Our Approaches to Optimizing RLS

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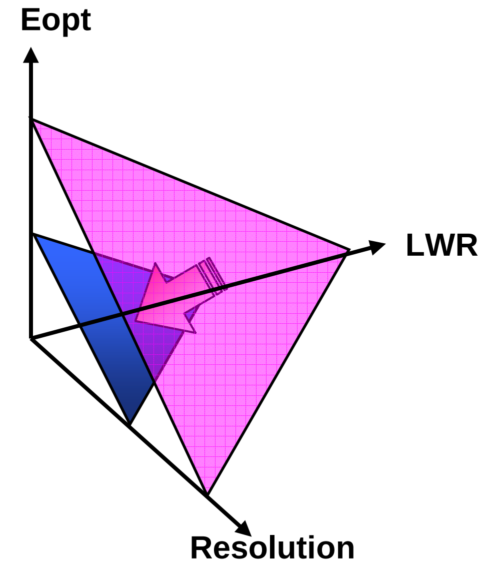
Outline

1. Challenges to EUV Resist Materials
2. Design Policy to Overcome RLS Trade-offs
3. Technologies to Improve RLS
4. Summary

1. Challenges to EUV Resist Materials

Critical Issues of EUV Resist



Simultaneous Improvement of
Resolution, LWR and Sensitivity

- ✓ **Will CAR indeed be able to meet the requirements for 22 nm HP spec and beyond?**
- ✓ **What technologies would be needed to do them?**

1. Challenges to EUV Resist Materials

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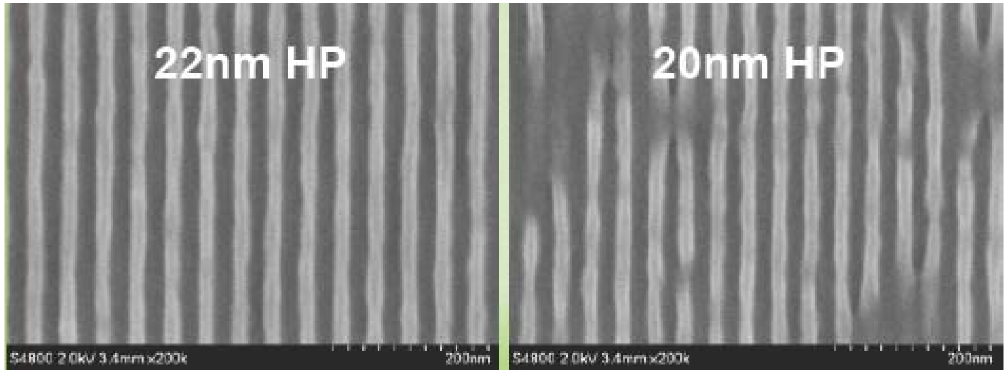
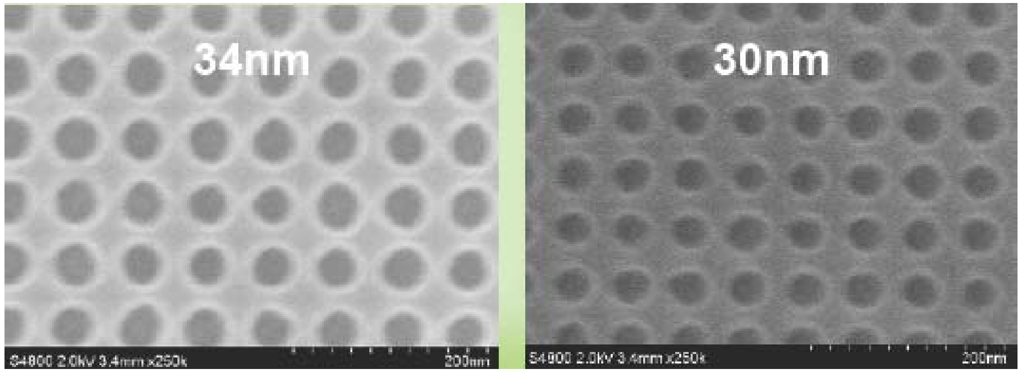
Lithographic Performance of the state of the art CAR





	Resolution	LWR	Sensitivity (E_{opt})	Collapse (AR)
ITRS HVM Specs	22 (nm)	1.2 (nm)	10 (mJ/cm^2)	2.5
The state of the art CAR	22 (nm)	5.6 (nm)	14.4 (mJ/cm^2)	1.92

- The state of the art CAR has demonstrated nearly 22 nm HP Resolution, however LWR and Sensitivity are still far behind the target at present.

