Resist Outgassing Spec Relaxation

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Resist TWG, SPIE 2015

Traditional (Current) Chemically Amplified Resist Definition

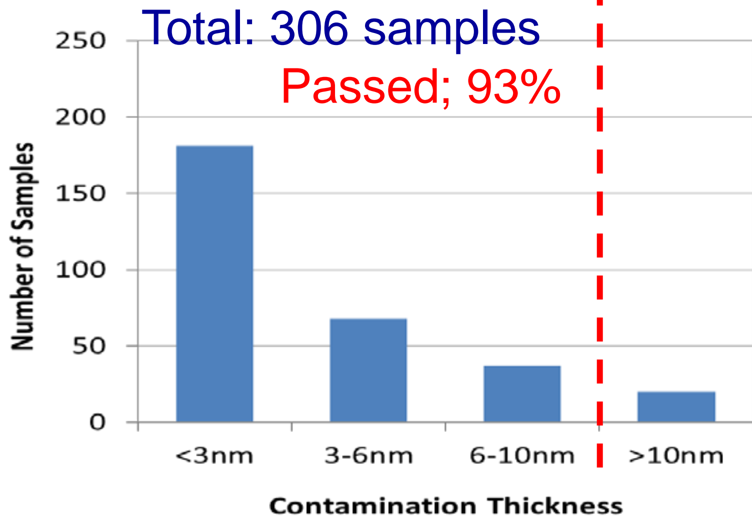
- Traditional chemically amplified resist is defined as a resist that has a reaction mechanism based on the generation of photo-acids during exposure and a subsequent acid catalyzed reaction, that changes the resist solubility in a developer, during a post exposure bake.
- It consists of a photo-acid generator, polymer, quencher, possible additives and residual solvent and consists of (a subset) the following elements: **C, H, O, N, S, F.**
  - If there are other elements that should be included, resist suppliers are asked to identify them to ASML
- For the purpose of resist outgas considerations, these resists are considered the currently available commercial platforms

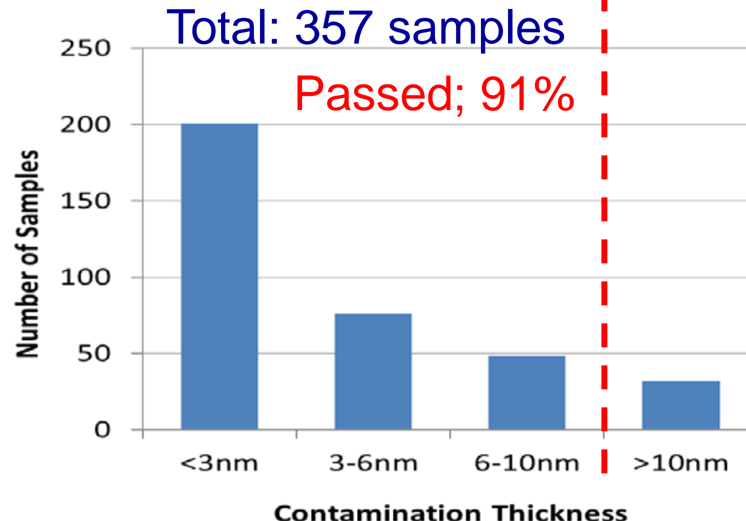
Outgas spec's for current resist platforms

Date	Cleanable contamination (Carbon)	Non-cleanable contamination
< SPIE 2014	3 nm	0.16%
> SPIE 2014	10 nm	0.16%

Cumulative Number of Commercial Samples (1)

