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Exposure tests and Status of the outgassing tool

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Outline

- Resists exposure test
- Outgassing equipment status

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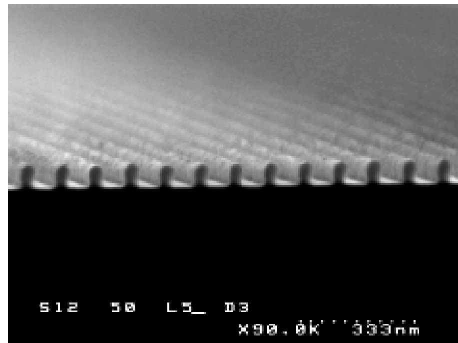
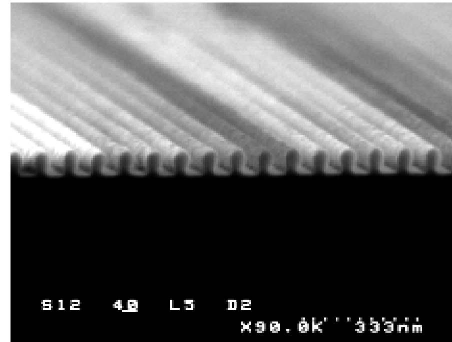
EUVIL Resist exposures

Exposures carried out at PSI, Switzerland

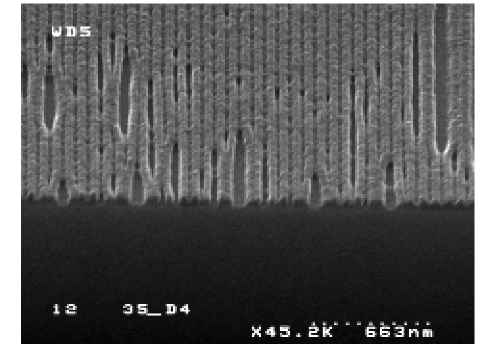
Thicknesses around 80nm



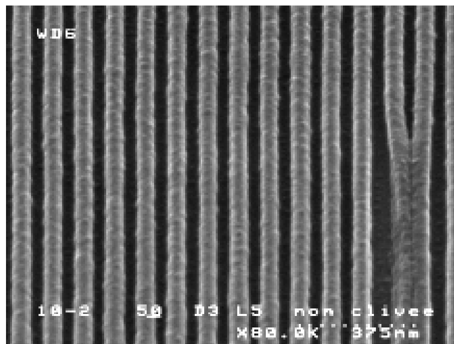
Resist A 50nm dense



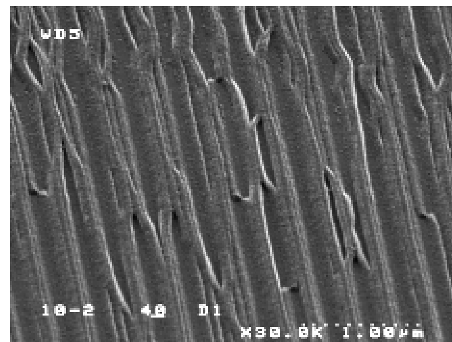
Resist A 40nm dense



Resist A 35nm dense

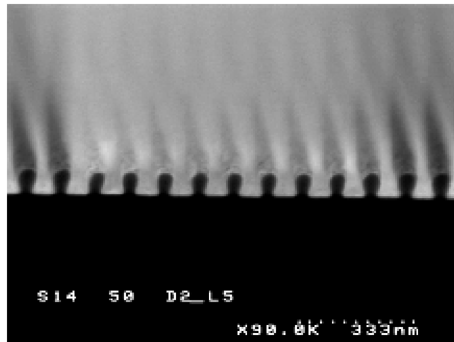


Resist B 50nm dense

