difference in RGA sampling time be responsible for a difference in outgassing result ?

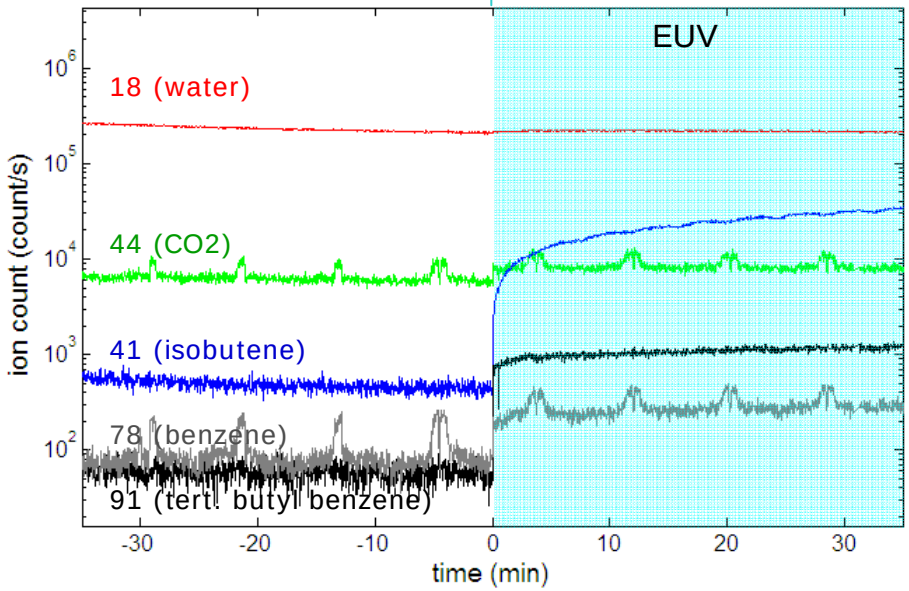
Total outgassing amu1..200 (molec/cm²)

Time dependency

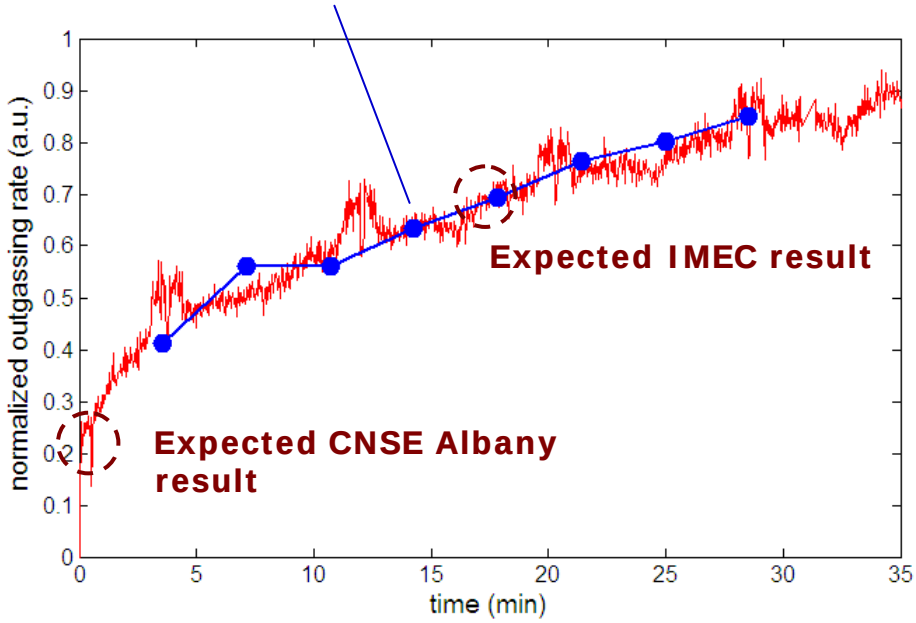
OS1 resist







From full cycles (RGA qualification procedure)



Clear impact by EUV exposure for resist related species

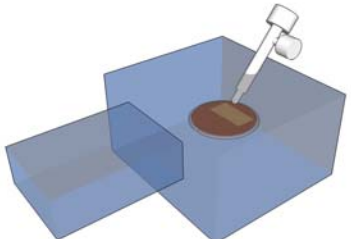
Difference in time dependent behavior at start of EUV exposure

