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# Absorption coefficient and Dill parameters of CAR and non-CAR resists at EUV


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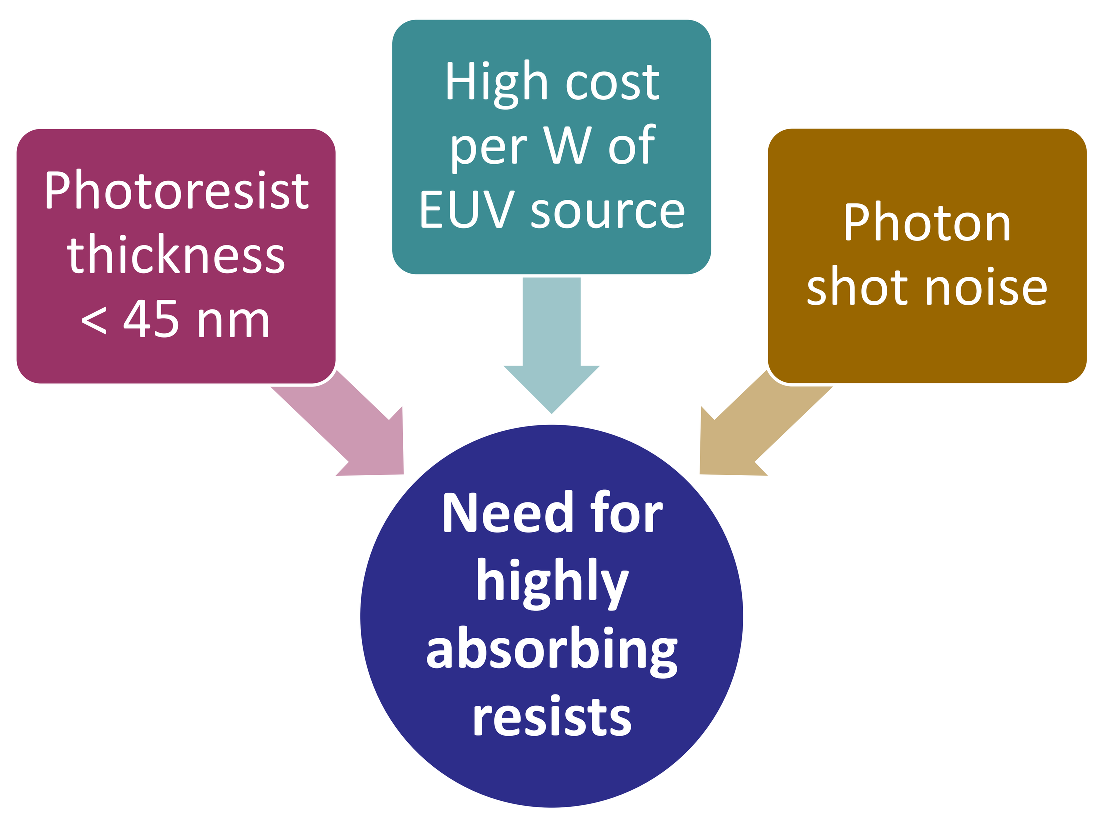
## Background

Photoresists for extreme ultraviolet (EUV) lithography are designed to coat thickness **between 25 and 45 nm**. As the photoresist thickness decreases, less light is absorbed.

