Comparison of Resist Out-gassing Testing with EUV and E-gun exposure; RGA and WS

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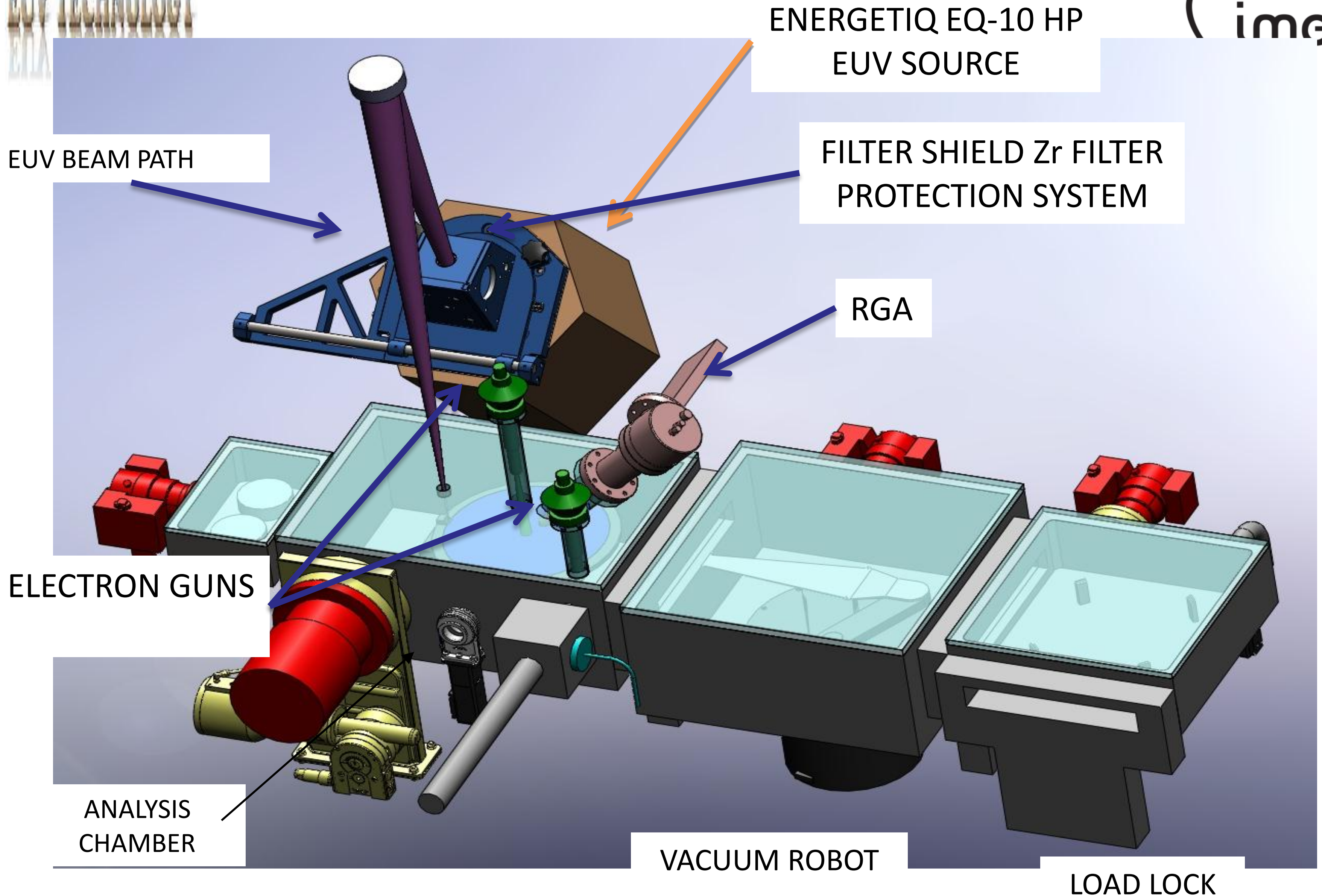
OUTLINE

- Introduction
- Comparison of Dose-to-Clear (E0) for EUV and Egun exposures
- Comparison of resist outgassing and WS contamination by EUV and Egun
- Conclusions



