UPDATE ON RESIST OUTGASSING QUALIFICATION TOWARDS NXE3100

I. POLLENTIER, R. LOKASANI, AND R. GRONHEID

EUV OUTGASSING

Status of resist outgassing qualification set-up for NXE3100

Related work towards understanding how qualification results can be affected :

- Resist process conditions
- Resist vs. stack materials
- EUV vs. E-gun exposure on resist

© IMEC 2012

EUV OUTGASSING

Status of resist outgassing qualification set-up for NXE3100

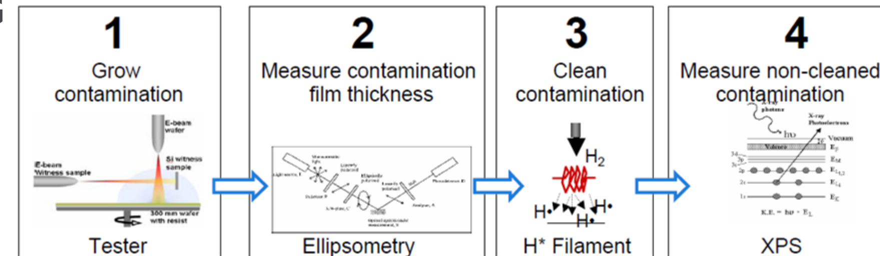
Related work towards understanding how qualification results can be affected :

- Resist process conditions
- Resist vs. stack materials
- EUV vs. E-gun exposure on resist

imec

Outgassing qualification for NXE3100

Status last TWG meeting

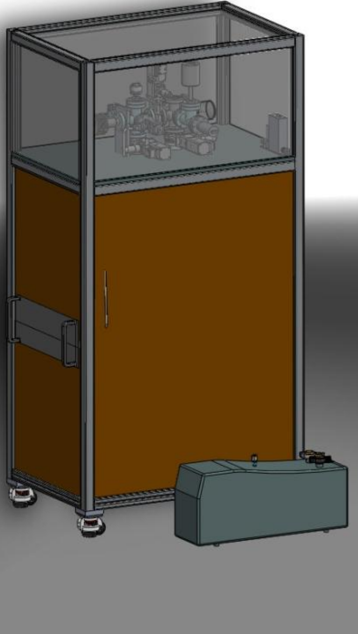


Data package		Data description
1 Facilities	a	Specification resist processing (uniformity and repro)
	b	Specification ellipsometer
	c	Ellipsometry C or SiO2 on Si sample (fixed thickness cross ref)
	d	Ellipsometry Si/Ru/C peak sample
	e	Specification XPS
	f	XPS 3-layer sample (SiN/TiN/SiN)
	g	XPS Si / Ru / cleaned contamination ASML refence sample
2 Vacuum	a	RGA spectrum of ultra clean vacuum with
	b	Pumping speed data of calibration mixture
Functionality	a	Witness sample e-beam stability data
	b	Wafer e-beam or photon stability data
3 Cleaning	a	Cleaning process conditions
	b	Sample temperature profile as a results of duty cycle
	c	Cleaning background contribution
4 Qualification tests	a	Contrast curve of specified resist to determine D2C
	b	D2C exposure W2W reproducibility
	c	D2C exposure within wafer uniformity
	d	Exposed area and test timing contamination growth test
	e	Reproducibilty of contamination growth exposure
	f	Contamination grown from background (total thickness)
	g	Contamination grown from background (content)
5 Calibration	a	Check outgassing limited contamination growth (bleeding tests)
	b	Calibration exposures (4 resists preferred)

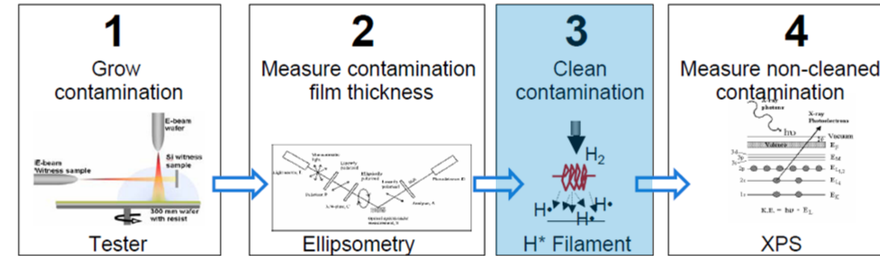
Most items are OK, except those that require WS cleaning...