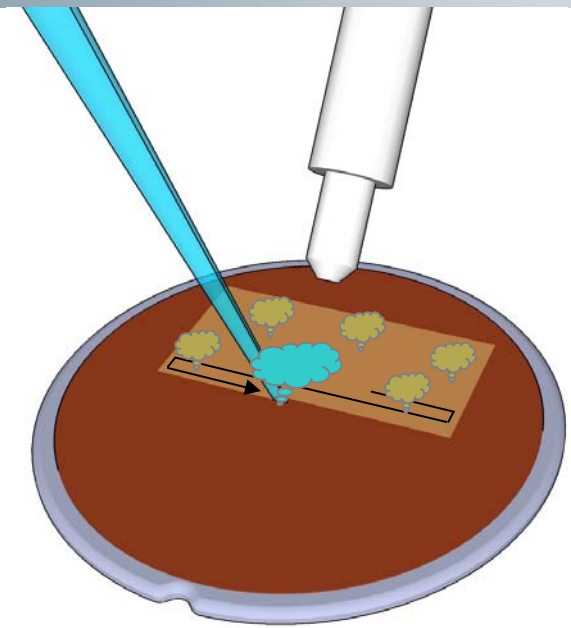
Resist related species continuously increase in time

Because of different time-frame of RGA measurements the outgassing result can change significantly

Time dependency

post-exposure outgassing (using resist F-PMMA UT1)





Measured outgassing is superposition of 'direct' EUV outgassing and post-exposure outgassing

Based on this, the RGA test criterion for 2-wfr exposure on ADT has been increased to 5e14 molec cm^{-2} s^{-1}

Using high outgassing UT1 resist

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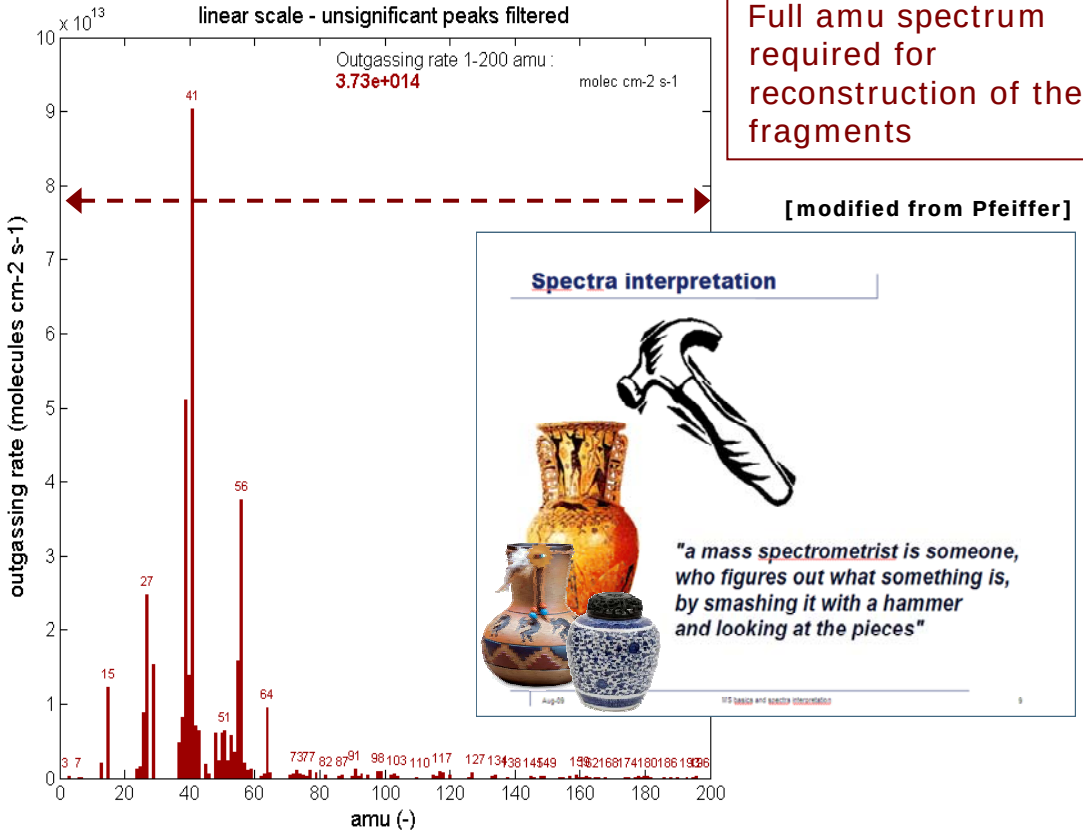
Characterization of resist outgassing by RGA