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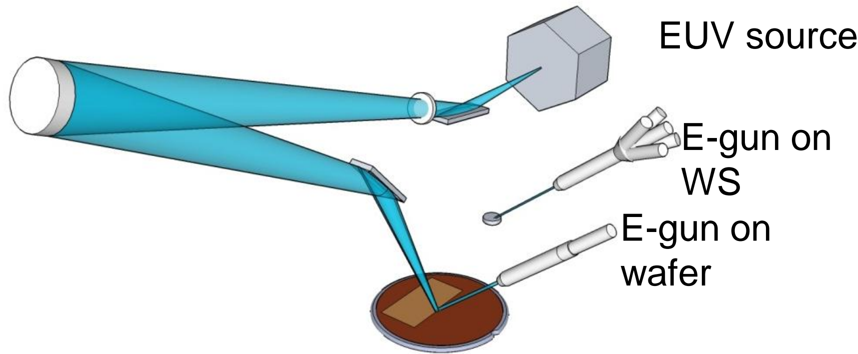
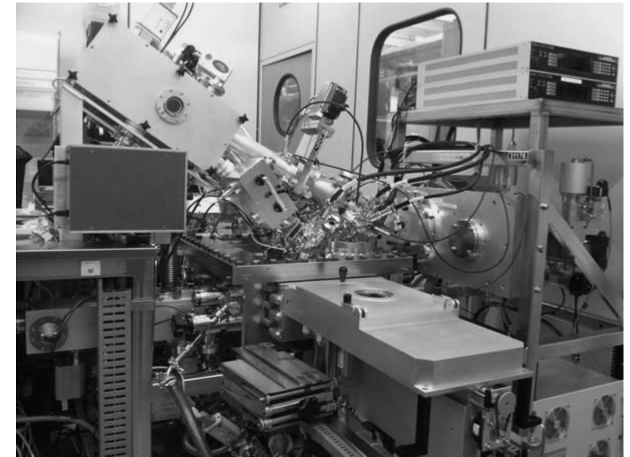
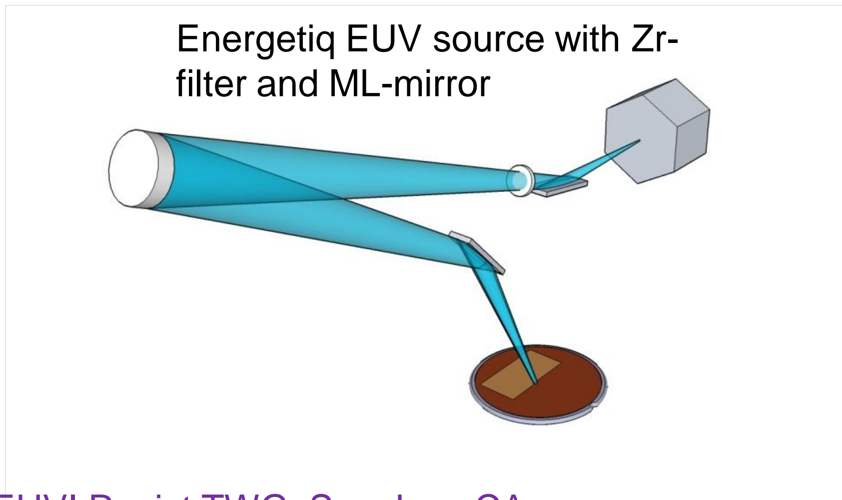
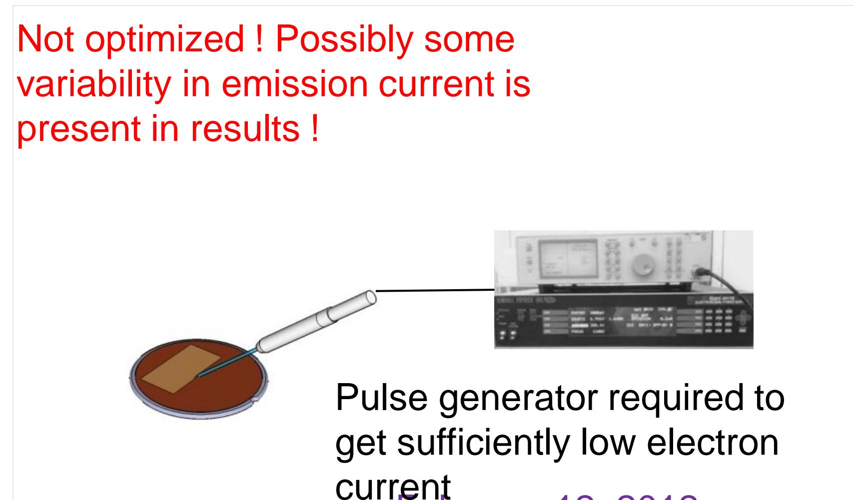
- Experimental set-up