© IMEC 2012

OUTGASSING QUALIFICATION FOR NXE3100



WS cleaner



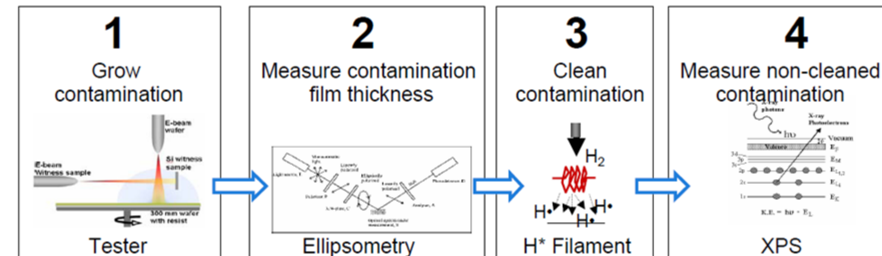
Oct'2011 : Design of WS cleaner by EUV Technology ready

3 Cleaning	a	Cleaning process conditions
	b	Sample temperature profile as a results of duty cycle
	c	Cleaning background contribution

Dec'2011 : First testing of WS cleaner at factory site; slight modifications were preferred.
Jan'2012 : Modifications implemented and shipment to imec; install ongoing

OUTGASSING QUALIFICATION FOR NXE3100

STATUS & SUMMARY



Data package		Data description
1 Facilities	a	Specification resist proces
	b	Specification ellipsometer
	c	Ellipsometry C or SiO2 on
	d	Ellipsometry Si/Ru/C peak
	e	Specification XPS
	f	XPS 3-layer sample (SiN/
	g	XPS Si / Ru / cleaned cont
2 Vacuum	a	RGA spectrum of ultra clea
	b	Pumping speed data of ca
Functionality	a	Witness sample e-beam s
	b	Wafer e-beam or photon s
3 Cleaning	a	Cleaning process conditior
	b	Sample temperature profil
	c	Cleaning background cont
4 Qualification tests	a	Contrast curve of specified
	b	D2C exposure W2W repro
	c	D2C exposure within wafe
	d	Exposed area and test tim
	e	Reproducibilty of contamin
	f	Contamination grown from
	g	Contamination grown from background (content)
5 Calibration	a	Check outgassing limited contamination growth (bleeding tests)
	b	Calibration exposures (4 resists preferred)

Now the H-cleaner is at imec, it is expected that good progress will be made towards NXE outgas qualification :

-H-cleaner process set-up : ~end February

-Full NXE outgas qualification : ~end March

Capacity is still expected to be ~5 samples/wk (limited by XPS)

Capacity for contamination growth ('cleanable contamination') will be 2x higher

EUV OUTGASSING

Status of resist outgassing qualification set-up for NXE3100

Related work towards understanding how qualification results can be affected :

- Resist process conditions
- Resist vs. stack materials
- EUV vs. E-gun exposure on resist

imec

© IMEC 2012

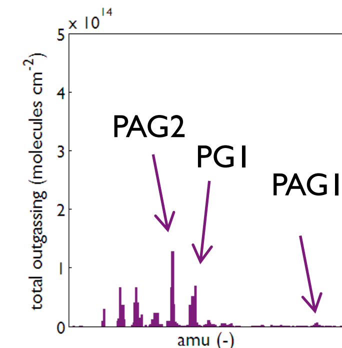
Impact of processing on outgas qualification results

On IEUVI resist TWG meeting Oct'2011, it was stated that a change in resist process conditions (cfr. SB, PEB, ...), would require a new WS test...

Triggered by this, this topic was discussed between Sematech and imec and investigation started using a common resist.

Experimental work at imec :

- Change SB : 90˚C, ***100˚C***, 110˚C
- Change PEB : 80˚C, ***90˚C***, 100˚C
- Change resist thickness : 40nm, ***60nm***, 80nm
- E_0, RGA and WS tests (current NXE procedure)

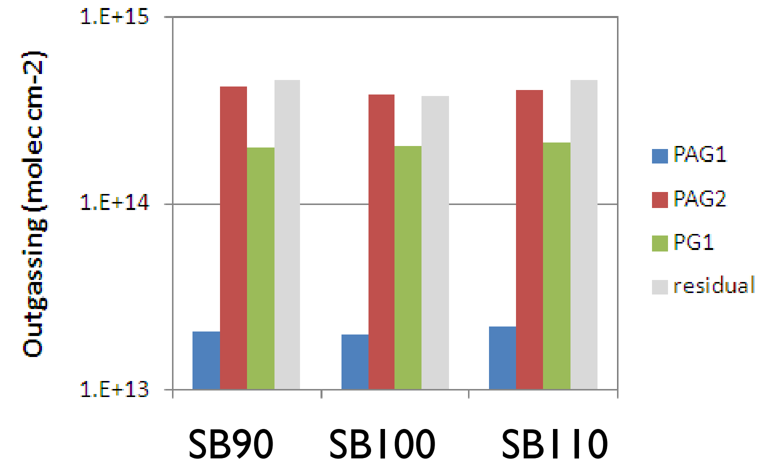


RGA results are decomposed in possible PAG and PG species

Impact of processing on outgas qualification results : Softbake

Softbake	E_0 (mJ/cm^2)	WS cont. th. (nm)	total outgassing (molec cm^{-2})
90	7.33	1.78	1.10e15
100	7.36	1.77	0.99e15
110	7.27	1.85	1.10e15