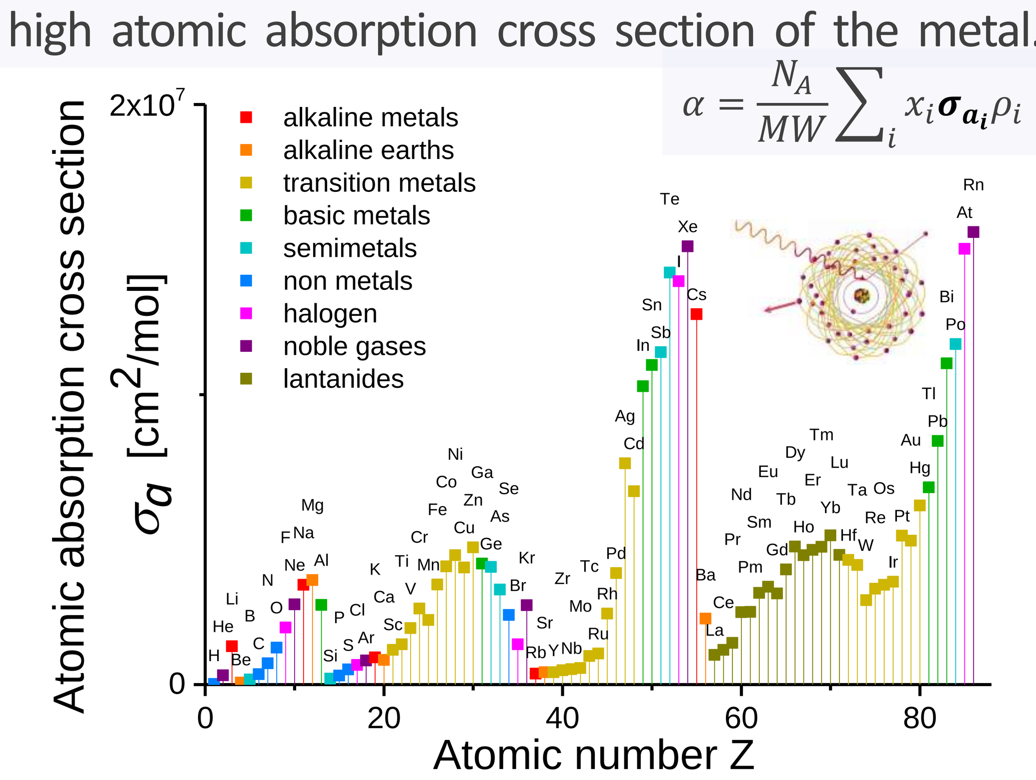
Operation of EUV source is **costly**: it is economically important to efficiently use the available illumination.

In addition, as fewer photons are absorbed, **photon shot noise** increases and results in worse line edge roughness.

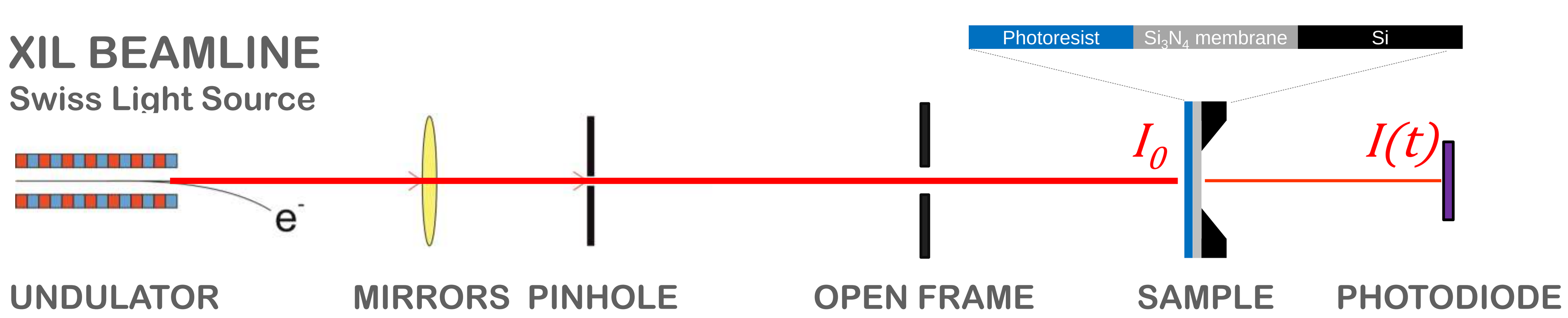
In this work, we study the linear absorption coefficient **α** and Dill parameters **A**, **B** and **C** of PMMA, HSQ, CAR resists and non-CAR metal oxide-based resists at EUV.




Novel **metal oxide-based resists** are expected to have a high absorption coefficient α because of the high atomic absorption cross section of the metal.