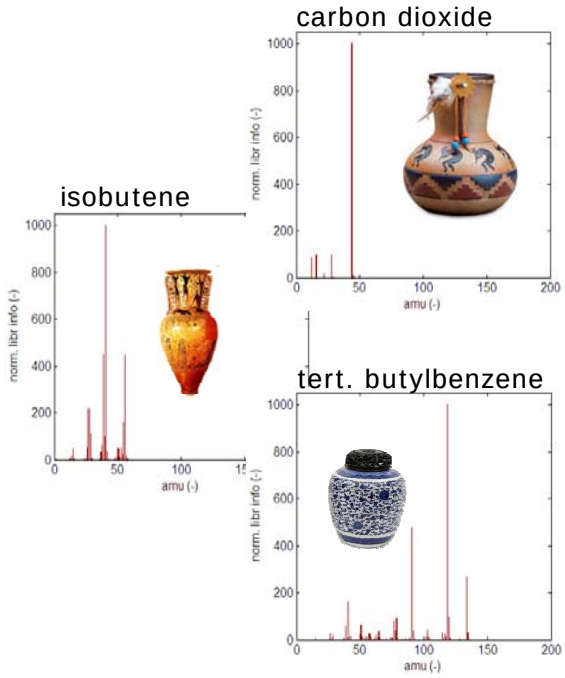
Identification of species



[modified from Pfeiffer]

Full amu spectrum required for reconstruction of the fragments

RGA contains data of fragments of different species

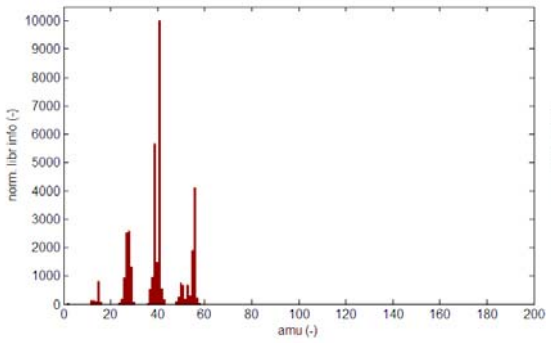


Resist outgassing is superposition of different species, each having a characteristic RGA spectrum

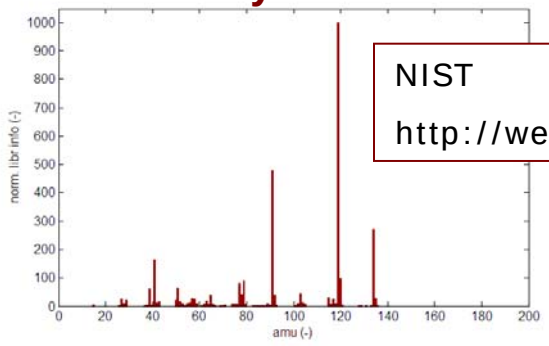
Characterization of resist outgassing by RGA

Identification of species

isobutene



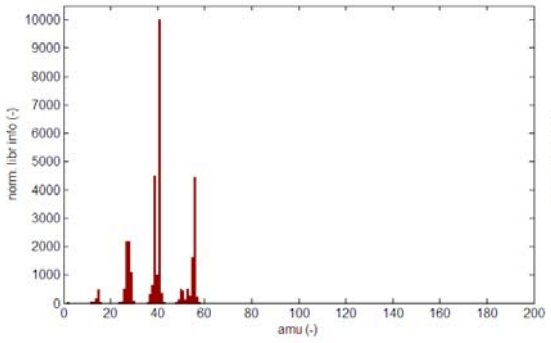
tert. butylbenzene



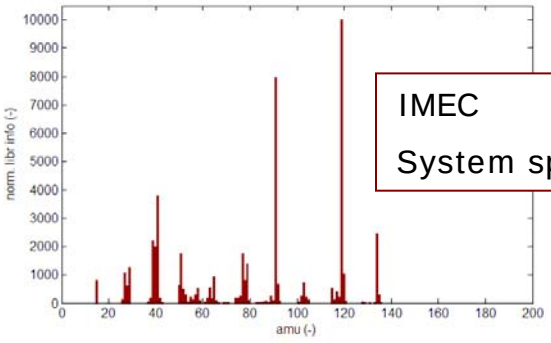
NIST

http://webbook.nist.gov/

isobutene

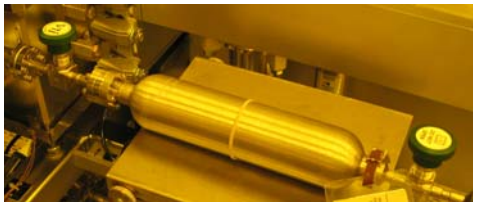


tert. butylbenzene



IMEC

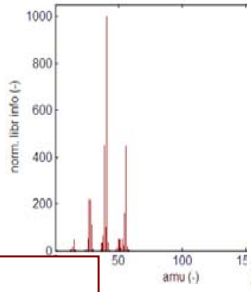
System specific spectrum



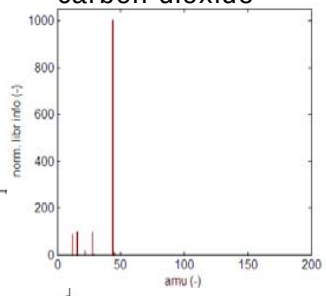
Determine system specific spectra by species (calibrated) leaks