FT 60nm; PEB 90C

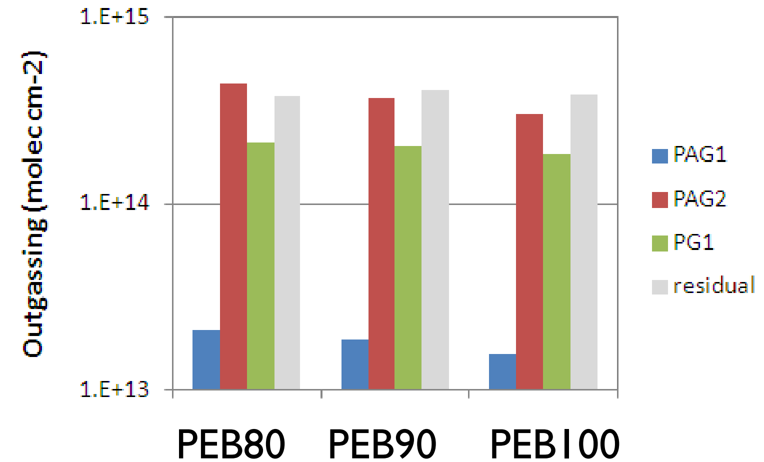


Softbake can be changed over +/- 10% without significant change on outgassing and contamination

IMPACT OF PROCESSING ON OUTGAS QUALIFICATION RESULTS : PEB

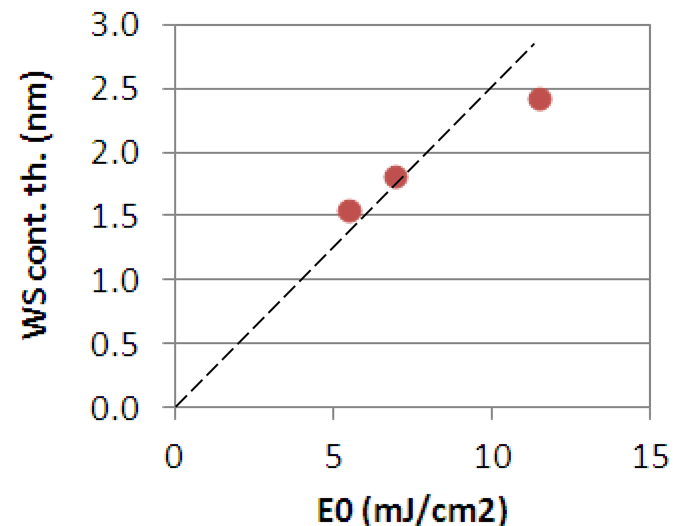
PEB	E_0 (mJ/cm²)	WS cont. th. (nm)	total outgassing (molec cm⁻²)
80	11.48	2.42	1.05e15
90	6.93	1.82	1.00e15
100	5.49	1.54	0.89e15

FT 60nm; SB 100C



Outgassing and contamination significantly changes with PEB (through dose) !

Fairly good correlation with E_0, therefore E_0 determination at different PEB can be used for (worst-case) scaling of the WS contamination.

