Proposal to use longer wavelength light for EUV Lithography

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Proposal

- We propose using “longer wavelength light ~ 20-40nm” as a shortcut to insertion EUVL in 70nm node.

Roadmap

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Delay of Schedule

- EUV LLC and VNL were established in September ’97.
  - Target node was 100nm.
  - The economic downturn in the semiconductor industry has occurred.
  - Difficulty of EUVL technology is more than we can imagine?
  - Current target node is 70nm.
- Poll at NGL meeting in Spring ’99
  - Although 13nm EUV lithography is expected of a likeliest winner in 50nm node, it isn’t expected of a candidate in 70nm node.

Difficulty in Realization of Required Wavefront Error

- Managing both figure and mid-frequency roughness is not demonstrated with practical mirror size in diameter.
  - <0.2nm is required.
- Mirror substrate fabrication is not the only issue.
  - Residual stress of multilayers, deformation by mirror mount and thermal loading must be overcame.
- Long term stability after integration into steppers is not estimated.
  - WFE measuring system is probably needed on steppers.

Proposal of High Numerical Aperture Camera

- High numerical aperture (N.A.) cameras were designed.
  - D. M. Williamson, SVG (USP5,815,310, filed on December 12, 1995)
  - D. W. Sweeney, LLNL (at NGL Critical Review at Colorado Springs on December 9, 1998)
- Wavelength at 13nm is not required for such high N.A. systems.

Wavelength and N.A.

- Longer wavelength EUV steppers are expected to be not only production tools in 70nm node also pre-production tools in 50nm node.
- In order to moderate wavefront error requirement, wavelength should not be close to 13nm.
- Resolution = k1 * λ / N.A.
  - Wavelength(λ): 30nm
  - N.A.: 0.3
  - Resolution: 60nm @ k1: 0.6
  - Resolution: 50nm @ k1: 0.5

Advantage of Longer Wavelength EUVL

- Wavefront error requirement is moderated.
  - For example, when wavefront error is 2.2nm, it is λ/6 at 13nm but λ/14 at 30nm.
  - Requirements for mirror substrate fabrication, multilayer coating, mirror mounting, PO box, and so on are also moderated.
- Steppers with same N.A. are usable in multiple generation~70-30nm.
  - Common mirror fabrication facility, multilayer coating facility and stepper platform are usable during multiple ganeration.

Disadvantage of Longer Wavelength EUVL

- New coating material, source and resist must be developed.
  - Coating: Theoretical solutions exist.
  - Source: Lower conversion efficiency of Xe LPP is problem. Alternative source is needed?
  - Resist: Lower transmittance is problem but higher than at 157nm.

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Verification of Validity of LW-EUVL

- Three approaches has been proposed.
  - Use common wavelength, change N.A. in each generation.
    - N.A.=0.14 for 70nm node, 0.20 for 50nm and 0.30 for 30nm. (J.Taylor et al. at SPIE's 44th Annual Meeting in Colorado in July 99)
  - Use common wavelength and N.A., improve wavefront error in each generation.
    - EUV LLC & VNL
  - Use common N.A. and different wavelength. (LW-EUVL)
- Which approach is the best for EUV lithography?
  - Optical simulation.
  - Development schedule.

Information Volume

- Information volume is useful for estimating wavelength and N.A.

$$IV = SI * (NA/\lambda)^2 * \{1 - (2\pi/\lambda)^2 \langle \Delta W^2 \rangle + (1/4)(2\pi/\lambda)^4 (\langle W^2 \rangle)^2 + (2/3)(2\pi/\lambda)^4 \langle W^2 \rangle \langle W \rangle^2 + \cdots\cdots\}$$

W: Wavefront Error

$$\langle W \rangle = \int\int W d\xi d\eta \,/\, \int\int d\xi d\eta$$

$$\langle W^2 \rangle = \int\int W^2 d\xi d\eta \,/\, \int\int d\xi d\eta$$

$$\langle \Delta W^2 \rangle = \langle W^2 \rangle - (\langle W \rangle)^2 = \text{rms}$$