(isobutene, benzene, tert. butylbenzene)

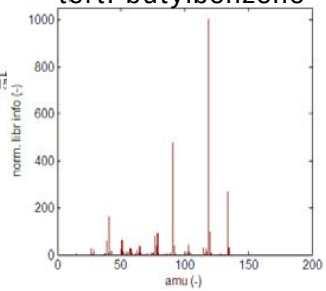
isobutene



carbon dioxide



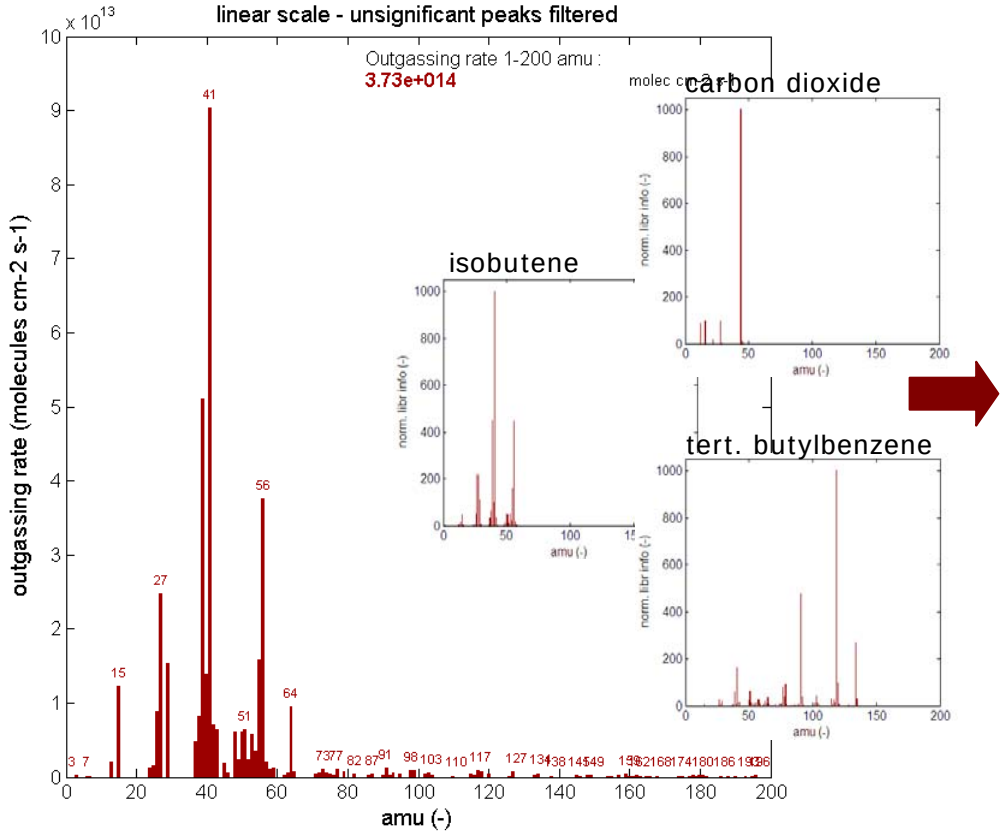
tert. butylbenzene



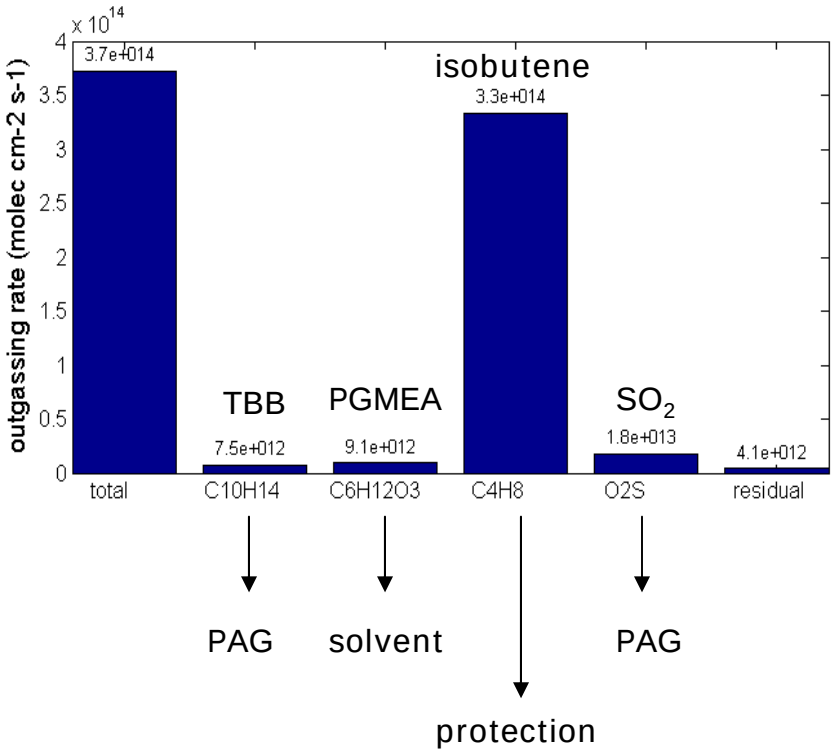
Characterization of resist outgassing by RGA