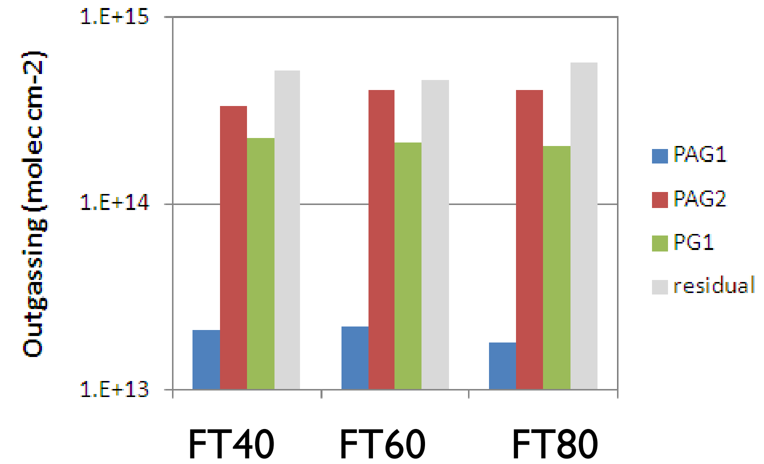


© IMEC 2012

Impact of processing on outgas qualification results : resist thickness

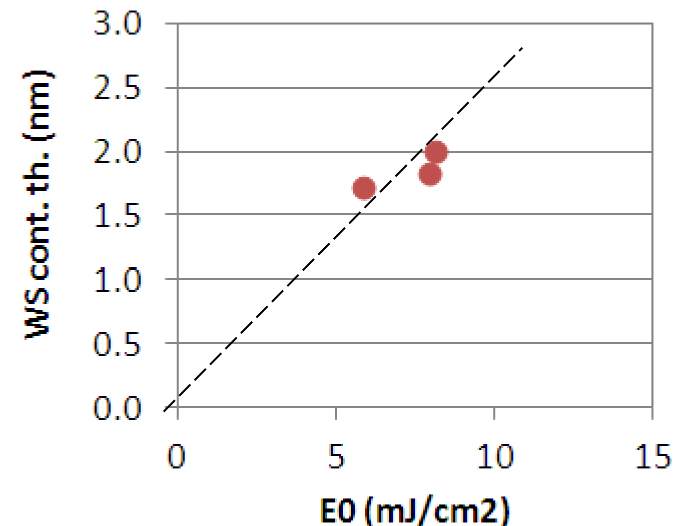
Resist thickness	E_0 (mJ/cm^2)	WS cont. th. (nm)	total outgassing (molec cm^{-2})
40	5.83	1.72	1.10e15
60	7.94	1.83	1.10e15
80	8.14	2.00	1.20e15

SB 100C; PEB 90C



Resist thickness has limited impact on contamination

If required, the impact could also be scaled by the change in E_0



IMPACT OF PROCESSING ON OUTGAS QUALIFICATION RESULTS : SUMMARY

Different process conditions have been investigated towards RGA outgassing and WS contamination.

- Changes in softbake seem to have no impact;
- Resist thickness has a minor impact, PEB has a more pronounced impact (as expected);
- Results suggest that a dose-to-clear measurement at new process condition is sufficient to predict possible changes in outgas qualification results

© IMEC 2012

EUV OUTGASSING

Status of resist outgassing qualification set-up for NXE3100

Related work towards understanding how qualification results can be affected :

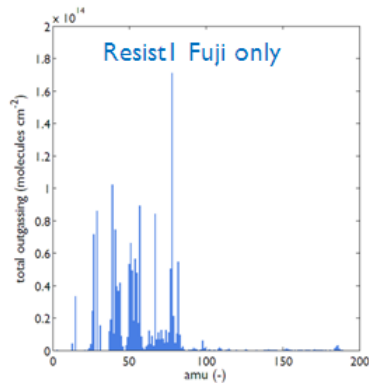
- Resist process conditions
- Resist vs. stack materials
- EUV vs. E-gun exposure on resist

imec

© IMEC 2012

OUTGASSING OF MATERIAL STACKS

IMPACT OF LAYERS BELOW RESIST

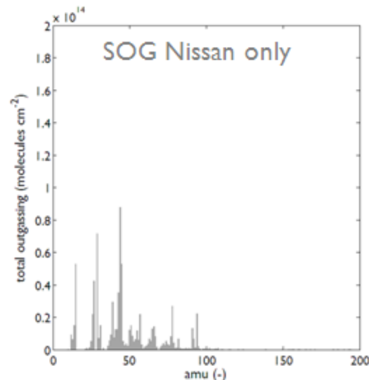


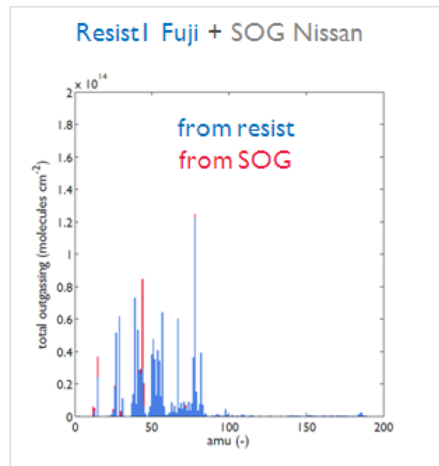
Resist outgassing amount is (slightly) changed
A small amount of SOG related outgassing is observed

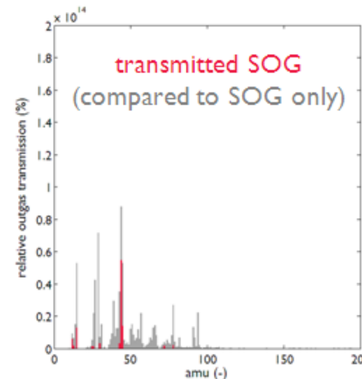
Why ?