2. Design Policy to Overcome RLS Trade-offs

Two important results leading to our design policy

The first : Dependence of LWR and sensitivity on quencher amount

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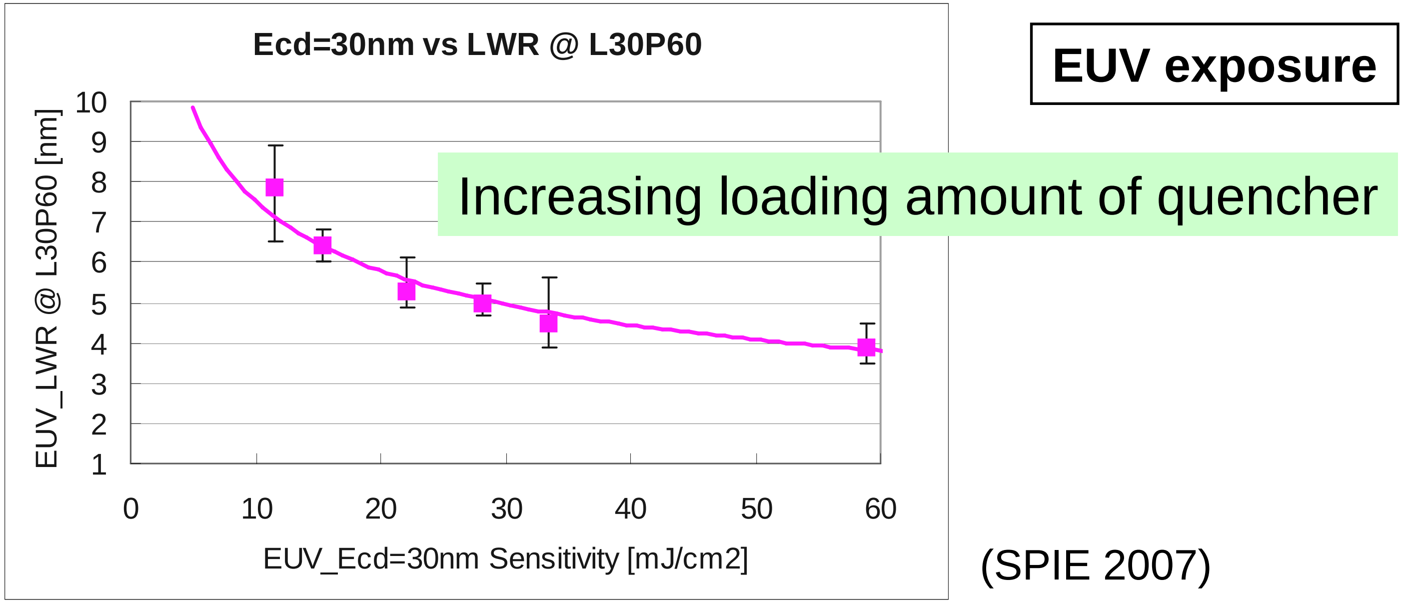


(SPIE 2007)

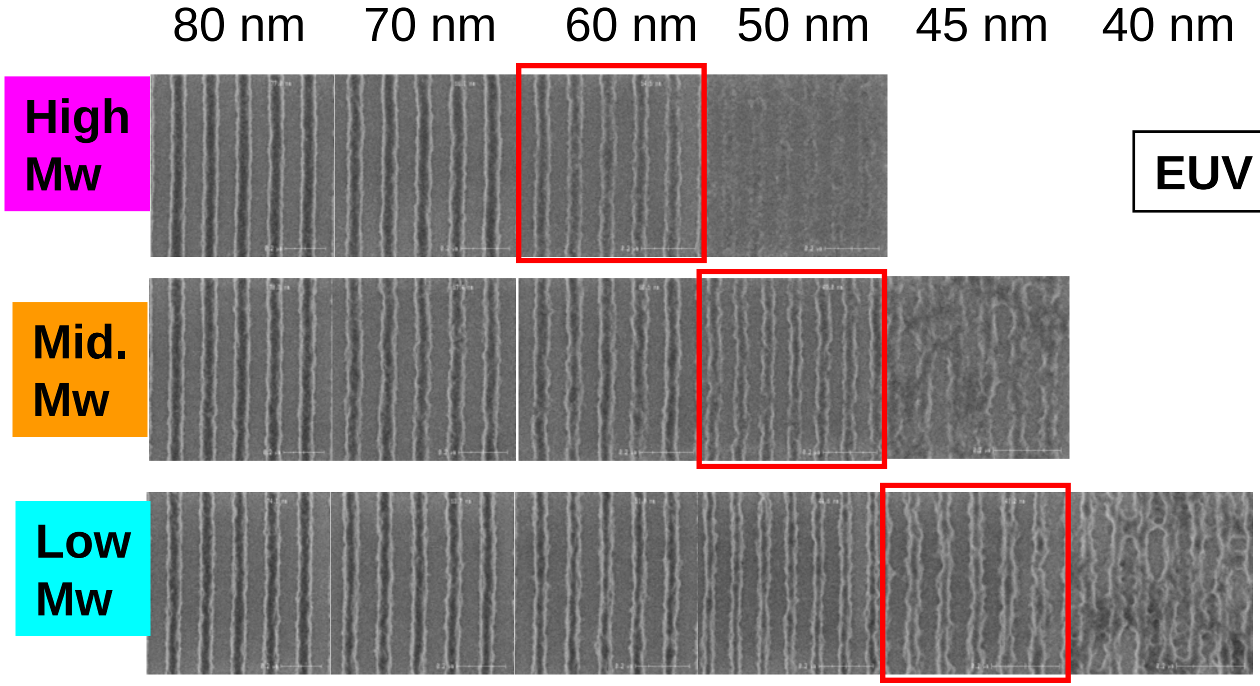
LWR is improved by increasing the loading amount of quencher with losing sensitivity.
How would LWR be improved without losing sensitivity?