Cleanable Contamination



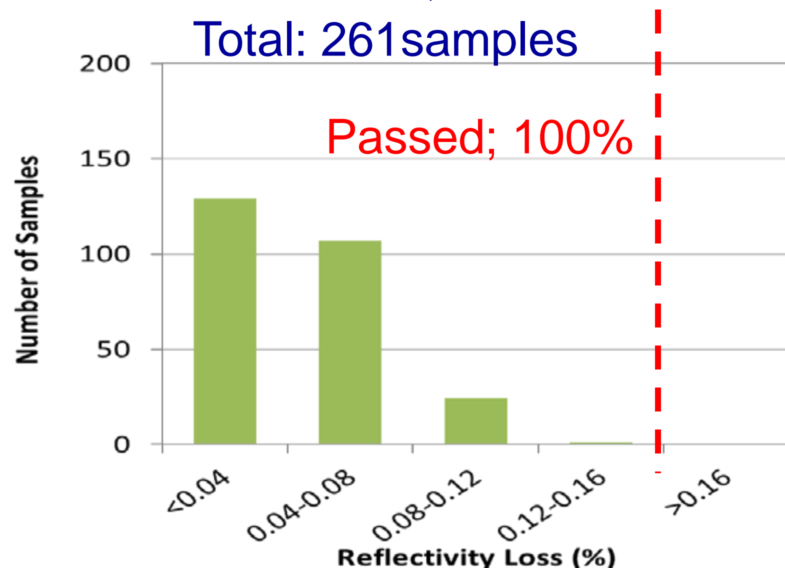


- Cumulative number of evaluated sample becomes over 350.
- After the relaxation of Cleanable spec, 91% of test samples have passed.

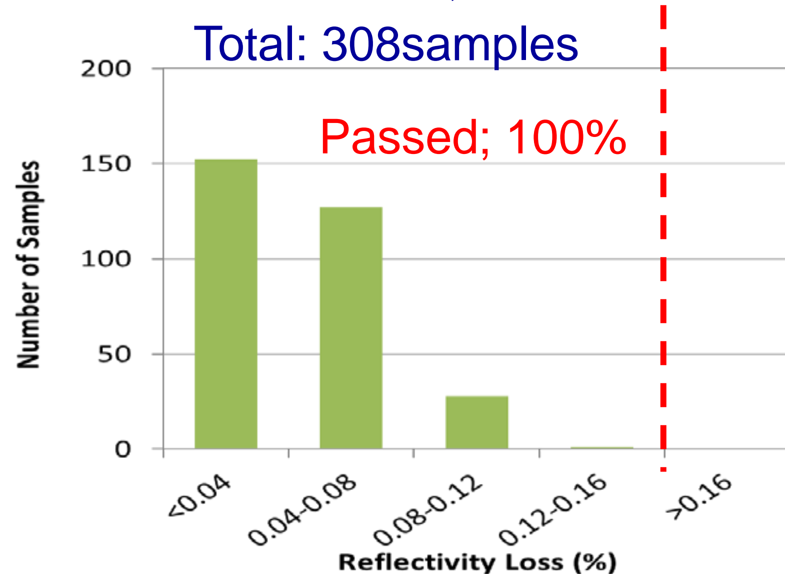
Cumulative Number of Commercial Samples (2)

Non-Cleanable Contamination

At previous TWG
Oct. 17, 2014



At present
Feb. 16, 2015



- In spite of the relaxation of cleanable spec, all samples are within the non-cleanable spec. (100 % passed)

Outgas spec's for current resist platforms → spec relaxation under consideration

Date	Cleanable contamination (Carbon)	Non-cleanable contamination
< SPIE 2014	3 nm	0.16%
> SPIE 2014	10 nm	0.16%
Q1/2015 (tbc)	no spec	no spec
	Relaxations possible due to: • higher gas flow in dynamic gas lock • increased EUV induced cleaning • suppression mechanism for high atomic masses is higher than expected	**Relaxation possible due to:** • higher gas flow in dynamic gas lock • budget allocation for NCC (non cleanable contamination) can be increased

Carbon growth is much lower than originally expected

ASML

Dynamic Gas Lock performance higher than specified

Supression factor

Measured supression

Fit

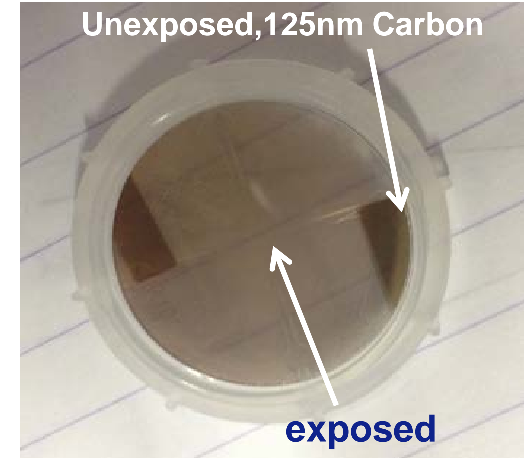
Actual operating point NXE:33X0

Specified suppression

DGL flow (Pa.m3/s)