Identification of species

- Example : MET2D

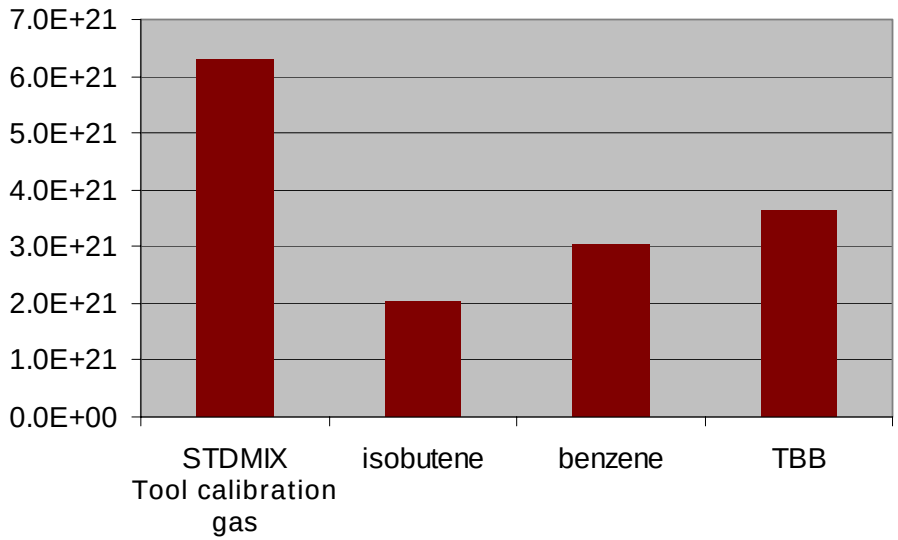


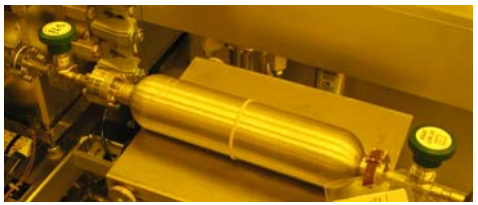
With (basic) knowledge of resist chemistry, it is possible to identify and quantify the individual outgassing components with low unknown residual !



Calibration of outgassing rate

No. of outgassed molecules per mbar partial pressure





Determine RGA response to calibrated leak rate

(isobutene, benzene, tert. butylbenzene)

Partial pressures of species as measured by RGA depend e.g. on species ionization probability, so they represent not always the same number of molecules !

Therefore, once species are identified, the outgassing rate needs to be corrected according to the ratio of the species behavior to the tool calibration gas !

