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Outgassing of CAR and alternative resists: The way forward

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EUVL Resist TWG, October 4 2015

Outline

- March 2015 resist TWG recap
- CAR resist outgassing status
- Non-CAR resist approval procedure
- Non-CAR waiver status
- Summary

March 2015 Resist TWG

Summary of framework for remainder of 2015

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- To enhance resist development (better resolution and sensitivity resist) the outgas spec for traditional CAR platforms has been removed for cleanables and non-cleanables
- Small wafer count exposures of new (not traditional CAR) resist platforms will be enabled via a waiver process through ASML that will not require an outgas test
  - Resist supplier must share material content with ASML to get waiver
  - Waiver will be provided to the supplier who will then share it with the NXE owner interested in doing exposures
  - NXE owner will monitor the logistics of the wafer exposures on their scanner
- For new resist platforms, theoretical and experimental risk assessment of outgas in an environment that mimics the scanner hydrogen environment will be done
  - Ideas are being generated for research testing; discussions are taking place for theoretical assessments
  - Support for this testing and theoretical analysis is essential

Chemically Amplified Resist Outgassing Spec

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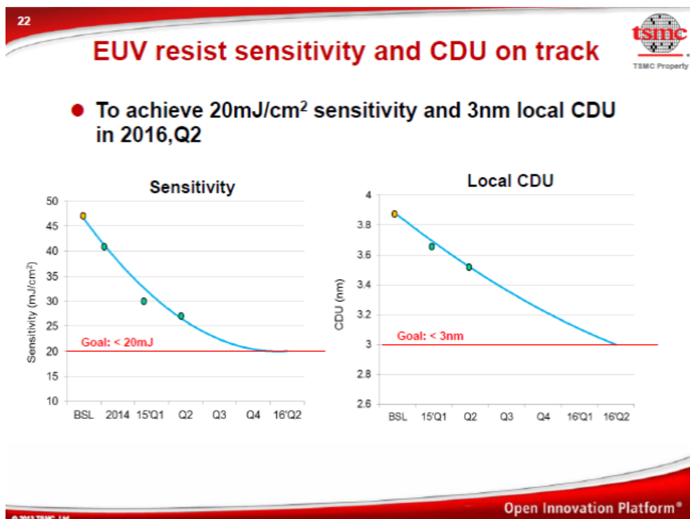
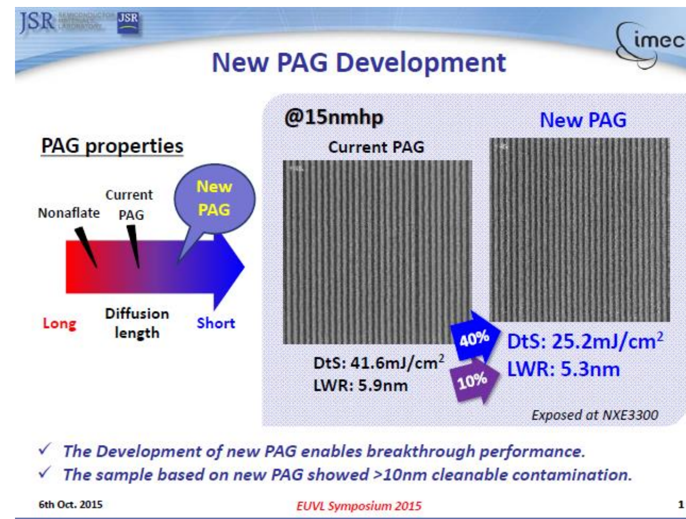
Developments since March 2015

- No degradation in EUV transmission is observed at NXE customers
  - ASML will continue to monitor EUV transmission of NXE scanners
- Resist sensitivity improvements are reported by customers and resist vendors that were enabled by releasing of the outgassing spec
- **The requirement for outgassing testing of ‘traditional’ CAR resists is removed permanently**





Waiver procedure for alternative resists

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1. Resist supplier requests waiver at ASML
   - Providing the chemical information needed to support approval flow
   - This chemical information also will be used to define the scope of the waiver
2. ASML reviews waiver request
   - Depending on the available data, this assessment may involve experiments at EIDEC
3. In case of a positive outcome of the risk assessment, ASML will grant a waiver to the resist supplier
   - Resist supplier shares the waiver with the NXE owner planning to use a resist covered under the waiver
   - The NXE owner keeps track of the exposures with a waivered resist on their scanner