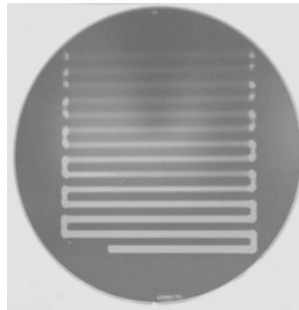
DOSE-TO-CLEAR (E_0)

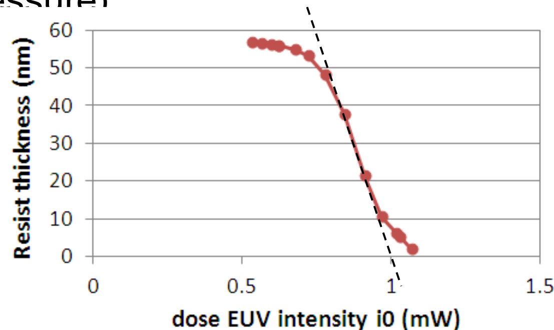
- Dose-to-clear (E_0) determination by meander exposure
  - From line to line the exposure dose is increased
  - Resist thickness of each line is measured by ellipsometry

Examples

EUV
(reference)

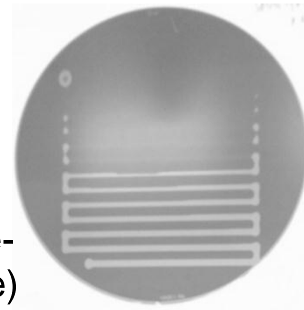
Dose change by Energetiq source intensity change (Xe-pressure)

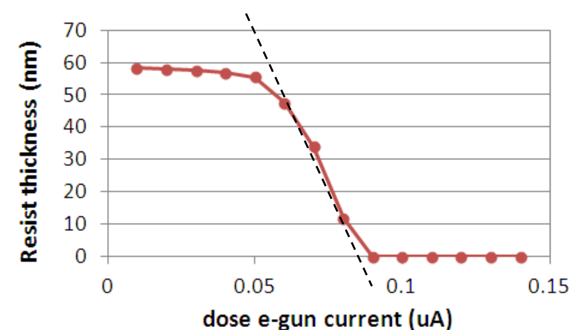




E-gun
(focus is adjusted to have similar spot size)

Dose change by change in e-gun current (pulse duty cycle)

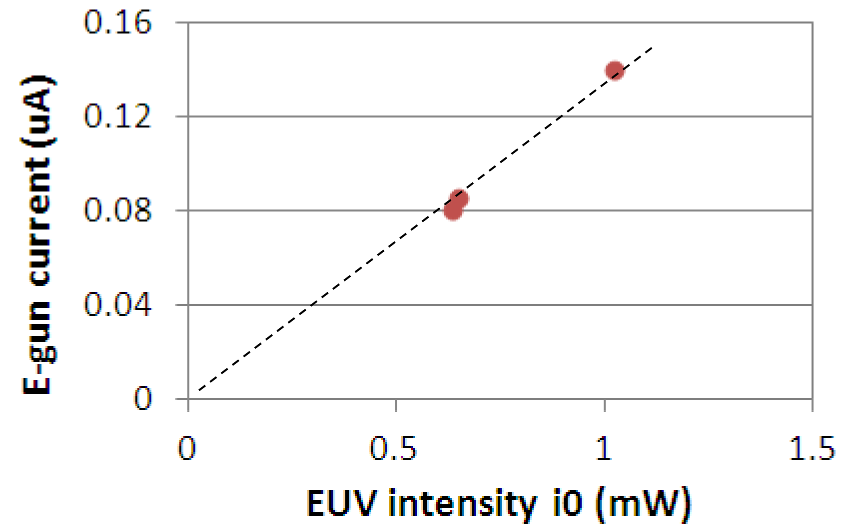




Close setpoint for E0 exposure can be obtained in both cases

DOSE-TO-CLEAR (E_0)