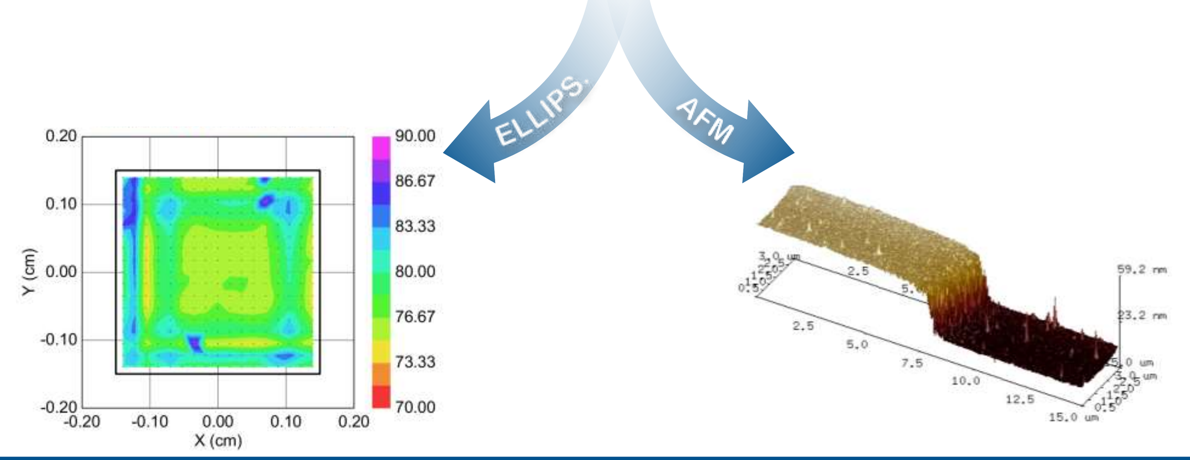



## Experimental




Methodology:

- One or more resist dilutions spin coated on $Si_3N_4$ membrane.
- **Resist thickness** measured by ellipsometry and AFM.



**Transmittance:**

$$T_X = \frac{I}{I_0} = e^{-\alpha d}$$

**Linear absorption coefficient:**

$$\alpha = -\frac{1}{d}\ln\frac{I(t_0)}{I_0}$$

**Standard deviation of α:**

$$\sigma_\alpha = \sqrt{\left(\frac{\partial\alpha}{\partial d}\right)^2 \sigma_d^2 + \left(\frac{\partial\alpha}{\partial I_0}\right)^2 \sigma_{I_0}^2}$$

*$\sigma_{I_0}$: calculated from blank membranes*
*$\sigma_d$: uncertainty of resist thickness*
*note: it is assumed $\sigma_{I(t)} = 0$*

