Progress on the development of EUV exposure tool in Nikon

November 7, 2005

Nikon Corporation

2nd Development Department

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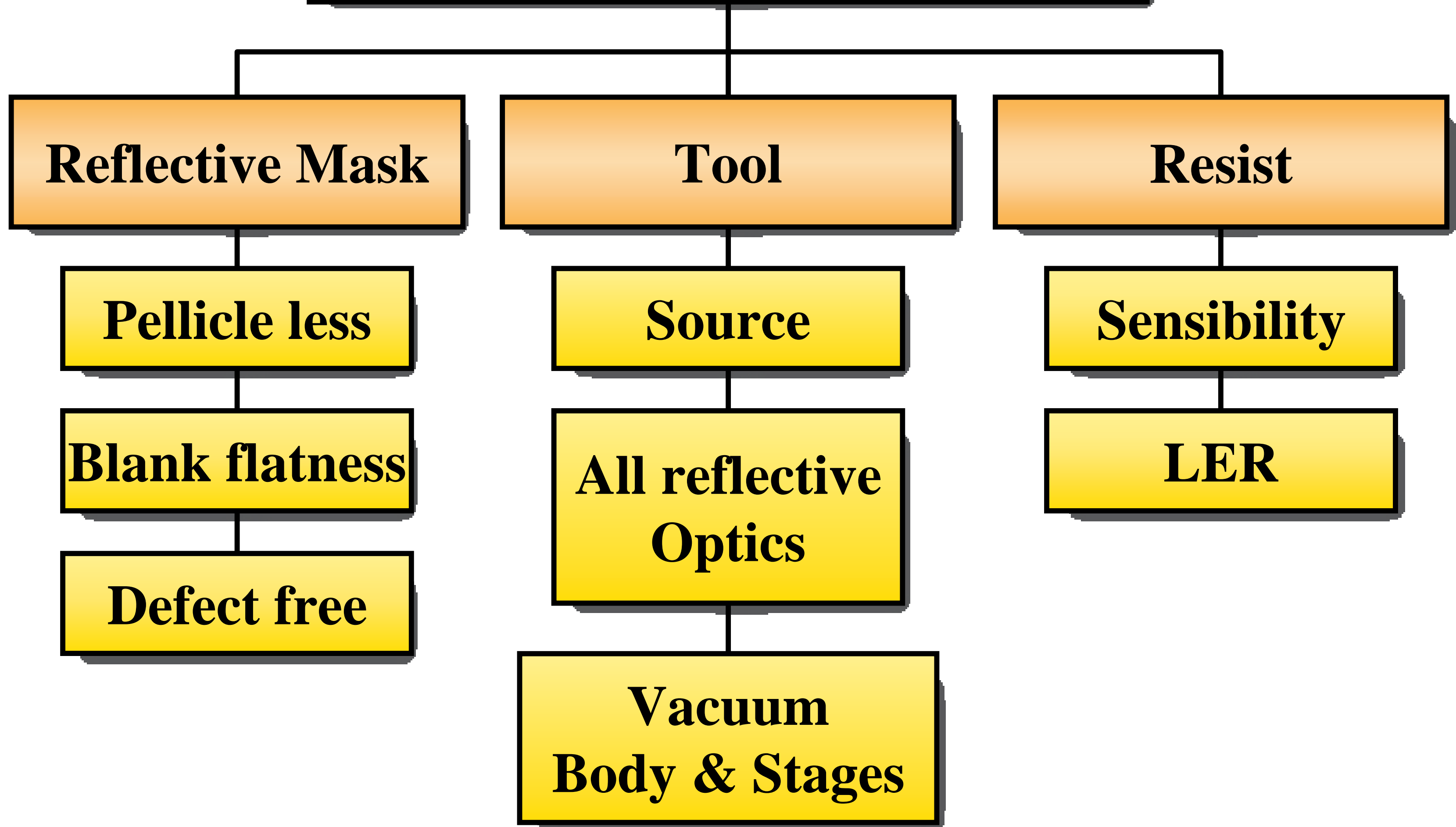
Presentation Outline

- EUVL Important Consideration Items
- Roadmap of Future Lithography and Nikon EUVL Development Plan
- EUVL Collaboration and Development Strategy
- Tool Development Status
- Projection Optics Development Status
- Contamination Control and Reticle Protection
- Critical Issues and Challenges
- EUV1 Tentative Specification
- Overall Development Status Summary