Note : in this comparison all samples were tested at same dose...

Is this consistent for many PR and UL's ?







imec © IMEC 2011 / CONFIDENTIAL IVAN POLLENTIER - IEUVI RESIST TWG OCT'2011 19

RESIST ON STACKS :WHY CAN RESIST OUTGASSING CHANGE BY STACK ?

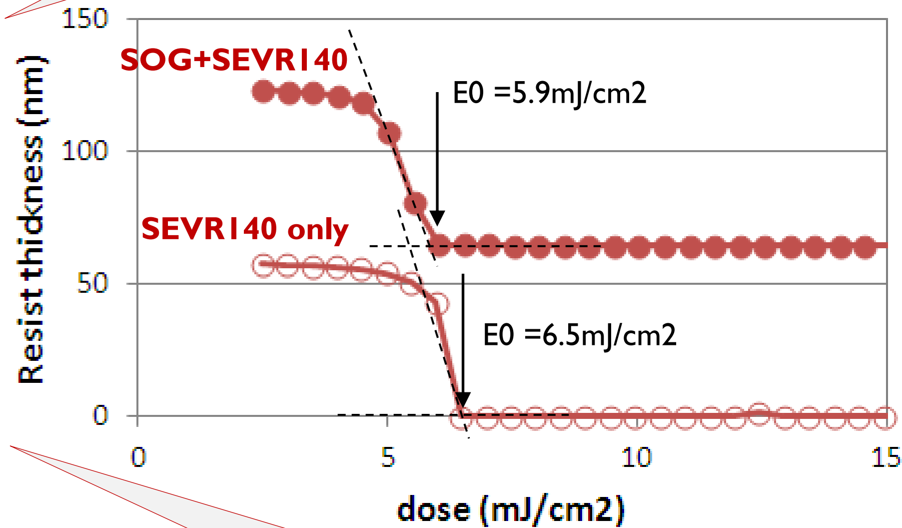
Previous testing (WS test; dose of resist only)

Layer	Dose (mJ/cm^2)	Resist outgassing ($mol.cm^{-2}$)	WS cont. thickn.(nm)
SEVR140	6.5	1.45e+15	0.75
SOG+SEVR140	6.5	1.66e+15	0.85

~15% difference in outgassing and contamination

New testing (RGA test; dose according to E0)

Layer	Dose (mJ/cm^2)	Resist outgassing ($mol.cm^{-2}$)	WS cont. thickn.(nm)
SEVR140	6.5	1.28e+15	
SOG+SEVR140	5.9	1.34e+15	



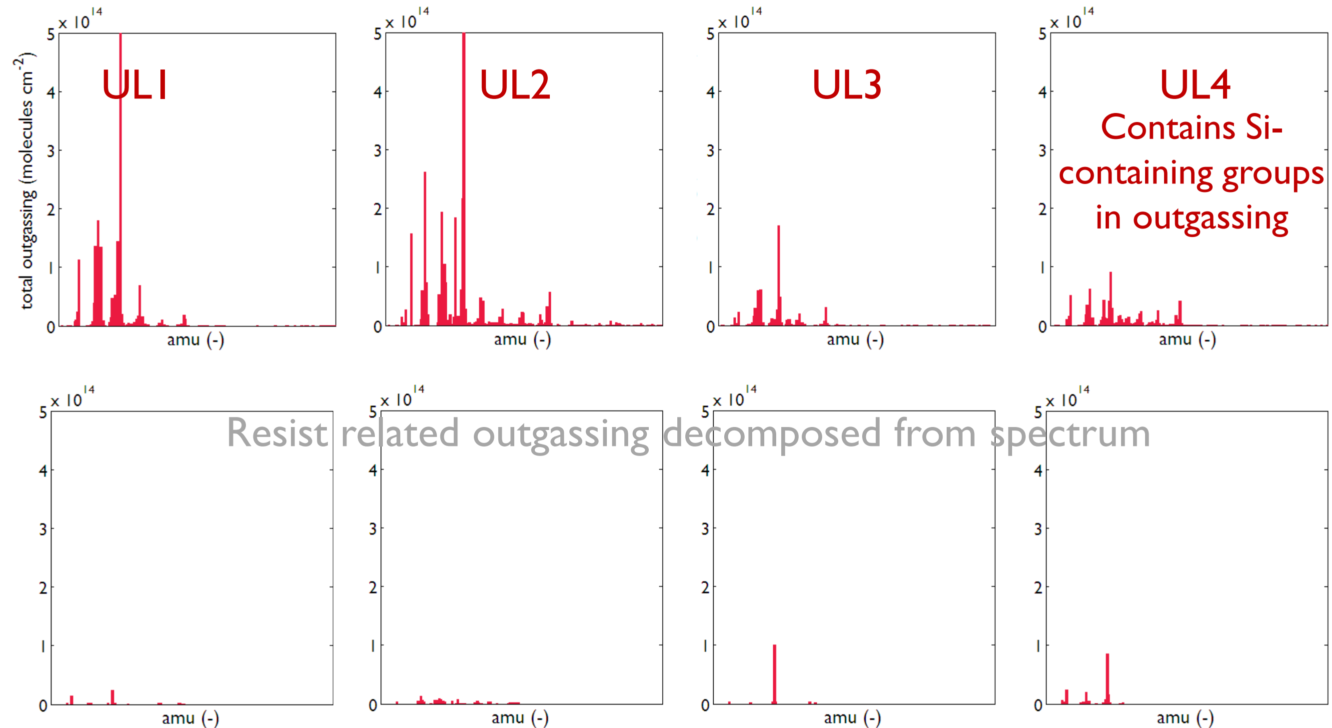
<5% difference in outgassing and contamination

