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Progress of Nikon EUV Exposure Tools

Nikon Corporation

2nd Development Department

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Presentation Outline

1. EUV tool development plan
2. EUV1 specification and status
3. Projection optics
4. Plan for EUV2
5. Infrastructures
6. Overall summary

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EUVL Tool Development Plan

Cal. Year	2006	2007	2008	2009	2010	2011	2012
ITRS2005 DRAM ½ p Flash ½ p MPU C. Hole	70 nm 64 nm 97 nm	65 nm 57 nm 84 nm	57 nm 51 nm 73 nm	50 nm 45 nm 64 nm	45 nm 40 nm 56 nm	40 nm 36 nm 50 nm	35 nm 32 nm 44 nm
R&D programs Collaboration	ASET (HiNA, small field) EUVA (Wavefront sensor, Contamination control) SELETE (EUV Lithography and Mask Program)						
Nikon Exposure tool	EUV1 For Process development Review				EUV2 For 32nm production		

EUV1 (Process Development Tool) is under system integration.

EUV1 Tool Specifications

EUV1: For 45nm hp node process development & 32nm hp node R&D

Specification Item	EUV1
Field Size	26 x 33 mm^2
NA and Magnification	0.25, x1/4
Resolution	Dense line: 45 nm @hp Isolated line: 25 nm (Target 32 nm @hp)
Flare	10 %
Overlay	target 10 nm (3s)
Wafer Size	300 mm
Throughput (10W & 5mJ/cm^2)	5-10 WPH

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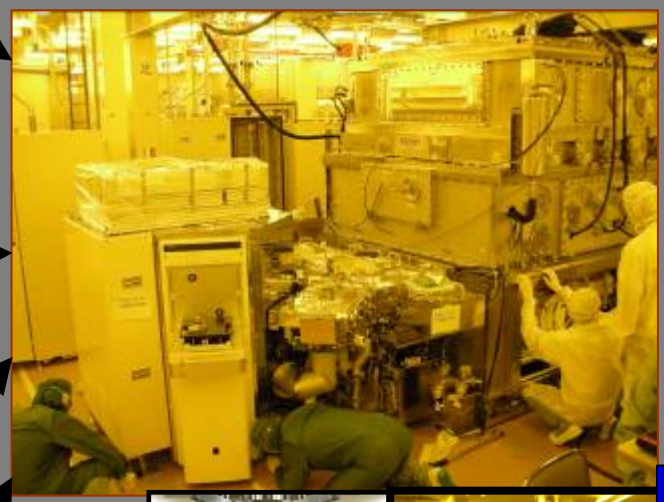
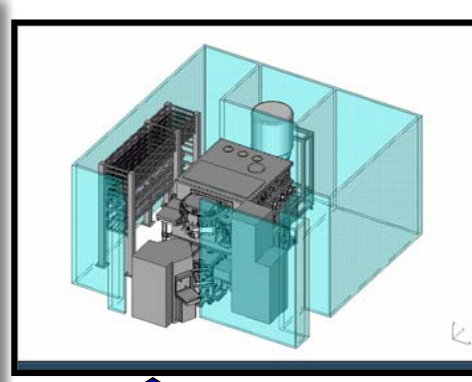
EUV1 Tool Development Status