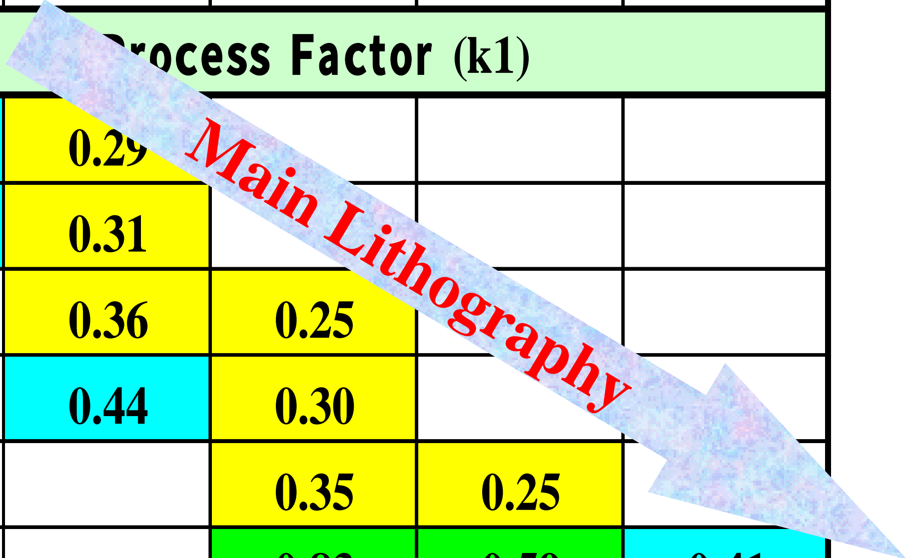
EUVL Important Consideration Items



Nikon Roadmap for Future Lithography

Critical layer exposure method

Year (CY)		2006	2007	2010	2013	2016
Technology node (hp nm)		90	65	45	32	22
Lithography	NA	Process Factor (k1)				
ArF	0.85	0.40	0.29			
	0.92	0.43	0.31			
ArF Immersion	1.07		0.36	0.25		
	1.30		0.44	0.30		
	1.48			0.35	0.25	
EUVL	0.25			0.83	0.59	0.41



Normal(K1>0.5) Weak RET(k1>0.4) Strong RET(k1>0.25)

- EUVL can be the main lithography technology after ArF Immersion technology.

Nikon EUVL Tool Development Plan

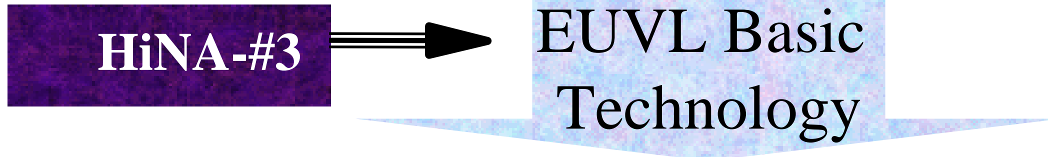
CY2003				CY2004				CY2005				CY2006				CY2007			
Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4

EUVA Tool Project

EUVA Metrology Project

Process development at ASET

HiNA-#3 → EUVL Basic Technology



Basic Development

EUV1 tool development

EUVL Tool Insertion plan

- EUV1 (Process Development Tool) — Delivery 1H/2007
- EUV2 (HVM) — Timing is considered

Development Collaboration Framework

EUVL Basic Technology

EUVL Tool Development

EUVA
Nikon / Canon
Komatsu / Ushio
Gigaphoton

Aspheric mirror
Contamination Control
Actinic WFS

Partner Companies

Body, Stages
Reticle Loaders,
Control & Software

Nikon

Total System Integration

ASET

HiNA set3 PO
Flare evaluation

MIRAI

Defect Detection

Universities Laboratory

Coating

Nikon has been developing EUVL tool with more than ten companies and organizations considering the most effective and best risk sharing way.