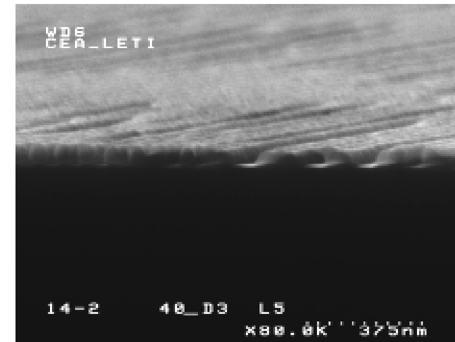


Resist B 40nm dense

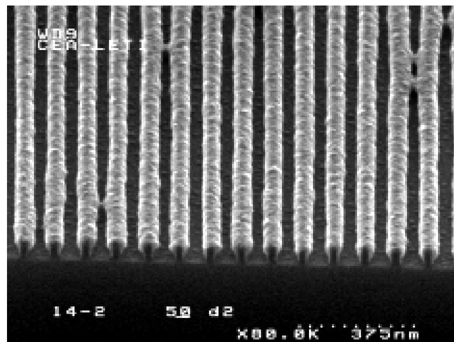
EUVIL Resist exposures



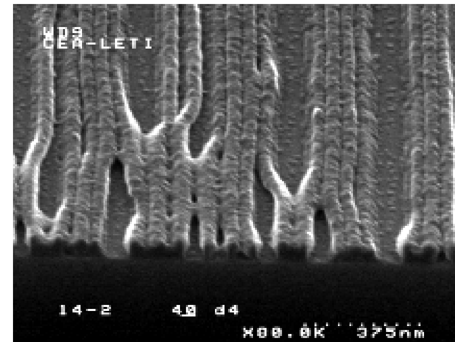
Resist C 50nm dense



Resist C 40nm dense



Resist D 50nm dense



Resist D 40nm dense

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conclusion on exposures

- All resists are able to print 50nm and some 40nm
- Actually, 40nm is always printed, but for some resists lines collapsed
- 35nm lines are sometimes printed but collapsed
- This collapse is most probably due to capillarity forces enhanced by a pear shaped profile of the lines

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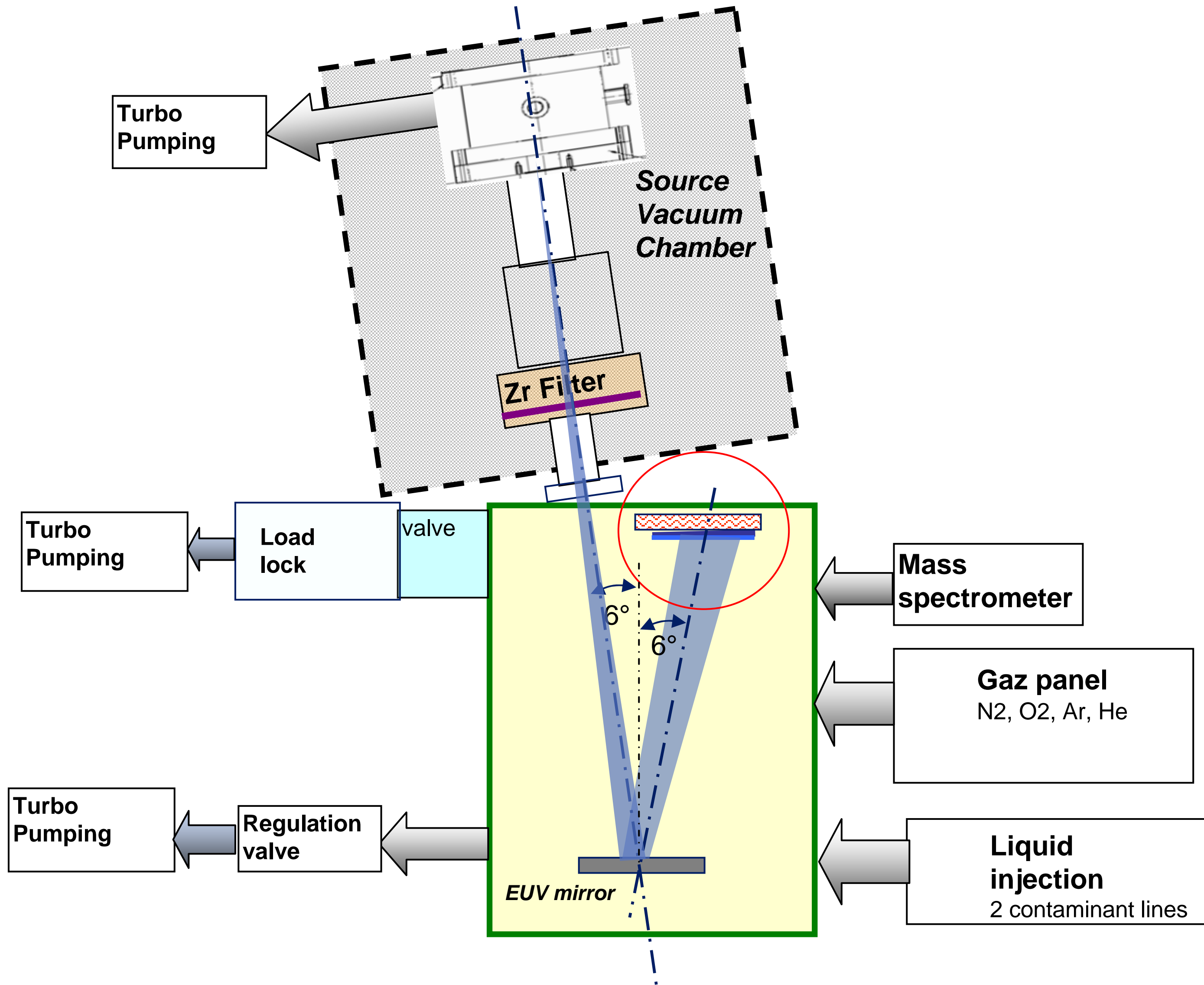
Experiment presentation