Module | **Module Integration** | **System Operation**

We are here

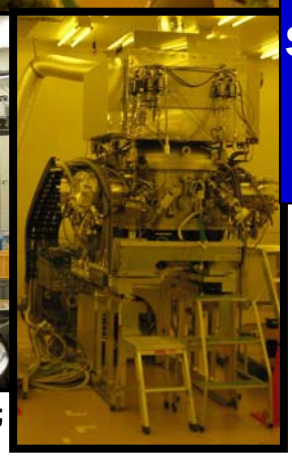
Reticle/ Wafer Loaders





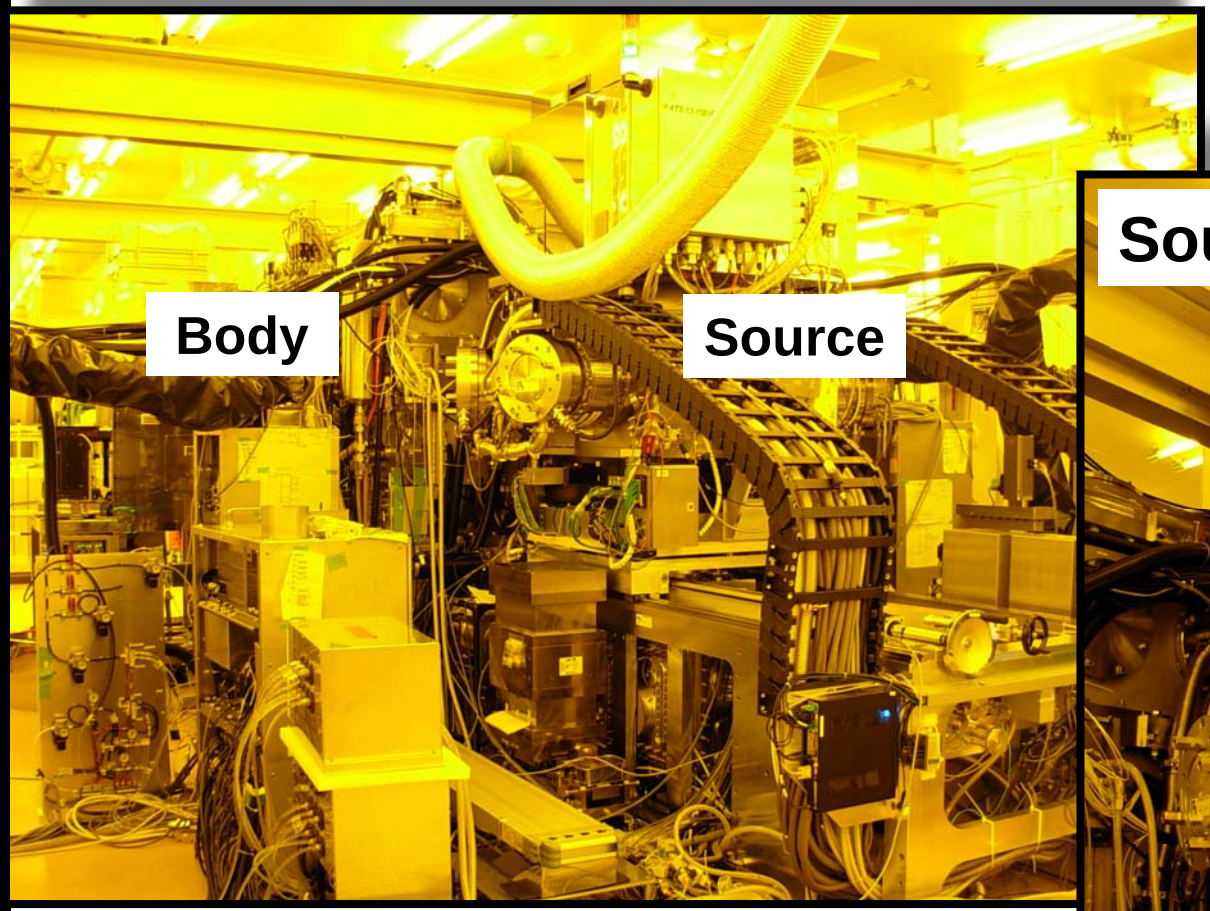
Reticle Stage

Wafer Stage



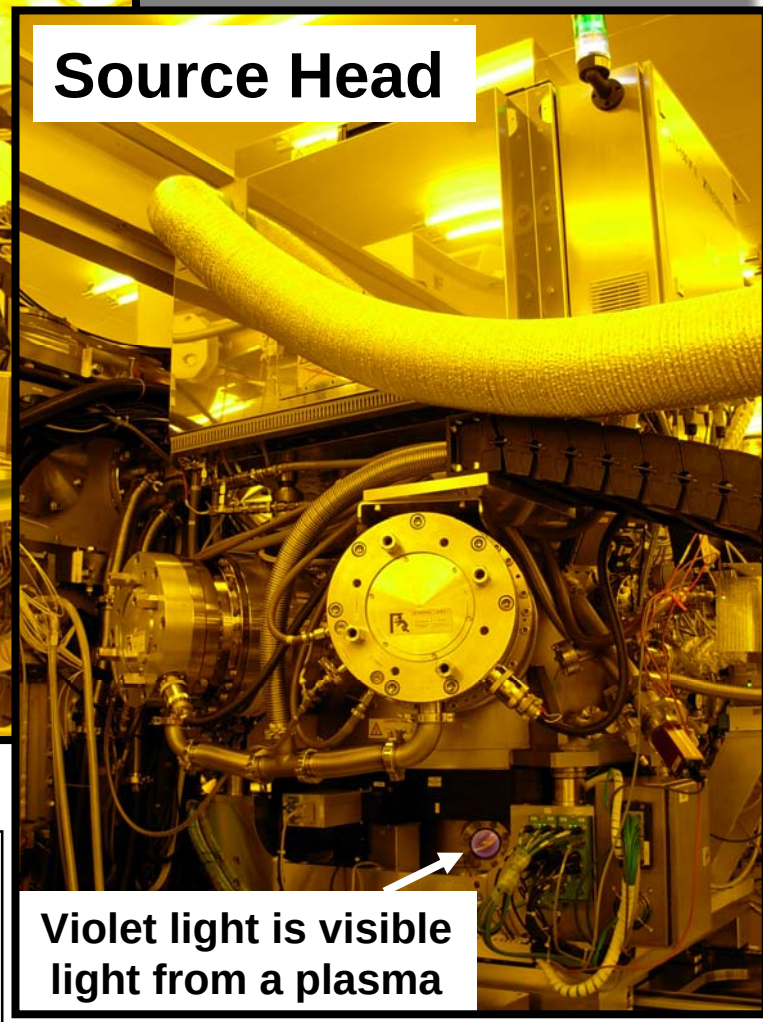
Static exposure data available in February

Light Source and IU Status



EUV1 and light source

- Aligning optical axis and tuning with illuminator ongoing.
- Light source IF power is the issue.



EUV1 IU Test Stand

- Visible light measurement

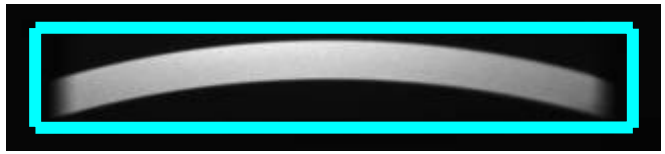
Back view

- EUV light measurement

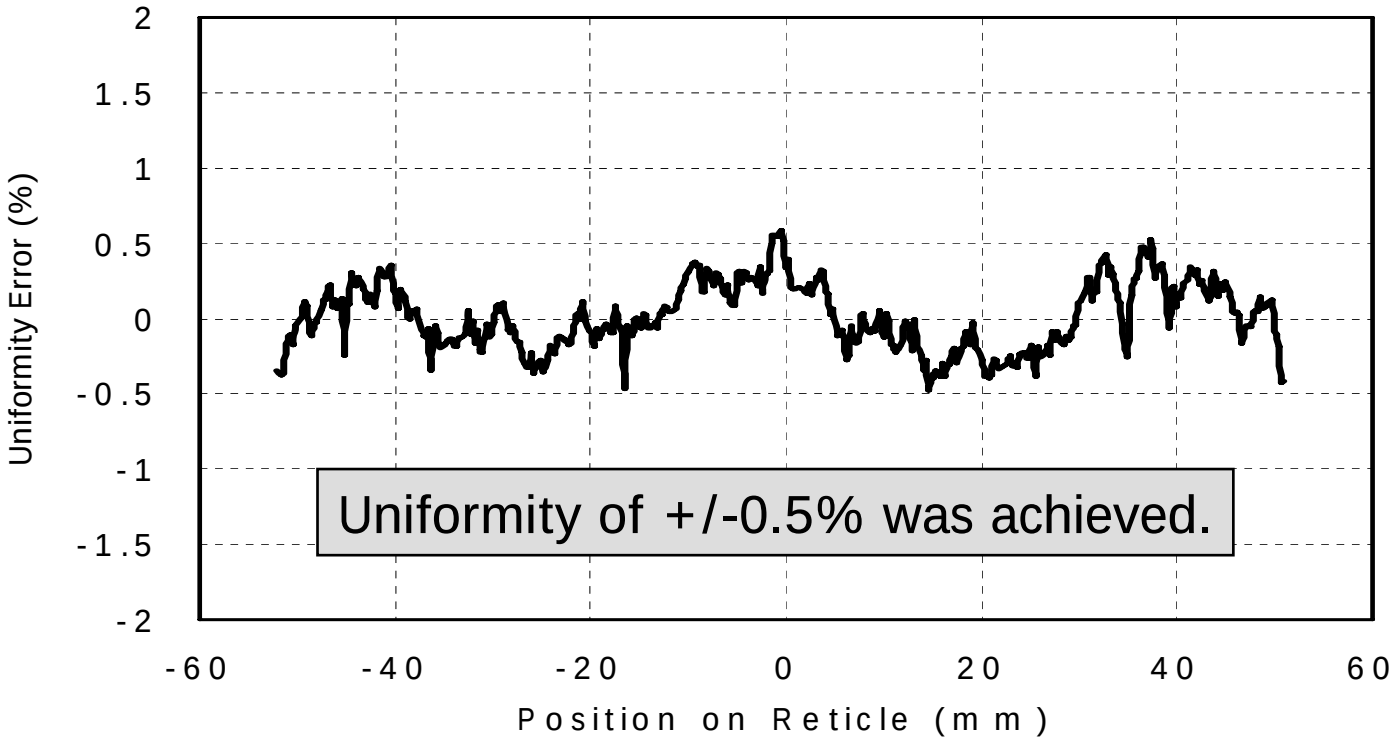
Side view

Status of EUV1 Illumination Unit (IU)