Change of resist outgassing by stack is dose related therefore the behavior is consistent ! (no need for additional qualification)

Resist on stacks : how much of stack outgassing can permeate through resist ?

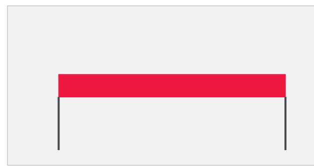
See also SPIE'2012, V. Truffert et al.

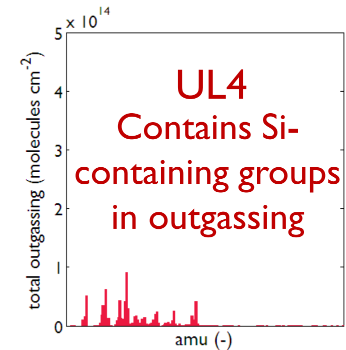
All UL's covered with SEVR140



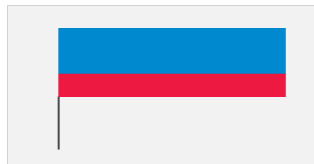
Outgassing of all UL materials is suppressed signficantly; no significant outgassing observed for species >80-90amu

RESIST ON STACKS : HOW MUCH OF STACK OUTGASSING CAN PERMEATE THROUGH RESIST ?

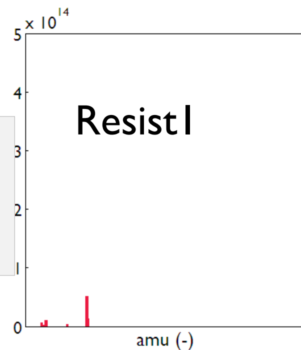


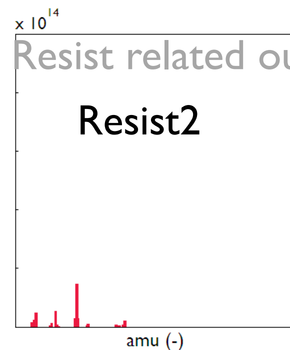


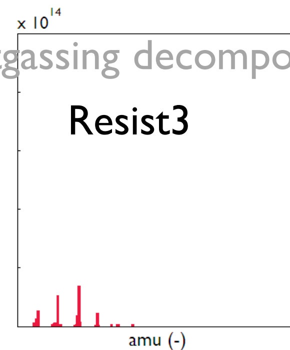
UL4 covered with different resists

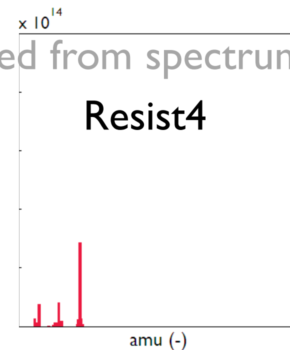


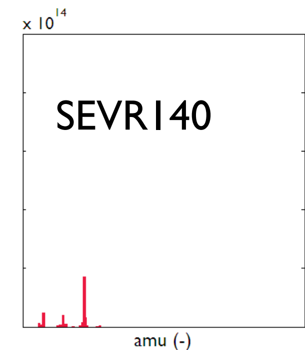
Resist related outgassing decomposed from spectrum











Although variation is seen in the permeating UL related outgassing, all resist suppress the outgassing significantly especially for species >80-90amu; WS tests planned (when available) to prove if UL related (non-) cleanables are present.

