Considerations for resist outgas testing with EUV and hydrogen at NIST

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Resist Outgas TWG
February 21, 2016
San Jose, California, USA
Existing outgas testing facility at NIST

Potential for outgas testing in hydrogen at NIST

Future plans

• New commitments to NASA/NOAA
• Continued support of EUVL
Existing outgas testing facility

- Synchrotron
- Mirror
- EUV
- Filter
- Witness sample
- Wafer
- Cryopump

Broadband EUV on WS
In-band 13.5 nm on wafer
Plan to increase power on wafer

- Remove relay mirror
Plan to increase power on wafer

- Remove relay mirror
- WS intercepts central 40% of beam

Broad-band EUV on WS and wafer

WS intensity: (10-20) mW/mm²
Wafer power: ~40 mW
Plan to add hydrogen flow

Contaminating vapors diffuse through hydrogen atmosphere from wafer to witness sample.
Hydrogen pressure and flow rate

How much hydrogen?
pressure  1 mbar (750 mTorr, 100 Pa)
flow rate  enough to remove outgassing of H$_2$O

Minimum pumping speed to keep up with H$_2$O outgassing

\[ \dot{V}_{\text{pumpMin}} = \frac{Q_{\text{water}}}{P_{\text{H2O}}} = \frac{(6 \times 10^{-7} \text{ mbar L s}^{-1})}{(1.0 \times 10^{-7} \text{ mbar})} = 6 \text{ L s}^{-1} \]

Corresponding flow rate

\[ Q_{\text{H2min}} = P \dot{V}_{\text{pumpMin}} = 6 \text{ mbar L s}^{-1} = 360 \text{ sccm} \]
Gas flow vs diffusion

Q: How much time is needed for outgas species to diffuse to the witness sample?  
A: 0.03 s

Q: How much time is needed for the H$_2$ flow to sweep out the volume $L^3$?  
A: 0.8 s

$$t_D \equiv \frac{L^2}{D} = 0.03 \text{ s}$$

$t_{\text{flow}} \approx \left( \frac{L}{L_{\text{chamber}}} \right) \frac{V_{\text{chamber}}}{V_{\text{pump}}} \approx \left( \frac{0.042 \text{ m}}{0.5 \text{ m}} \right) \left( \frac{56 \text{ L}}{6 \text{ L s}^{-1}} \right) = 0.8 \text{ s} \gg t_D$

Outgas molecules will reach WS before being swept away
Protecting the NIST synchrotron (SURF III) from hydrogen

Risks

• A large, one-time dose of H\textsubscript{2} could permanently degrade SURF ion pumps
• Ion pumps are integral to the storage ring so cannot be repaired/replaced

Consequences

• Damaged ion pumps = new synchrotron!

SURF must be protected against a burst of hydrogen.
Plan to protect the synchrotron

Stop the flow if chamber pressure exceeds 1 mbar.
Plan to protect the synchrotron

Add a second filter that sees no H₂.
Plan to protect the synchrotron

Shut the fast valve (<10 ms) if pressure in the beamline rises.
Plan to protect the synchrotron

Stop the synchrotron’s ion pumps if pressure in the beamline rises.
Plan to protect the synchrotron

Significant capital investment for H₂ upgrade
Summary: proposed H$_2$ outgas testing facility

Hydrogen atmosphere
- Max pressure: 1 mbar
- Flow rate: 360 sccm

Average witness sample intensity
- (10-20) mW/mm$^2$

Average power on wafer
- ~40 mW

Pulse structure of EUV
- Rep rate: 114 MHz
- Pulse duration 1 ns
- Duty factor 10 %

Broad-band EUV on
- witness sample
- AND wafer

![EUV power density graph](graph.png)
Future plans

Substantial support from NOAA/NASA to study degradation of solar-observing satellite instruments

Requires commitment to one of following options by April 2016

**Current plan**: modify outgas testing beamline for NOAA program
- Standard outgas tests may require extra time
- Upgrade to H2 configuration would require greater support and time

**Optional plan**: perform NOAA work on new beamline
- Continued availability of standard resist-outgas testing
- Easier upgrade of outgas beamline to H2 configuration
- Substantially increases cost/time for NOAA work