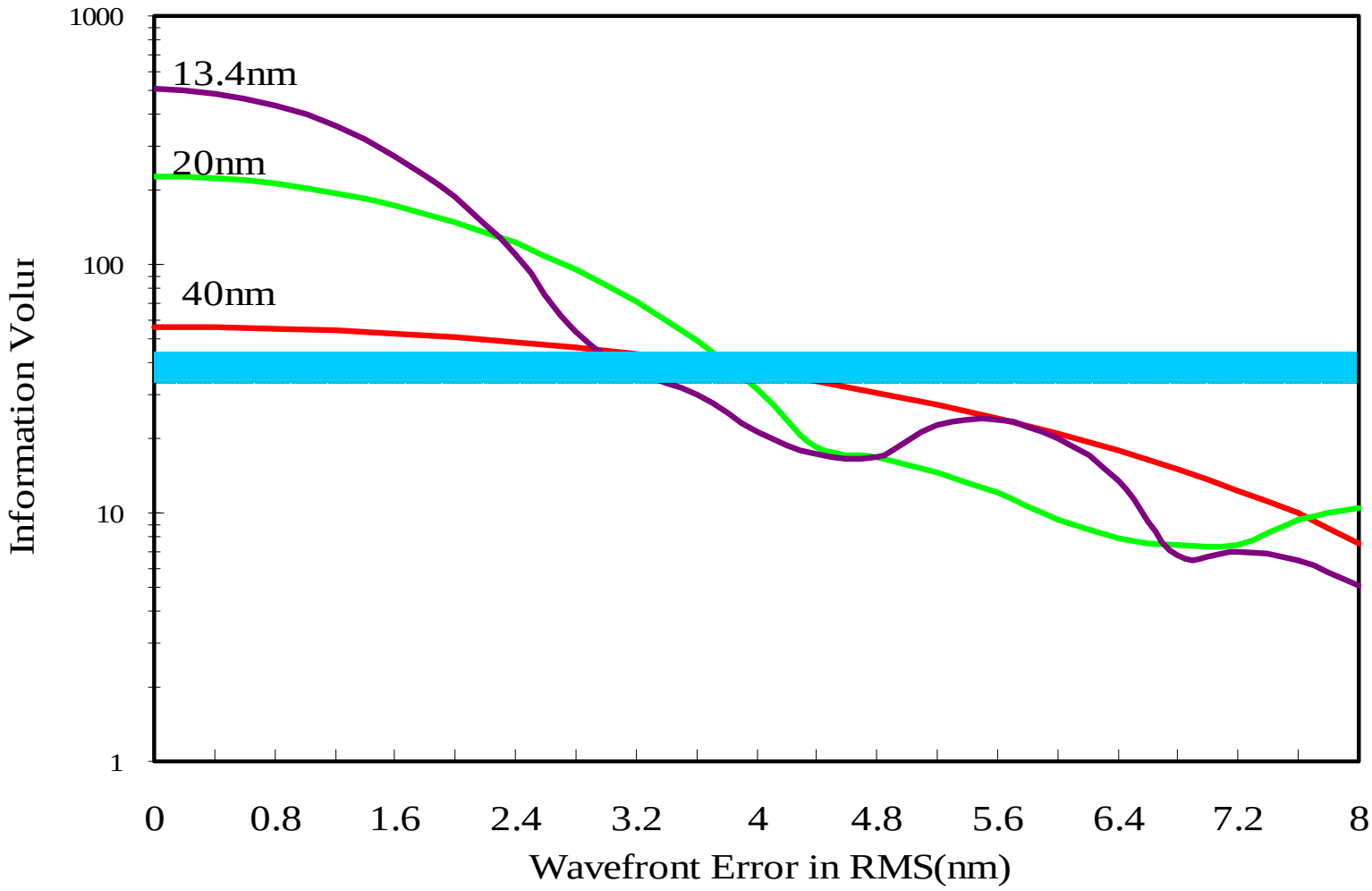
Required Information Volume for 70nm node

- Required information volume for 70nm node is 35-46.

Information volume in each generation

Node (nm)	Wavelength (nm)	N.A.	IV@W=0	Increasing Ratio
250	248	0.6	5.8	-
180	248	0.75	9.1	1.56
130	193	0.75	15	1.65
100	157	0.75	23	1.51
70	?	?	*35/46*	1.5/2.0