	EUV (mW)	Egun (uA) (at 2keV)
Resist1	0.65	0.085
Resist2	1.02	0.14
Resist3	0.634	0.08

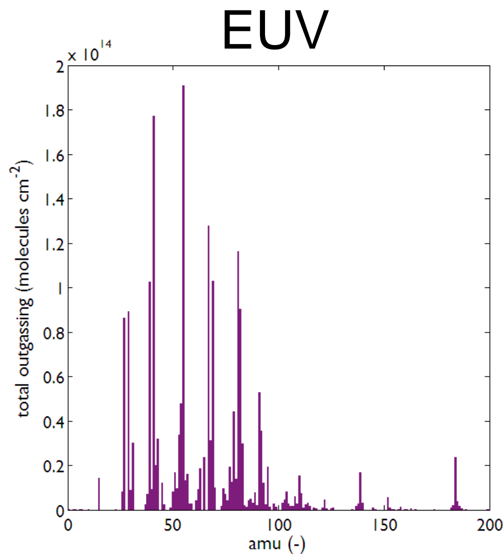


Good correlation of E_0 results between the 3 tested resists !

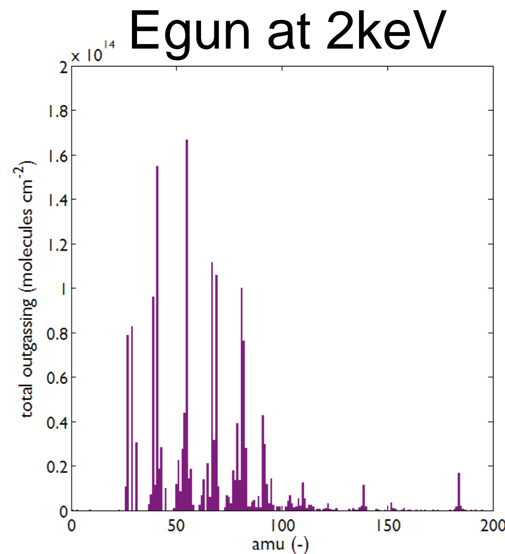
RGA OUTGASSING COMPARISON

- Resist 1

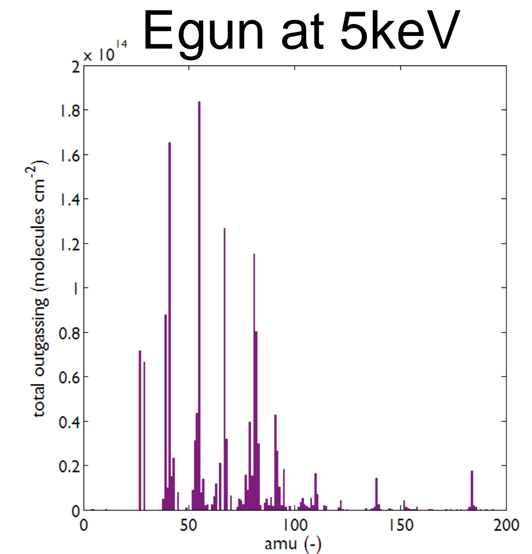
EUV



Egun at 2keV



Egun at 5keV



The RGA outgas spectrum is very similar; this means the same outgassing species are present in the outgassing and in same relative contribution. The mganitude of outgassing is slightly different, which can be caused by slight differences in dose control.