Characterization of outgassing species

Outgassing rate with identified species

- Example : MET2D

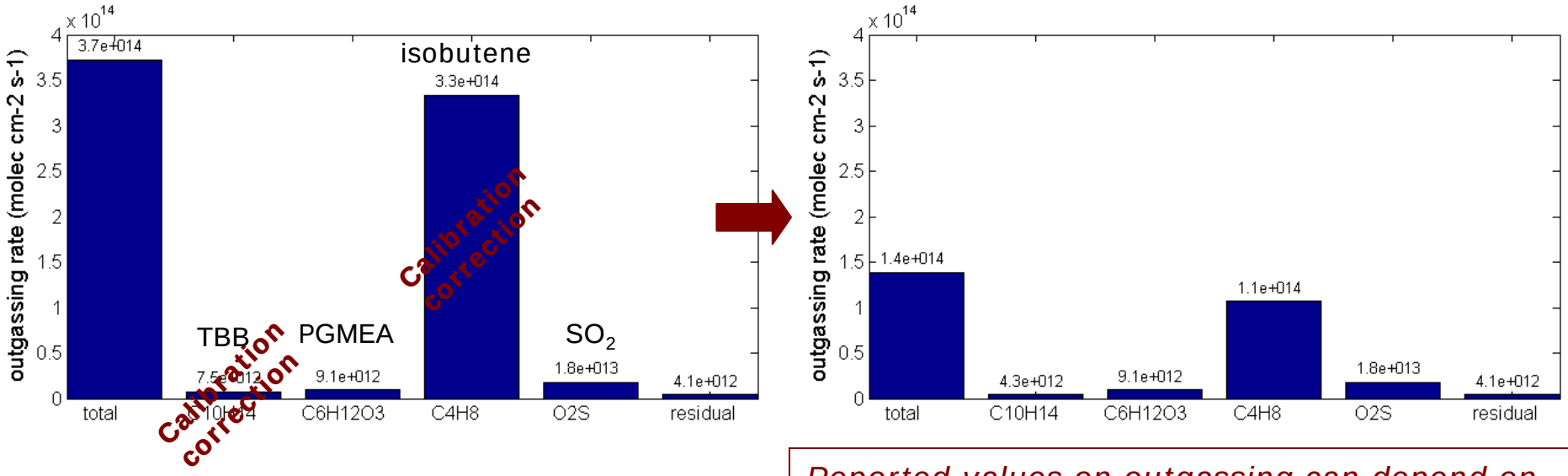
Unidentified OR

= OR(sp 1) + OR(sp 2) + … + OR (sp i)

tert. butylbenzene, PGMEA, isobutene , SO2

Identified OR

= α_1 OR(sp 1) + α_2 OR(sp 2) + … + α_i OR (sp i)



Reported values on outgassing can depend on test gas calibration and species identification

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Impact of processing on outgassing