⇒ Enhancement of Aerial Image Contrast

2. Design Policy to Overcome RLS Trade-offs

Two important results leading to our design policy

The second : Dependence of resolution on polymer MW



EUV exposure

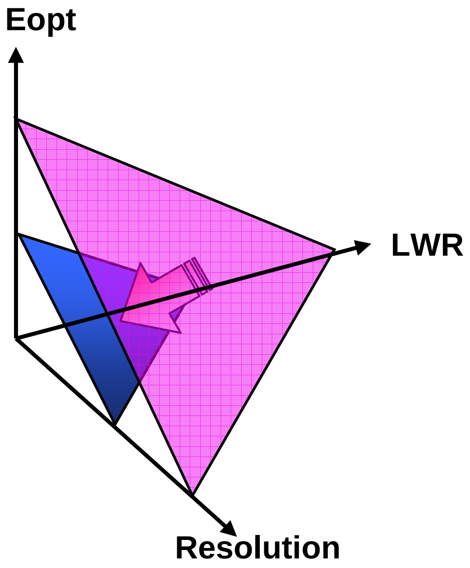
Process Condition: FT=125 nm, PB = 120 oC/ 90 sec, MS-13 Microstepper (NA=0.3), PEB = 110 oC/90sec, Deve.= TMAH 2.38% 60 sec,

Resolution is improved by lowering the Mw of polymer.

⇒ Minimization of Dissolution Unit Size

2. Design Policy to Overcome RLS Trade-offs

Critical Issues of EUV Resist



Simultaneous Improvement of Resolution, LWR and Sensitivity

Design Policy to overcome those trade-offs

- ✓ **Enhancement of aerial image contrast**
- ✓ **Minimization of dissolution unit size**

2. Design Policy to Overcome RLS Trade-offs

Pattern Formation Mechanism of EUVL

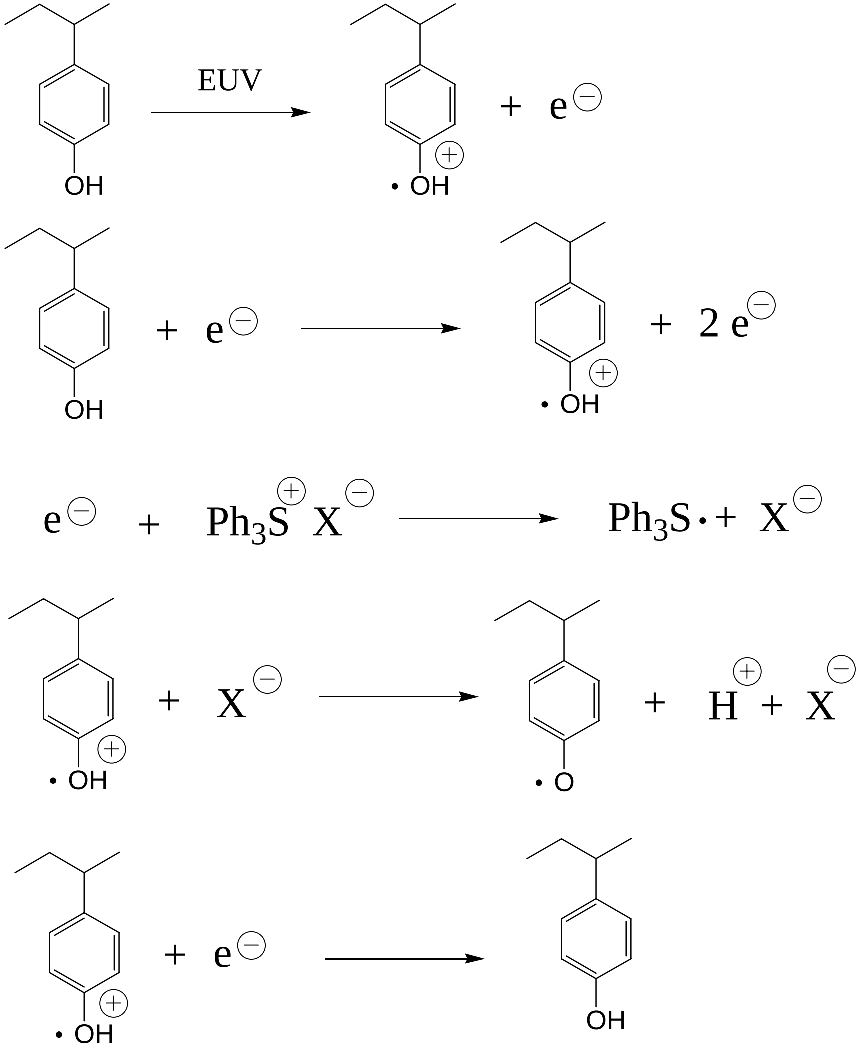
EUV absorption / R$^{\cdot}$ & 2nde^{-} generation

Ionization by 2nde^{-} / R$^{\cdot}$ & 2nde^{-} amplification

e^{-} trap / anion generation

Combination of R$^{\cdot}$ & anion / acid generation

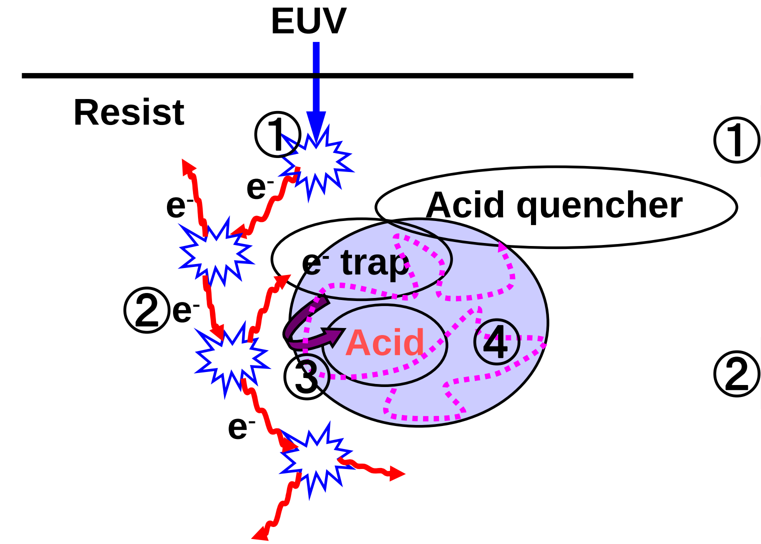
Recombination of R$^{\cdot}$ & e^{-} / loss channel