© IMEC 2012

OUTGASSING OF MATERIAL STACKS : SUMMARY

Differences in resist related outgassing when a resist is present on different stacks can be explained by changes in E_0. Therefore no additional qualification is required.

Different UL/resist combinations are tested to verify how much of the UL related outgassing can permeate through the resist. The results suggest that species >80-90amu are not significantly measured. This suggests that the risk for UL related (cleanable and non-cleanable) contamination is very low. Further WS tests are planned when available.

EUV OUTGASSING

Status of resist outgassing qualification set-up for NXE3100

Related work towards understanding how qualification results can be affected :

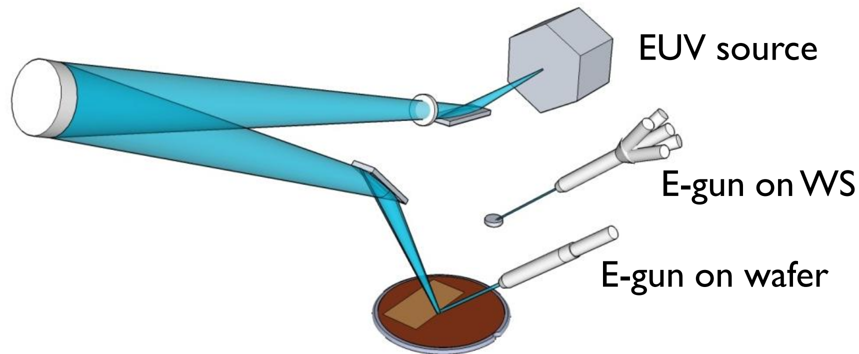
- Resist process conditions
- Resist vs. stack materials
- EUV vs. E-gun exposure on resist

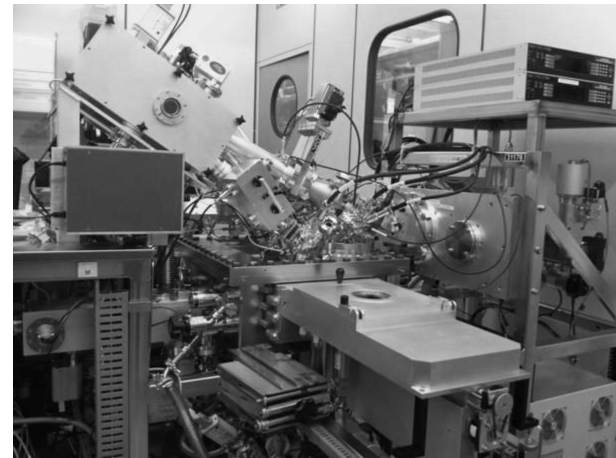
© IMEC 2012

Comparison of EUV and E-gun for resist exposure

At IEUVI resist TWG meeting, the possible difference in outgassing and contamination has been debated, when resist is exposed either by EUV or e-gun. No clear view and consensus was found on this.

Recently investigation was done at imec (collaboration with EUVT towards SPIE)

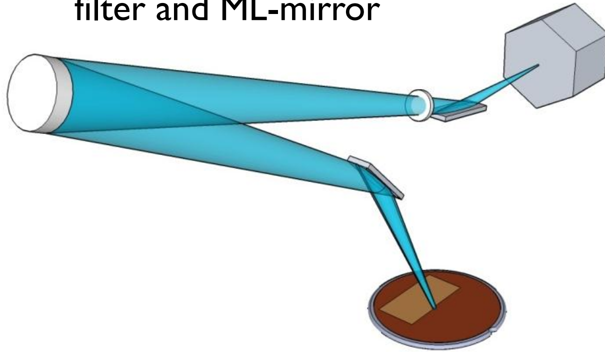


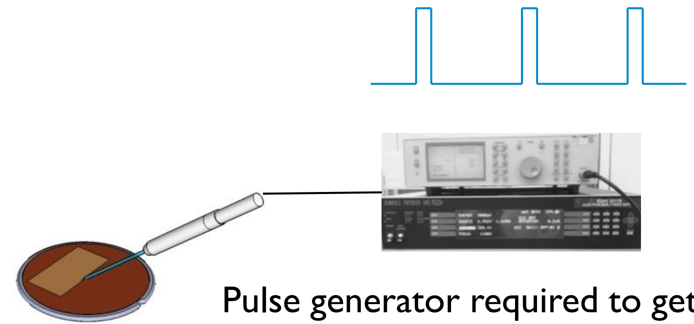


© IMEC 2012

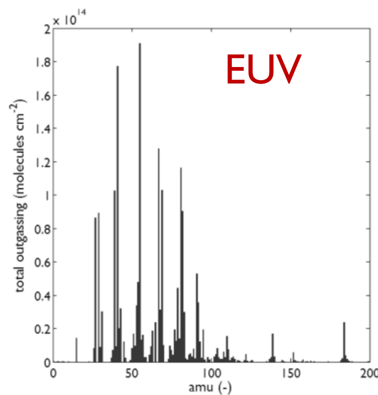
Comparison of EUV and E-gun for resist exposure