Tool Features

EUV source:

Gas Discharge Plasma source from AIXUV
Nominal power at the exit of the source vacuum :
in EUV broadband (just after Zr filter) = 100 mW/cm^2
at 13.5 nm (2% in band) = 25 mW/cm^2
Source tilt of 6°

UHV experimentation chamber:

Vacuum Limit : 2. 10^{-7} mbar
Experimentation chamber isolated from source by Zr Filter
Load lock for sample and mirror introduction
Turbo pumping through variable-conductance regulation valve
Internal bake-out with temperature regulation: 20 to 150 °C
Heating chuck temperature range: 20 to 150 °C

Injection system: Gas and contaminants

Gas injection for MS calibration &/or optics contamination
Vaporization system for liquid contaminants (2 lines)

Mass Spectrometer:

Quadrupole Mass spectrometer: Mass range 1 – 200 amu
Detector system: Faraday and secondary Electron Multiplier
Maximum Operating pressure 1.3 10^{-4} mbar
Minimum detectable Partial Pressure : 6.7 10^{-14} mbar
Mass stability: Better than +/- 0.1 amu
Wafer edge-MS distance ≅ 1cm
Electron Energy variable from 30-100eV

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Calibration of Mass spectrometer

$$Pi \propto I$$

- Using one or several calibration gas, calibration factor F is determined:

$$P_{CG} = F \cdot I$$

Measured by a vacuum gauge → P_{CG}; *Measured by MS* → I

- Applying F gives Partial Pressure of the i gas species with an absolute error linked to:

✓ Gauge absolute error (known by gauge calibration): ε^G

✓ Cross section error ε^σ, which can be more than an order of magnitude: Only Atomic gas (rare gas…) and simple molecules (CO_2, O_2…) cross sections are available

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Outgassing measurement

- The quantity of interest is the outgassing rate of a given molecule under exposure :