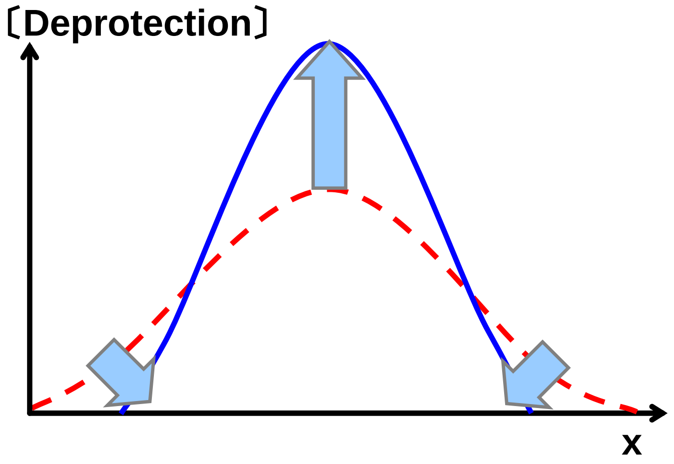


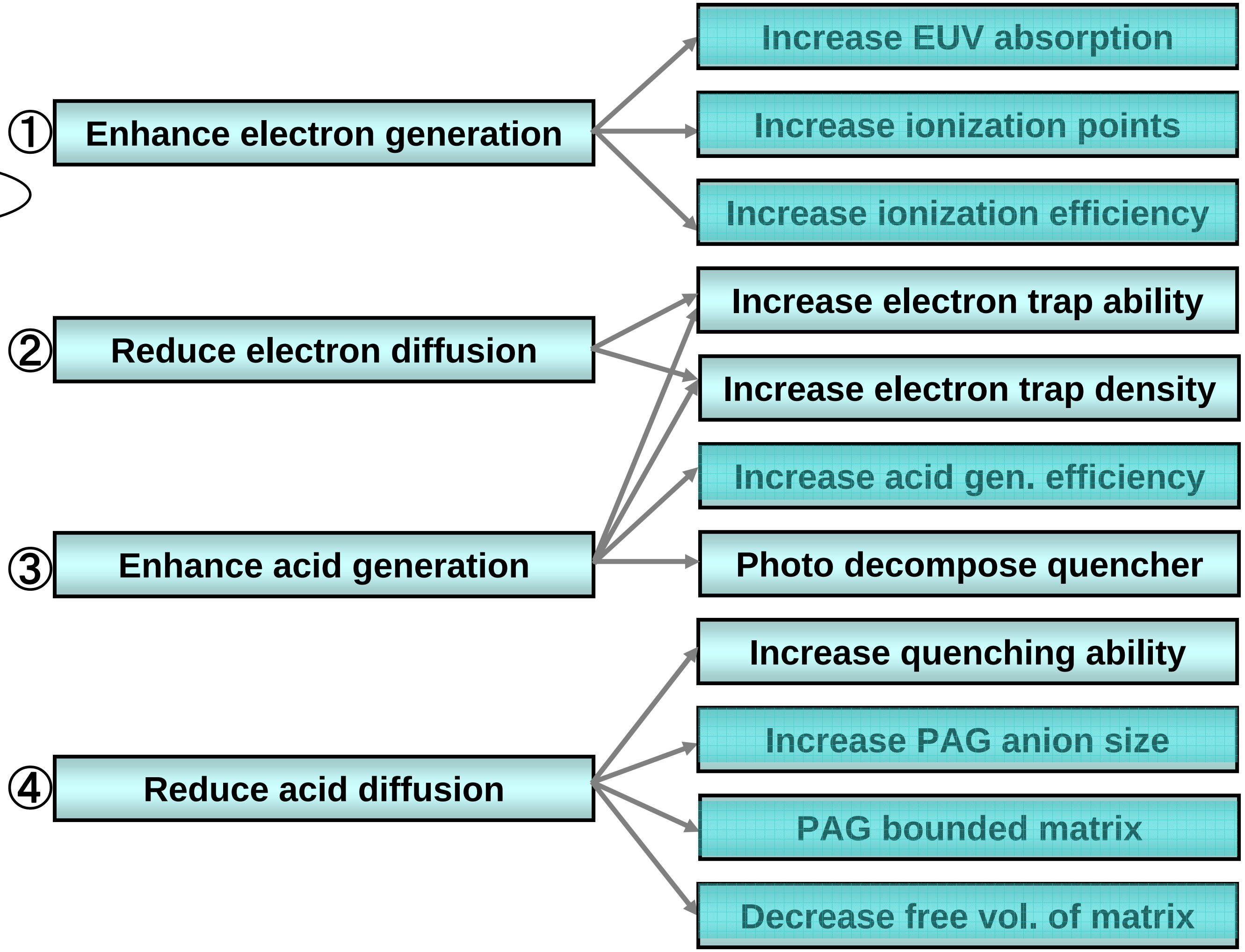
Based on the model proposed by Prof.s Kozawa and Tagawa

2. Design Policy to Overcome RLS Trade-offs

Enhancement of Aerial Image Contrast







① Enhance electron generation
- Increase EUV absorption
- Increase ionization points
- Increase ionization efficiency

② Reduce electron diffusion
- Increase electron trap ability
- Increase electron trap density

