

Exposure tests and Status of the outgassing tool

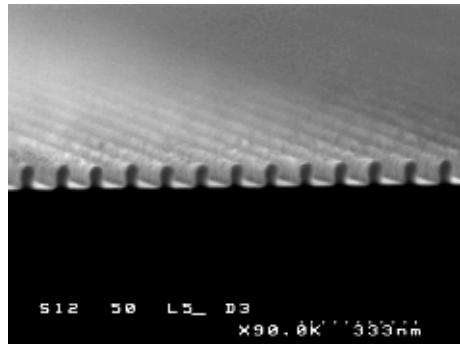
C. Vannuffel, J. Simon, P. Michallon, B.
Dal'zotto



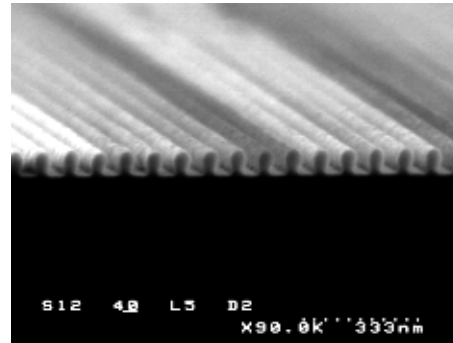
- Resists exposure test
- Outgassing equipment status

EUVIL Resist exposures

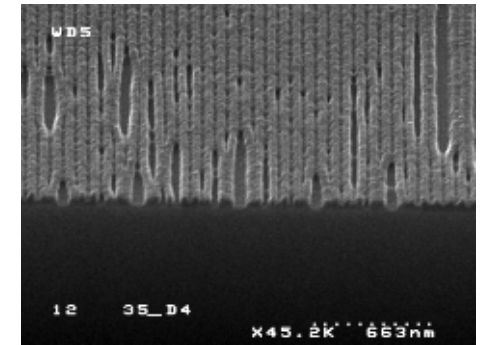
Exposures carried out at PSI, Switzerland
Thicknesses around 80nm



