Update on NIST resist-outgas testing program

Shannon Hill, Nadir Faradzhev, Charles Tarrio, Steve Grantham Lee Richter and Tom Lucatorto

National Institute of Standards and Technology
Outline

• Status and progress of resist testing at NIST

• Investigation of atomic-H cleaning efficacy for non-carbon contaminants

• Propose study to compare contamination rates of electrons and EUV photons
Update on resist-outgas testing at NIST

• Agreements to perform testing with four resist manufacturers

• NIST witness sample (WS) resist-outgas test
  - E0 measurement
  - Includes 2 separate WS exposures to verify reproducibility
  - Cost $9,363 per resist test
  - Current throughput ≈ 1.5 resists per week

• Once reproducibility is established for several resists, may lower cost and increase throughput by performing only one WS exposure per resist.

• NIST will adopt one or two widely used resists as working standards for comparison with other testing facilities.

• Limited data base of 8 different resists tested to date. All but one met NXE-3300 specifications.
Atomic-H cleaning of non-C contaminants

• At 2011 EUVLS Resist TWG ASML indicated little/no data on efficacy of atomic H cleaning of non-C contaminants (S, P, I, F, etc.)

• Direct comparison of XPS before and after AH cleaning of resist-outgas samples is constrained by limited XPS time and low levels of non-C contaminants from resist outgas test to date.

• In one case when XPS could be performed before and after cleaning of resist outgas sample, ~3 At% of S was completely removed by AH.

• NIST is attempting a more systematic investigation by AH cleaning of EUV-exposed spin-coated polymers containing appropriate species.

• First test of S-containing polymers on Si substrate have been completed
Polymer-based atomic-H cleaning study

S-containing polymer: \((\text{C}_{10}\text{H}_{18}\text{S})_n\)

Poly(3-hexylthiophene) or P3HT

1) Spin coat 6 nm film of P3HT onto Si substrate

2) Perform 4 high-EUV-dose exposures (10-200 J/mm²) on single sample

3) Inspect with spectroscopic ellipsometry (SE) and XPS

4) Clean with atomic H (AH) for time to remove equivalent amount of EUV-deposited C
   
   ➢ Preliminary results suggest: (unexposed P3HT cleaning rate) \(\geq\) (EUV-deposited carbon rate).

5) Inspect with spectroscopic ellipsometry (SE) and XPS
P3HT after EUV exposures: SE & XPS

Spectroscopic ellipsometry
(using optical constants of unexposed resist)

Effect of EUV on composition

• Lowest-dose of EUV significantly affected S and O content
• Increasing EUV dose had little effect: suggests EUV saturation

Feb. 12, 2012, Resist TWG, San Jose
EUV decreases C concentration only slightly.

Lowest EUV dose dramatically alters P3HT C1s peak to similar shape and energy of typical admitted-gas EUV-C.

C1s binding energy shifts toward graphitic state with increasing EUV dose – as observed with admitted-gas EUV-C deposits.
Compare before & after AH cleaning

XPS Atomic concentration

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<th>EUV dose J/mm²</th>
<th>C 1s at%</th>
<th>O 1s at%</th>
<th>S 2s at%</th>
<th>Si 2p at%</th>
<th>N 1s at%</th>
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</table>

Before cleaning

After cleaning

XPS S 2s map

SE map
Atomic-H cleaning of non-C contaminants

• Initial results indicate AH can effectively remove S from native and EUV-exposed P3HT-coated Si

• XPS C 1s peak for EUV irradiated P3HT is similar to EUV-deposited C, but XPS provides only limited insight into chemical nature.

• Procedure will be repeated for P3HT on Ru-MLMs then other polymers will be explored.

• AH cleaning on contamination from actual admitted-gas exposures of diphenyl sulfide will be performed to test use of polymers as proxy.
Propose direct comparison of electron and photon contamination rates

- Exploring feasibility of adding a small electron gun to the NIST optics contamination facility.

- Perform e-beam and EUV-photon exposures on same sample in same vacuum environment of admitted gas.

- Real-time monitoring of carbon growth with Nulling Ellispometric Imaging System (NEIS)

- Comparison of contamination rates and morphology of deposits (XPS, SE, NEXAFS) from EUV and e-beam exposures in admitted-gas.