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RGA OUTGASSING: RESIST 1

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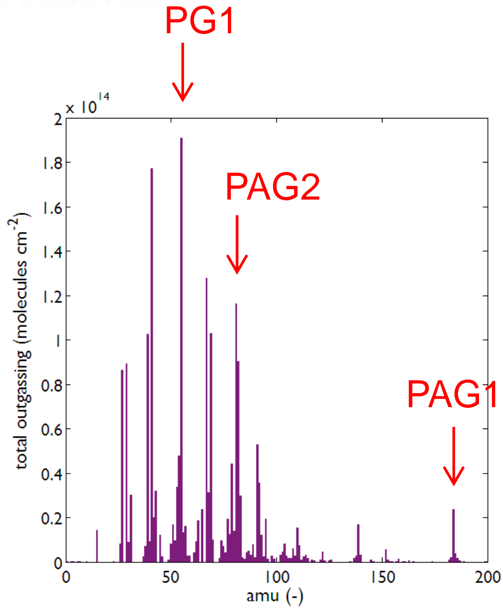
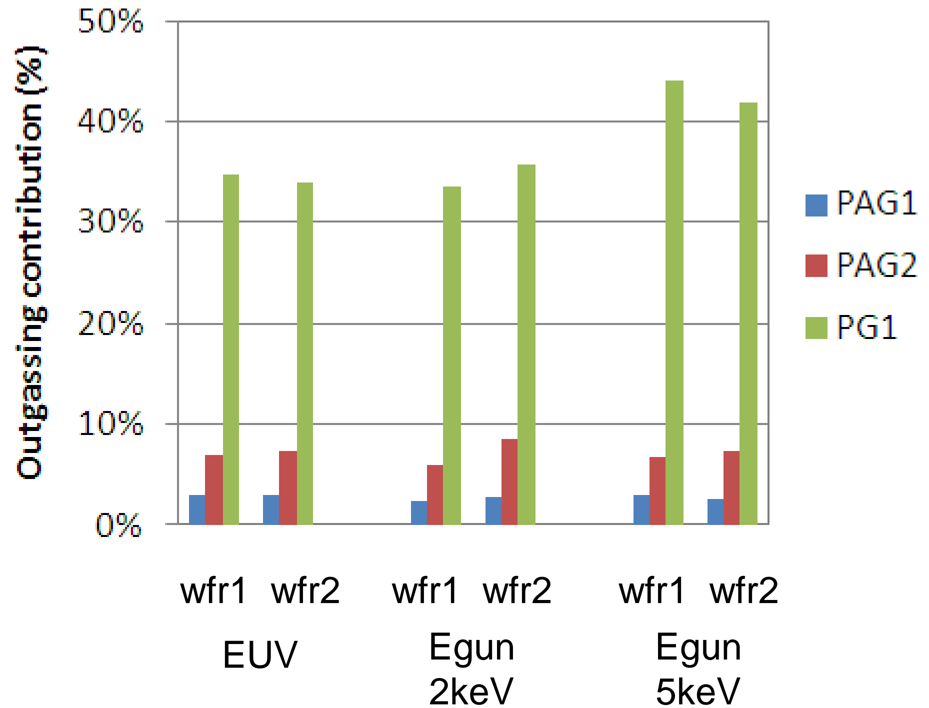


From the RGA spectrum of resist 1 some species can be identified, e.g. species related to PAG (Photo acid generator) or PG (protection groups).



The contribution of the identified species PAG1, PAG2, and PG1, are compared towards the total outgassing. Over-all this confirms that a very similar composition of outgassing is obtained both for EUV and Egun exposure.

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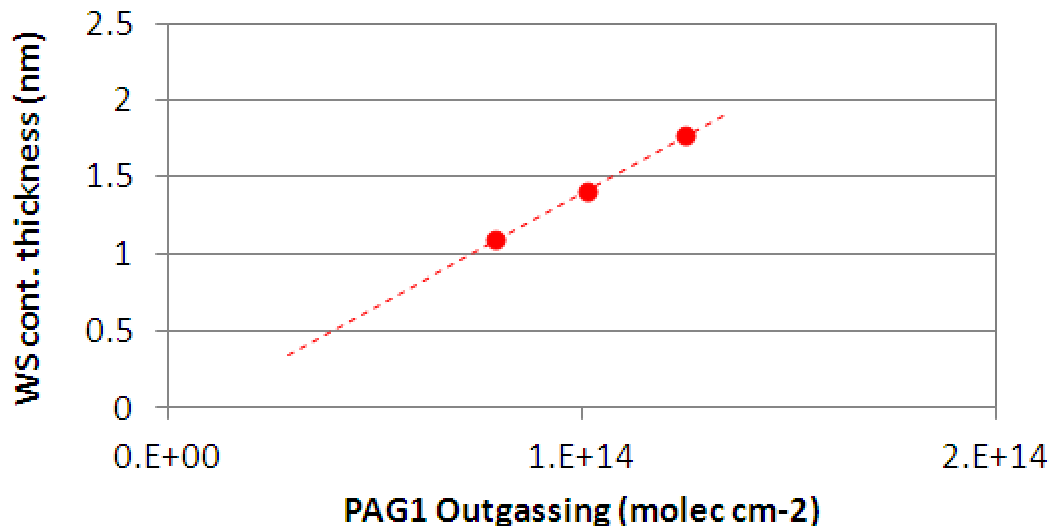
Resist 1