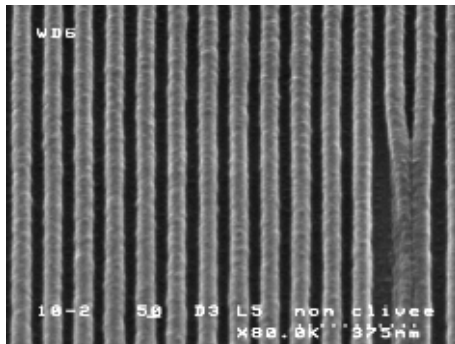
Resist A 50nm dense



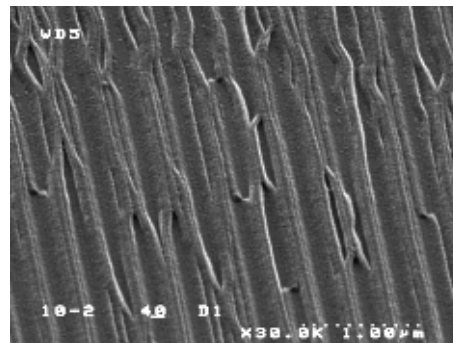
Resist A 40nm dense



Resist A 35nm dense

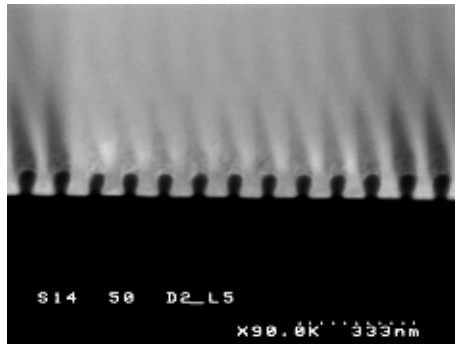


Resist B 50nm dense

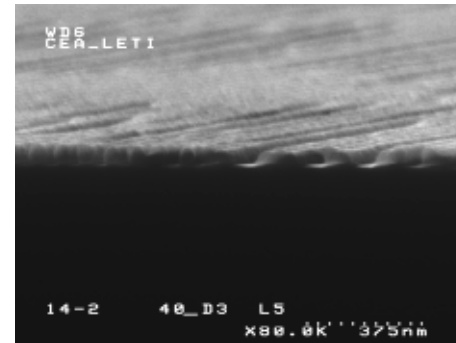


Resist B 40nm dense

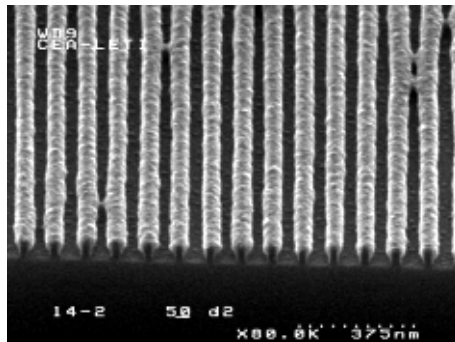
EUVIL Resist exposures



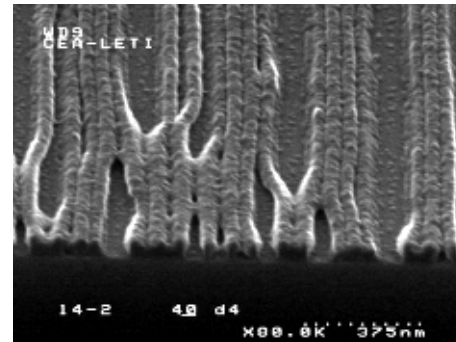
Resist C 50nm dense



Resist C 40nm dense



Resist D 50nm dense

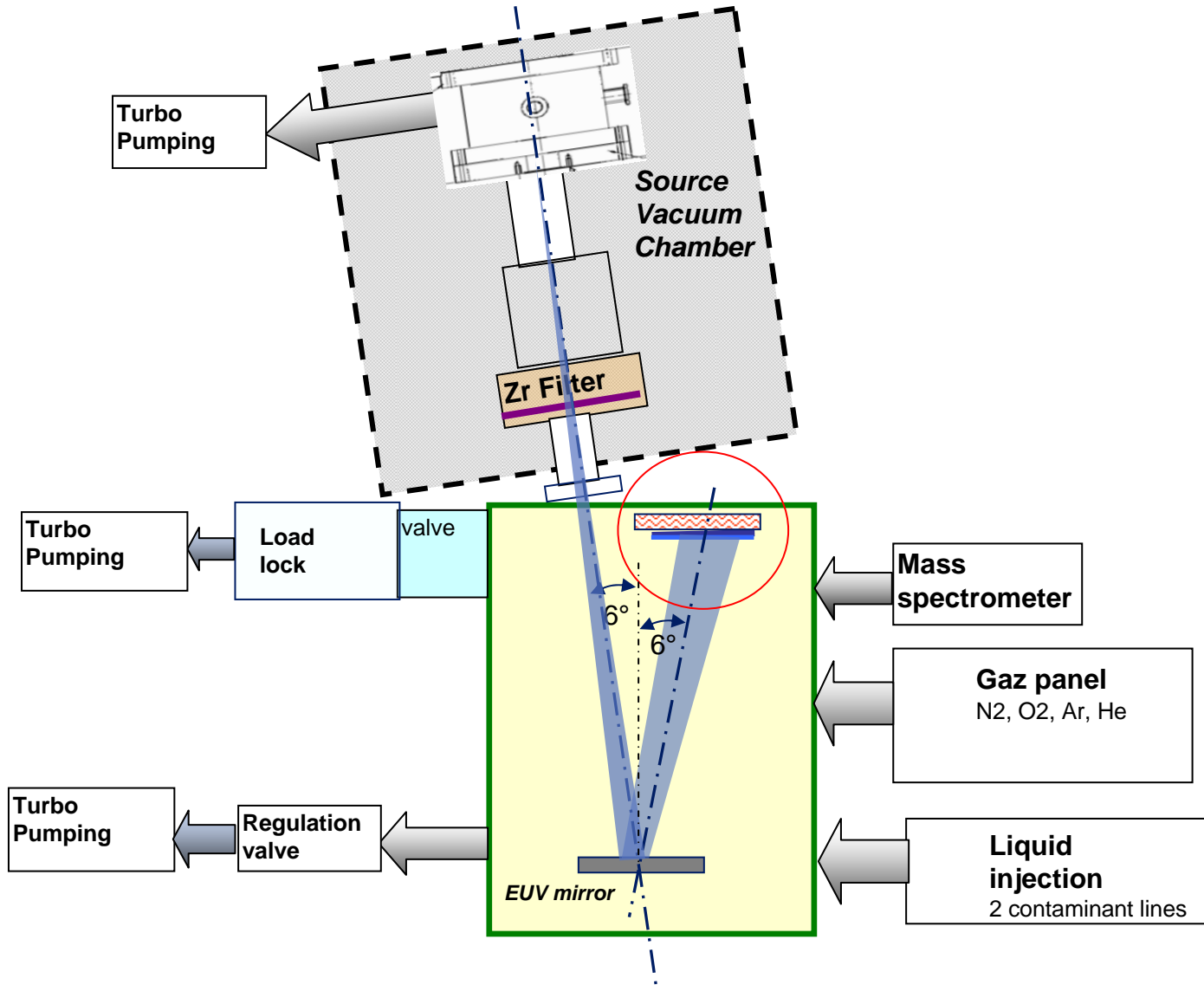


Resist D 40nm dense

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

Experiment presentation



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/cm²

at 13.5 nm (2% in band) = 25 mW/cm²

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



$$P_i \propto I$$

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

$$\text{Measured by a vacuum gauge} \rightarrow P_{CG} = F \cdot I \leftarrow \text{Measured by MS}$$