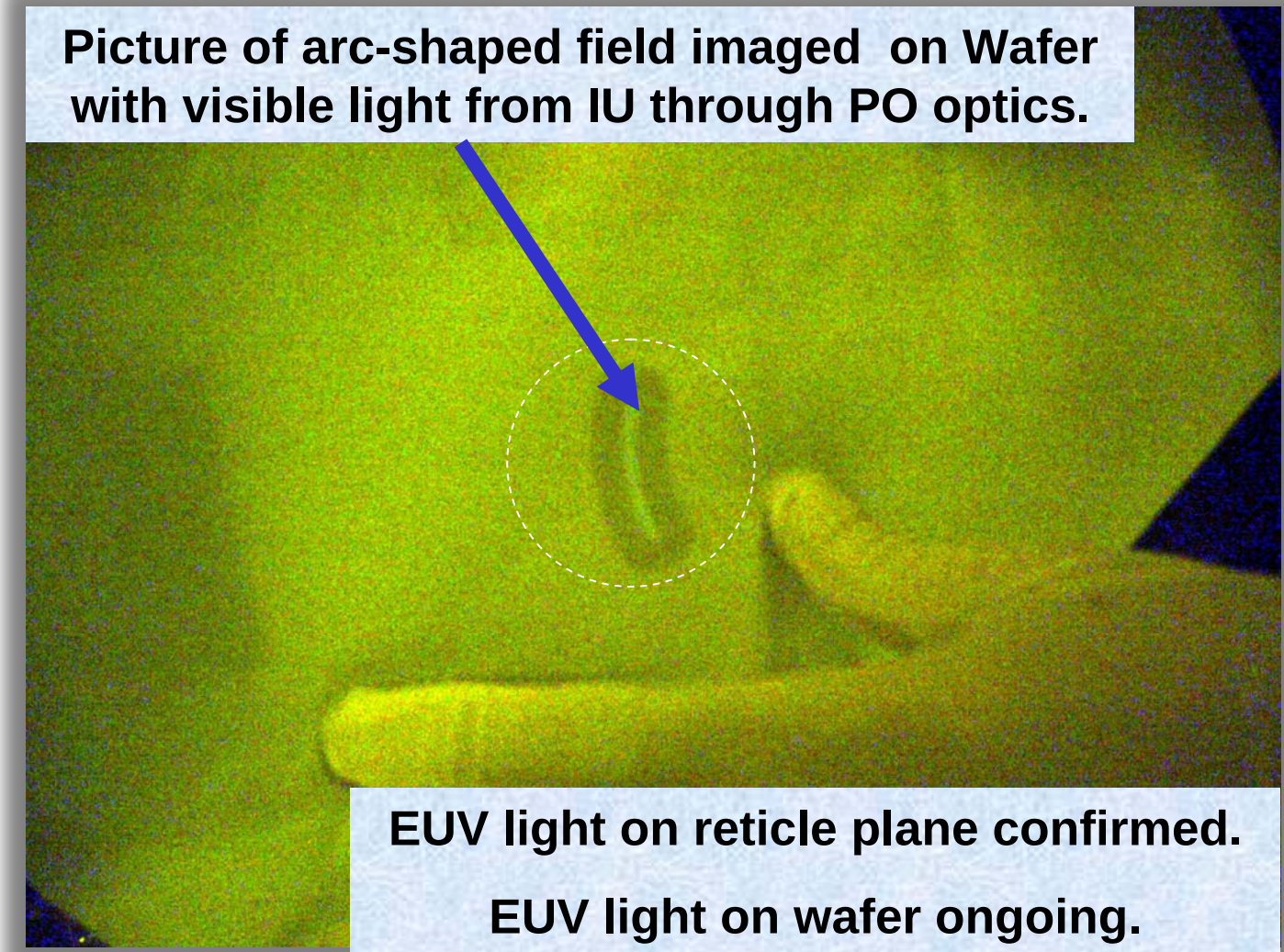
- **Visible light image on test stand**



- **Illumination uniformity on test stand (EUV light)**



First light (visible light) on Body

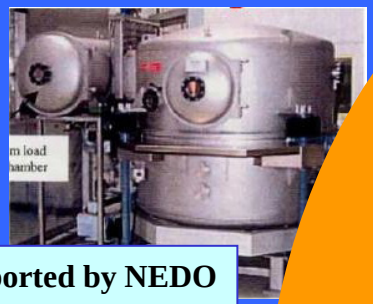


Reflective Projection Optics Development

Key technologies

- **Metrology**
  - High repeatability interferometers
  - Visible light wavefront metrology system
  - EUV wavefront metrology system
- **Polishing**
  - New polishing technology (IBF, EEM)
  - The state of the art for mirror polishing
- **Coating**
  - Multilayer coating process using magnetron sputtering
- **Assemble and Adjustment**
  - Ultra-precise position control