WS testing

imec

	Total outgassing	PAG1	WS cont. (nm)
EUV	4.20E+15	1.25E+14	1.77
Egun 2keV	3.10E+15	7.90E+13	1.09
Egun 5keV	3.70E+15	1.01E+14	1.4

Differences in WS contamination are observed. It is believed that these changes are mainly due to changes in dose (less good control for Egun exposures). For this resist it is known that the WS contamination is determined by the PAG1 outgassing species.



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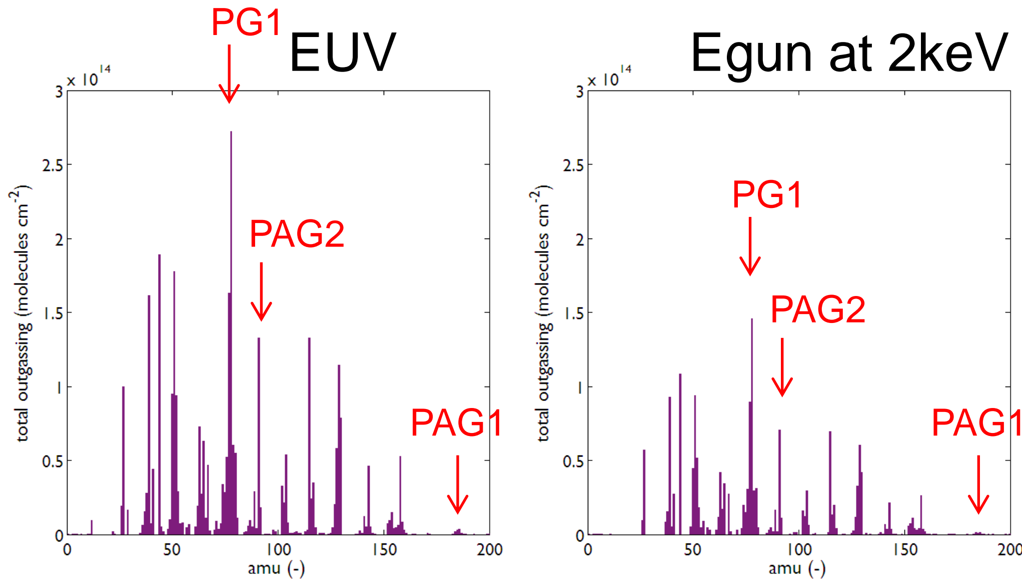
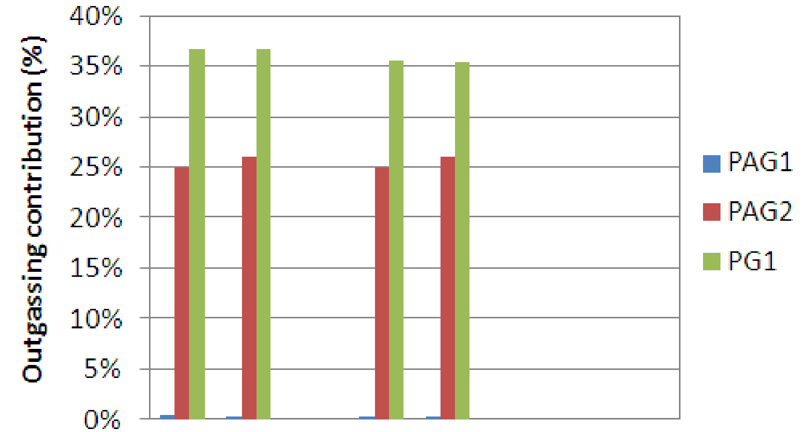
RGA OUTGASSING COMPARISON: RESIST 2





	PG1	PAG2	PAG1	WS cont. (nm)
EUV	2.20E+15	1.53E+15	2.20E+13	3.2
Egun 2keV	1.10E+15	7.90E+14	1.02E+13	1.44

Similar conclusions can be drawn for Resist 2. The composition of the outgassing is quasi-identical, but the magnitude is different due to differences in dose control (it was verified by resist development after testing that Egun exposed with less dose than EUV.