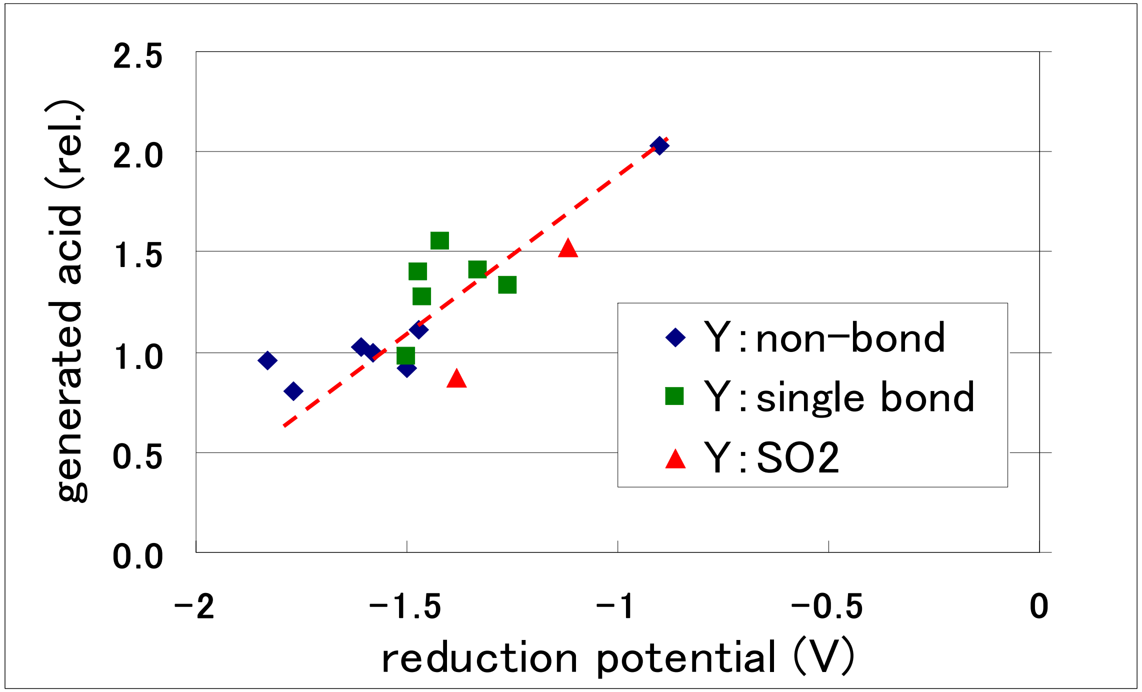
③ Enhance acid generation
- Increase electron trap ability
- Increase electron trap density
- Increase acid gen. efficiency
- Photo decompose quencher

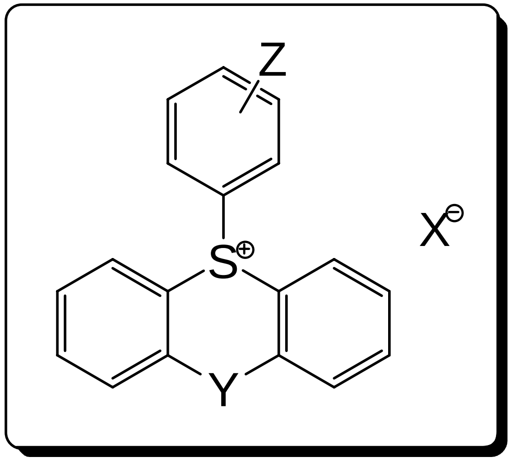
④ Reduce acid diffusion
- Increase quenching ability
- Increase PAG anion size
- PAG bounded matrix
- Decrease free vol. of matrix