Energetiq EUV source with Zr-filter and ML-mirror

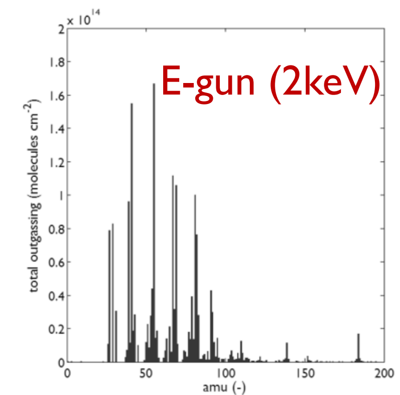




Pulse generator required to get sufficiently low electron current



☺ **RGA spectrum very similar (same species involved)**

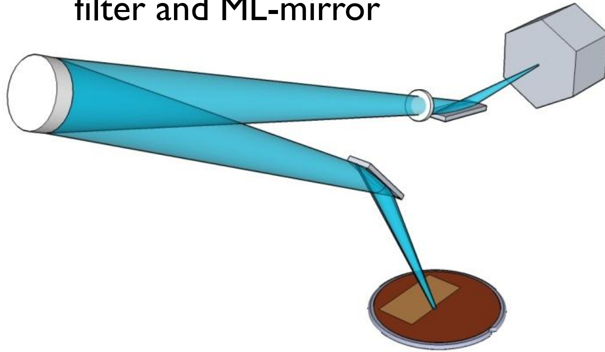


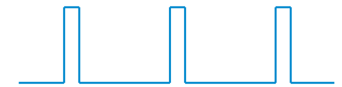
For more details, see presentation R. Perera (EUVT)

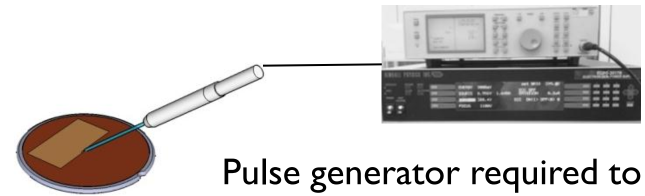
© IMEC 2012

COMPARISON OF EUV AND E-GUN FOR RESIST EXPOSURE

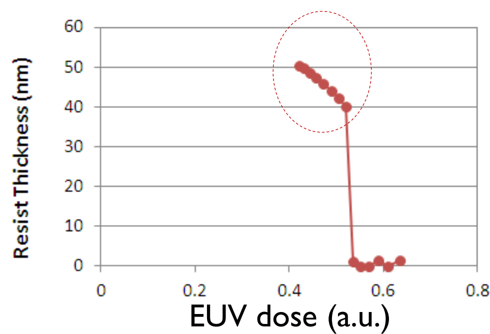
Energetiq EUV source with Zr-filter and ML-mirror





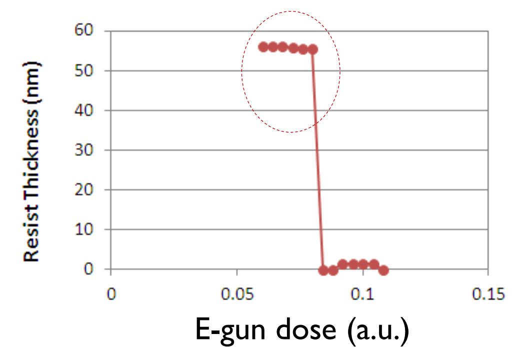


Pulse generator required to get sufficiently low electron current



EUV dose (a.u.)

☹ **Different behavior in contrast curve (dose distribution inside resist)**



E-gun dose (a.u.)

© IMEC 2012

ACKNOWLEDGEMENTS

R. Perera, D. Houser, and J. Underwood (EUVT) for tool support and discussions.

K. Petrillo (Sematech) and G. Denbeaux (CNSE) for discussions on process condition qualification

V. Truffert (imec), JSR and Nissan Chemicals for helpful discussions on spin-on materials.

© IMEC 2012

ASPIRE
INVENT
ACHIEVE