ASML way of working for alternative resist approval

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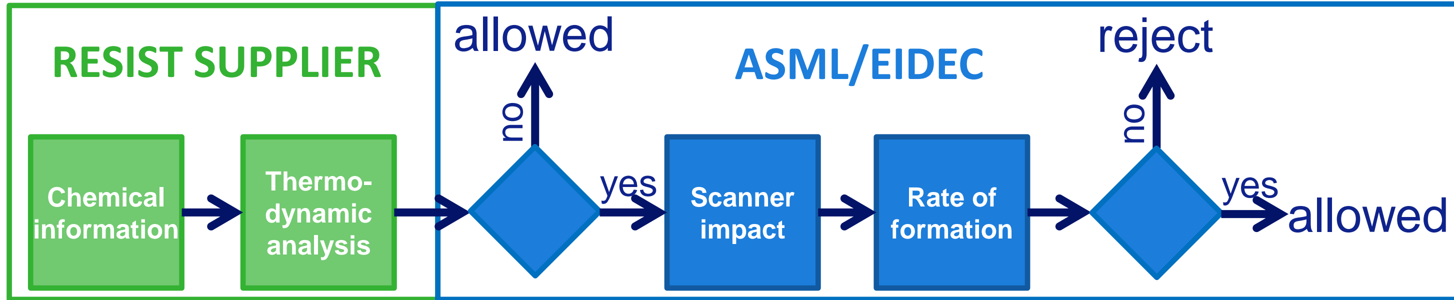

- What non-standard elements are present in the resist?
- What volatile species are expected?
  - Is formation of volatile (metal) hydrides possible?

Volatile elements expected other than *C, N, O, H, S?*

- What is the impact of the expected outgassing species on the scanner?
- What is the rate of formation of the expected outgassing species

Safe over scanner lifetime?

- Waivers are given to resist supplier
- Database of allowed materials maintained by ASML

- This flow is aimed at broad resist families based on the elements or compounds present.
- By creating a database of safe elements and compounds the flow can be accelerated.
- **ASML is not planning to develop a routine (per resist) outgassing qualification test**

Example: Outgassing of SnO_x based resist

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- Thermodynamics predicts formation of volatile SnH_4 from SnO_2 and H radicals is possible.
- Multiple witness sample tests under hydrogen conditions were conducted at 2 different locations:
  1. PSI XIL II beamline
  2. IMEC NXE:3100
- None of the tests resulted in a measurable Sn contamination on the witness samples
- This shows the importance of kinetic data. Even if the formation of a volatile hydride is expected from thermodynamics, the reaction may not happen at a measurable rate
- A limited waiver was granted. Assessment towards unlimited waiver ongoing.

Planning for finalizing approval procedure for alternative resists

Procedure should be final at SPIE 2016

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Today — SPIE

	2015				2016		
	Sept	Oct	Nov	Dec	Jan	Feb	Mar
1. Tool selection							
2. Experiments							
3. Interpretation							
4. Risk Assessment							

1. Selection of a tool that can support the requirements (H_2 + EUV)
2. Outgassing experiments under various conditions with known materials (SnO_x)
3. Interpretation of the experimental results and tuning of experimental conditions in order to be able to assess the risk of novel materials over scanner lifetime
4. Risk assessment of novel materials (supporting resist approval procedure)

Two way approach towards alternative resist approval

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1. Reactive
   - Resist supplier asks for waiver for a specific resist (family) and ASML will assess according to outlined way of working.
     - Limited 100 wafer waivers will be the baseline until the experimental conditions for the risk assessment are finalized
     - The aim is to assess a waiver request within 1 month

2. Pro-active
   - ASML will systematically assess the risk of elements and pure compounds
     - Input from resist suppliers and NXE owners on the priorities for material screening would be very welcome.
   - Creation of a database of safe resist materials will speed up the resist approval process and allows for very broad waivers
     - Upon request, ASML will provide an unlimited waiver for HfO_x and ZrO_x based resists to any resist supplier

The waiver will be granted to the resist supplier, not the NXE tool owner

ASML's primary focus is on the high EUV absorbing elements

Input from resist vendors and NXE owners on material choice and priority setting is welcomed