EUV1 PO and production tools



Supported by NEDO

Supported by NEDO

Supported by NEDO

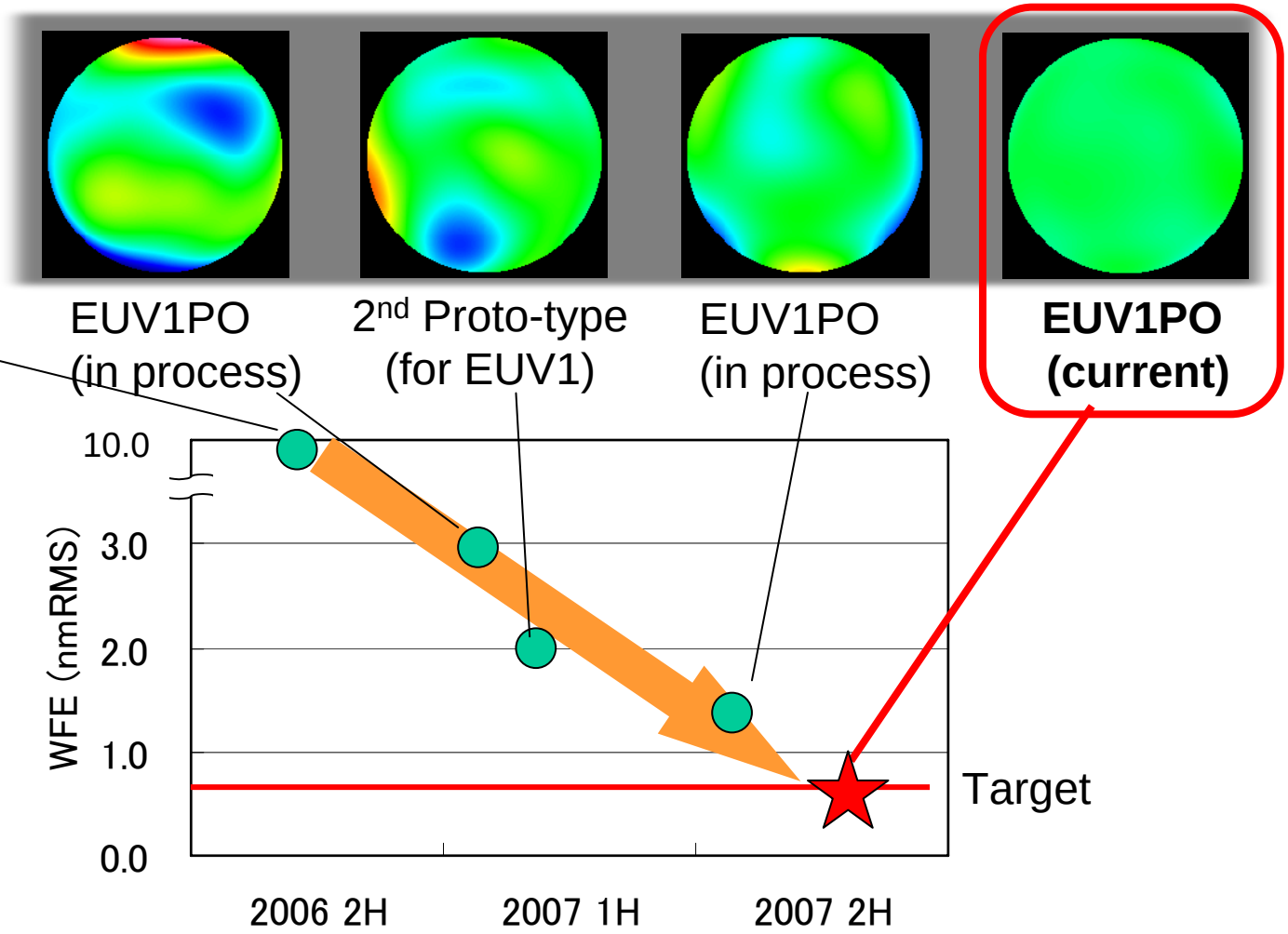
EUV1 Projection optics

Supported by NEDO

Mirror fabrication tools

Optical evaluation tools

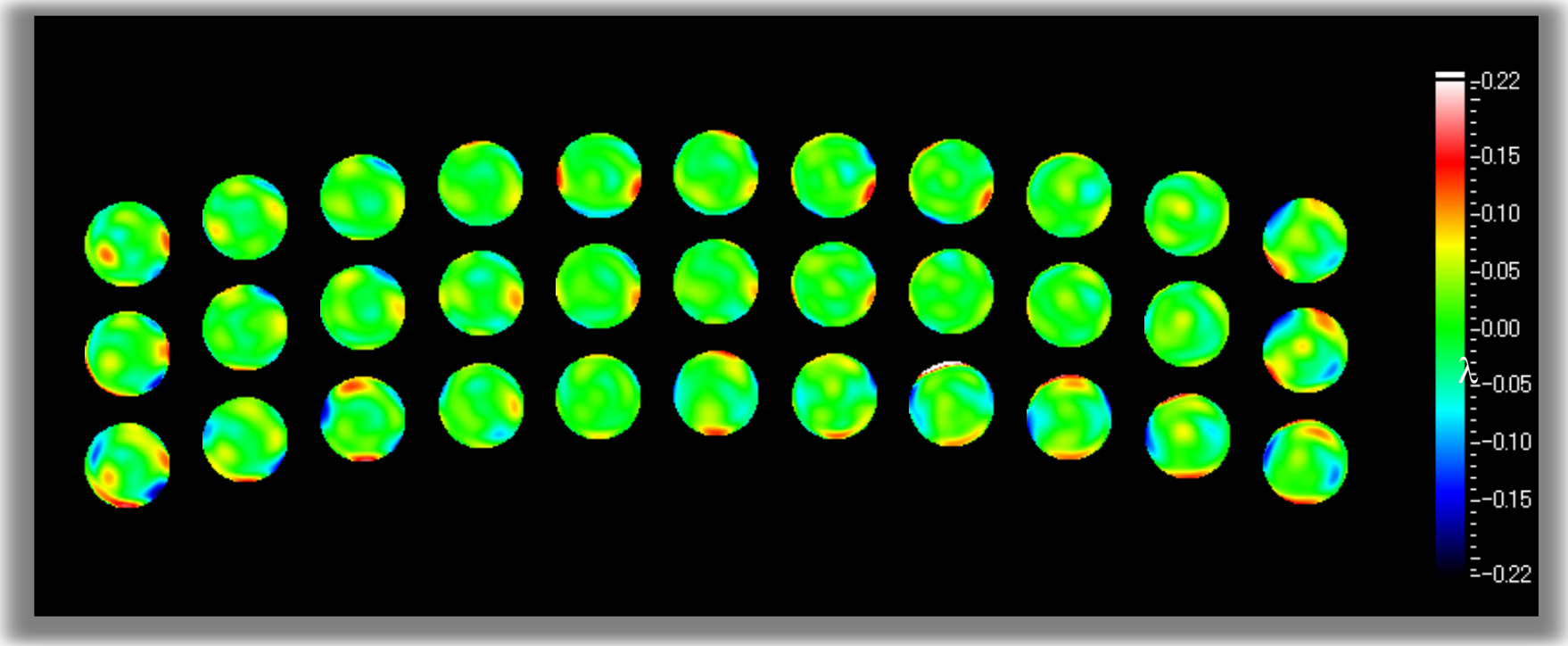
Wave front error improvement



Wave front error has been reduced drastically less than 1nm RMS.