3. Technologies to Improve RLS

Ex. 1 ; Increase of Electron Trap Ability and Density

Electrons trapping ability of PAGs



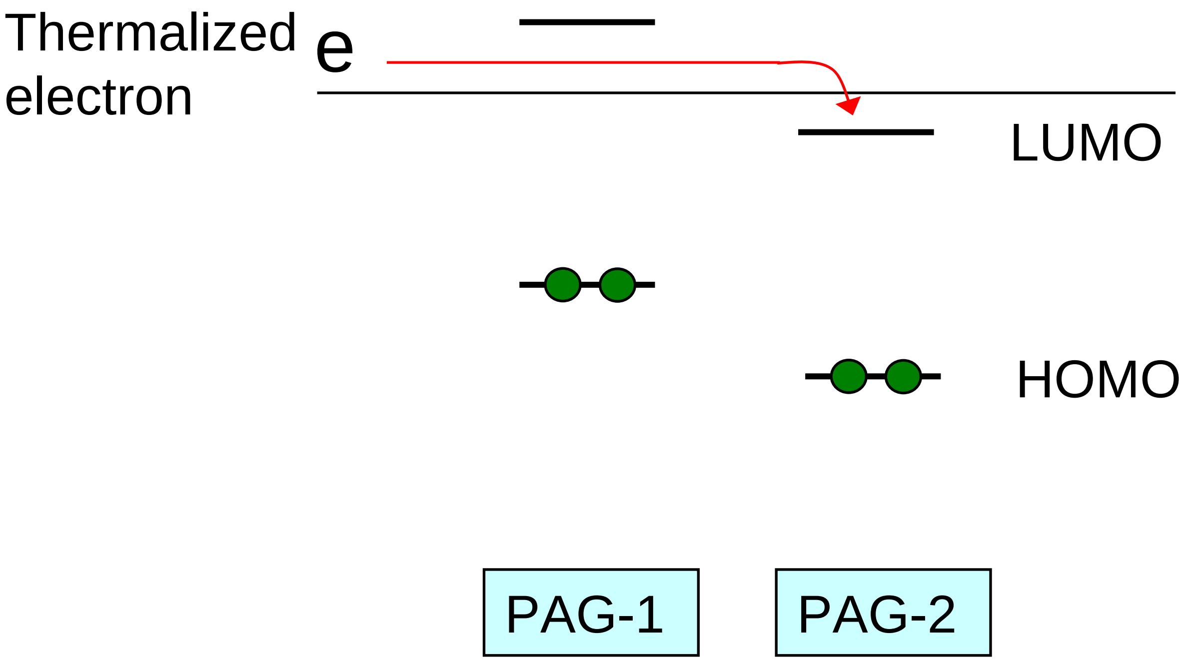


The amount of generated acid, that would be related to electron trapping ability of PAGs, could be increased by raising the reduction potential of PAGs.

3. Technologies to Improve RLS

Ex. 1 ; Increase of Electron Trap Ability and Density

Why the amount of generated acid was increased as reduction potential of PAG becomes higher?



Thermalized electron

e

LUMO

HOMO

PAG-1

PAG-2

Energy diagram for an electron in resist matrix

electron trapping ability

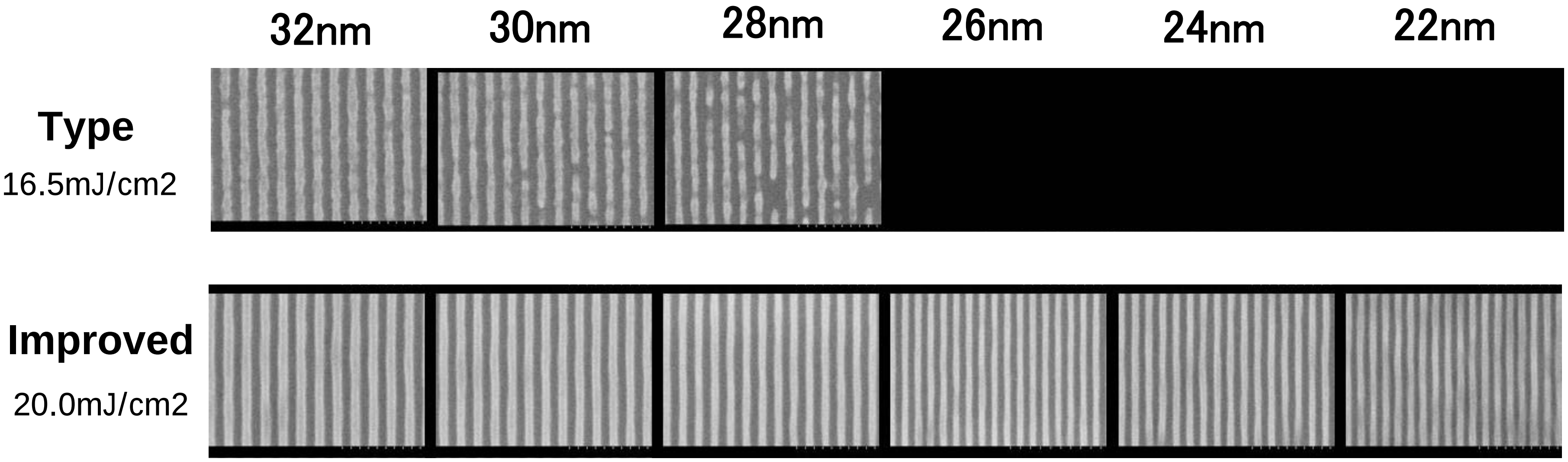
PAG-1 < PAG-2

3. Technologies to Improve RLS

Ex. 1 ; Increase of Electron Trap Ability and Density

The loading amount of quenchers is also increased in the sample to reduce acid diffusion.

- Illumination Conditions : Rot-Dipole



- **Resolution and LWR has been improved in the sample based on electron and acid diffusion control.**

