Progress in EUV resists towards high-NA EUV Lithography

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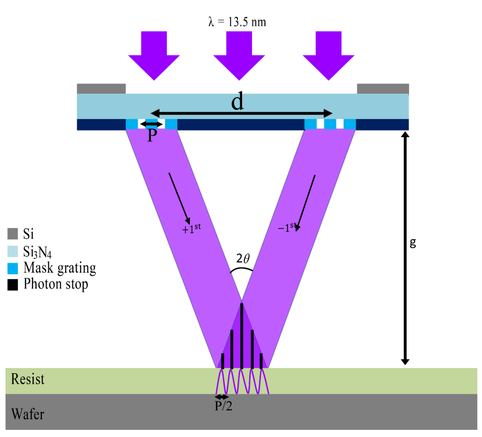
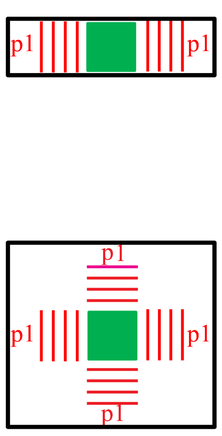
Motivation and EUV interference lithography @ PSI

Summary: We report the progress of EUV resists towards next generation high-NA EUVL evaluated with 2-beam EUV interference lithography (EUV-IL) at PSI. We have shown six best performance EUV resists out of hundred and fifty types. The inorganic resist demonstrated very high resolution capability down to HP 11 nm with relative low LWR and high sensitivity. Thus, inorganic resist B can be considered as a potential candidate for the HVM high-NA EUVL.

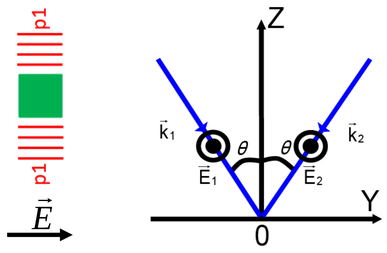
Interference lithography



Grating configuration



TE mode EUV-IL



$$E_1 = A e^{[i(kx\sin\theta)]}$$

$$E_2 = A e^{[i(-kx\sin\theta)]}$$

$$I = 2A^2 + 2A^2\cos(2kx\sin\theta)$$

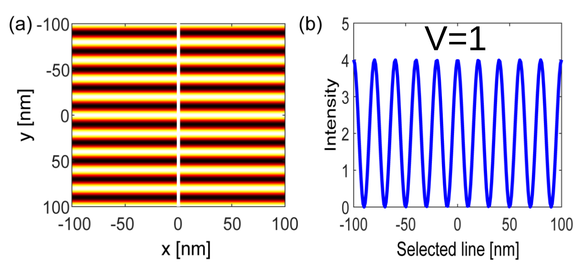
Printed resist pattern pitch

$$p = \frac{\lambda}{2\sin(\theta)} = \frac{p_g}{2m}$$

p_g : grating period
m : diffraction order

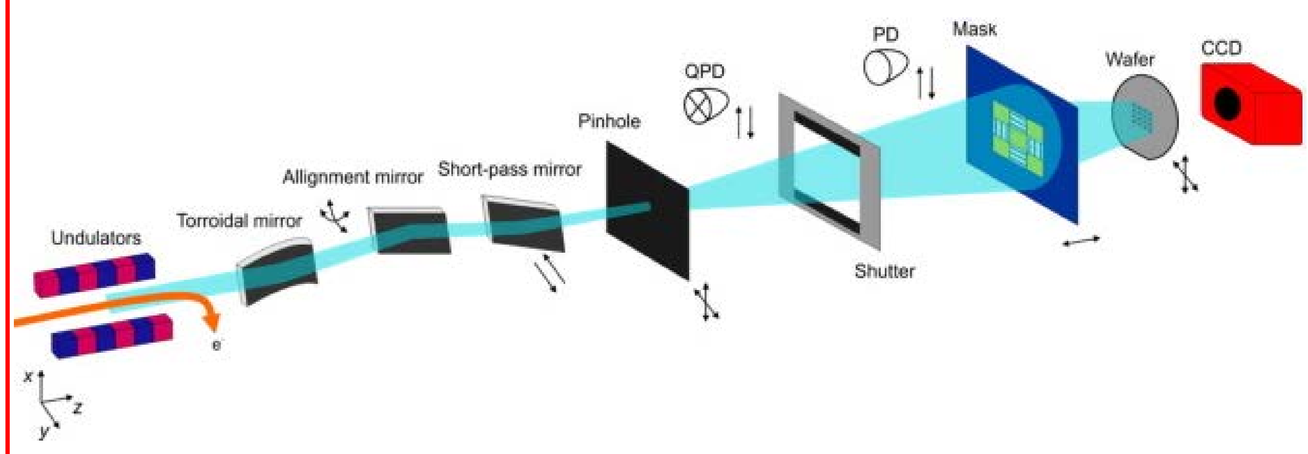
Contrast

$$V = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$$



Methodology:

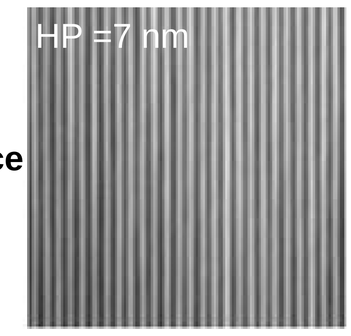
XIL-II Beamline exposure system[1] based on Swiss Light Source (SLS):
Low cost and flexible for photoresist testing
High-resolution: theoretical limit down to HP = 3.5 nm
Pitch independent and high (1) contrast



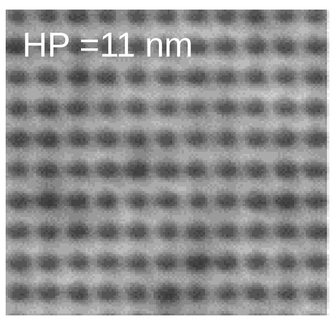
Highlight of the EUV resist screening with EUV-IL

Record resolution

Line/space

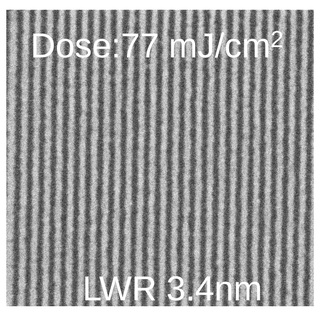


Contact

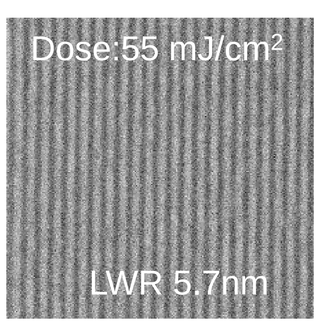


EUV resists

Inorganic down to HP 11 nm

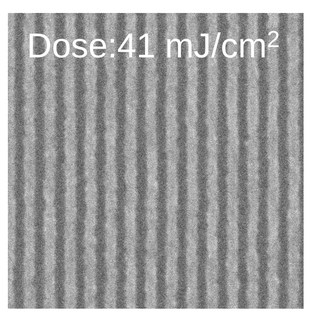


CAR down to HP 12 nm

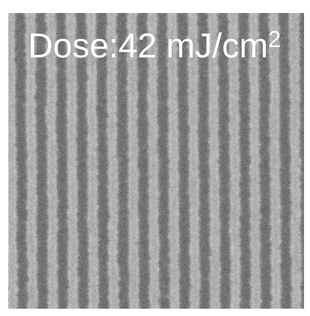


Six high performance CAR resists at HP 14 nm from 2017-2018

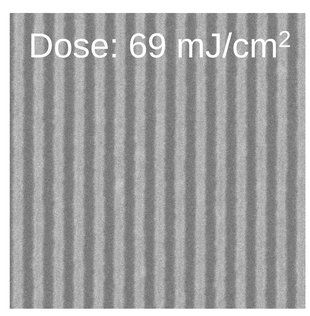
Vendor 1: molecular

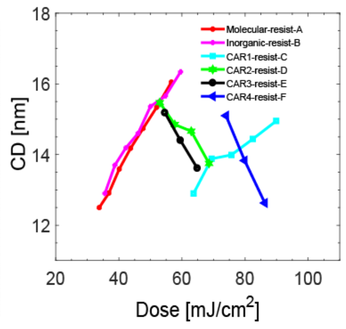


Vendor 2: inorganic

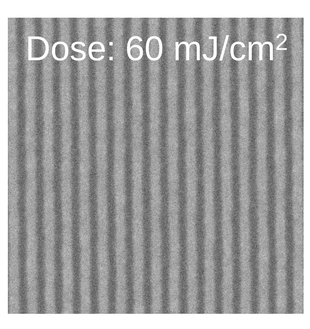


Vendor 3: CAR

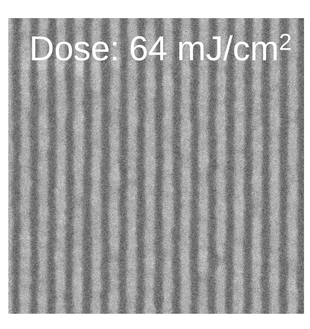




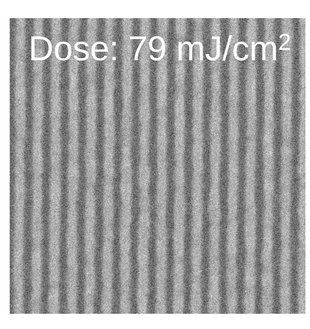
Vendor 4: CAR

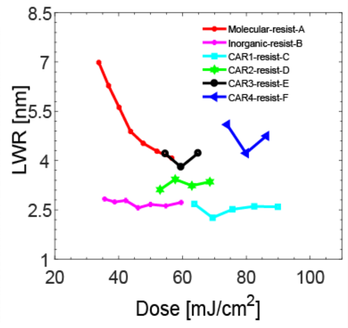


Vendor 5: CAR