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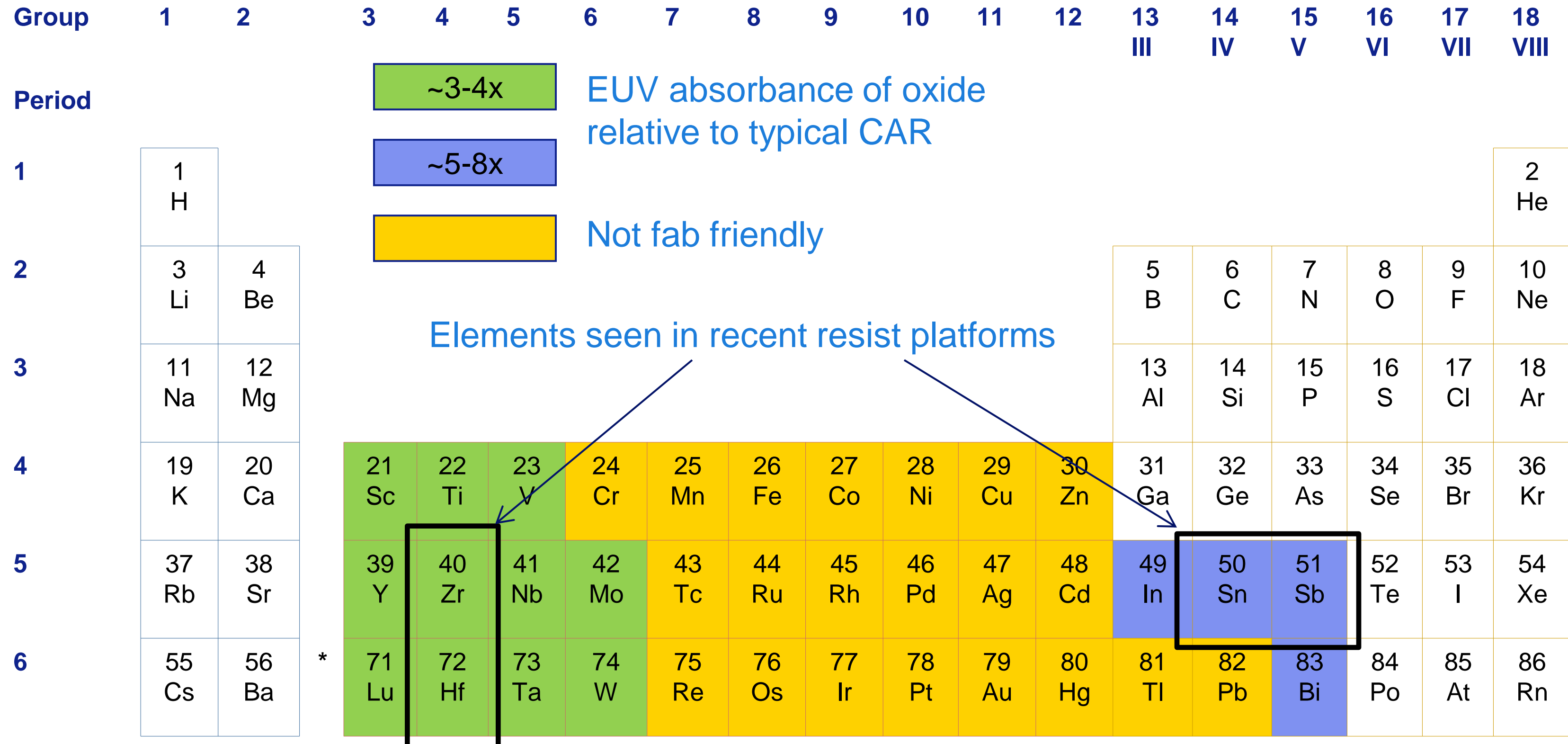

Alternative resist waiver status

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- (Un)limited waivers have been granted to 3 different resist suppliers
- These waivers cover 4 different chemical elements
- 2 waivers are under consideration

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ASML Netherlands B.V.

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Company: XXXXX

Date: YYY

ASML has evaluated XXXX's resist platform ZZZZ and has deemed it acceptable for small wafer count exposures (max of 100) on NXE systems.

This letter can be shared under NDA with any NXE owner that wishes to use this resist platform for experimental exposures. It is the responsibility of the NXE owner to track the use of the material such that the small wafer account covered by this waiver is not exceeded.

ASML is of course interested in the results of such exposures and hopes that these can be shared with ASML.

Regards

Summary

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- Traditional CAR
  - The requirement for outgassing testing of ‘traditional’ CAR resists is removed permanently
  - ASML will continuously monitor EUV transmission of NXE tools

- Alternative resists
  - Procedure for resist approval is in place
  - Tool for experimental part of the procedure is available
    - Tuning of experimental conditions and interpretation of the results are the next steps towards finalizing the procedure
  - Multiple waivers have been granted and more are under consideration

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

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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

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