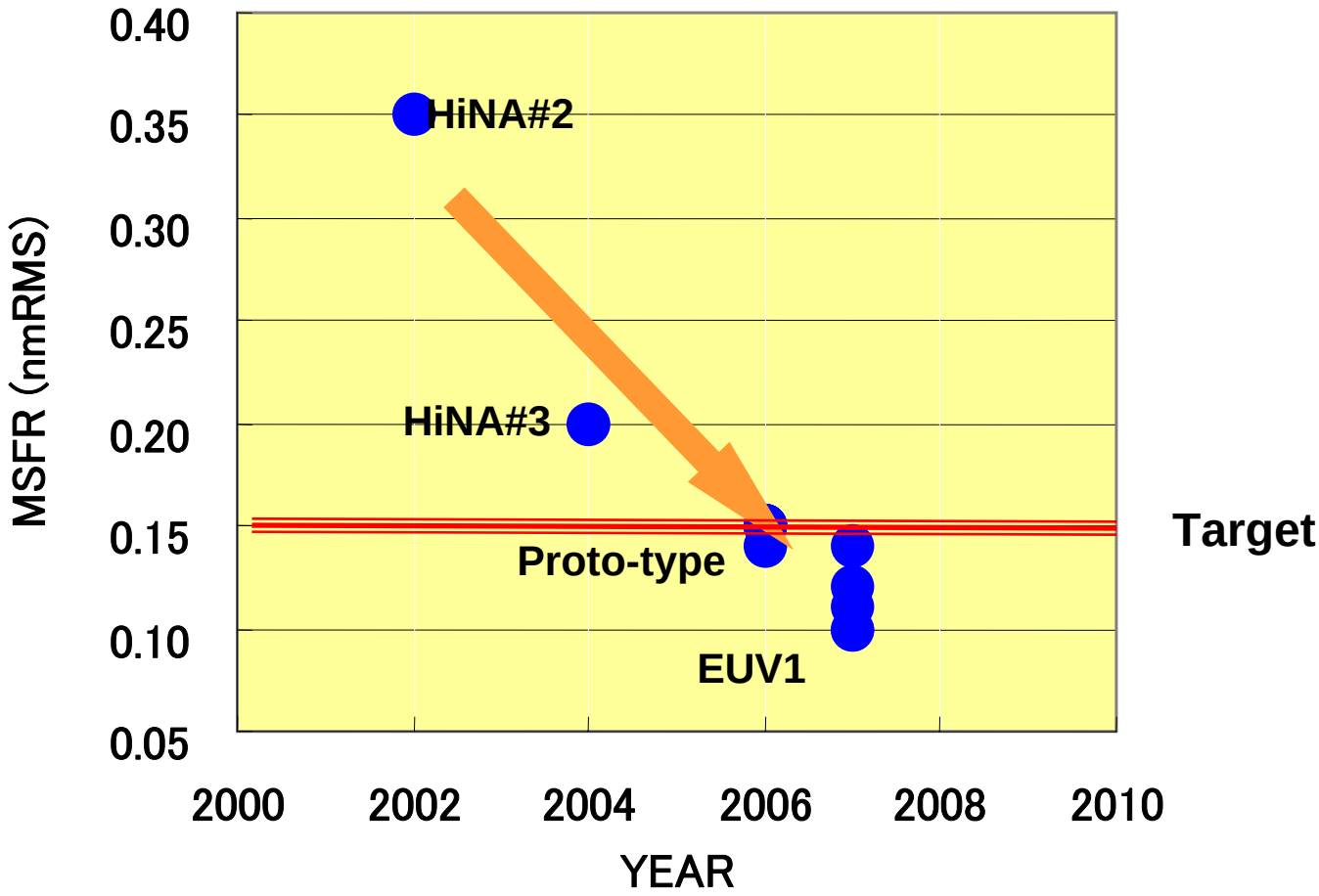
Wave front map of EUV1PO

Extremely small WFE below 1 nm RMS was achieved in the ring field !



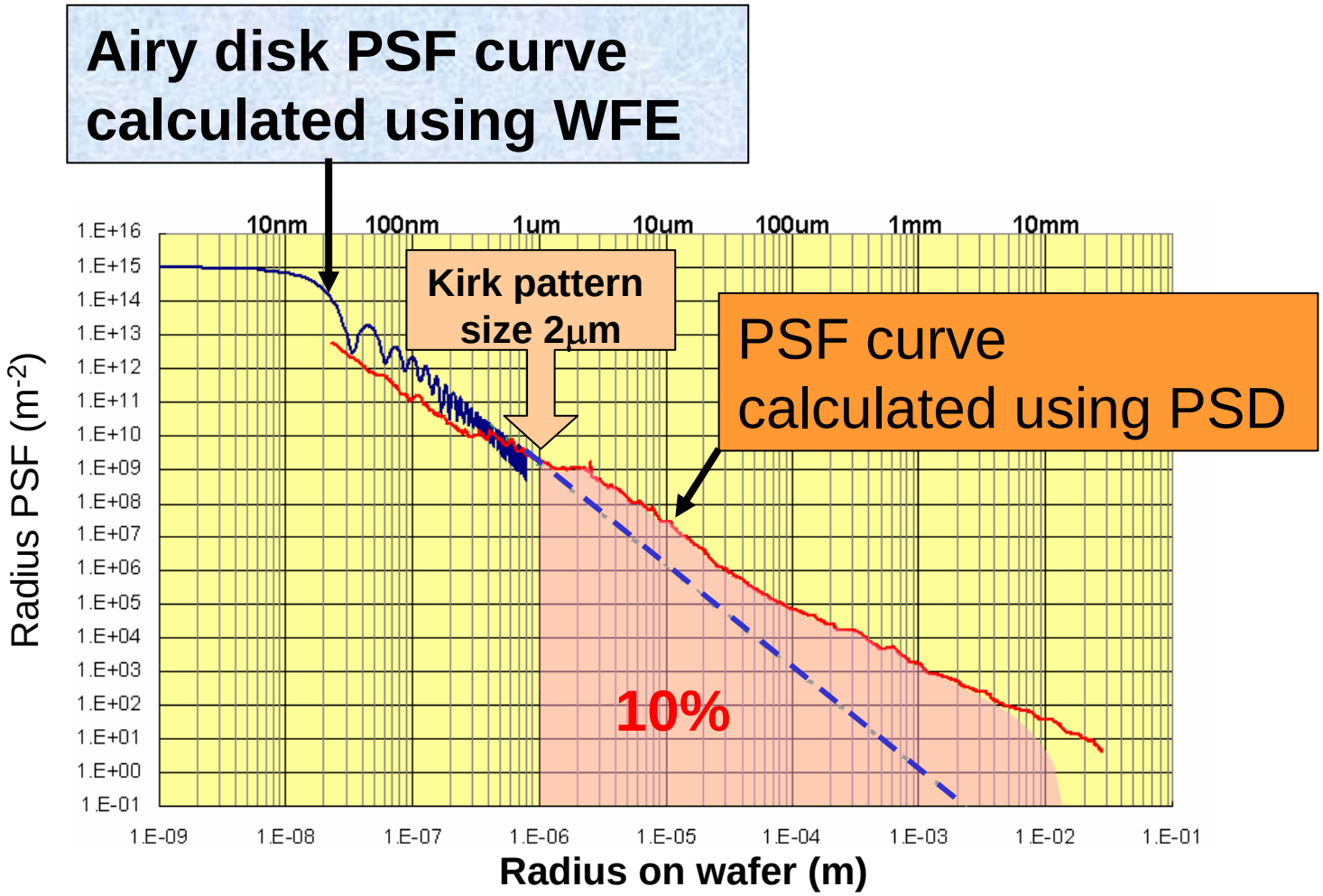
WFE 0.6 nm RMS (average)

MSFR improvement



Extremely small MSFR was achieved on all mirrors.

Calculated PSF and flare estimation



Point spread function in the range of >1mm is dominated by flare.

Estimated flare number is 10%.

Short Summary on Optics

1. Projection optics

- Metrology, polishing and coating technologies were developed and steadily improved.
- Extremely small wavefront error of 0.6nm RMS was achieved.

2. Illumination optics

- Fabrication process of fly's eye mirrors which is key device of illumination optics was established.
- Evaluation of illumination optics using IU test stand was completed.
- Illumination uniformity with EUV light on a reticle plane of less than +/- 0.5% was confirmed.

Short Summary on Light source and Tool

1. Light source module

- System test completed.
  Output power @ IF currently 2-3 W level.
  Further improvement works ongoing.
- Docking with the tool completed.
- Fine tuning with IU optics ongoing.

3. System integration

- Module integration completed.
- EUV light on reticle confirmed.
- EUV light on wafer and preparation for static exposure ongoing.
  - Static exposure scheduled by March/2008.
    Static exposure data available in February/2008.

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EUV2 Tool Development Plan

Cal. Year	2006	2007	2008	2009	2010	2011	2012
ITRS2005 DRAM ½ p Flash ½ p MPU C. Hole	70 nm 64 nm 97 nm	65 nm 57 nm 84 nm	57 nm 51 nm 73 nm	50 nm 45 nm 64 nm	45 nm 40 nm 56 nm	40 nm 36 nm 50 nm	35 nm 32 nm 44 nm
R&D programs Collaboration	ASET (HiNA, small field) EUVA (Wavefront sensor, Contamination control) SELETE (EUV Lithography and Mask Program)						
Nikon Exposure tool		EUV1 For Process development Review			EUV2	For 32nm production	

- Best available light source and infrastructure.