- 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

Outgassing measurement

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

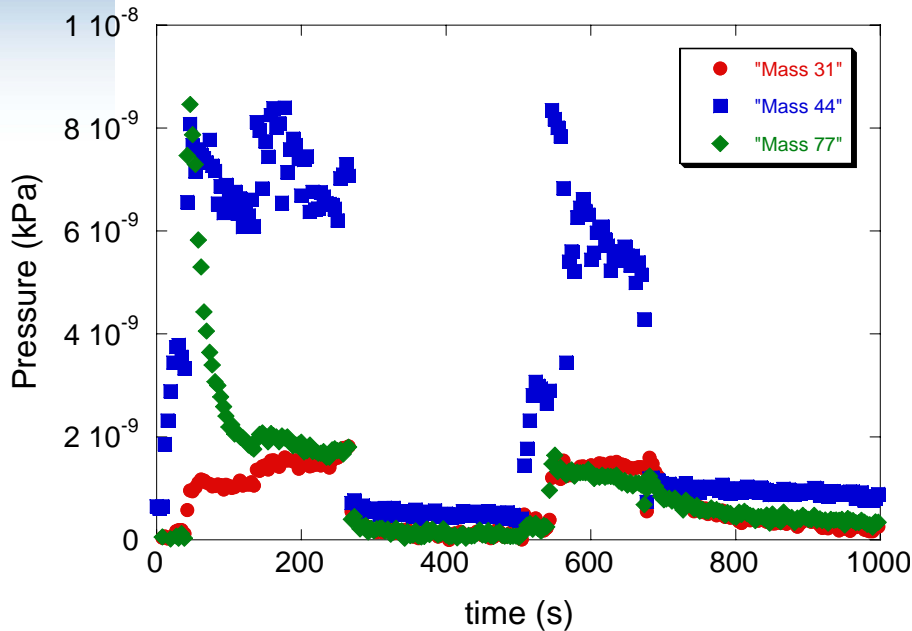
$$Q_i = \frac{P_i \cdot S_i}{k_B T} \quad \longrightarrow \quad \text{Pumping speed}$$

- 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

$$\Rightarrow \varepsilon^S$$

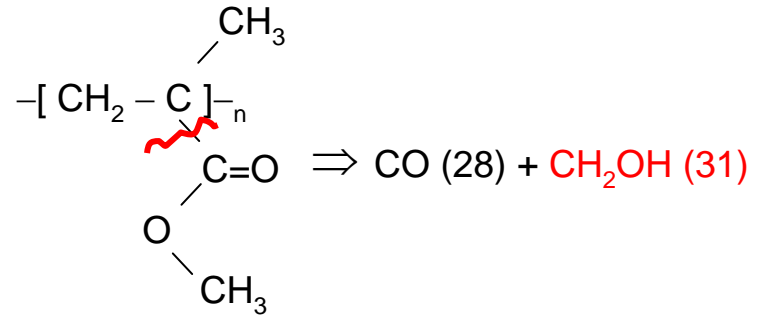
- ⇒ Experimental knowledge of S_i
- ⇒ Choice of calibration gas where σ is known (Xe)
- ⇒ Possible absolute calibration when knowing σ_i
- ⇒ No correction of fragmentation factor
with commercial resist (influence of E_{e-} to be studied)
- ⇒ Correction possible with known model PAGs, Polymer...
(for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

Typical out-gassing experiment



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

Mass 31 attributed to side chain scission :



Mass 44 attributed to side chain scission \Rightarrow CO_2

Mass 77 attributed to phenyl scission from the PAG \Rightarrow



During exposure : $r_e(t) = r_e$

for major resist components (main chain fragments, side chain, protecting group...)

$$r_e(t) = A \cdot e^{-\lambda \cdot t}$$

for minor resist components (PAGs, quenchers...)

After exposure : $r(t) = r_e \cdot e^{-\frac{t}{\tau}}$

with r_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

Acknowledgement

Harun Solack from PSI