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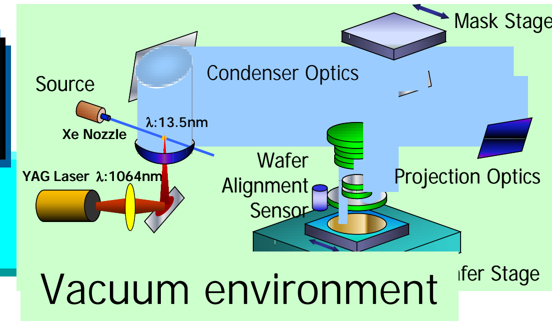
EUVL Tool Development Strategy

EUVL Tool Development

Module Concept



EUVL

Effective Utilization of Common Technologies

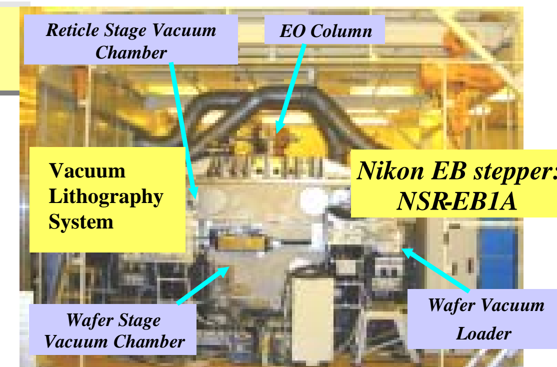
Improvements from EPL

EUVL Basic Development

Latest Optical Scanner Development

EPL Development

- **Vacuum System & Outgas Control**
- **Vacuum Loader**
- **Vacuum Body & Thermal Control**
- **Vacuum Air-guide Stages & E. S. Chuck. He Cooling**



EPL NSR-EB1A

✧**EPL has been operated in the pilot line at Selete in Japan for several years.**

Projection Optics Development Strategy

EUV1 projection Optics

Effective Utilization of Common Technologies

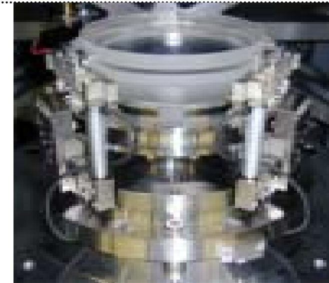
6-mirror system NA=0.25

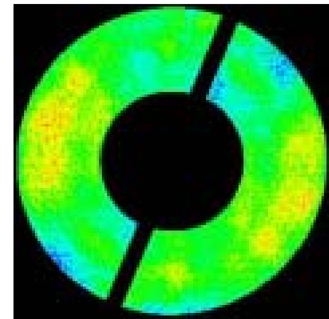
EUVL P.O. Basic Development

EUV1 P.O. Proto-type

2-mirror system NA=0.3

2004	HiNA#3	WFE=0.9nm Flare=7%	New polishing technology
2002	HiNA#2	WFE=1.9nm Flare=25%	New mounting technology New PDI system
2001	HiNA#1	WFE=7.5nm Flare=N/A	