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Summary

- Resist outgassing and contamination has been compared towards wfr exposure by EUV and Egun; Dose control with egun was found to be difficult using the present set-up(can be solved by more optimized pulse generator)
- Dose-to-clear exposure results are very consistent for different resists.
- Outgassing is very similar in species and composition. Changes in amplitude could be due to variability in dose control.
- WS test results are consistent with the outgassing results in the PAG region.

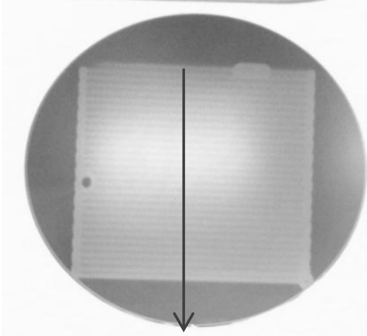
POSSIBLE DOSE VARIATIONS

- Additional measurements to clarify more the possible dose variations.
- Measurement of the remaining resist thickness after development the resist wafers after WS testing

NOTES ON DOSE CONTROL

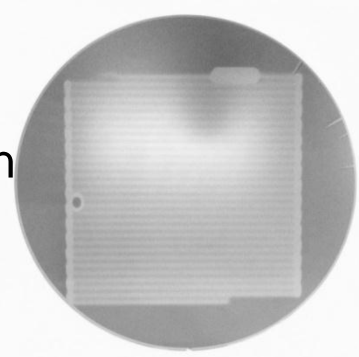
Resist1

E-gun 2keV

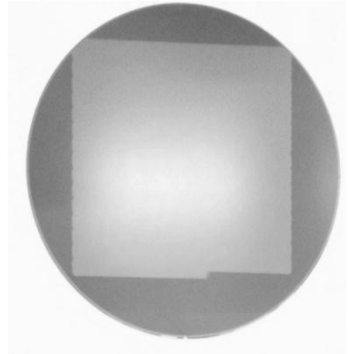


resist developmen t after WS test

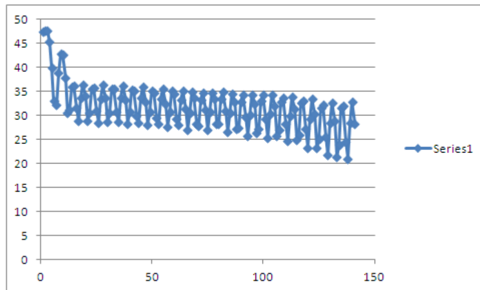
E-gun 5keV

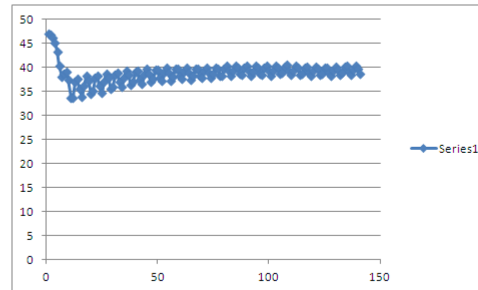


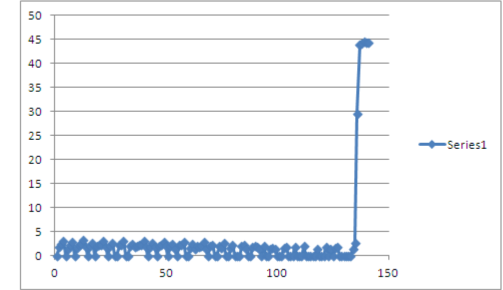
EUV



Ellipsometer measurement scan along exposed area (see picture)







In case of E-gun the resist is not fully developed in the exposed regions (despite that dose was matched well by the E0 contrast curves).

Possible reasons : Exposure beam spot still slightly smaller; non-uniformity of beam (E-gun beam more Gaussion, while EUV beam is more uniform).