Vendor 6: CAR





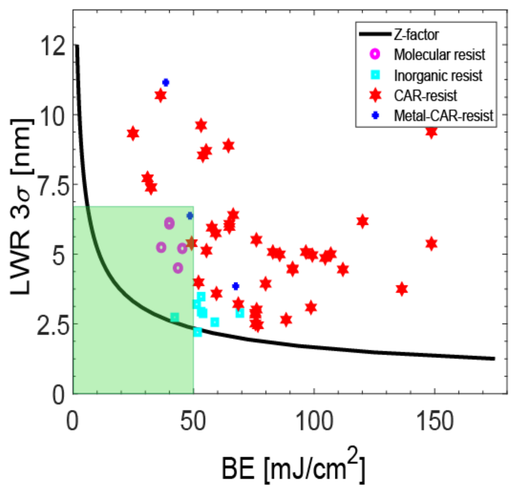
Comparison of the six high performance CAR resists

Vendor	Resist	Dose (mJ/cm²)	Exposure latitude (%)	LWR (nm)	**Z-factor** [mJ*nm³] (10^{-8})
Vendor 1	Molecular	41	13	5.1	1.5
Vendor 2	Inorganic	42	20	2.9	**0.97**
Vendor 3	CAR	69	27	2.5	**1.3**
Vendor 4	CAR	60	23	3.6	2.1
Vendor 5	CAR	64	4	4.3	3.2
Vendor 6	CAR	79	39	4.8	4.9

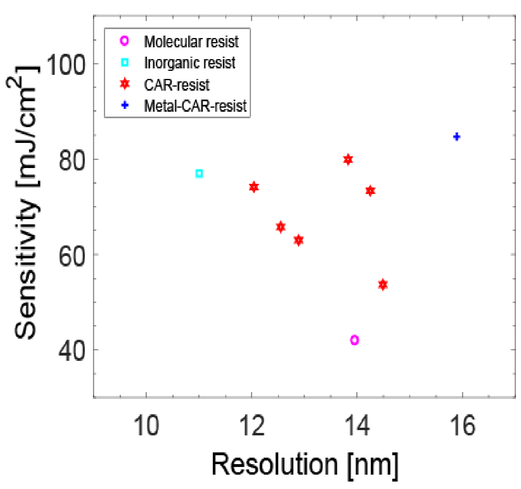
LRS model fitting statistics of LWR and resolution of resists

LRS model

$$Z = (\text{Sensitivity}) \times (\text{LWR})^2 \times (\text{HP})^3$$



Resolved resolution (HP) for different resists



References

[1] N. Mojarad et al., “Interference lithography at EUV and soft X-ray wavelengths: Principles, methods and applications,” Microelectronic Engineering, **143**, 55 (2015).
[2] D. Fan, and Y. Ekinci, “Photolithography reaches 6 nm half-pitch using EUV light,” Proc. SPIE, 9776, 11 (2016).
[3] X. L. Wang et. al., “ Progress in EUV resists towards high-NA EUV lithography”, Proc. SPIE, 10957, 10957A (2019).