EUV Resist Status And Challenges

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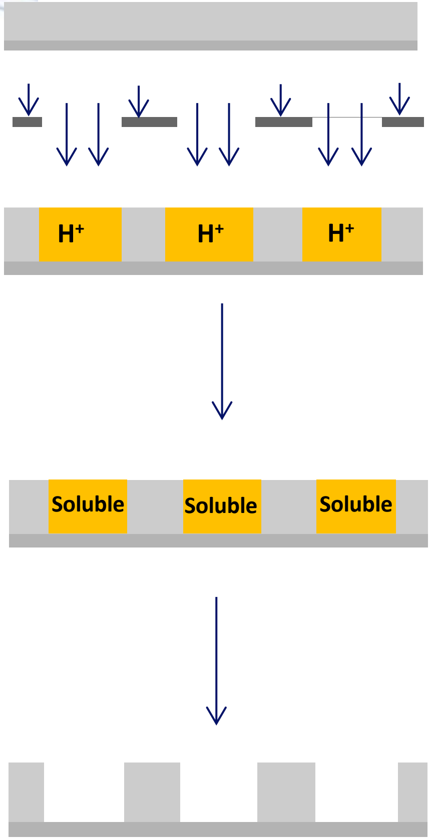
Main Knobs to turn in (CAR) Resist



Exposure
EUV absorption.
Secondary electron generation.
Acid formation

- **Absorption**
  - Absorptivity (Dill B)
  - Resist Thickness
  - Out of band (OOB) sensitivity (photoacid generator (PAG) type, TC)
- **(Secondary) electron yield**
- **Electron blur**
  - Material type
- **QE (acid yield)**
  - PAG type (polarity), PAG load

Post Exposure Bake (PEB)
Acid diffusion.
Acid catalyzed deprotection→ solubility switch

- **Acid diffusion (blur)** *(Q diff as well)*
  - Bulky/Polar/ Bound (PAG,), Tg,
  - Quencher (Photodecomposable)
  - PEB Temperature
- **Reaction Efficiency**
  - Ea of Protecting Group

Development
Dissolution of exposed regions by developer, pattern formation

- **Pattern Collapse**
  - Rinse material
  - Resist type, adhesion
- **Development**
  - Developer type/size, strength
  - Wetting…

→

Resolution

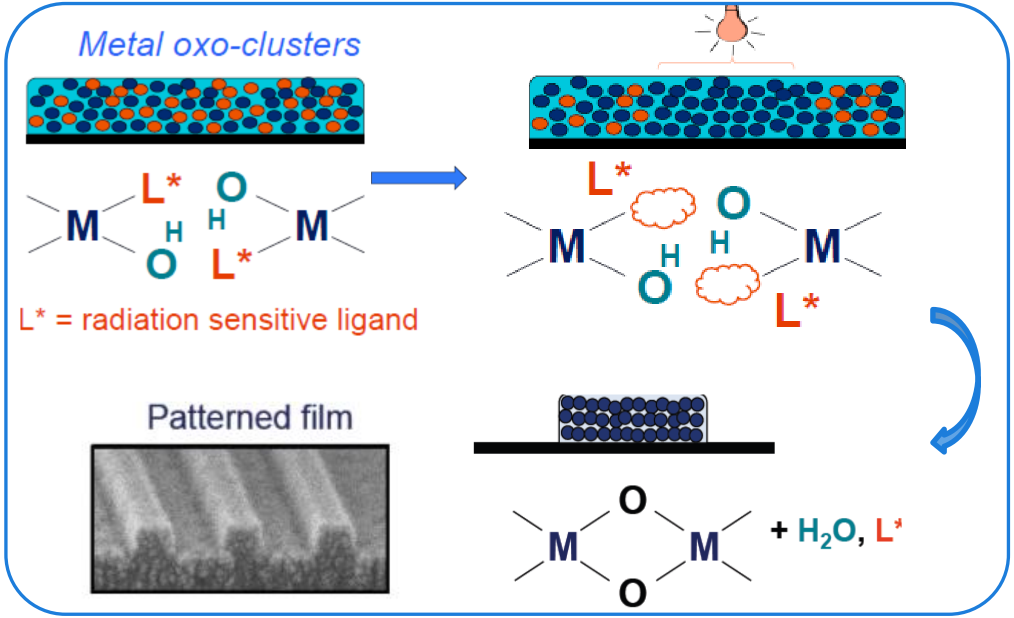
LWR

Sensitivity

Inorganic Non-CAR EUV resists

- Can print resolutions down to 8 nm lines and spaces
- Consists of nano clusters of ~1nm in size
- Metal Core→ ~4x higher absorptivity than CAR resist (capture more photons/volume)
- There are no acids, so no acid diffusion→ only electron blur