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Challenging items in EUV2 development

Imaging Performance

- Exchange of illumination condition
- Low aberration, low flare optics

Reticle

- Strategy for library
- Carrier complied with SEMI standard

Overlay

- Tool stability

Throughput

- Rigid body for high throughput
- High speed & precision vacuum compatible stage
- High power EUV source

Thermal management

- Heat rejection from mirrors of illumination optics

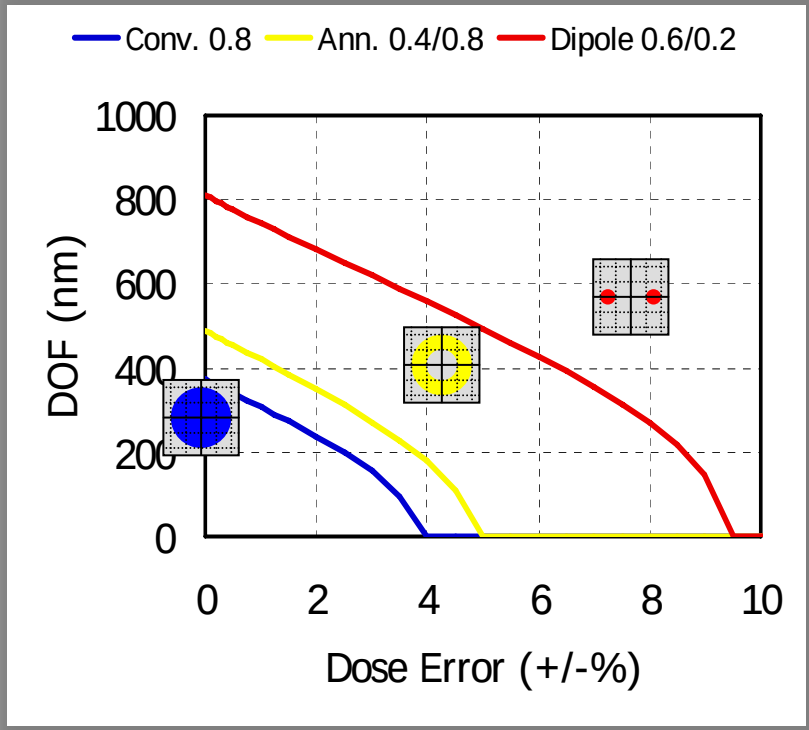
Improvement of CoO

- Lifetime of EUV mirrors
- Downtime during maintenance

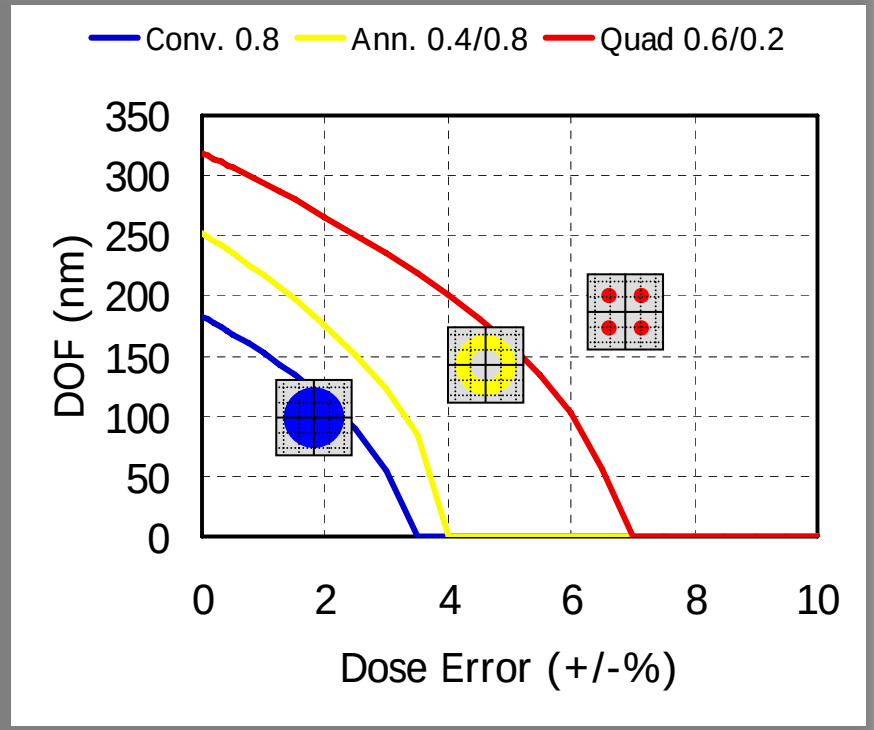
Imaging Performance Simulation

Process window vs. illumination condition

22nm L/S



25nm H/S



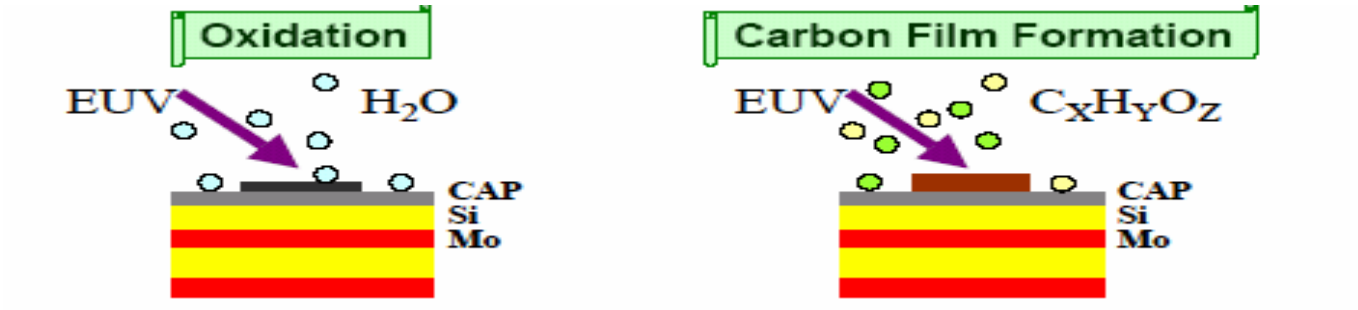
ED-Tree DOF Conditions:
Lambda: 13.5nm, NA: 0.25,
CD error: +/-10% of CD, Mask CD error: +/-0.5nm,
Mask contrast: 1:100, Flare: 7%*pattern density

NA0.25 Projection Optics:
Useful for 22nm hp node for process development.