3. Technologies to Improve RLS

Ex. 2 ; Effect of Photo decomposable Quencher

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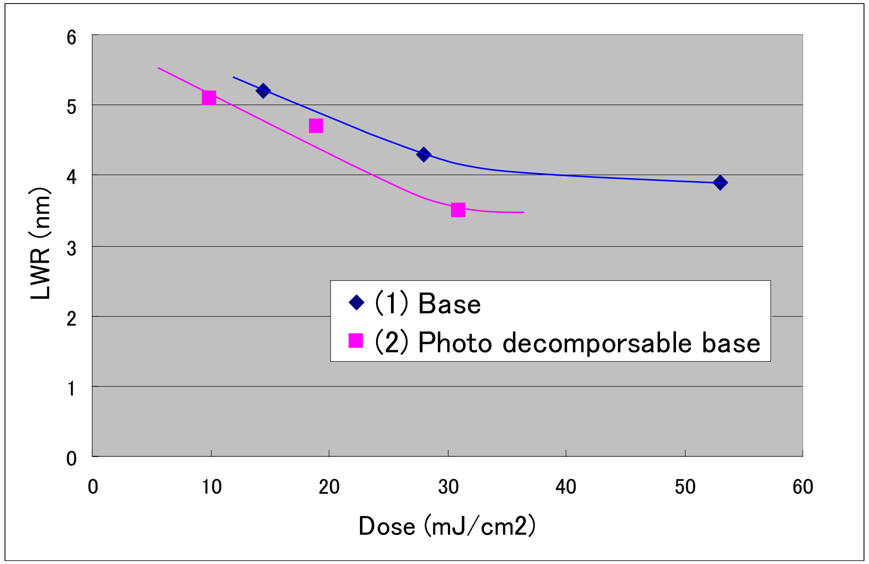
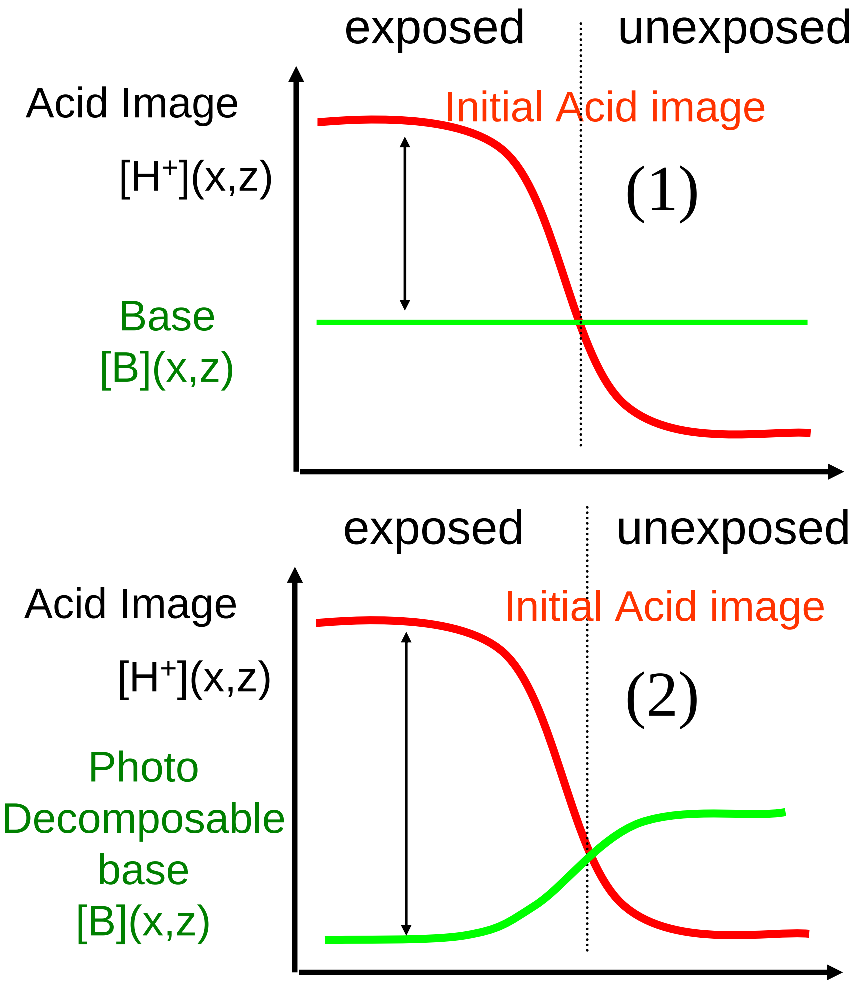


Photo decomposable quencher could improve the relationship between LWR and sensitivity.



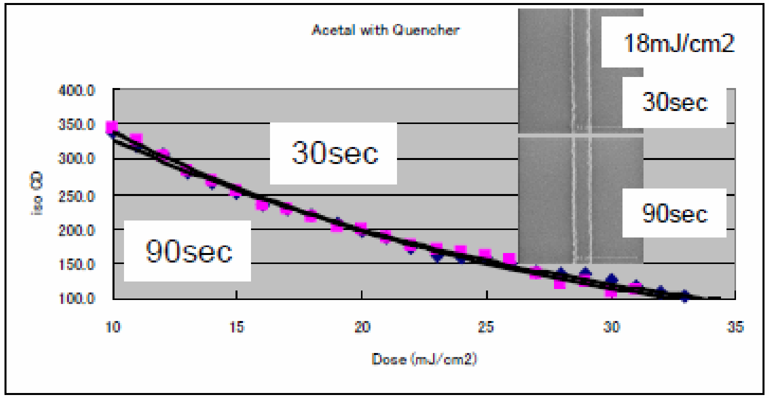
3. Technologies to Improve RLS

Ex. 3 ; Increase of Quenching Ability

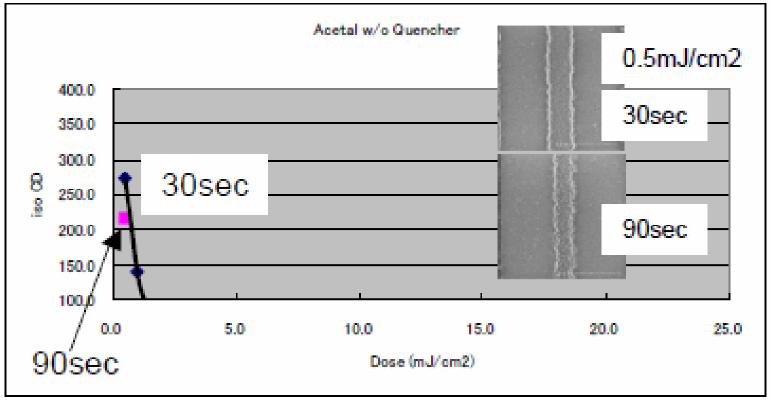
Function of quencher

PEB time dependency of iso-line width (KrF exposure)