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Dose control correction

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Average resist thickness (nm)	30.8
Estimated dose compared to E0	64.2%
Esitimated dose compared to EUV WS	65.2%

Average resist thickness (nm)	38.6
Estimated dose compared to E0	58.6%
Esitimated dose compared to EUV WS	59.5%

Average resist thickness (nm)	1.2
Estimated dose compared to E0	98.5%
Esitimated dose compared to EUV WS	100%

With this, the WS cont. thicknesses previously determined could be scaled in first approximation :

	Total outgassing	PAG1	WS cont. (nm)	
EUV	4.20E+15	1.25E+14	1.77	
Egun 2keV	3.10E+15	7.90E+13	1.09	-> x 1/0.65 = 1.68
Egun 5keV	3.70E+15	1.01E+14	1.4	-> x 1/0.60 = 2.33

With this scaling, the value for E-gun 2keV comes close to that of EUV, however the scaled value for E-gun 5keV is significantly different. So possibly, there might be an intrinsic difference between contamination levels when the exposure is done at different energies (to be investigated)

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Resist2

NOTES ON DOSE CONTROL

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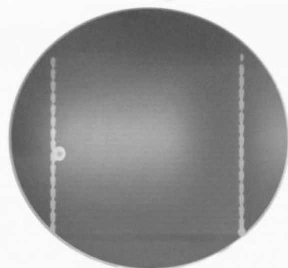
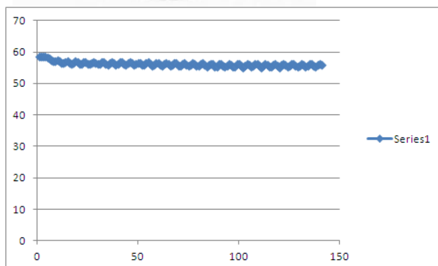
resist development after WS test

E-gun 2keV

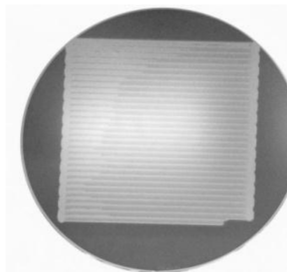


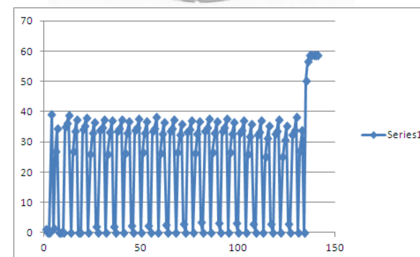


Average resist thickness (nm)	56.1
Estimated dose compared to E0	57.1%
Esitimated dose compared to EUV WS	62.7%

resist development after WS test

EUV





Average resist thickness (nm)	21.8
Estimated dose compared to E0	91%
Esitimated dose compared to EUV WS	100%

	PG1	PAG2	PAG1	WS cont. (nm)
EUV	2.20E+15	1.53E+15	2.20E+13	3.2
Egun 2keV	1.10E+15	7.90E+14	1.02E+13	1.44

-> x 1/0.63 = 2.29

Still large difference; E-gun at 2keV seems to give a lower contamination result than EUV

Summary on these dose notes

- Taking into account the calculated dose difference, part of the differences between EUV and E-gun WS test results can be explained, but not fully...

Advantages of using 13.5 nm photons over electrons

- The EUVL stepper uses photons
- True dose to clear exposure.
- Non destructive.
  - Only detect photo-induced decomposition.
- Represent bulk properties.
  - Not sensitive to surface contamination.

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Filament Based H2 Radical Cleaner for EUV Resist Testing

(Based on NIST design)

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Design Specifications

- Filament temperature:1850 to 2000 C
  - Calibrated to filament current
  - Filament always under vacuum
- H2 flow: 500 SCCM (max)
- H2 pressure: 20 mbar (max)
- Sample temperature: 60 C (max)
  - Thermocouple
- Fully automated user friendly operation
  - Except loading and unloading WS

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EUV TECHNOLOGY

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H2 Flow Control

MFC to control the H2 flow

Another MFC to control the N2 flow.

Diluted to 1% by volume before exhausting.

Interlocked so that H2 will not flow if there is not sufficient N2 flow to dilute the H2

Installed at Imec Feb 8, 2012

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- James Underwood, Senn Ly and Dave Houser (EUV Technology)
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Thank You

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