~8 X improved gas flow

Measured EUV induced cleaning



Modeled amount of cleaning	Measured amount of cleaning
6-7 nm	~60 nm

~10 X improved cleaning

Dropping outgas specification has potential scanner system productivity risk → improved resist sensitivity should offset this

Productivity impact

- Cleanable species: high outgassing requires more cleaning (using on-board cleaning system) and leads thus to some system non availability (at HVM)
  - At higher source power (>200W) EUV induced cleaning might dominate depending on the outgas rate → potentially on-board system cleaning might not be needed
- Non-cleanable species: high levels can lead to:
  - Uniform transmission loss (for current system configuration, ~40x current spec leads to >1% light loss)
  - Non-uniform transmission loss that can be compensated for by scanner adjustments (Unicom adjustments can be made but with potential productivity impact)

New resist platforms other than Traditional CAR are unknown for outgassing

- Must maintain dialog with resist suppliers as new materials are implemented to continuously evaluate risk in scanner environment

New resist platforms other than traditional CAR need evaluation of outgas impact and risk

- New resist platforms (non-CAR, nanoparticles, etc) are unknown with respect to outgassing in an NXE environment
- Cleanable spec relaxation is possible for the same reasons as traditional CAR and carries the same productivity risks
- Non Cleanable Contamination needs investigation into the impact of the elements (not exact formulations) used. To determine the impact, ASML needs:
  - Sharing of material content for theoretical risk assessment of materials
  - Experimental validation in hydrogen to confirm theoretical risk
- Proposal is to allow limited litho testing while evaluating the outgas risk
  - Based on a waiver per resist platform, allow during 2015 a maximum of 100 wafers to be exposed per system without any outgas testing during 2015
  - Must share with ASML the material content (not formulations) to get the waiver
- Target is to ultimately have no outgas spec but, risks are likely the same → need to either accept potential transmission loss or compensate with faster resist

Classification and structure of known hydrides and estimation of associated risk to the scanner has been made

- Metallic — Low risk
- Saline — Low risk but vapor pressure issues
- Intermediate — Medium risk
- Molecular — High risk (known to form volatile species)
- Unknown

Group / Period	1	2		3	4	5	6	7	8	9	10	11	12	13 III	14 IV	15 V	16 VI	17 VII	18 VIII
1	1 H																		2 He
2	3 Li	4 Be												5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg												13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca		21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr		39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	*	71 Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn

Magnitude of the risk will be dependent on the chemical bond of the atom in question but dependence is unknown

Source: Inorganic chemistry, D.F. Shriver et al, 2 nd edition,1994, Chp 9

ASML

Experimental validation of risk of new resist platforms requires a few key items

- EUV photons to expose witness sample and wafer with EUV flux to mimic the H plasma + H radical composition in NXE scanner
- Hydrogen environment
  - Pressure similar to what wafer sees in scanner with dynamic gas lock → ~1 mbar
- Means of simulating exposures over scanner “lifetime”
  - Variable pump speed
  - Scanning stage with adjustable velocity (timing)
  - Ability to do multiple wafer exposures per test to expose large amount of resist
- Temperature controlled chamber with appropriate geometry to optimize Contamination Growth and HRG for witness sample carbon cleaning
- XPS and spectral ellipsometry for metrology

Summary of proposal

- To enhance resist development (better resolution and sensitivity), under consideration is to drop resist outgas spec for current CAR resist platforms, recognizing that there might be a scanner productivity impact
    - Monitor during 2015 to understand risk
- Do experimental risk assessment of outgas from new resist platforms in an environment that mimics the scanner hydrogen environment
- Enable small wafer count exposures in 2015 of new (not traditional CAR) resist platforms via waiver process through ASML as outgas risk assessment is done
    - No outgas test required
    - Must share material content with ASML
    - Small wafer count exposure to limit risk
- Goal is to ultimately have no outgas requirement for all resist platforms
- Need stakeholder alignment by end of Q1 2015 to proposal and risks, including potential productivity impact and that is offset with faster resist