$$\dot{n}_i = \frac{P_i \cdot S_i}{k_B T}$$

→ *Pumping speed*

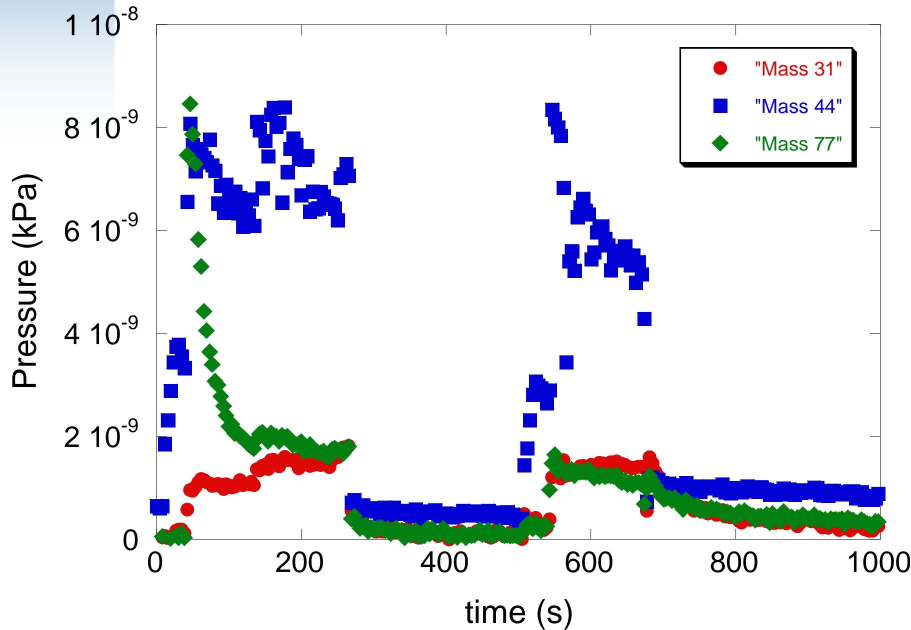
- Pumping speed depends on the gas molecule (up to one order of magnitude) and is given only for 2 or 3 typical gas by pumps manufacturers. Usually, outgassing rates are given using Nitrogen pumping speed

$\Rightarrow \varepsilon^S$

Outgassing measurement

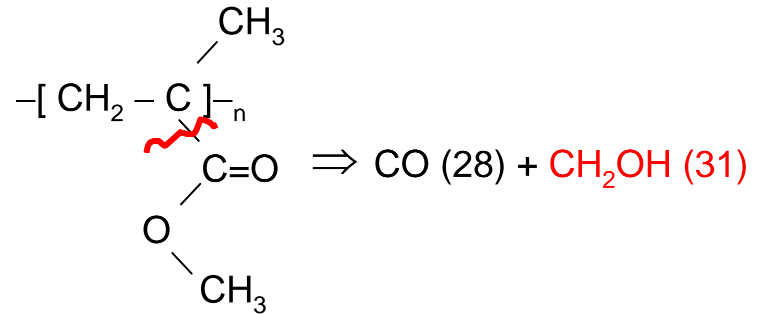
⇒ Experimental knowledge of S_i
⇒ Choice of calibration gas where σ is known (Xe)
⇒ Possible absolute calibration when knowing σ_i
⇒ No correction of fragmentation factor
with commercial resist (influence of E_{e-} to be studied)
⇒ Correction possible with known model PAGs, Polymer…
(for more fundamental studies)

Typical out-gassing experiment

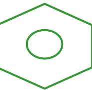


- Mass spectrum of PMMA with 50% load of diphenyliodonium hexafluorophosphide
- exposed with Broad Band EUV photons

Mass 31 attributed to side chain scission :



Mass 44 attributed to side chain scission ⇒ CO_2

Mass 77 attributed to phenyl scission from the PAG ⇒ 

During exposure : $\dot{n}(t) = \dot{n}_e$ for major resist components (main chain fragments, side chain, protecting group…)

$\dot{n}(t) = A \cdot e^{-\lambda \cdot t}$ for minor resist components (PAGs, quenchers…)

After exposure : $\dot{n}(t) = \dot{n}_e \cdot e^{-\frac{t}{\tau}}$

with $\dot{n}_e$ the out-gassing rate during exposure

τ the diffusion time constant out of the resist film

Short outgassing planning
Next two months

- Characterization of EUV source: Surface, flux…
- Calibration of MS using Xe, cold cathode Piranni Gauge
- First results with Sematech Round Robin resist
- Improvement of current experiment: Accurate gauge, calibration check protocol

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Acknowledgement

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