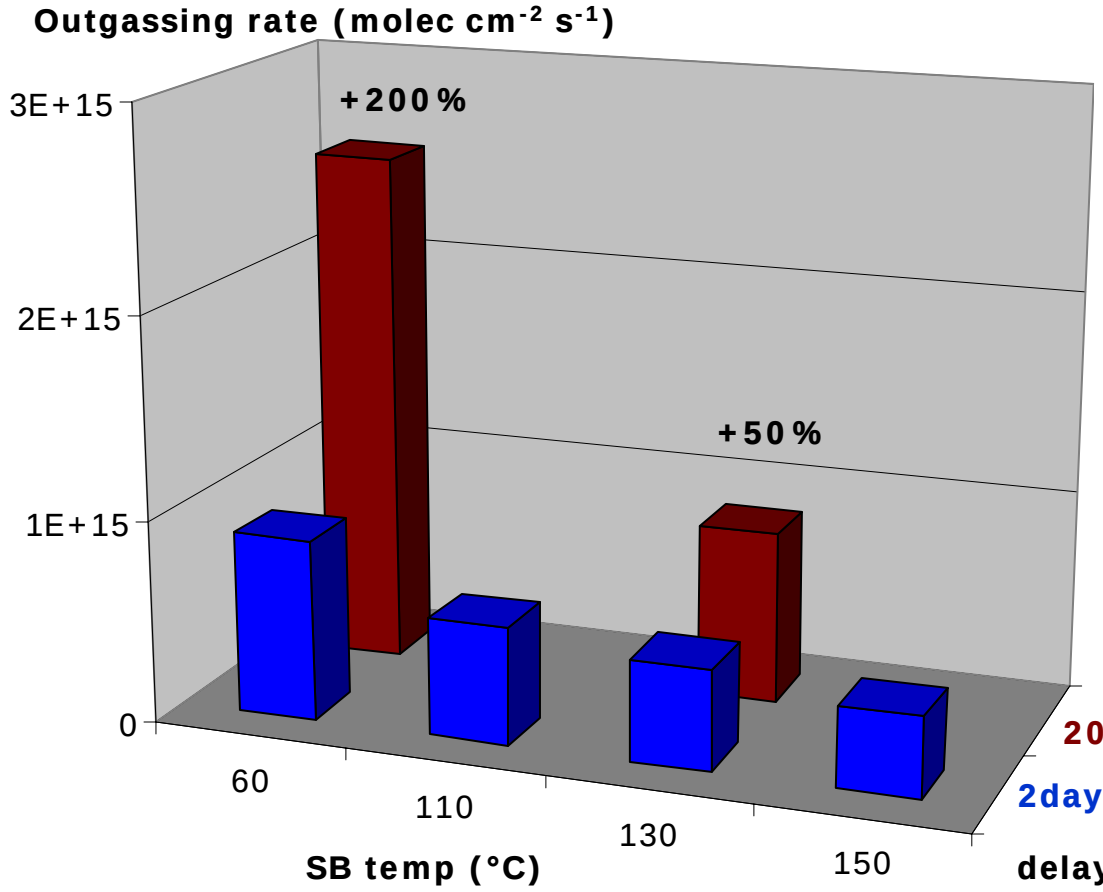
Use case : MET2D softbake/delay

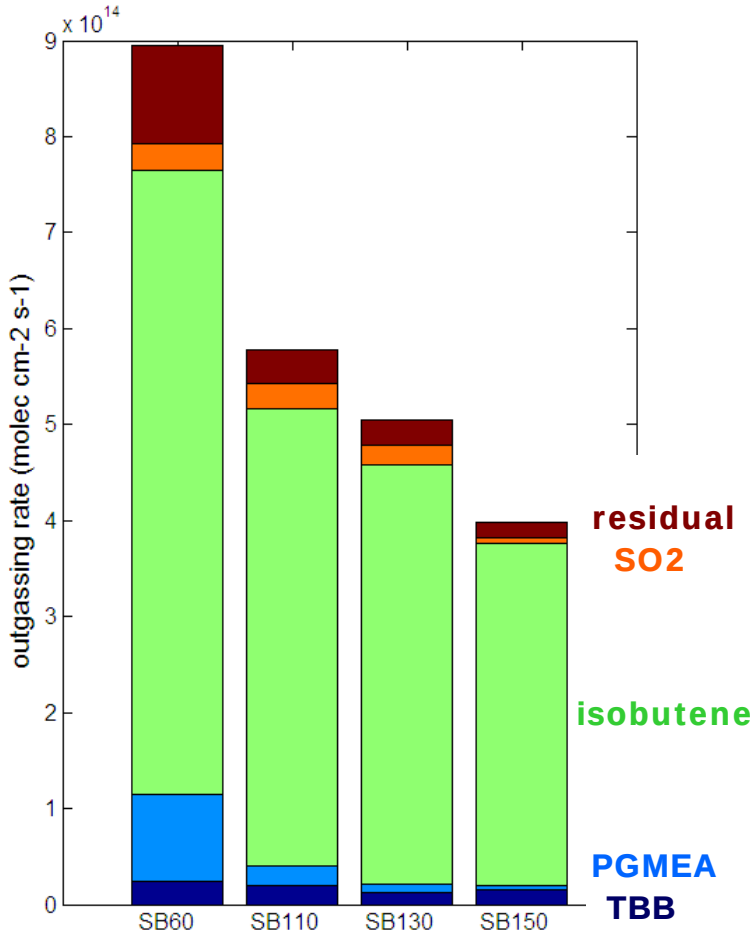
Softbake temperature : 60, 110, **130**, 150 °C

Delay bake-exposure : 2days, 20min

Typical for outgassing testing

Closer to EUV scanner





SB/delay effects can not be ignored in outgassing and contamination testing !

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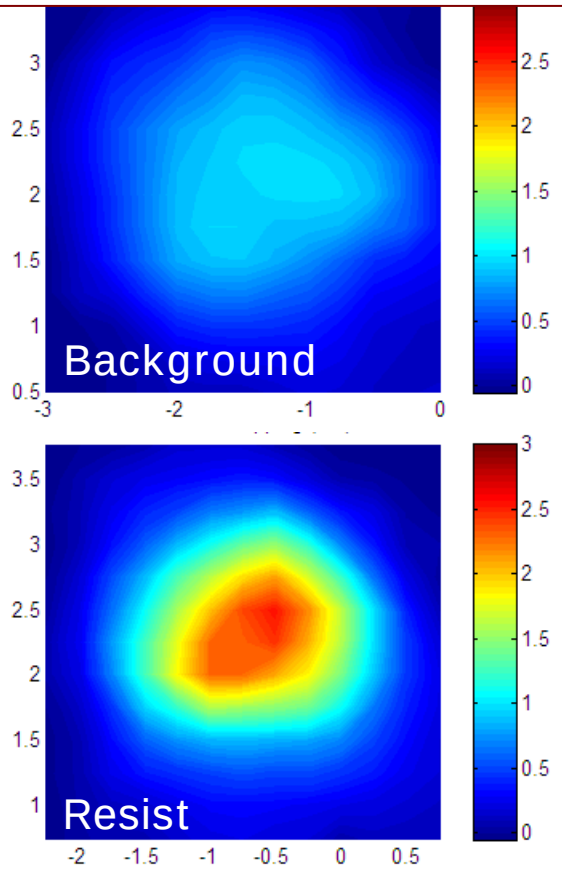
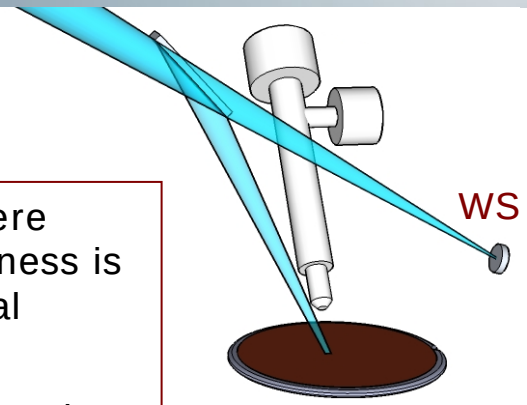
Witness sample (WS) testing

Resist related contamination

WS contamination thickness‡ measured with ellipsometry (nm)



WS exposure during ~100cm^2 wafer exposure at dose 2.5*E_0



WS test procedure developed where resist related contamination thickness is compared to background (identical procedure using Si wafer).

Consistent results were found for various resists.