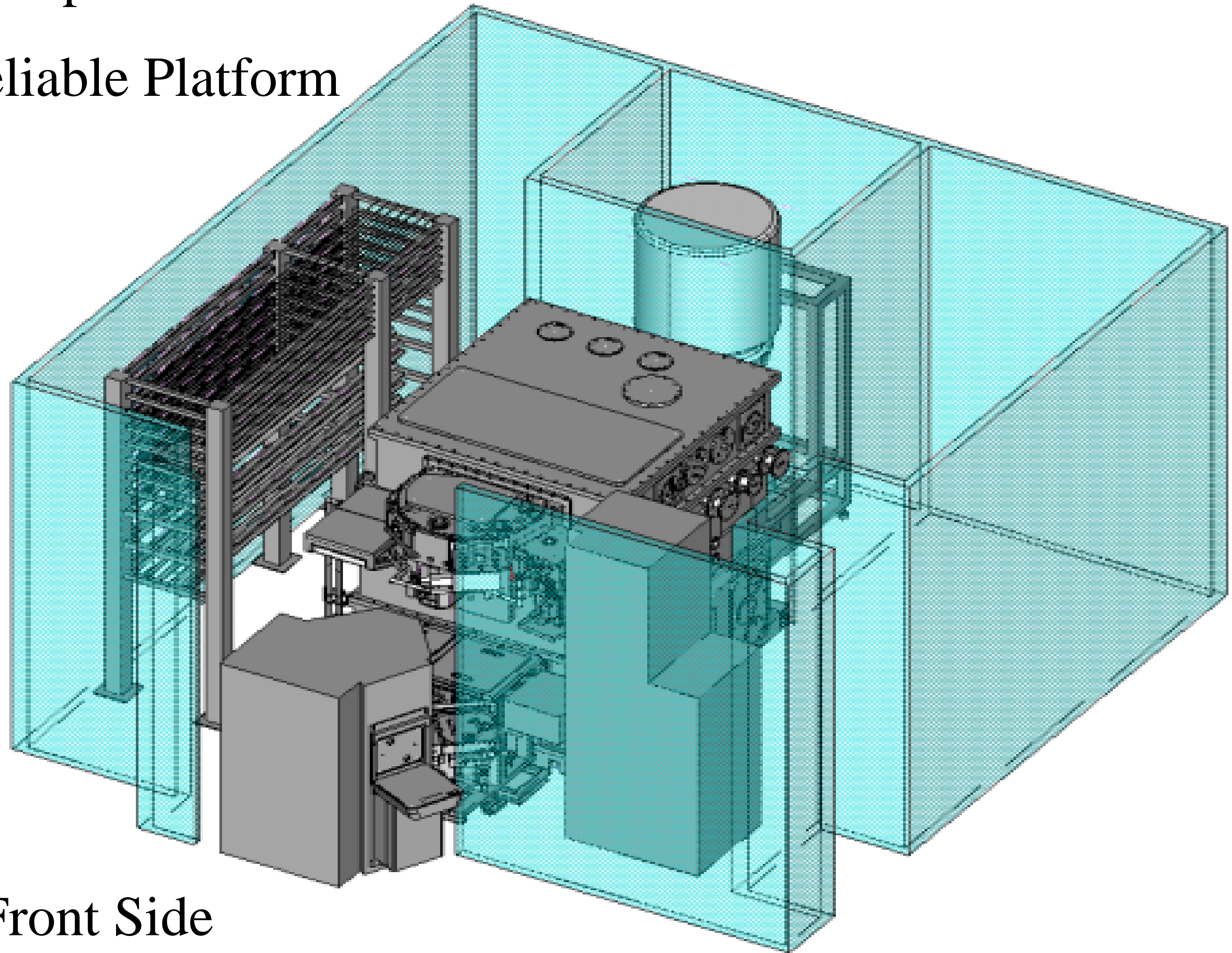




HiNA#3

EUVL Tool Overall Concept Design

- Module Concept
- Stable & Reliable Platform



Front Side

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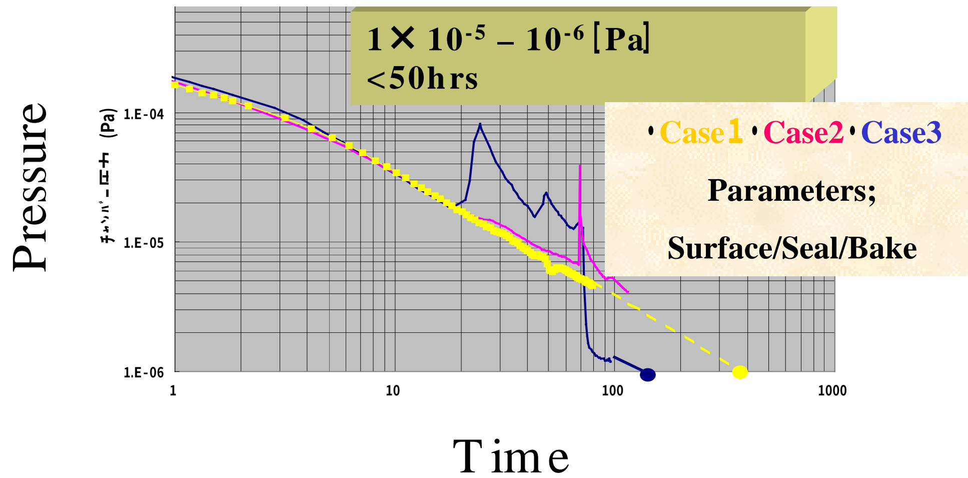
Nikon

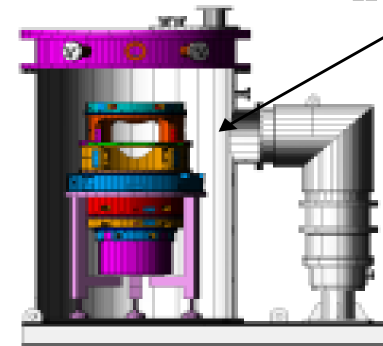
Vacuum Body Technology Development

Vacuum Testing and Evaluation

➢ Verification of vacuum design and improvement measures.