With Quencher



W/O Quencher

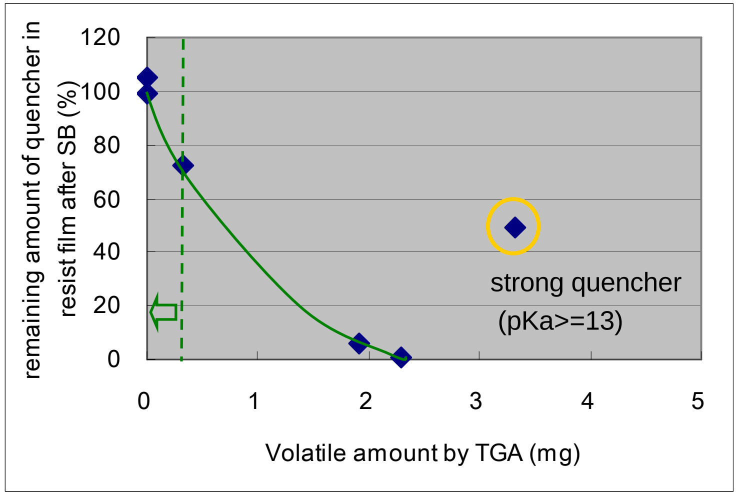


Quencher would dominate the substantial acid diffusion length.

3. Technologies to Improve RLS

Ex. 3 ; Increase of Quenching Ability

Volatility of quencher



Film thickness: 60nm
SB condition: 120degree/90sec
TGA condition: 120degree/20min

It appears that many kinds of quencher do not remain in the resist film, because EUV resist film is quite thin compared to conventional one.

✓The remaining amount of quencher in resist film after SB is almost related to volatility of quencher in itself.

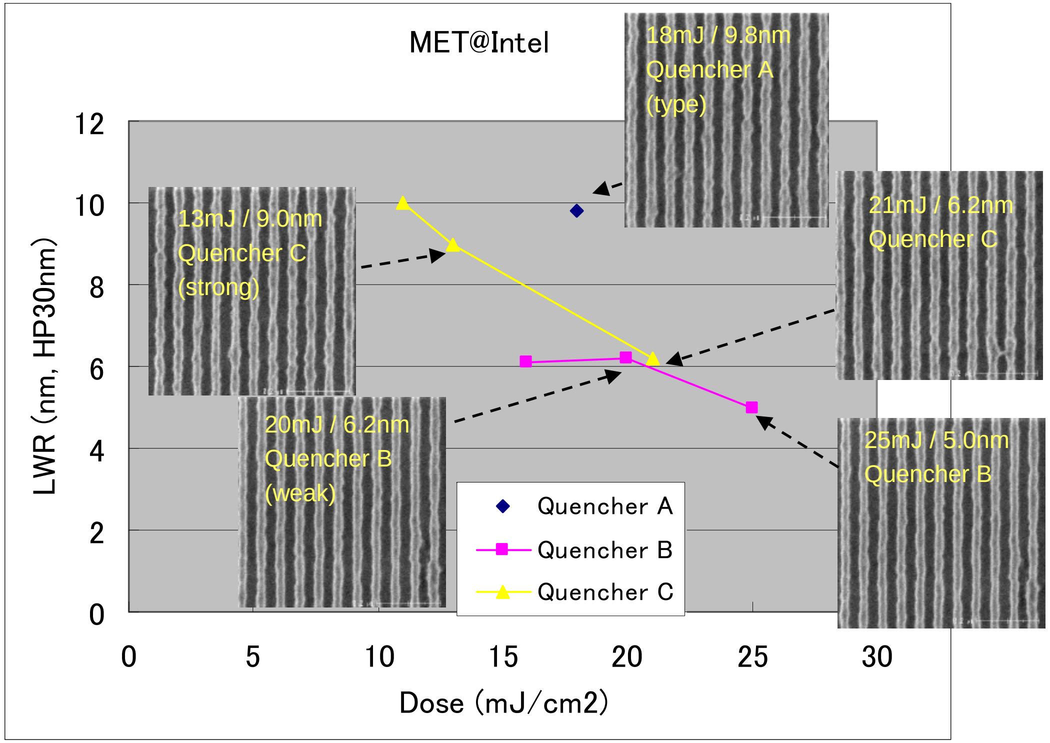
✓Strong quencher tends to remain in resist film,even if it has high volatility. It is suggested that the interaction between week acid, phenol, and the strong quencher could operate.

Quencher for EUV resist must be sufficiently low in volatility in itself.

3. Technologies to Improve RLS

Ex. 3 ; Increase of Quenching Ability

LWR vs sensitivity in EUV exposure



- ✓Several quenchers showed better LWR vs sensitivity performance against type quencher.
- ✓There is no relationship between basicity, LogP, or Mw of quencher and the performance.
- ✓We assume that the performance relates to the uniformity of aerial distribution of quencher in resist film, but we have no evidence yet.

4. Summary

- ✓ **The state of the art CAR has demonstrated nearly 22 nm HP Resolution, however LWR and Sensitivity are still far behind the target at present.**
- ✓ **Our design policy to improve RLS farther consists of enhancement of aerial image contrast and minimization of dissolution unit size.**
- ✓ **The enhancement of aerial image contrast could be achieved by the following ways.**
  - **Enhance electron and acid generation**
  - **Reduce electron and acid diffusion**
- ✓ **Some concrete examples to enhance acid generation and reduce electron and acid diffusion are presented to be effective to improve RLS. Farther investigation must be necessary to meet the target.**
- ✓ **It would be also important to realize minimization of the dissolution unit size.**

Acknowledgement

- **Mr. Chawon Koh from SEMATECH**
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