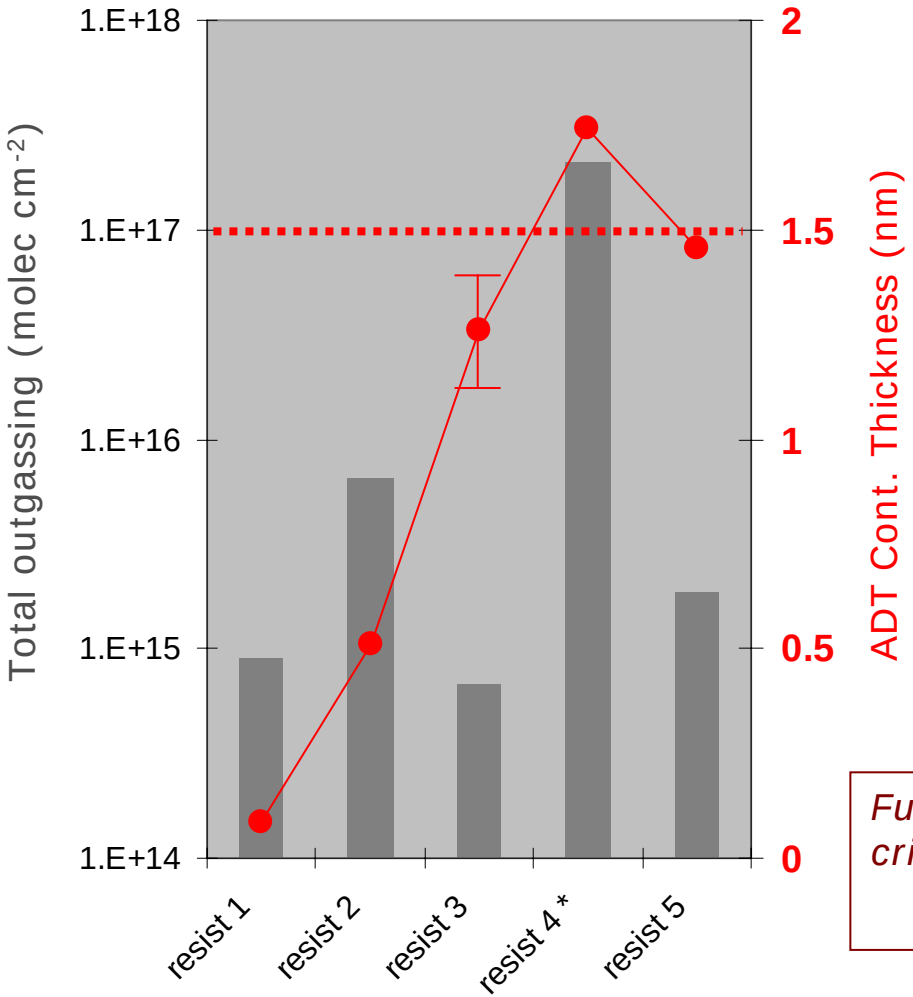
‡ In order to obtain a well defined parameter for contamination thickness which is also applicable to ADT conditions, ASML provided a 'system correlation factor' between the IMEC thickness difference and the corresponding value for ADT :

ADT equivalent contamination thickness =

*system correlation factor * (IMEC thickness diff.)*

Witness sample (WS) testing

Resist related contamination



* Result extrapolated from limited resist exposed area

Five resists tested according to the test procedure.

Significant difference in contamination behavior between 5 tested resists.

Resist induced contamination thickness has no direct correlation with (unidentified) outgassing rate !

Full qualification method for ADT - Pass-fail criterion :

ADT eq. contam. thickness < 1.5nm

[Resist 4 is poly-sulfone based chemistry, see poster 14, K. Lawry et al. (Univ. Queensland)]

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- RGA outgassing measurement has been characterized; it was found that reported values can depend on
  - the time dependent RGA sampling plan with respect to resist exposure (amount of post-exposure outgassing);
  - the used test gas in RGA calibration and whether a correction is applied based on species identification;
  - the resist process conditions, e.g. softbake and coat-exposure delay variations

  All items can result in changes in outgassing result with factor ~1.5-3.

- Witness sample (WS) testing
  - No direct correlation found between RGA outgassing and WS contamination, therefore information on species identification and species contamination probability is required to predict contamination from outgassing results;
  - Agreement with ASML to use WS testing for full resist outgassing qualification.

Acknowledgements :

K. Lawry (UQ), Resist suppliers and affiliates, A. Lin (Powerchip), F. Linskens (RHEM), J. Steinhoff (ASML), J. Van Dijk (ASML), N. Harned (ASML), K. Feenstra (ASML), G. Denbeaux (NCSE), G. Claeys, M. Baklanov, R. Perera (EUVT), D. Houser (EUVT).


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