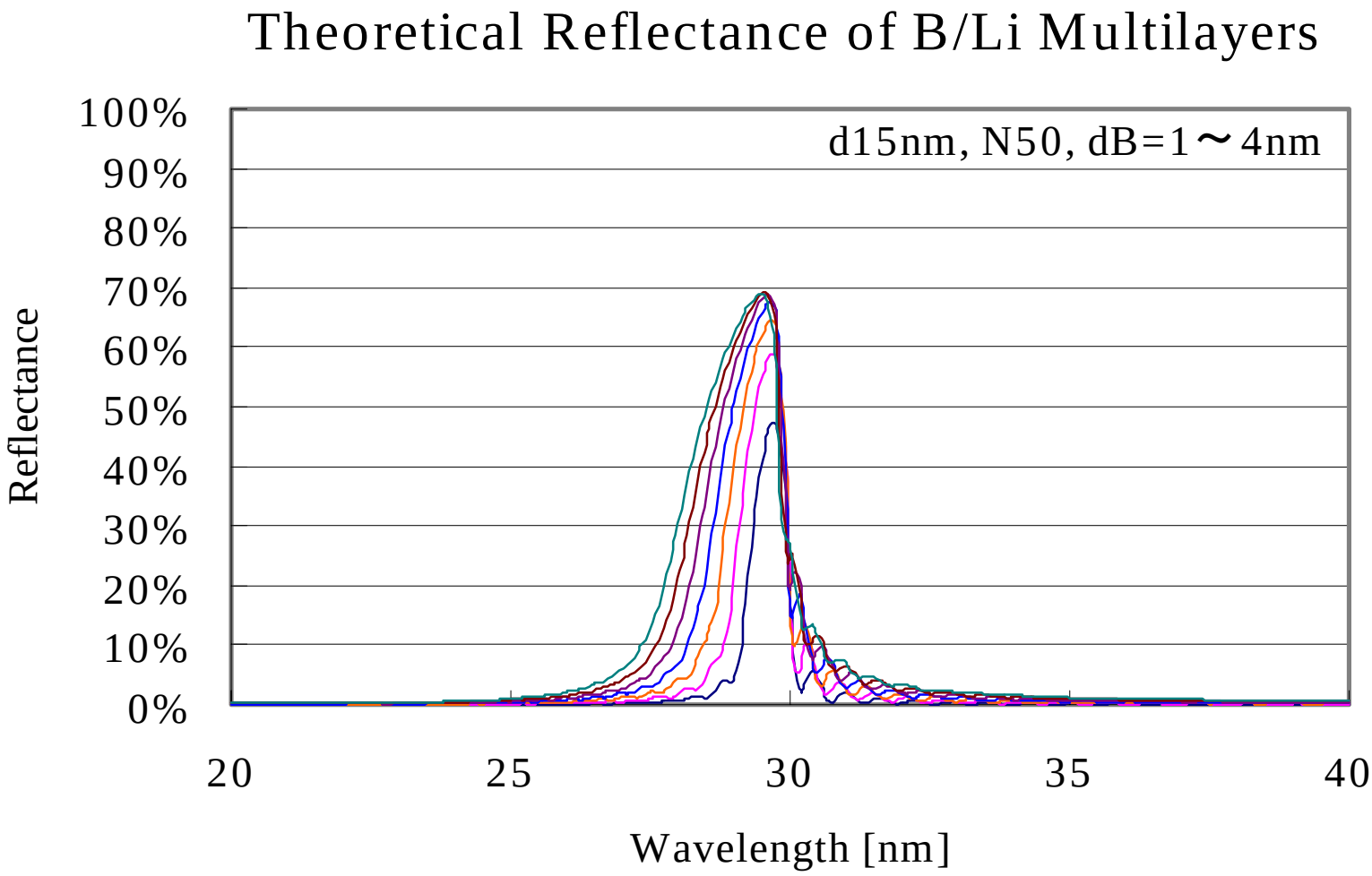
Information Volume of Each Condition



Selection of Wavelength

- Meaningful wavelength must be selected.
  - Little difference from 13nm hardly moderates mirror surface figure requirements.
  - Much difference from 13nm shorten its life.
- Multilayers with sufficient reflectance, low residual stress, long term stability and productivity are needed.
  - Not only theoretical data also experimental data is needed.
- Source and resist issues must be considered.

Example of Multilayers for Longer Wavelength



Estimation of Development Load and International Cooperation

- Can the insertion point of EUVL be brought forward by LW-EUVL?
  - Loads on optics will decrease but new loads will be added to others.
- Developing time is limited.
  - International cooperation and collaboration are needed.

Conclusion

- We propose using “longer wavelength light ~ 20-40nm” as a shortcut to insertion EUVL in 70nm node.

Acknowledgement

- We thank ASET for giving us good advice.