	CAR	Non-CAR
Resolution	Lower	Higher
Photon absorption	Low (C,H,O) $\sim 5\ \mu m^{-1}$	High (Sn, Hf) $\sim 20\ \mu m^{-1}$
Chemical noise	High: low PAG concentration	Potentially lower: no acids required
Etch resistance	Lower	Higher

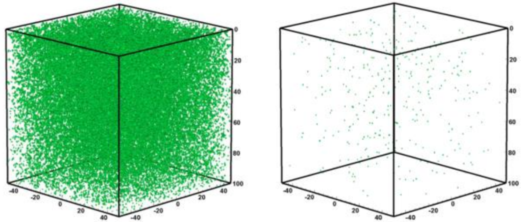


Current EUV resists face several challenges

Challenging to improve **R**, **L** and **S** simultaneously

- Photon Shot Noise: enough photons needed to have low roughness (dose↑ PSN↓)

$$\mathrm{PSN} \propto \frac{1}{\sqrt{N_{photon}}}$$



$ArF, 10\,mJ/cm^2, \alpha = 4/um$

$n_{absorbed} = 366528,\ E_{absorbed} = 2354\,keV$

$EUV, 10\,mJ/cm^2, \alpha = 4/um$

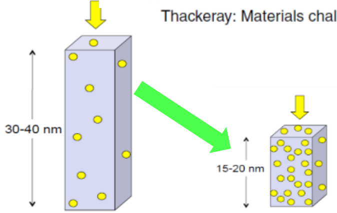
$n_{absorbed} = 25328,\ E_{absorbed} = 2326\,keV$

Fig. 3 Comparison of shot noise statistics for an ArF versus EUV 10-mj exposed resist (see Ref. 28).

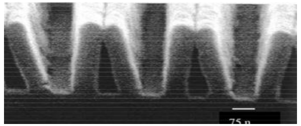
Thackeray: Materials challenges for sub-20-nm lithography

- Smaller blur needed at smaller pitches

- Absorptivity should increase (Film thickness going down)



- Pattern Collapse: (due to High Aspect Ratio at small pitch)

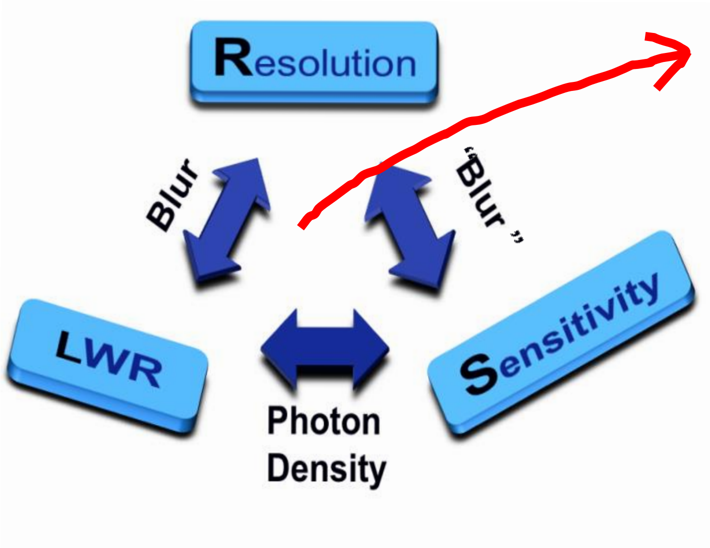


- Etch resistance should increase (FT going down)

R, **L** and **S** are coupled

challenging to improve simultaneously

RLS TRIANGLE

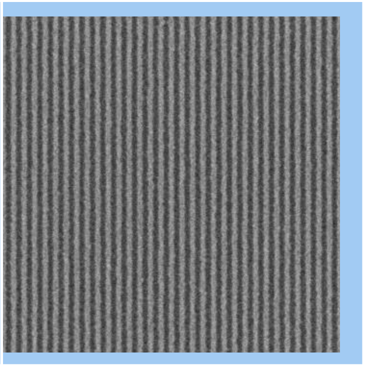


Is it fate? (what) can be improved?

The relation is for a given contrast:

- Improve the Contrast →scanner side
- Improve the relation between R, L and S → resist companies, academia

Non-CAR 13nm dense lines performance

13nm H Dense Lines	New Non-CAR
SEM image @BE/BF	
Dose	34 mJ/cm^2
EL	21 %
DoF	160nm
LWR	3.8 nm

Exposures done on NXE:3400 system with standard leafshape dipoleY illumination

EUV Resist Discussion Points for TWG

1. Models point towards benefit of high absorption→ how to efficiently make use of the high absorption?
2. What is the spatial distribution of electrons (secondary electron blur), how to prove experimentally?
3. Does the energy (distribution) of secondary electrons relate to the energy needed for the chemical reaction?
4. Attention to theory and modelling part of development process can be beneficial→ how the LWR/LCDU are affected from development?
5. Experimental work on how building block size of resist affect resolution/roughness/dose can be helpful.