Main Specification of EUV2

Specification Item	EUV1	EUV2 (Provisional)
Field Size	26 x 33 mm^2	26 x 33 mm^2
NA and Magnification	0.25, x1/4	0.25, x1/4
Resolution	Dense line: 45 nm Isolated line: 25 nm (Target 32 nm dense line)	Dense line: 32nm Isolated line: 21nm (Target 22nm dense line)
Wavefront	0.7 nm rms	0.5 nm rms
Flare	10 %	7 %
Overlay	Target 10 nm (3s)	7 nm (3s)
Wafer Size	300 mm	300mm
Throughput	5-10 wph (10W IF, 5mJ/cm^2)	50 wph (50W IF, 5mJ/cm^2)

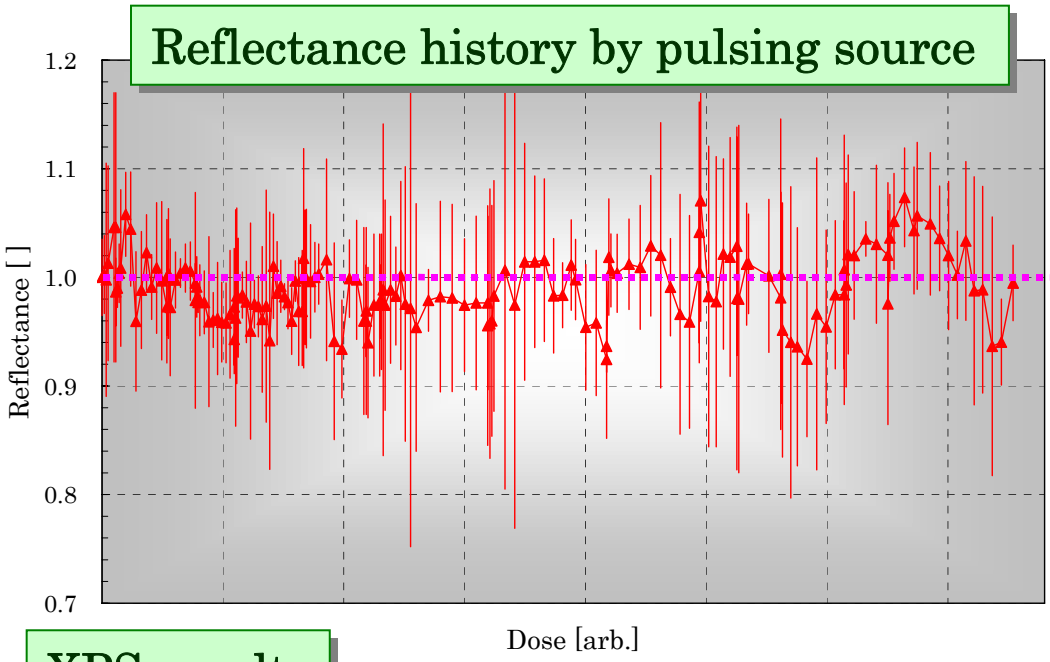
Contamination Control



Contamination Control Strategy

1. Anti-oxidation capping layer
2. Carbon-film suppression and removal
3. Resist outgassing
   - Proposal of outgassing rate of H_2O and CxHy
4. Experiment facilities
   - SR “Super-ALIS” in Atsugi (NTT) and SR+Undulator “New SUBARU” in Himeji (Univ. of Hyogo)

Difference between Pulsing & SR Source



- EUV irradiation by in-house solid-state target source
- High H2O pressure
- No OoB light with SPF

No evident reflectance drop

XPS results

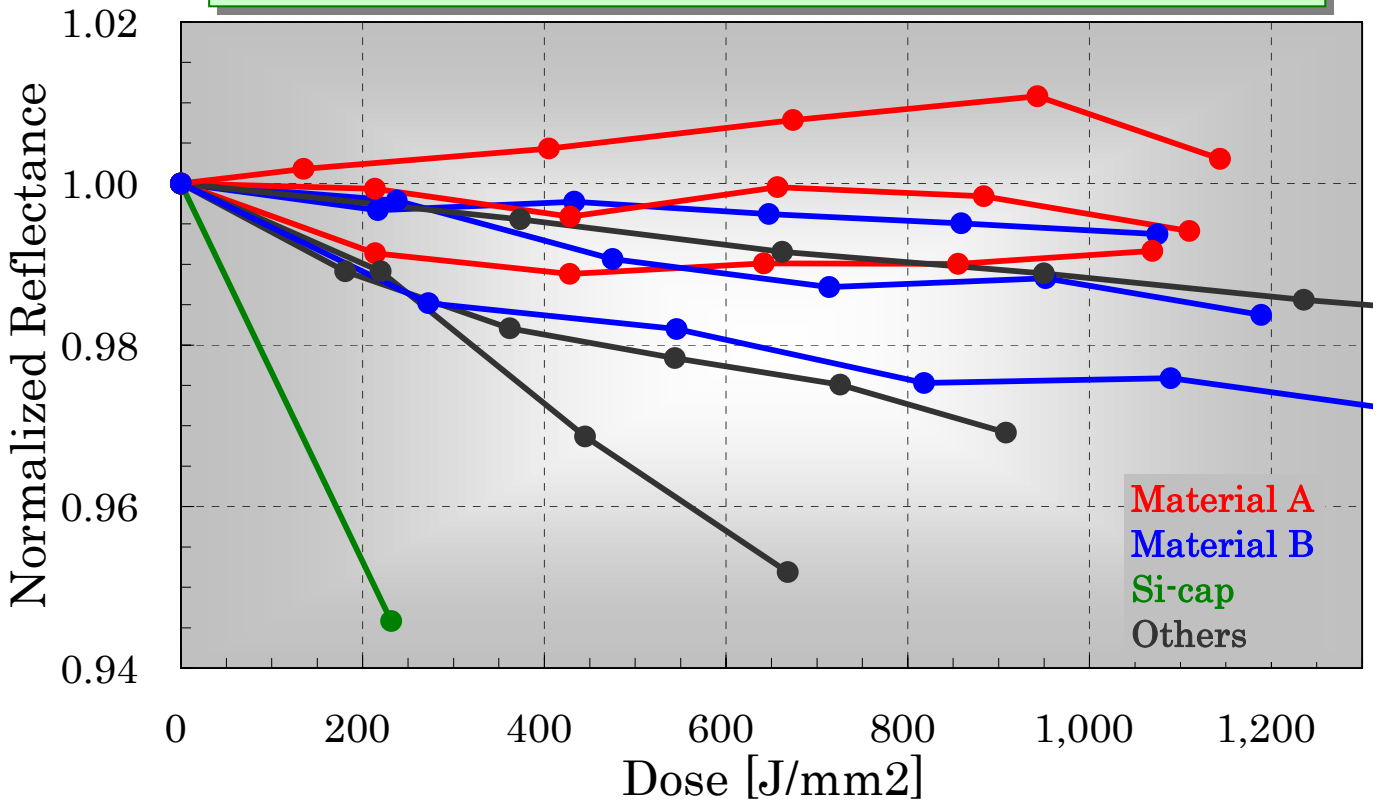
SRC	Position	XPS [atomic %] (Error±1%) Si-Si	XPS [atomic %] (Error±1%) Six-Ox	Si DoO degree of oxidation	ΔSi DoO
SR	irradiated	18.0	24.4	57.5%	4.1%
	reference	20.7	23.8	53.5%	
Pulse	irradiated	11.6	17.5	60.1%	4.5%
	reference	13.5	16.9	55.6%	