Test Chamber



ϕ ;1000mm
H ;1500mm

【Test Items】

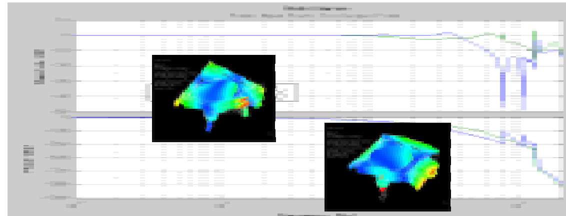
- ◆ Out gassing
- ◆ Pumping efficiency
- ◆ Sealing
- ◆ Surface finishing

Vacuum Stage Technology Development

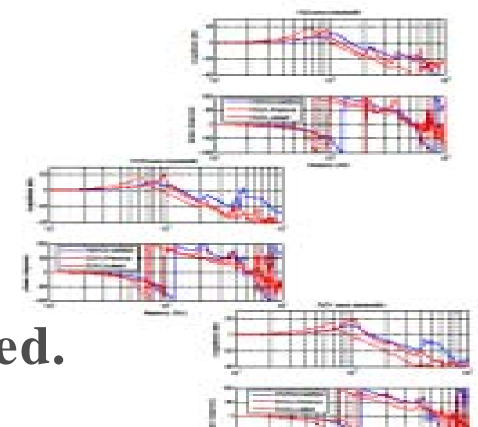
- Vacuum Fine Stage Development
  - High Servo Controllability
  - High Vibration Isolation

Proto-typing

Structural & Control Simulation



Test Results



The good results have been obtained.

EUV1 Body and Stages

■Reliable Vacuum Main Body reflecting EPL technology

- ➢Completed structural, thermal and vacuum simulation
- ➢Completed detailed mechanical, vacuum and electrical design
- ➢Completed vacuum experiments in the test chamber

■Reliable Vacuum Reticle and Wafer Stages reflecting EPL technology

- ➢Completed structural, thermal and motion control simulation
- ➢Completed detailed mechanical,vacuum and control design
- ➢Completed new vacuum fine stage development

Illumination Unit

■Completed optical design and structural, thermal and vacuum simulations

■Proceeding detailed design

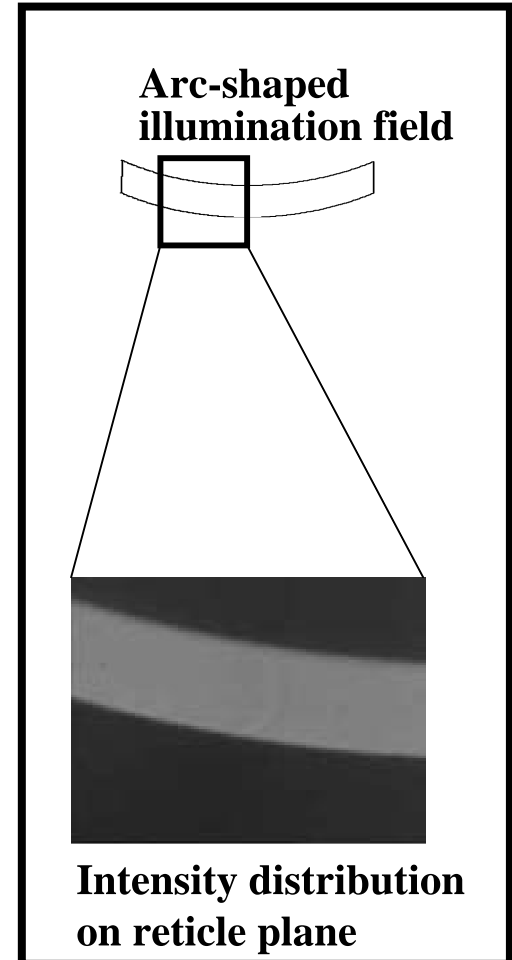
■Proceeding Fly-eye mirror development

➢Completed Input fly's eye mirror and Output fly's eye mirror fabrication study

➢Proceeding mirror fabrication experiment and optimization

■Illumination uniformity optimization is going on considering light source and IU optics properties.