### Dill parameters

**Bleachable absorption coefficient:**

$$A = \frac{1}{d}\ln\frac{I(t_{exp})}{I(t_0)} \quad [\mu m^{-1}]$$

**Unbleachable absorption coefficient:**

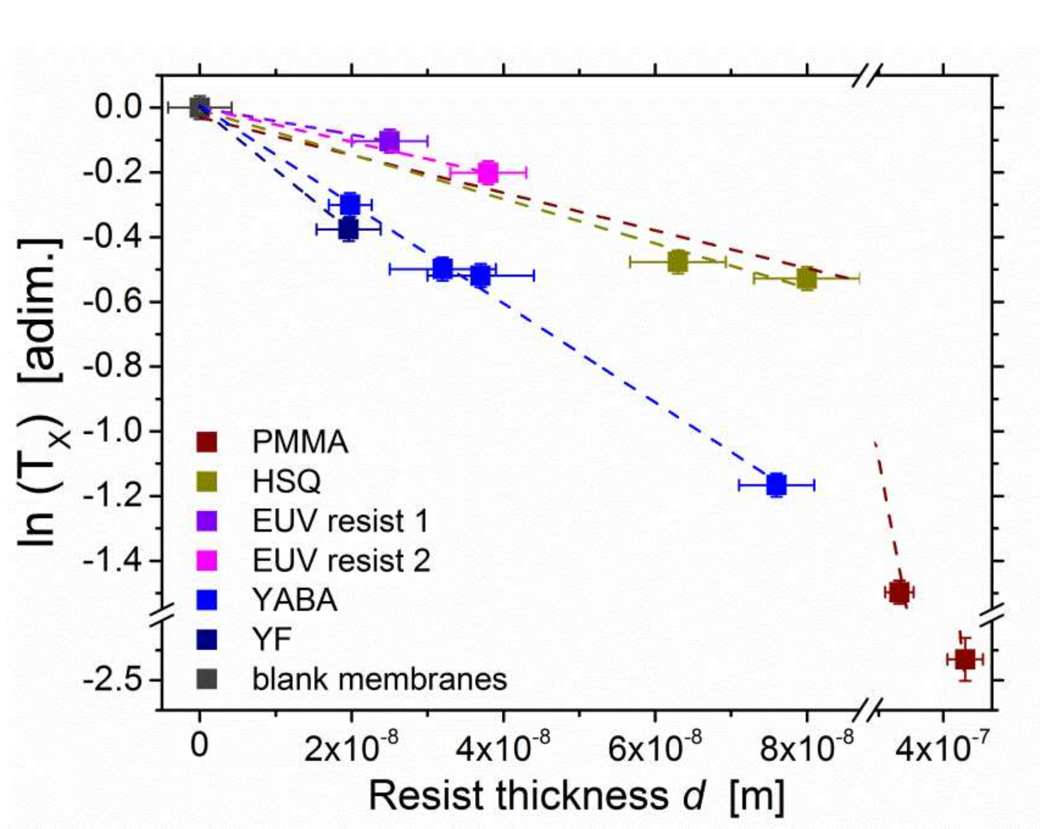
$$B = -\frac{1}{d}\ln\frac{I(t_{exp})}{I_0} = \alpha - A \quad [\mu m^{-1}]$$

**Exposure rate constant:**

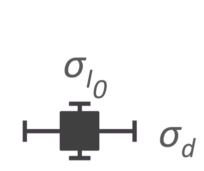
$$C = \frac{A+B}{A\Phi[I(0) - I(0)^2/I_0]}\left.\frac{dI}{dt}\right|_{t=0} \quad \left[\frac{cm^2}{mJ}\right]$$