No evident difference of oxidation state

No significant difference between pulsing and SR source

Capping Layer: Screening & Optimization

Capping Layer Candidates: Durability Test



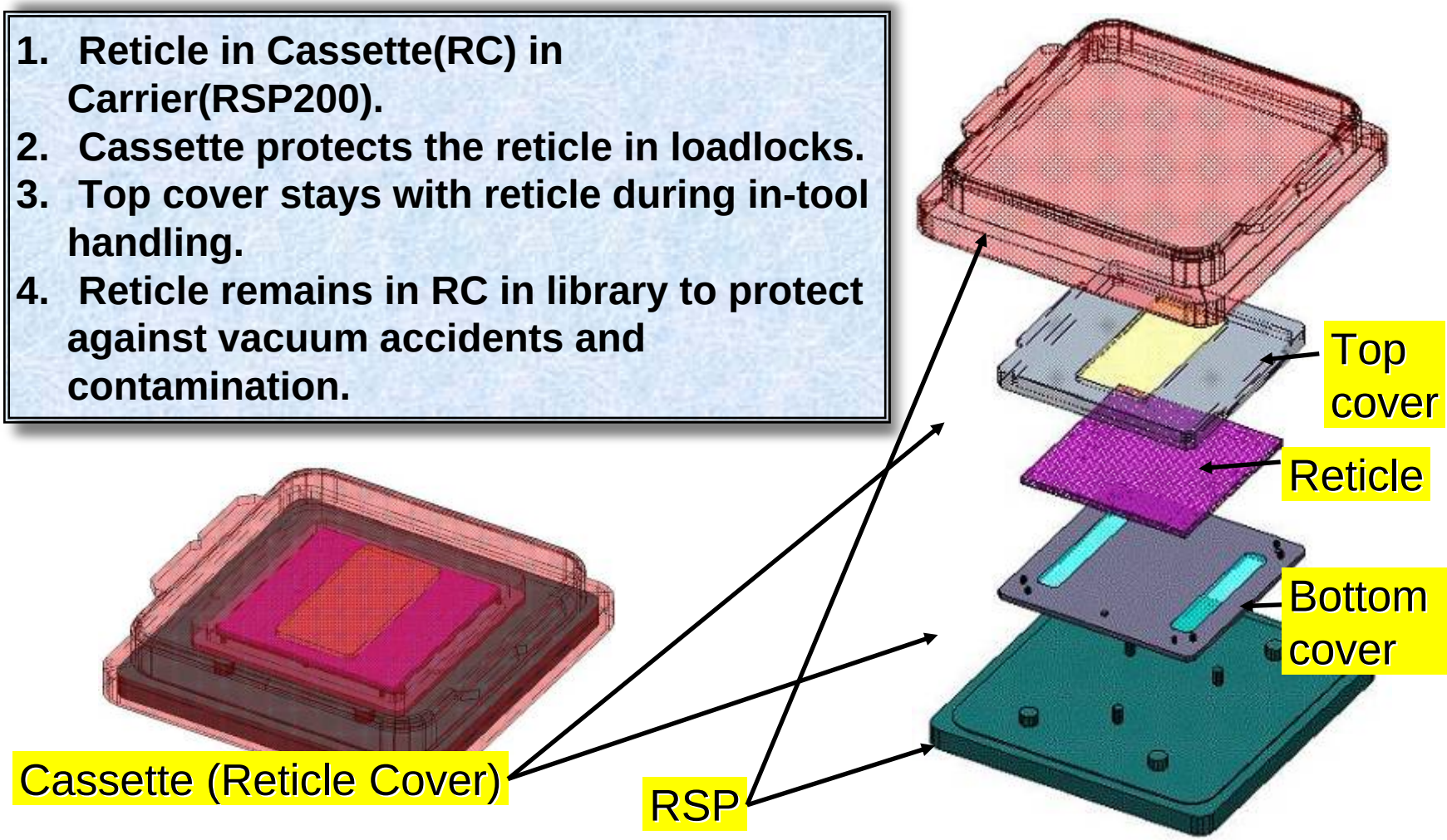
- EUV irradiation to capping material candidates with intense undulator was performed under H2O vapor introduction.
- Optimization of coating condition of the candidates is also ongoing.

Some of candidates shows no significant degradation

Reticle Protection

* Dual Pod Concept by Canon and Nikon

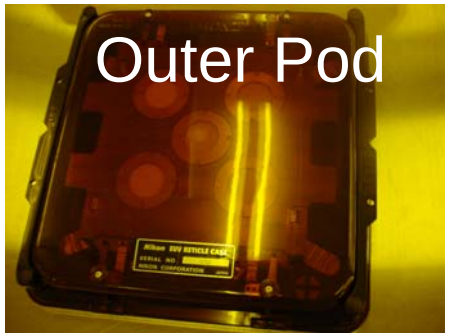
1. Reticle in Cassette(RC) in Carrier(RSP200).
2. Cassette protects the reticle in loadlocks.
3. Top cover stays with reticle during in-tool handling.
4. Reticle remains in RC in library to protect against vacuum accidents and contamination.

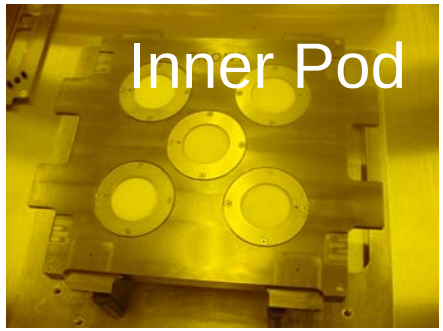


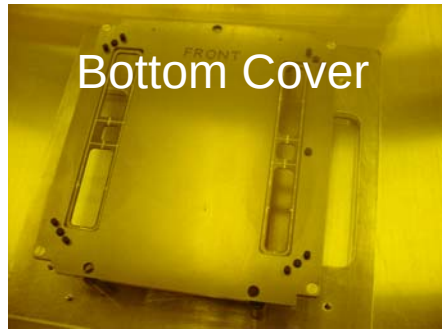
Reticle Protection Development Status

1. **Nikon has been developing Dual Pod Concept for EUV reticle carrier standardization in cooperation with Canon and Entegris.**
2. **Nikon also has developed the reticle cover for EUV1 tool.**
   - **The average added particles reported in SPIE 2006.**
     "0 - 0.3 per cycle during 10 cycles"
   - **The reticle cover for EUV1 tool manufactured.**
   - **Reticle handling trial on the tool has started.**

Reticle Carrier for EUV1 (Dual Pod)







Overall Summary

1. **EUVL can be the main lithography technology after ArF immersion.**
2. **Nikon is developing a full field exposure tool (EUV1) for 45nm hp process development and 32nm hp R&D.**
3. **EUV2 (HVM) can be developed adopting the best available EUV light source and infrastructure.**
   - Technology and business assessments in 2007.
4. **Performance of light source and infrastructure such as EUV reticle, resist, etc. is steadily improving.**

Acknowledgements

1. A part of this work was conducted under *EUVA* projects. EUVA projects have been supported by New Energy and Industrial Technology Development Organization (NEDO).
   - Nikon gratefully acknowledges *Japan Ministry of Economy, Trade and Industry (METI) and NEDO* for their supports.

2. Nikon also participate in *Selete* program and appreciate Selete members for their useful discussion and advice.

3. The work presented here is the result of team effort in both Nikon and partner companies.