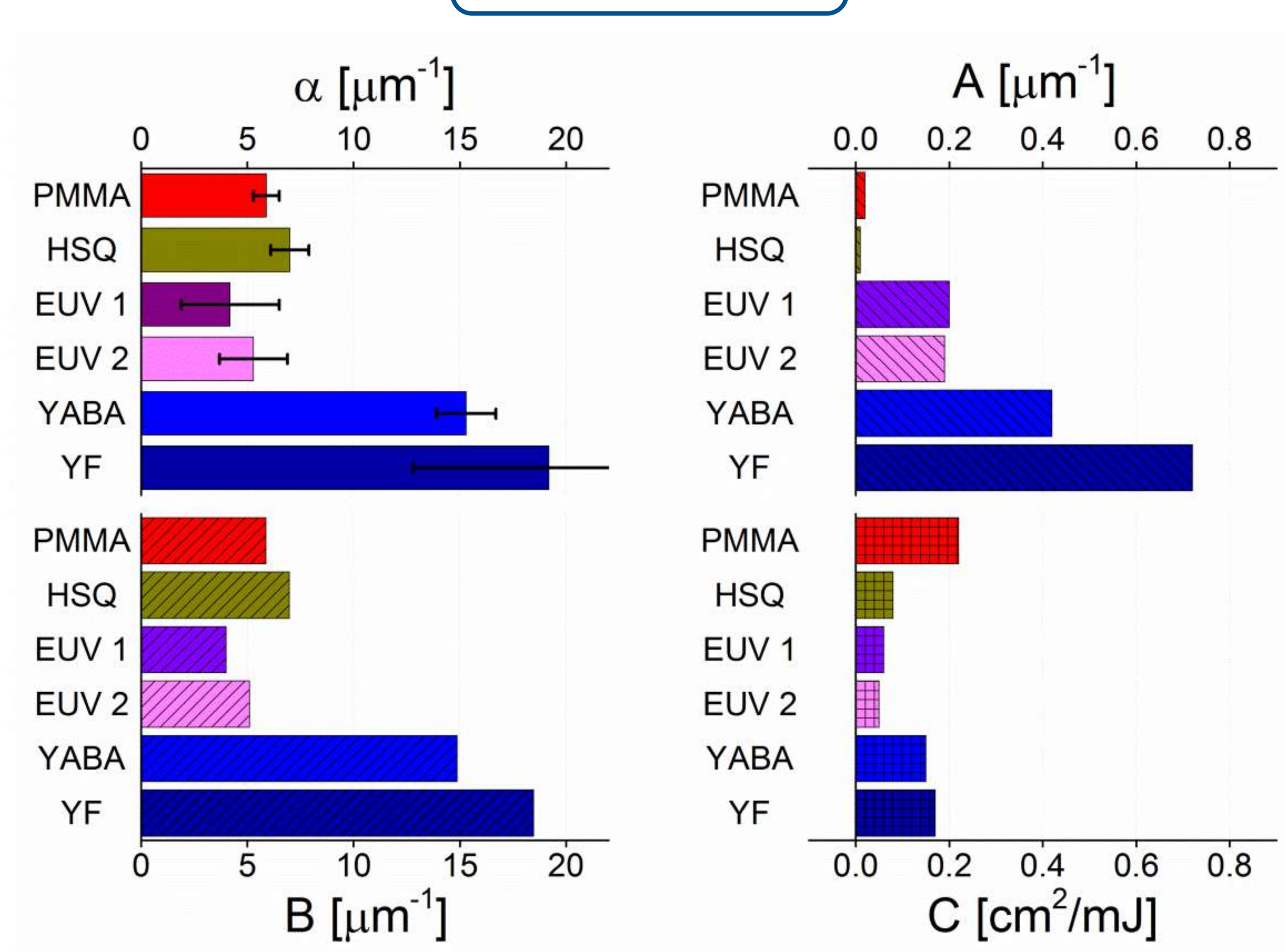
## Results

**Log of transmittance vs. resist thickness**




For all samples, $\ln(T_X)$ varies linearly with $d$: **homogenous absorption**. Dashed lines are linear fit, **weighted** on $\sigma_{I_0}$ and $\sigma_d$; their **slope** gives α.




Dill parameters define how the absorption of a photoresist varies after exposure (A), its final value (B) and its rate of change (C).

| | $\alpha_{meas}$ [μm⁻¹] | $\alpha_{theor}$[6] [μm⁻¹] | A [μm⁻¹] | B [μm⁻¹] | C [cm²/mJ] |
|---|---|---|---|---|---|
| **PMMA** *organic, not CA* | **5.9 ± 0.6** | 5.3[1] | 0.02 | 5.9 | 0.22 |
| **HSQ** *inorganic, not CA* | **7.0 ± 0.9** | 5.6[1] | 0.01 | 7.0 | 0.08 |
| **EUV resist 1** *organic, CA* | **4.2 ± 2.3** | 5[1] | 0.20 | 4.0 | 0.06 |
| **EUV resist 2** *organic, CA* | **5.3 ± 1.6** | n/a | 0.19 | 5.1 | 0.05 |
| **Inpria YABA** *metal oxide based* | **15.3 ± 1.4** | 20[5] | 0.42 | 15 | 0.15 |
| **Inpria YF** *metal oxide based* | **19.2 ± 6.4** | 20[5] | 0.72 | 18 | 0.17 |

Absorption α of PMMA from literature: 5[3] μm⁻¹ and 4.8[4] μm⁻¹. As reported by other studies[4], most polymers have α ≈ 3-5 μm⁻¹.

## Conclusions

- We developed a methodology for the measurement of the absorption coefficient and Dill parameters of photoresists at EUV.
- Our results are consistent with those reported previously for PMMA, and with theoretical estimation.
- Metal oxide-based resists absorb up to x4 more photons than chemically amplified resists.
- In all EUV resists studied in this work, the Dill parameter $A \ll B$, contrarily to pre-EUV resists.


*References*

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[5] A. Grenville et al., *Integrated Fab Process for Metal Oxide EUV Photoresist*, Proc. of SPIE Vol. 9425 94250S-1

[6] Values used in the theoretical estimation of α: HSQ ($Si_8O_{12}H_8$) density 1.4 g/cm³; PMMA ($C_5O_2H_8$), MW 950k, 4%, density 1.2 g/cm³.



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