Visible light test



EUV1 Light Source

■ **Xe DPP source will be employed.**

- **Most matured technique among various schemes of light source**
- **Cleaner source than that uses solid target**

■ **Basic requirements :**

Power at IF : ≧10W

Repetition Rate : ≧5KHz

Etendue : ≦5.5mm^{2}sr

Projection Optics

■Projection Optics Barrel

- ➢Completed projection optics barrel proto-typing
- ➢Completed mechanical, thermal, control simulation and detailed design

■Mirror Polishing and Coating

- ➢Started polishing 6 mirrors
- ➢Proceeding coating optimization

■High repeatability interferometer

- ➢Reached below 50pm rms repeatability

■Actinic Wave Front Sensor (EWMS)

- ➢Completed comparison between CG-LSI and PDI
- ➢Proceeding construction on schedule

Proto-type Projection Optics barrel

Proto-type mirror(M1)

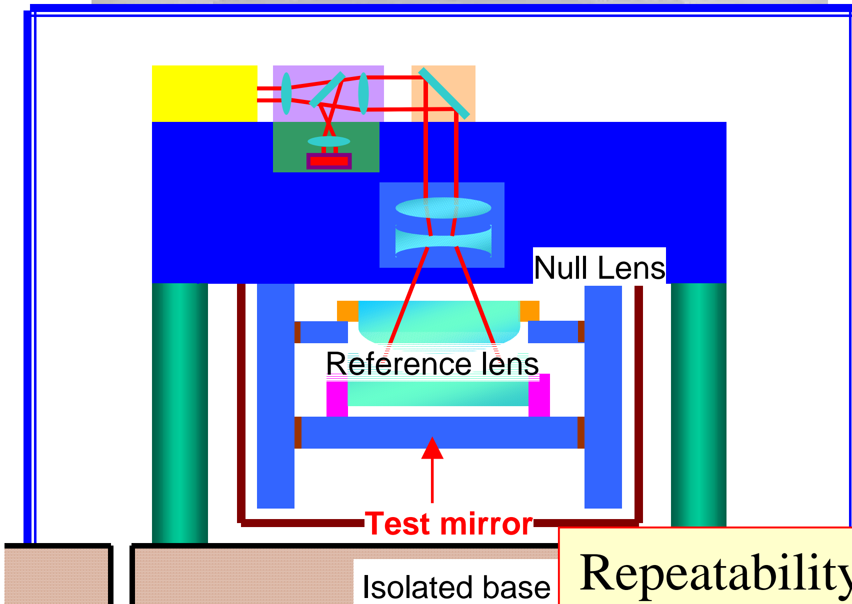
High repeatability interferometer

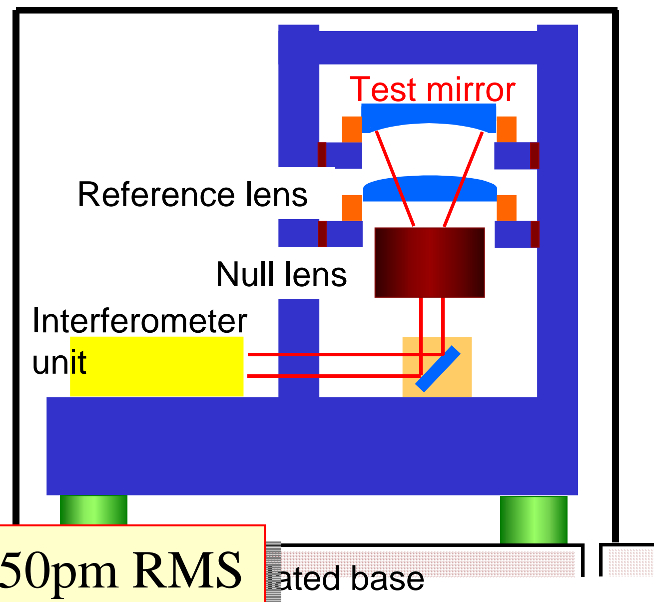
Interferometer Type 1

Interferometer Type 2

Both are in operation

Supported by NEDO





Repeatability Spec.: 50pm RMS

High Repeatability of interferometer

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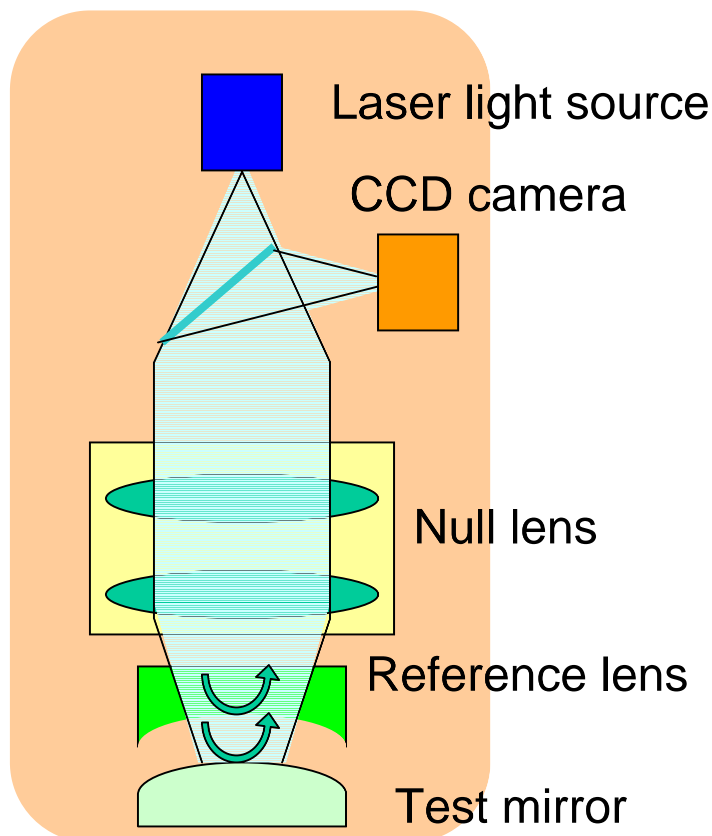
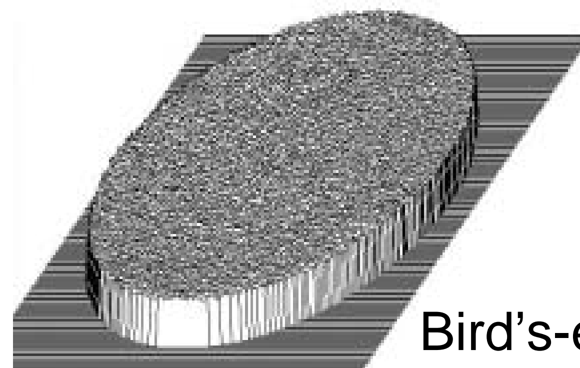
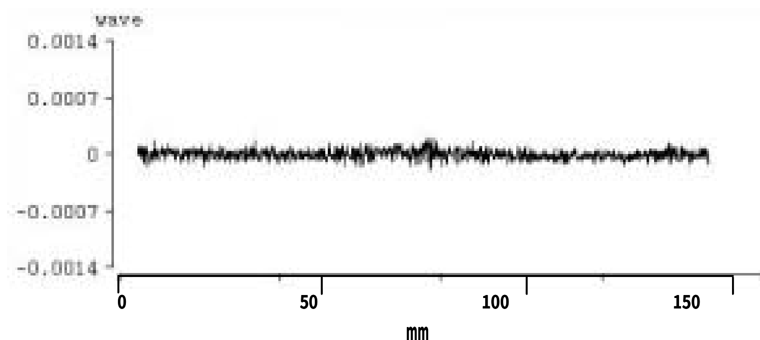




Bird's-eye view



Cross section

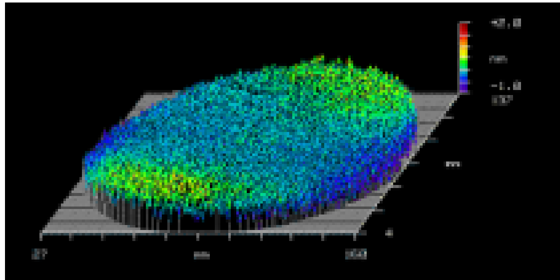
- **Repeatability of 32pmRMS was confirmed in the measurement of aspheric surface.**

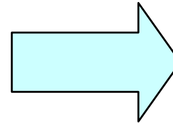
Ion Beam Figuring (IBF)

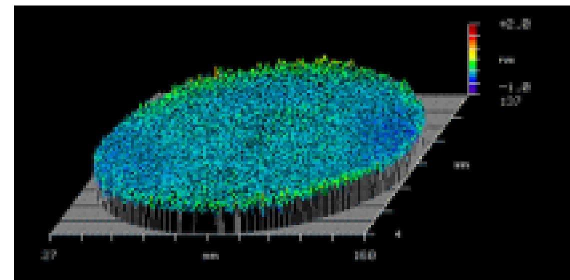
Supported by NEDO

Now in operation

Much improved







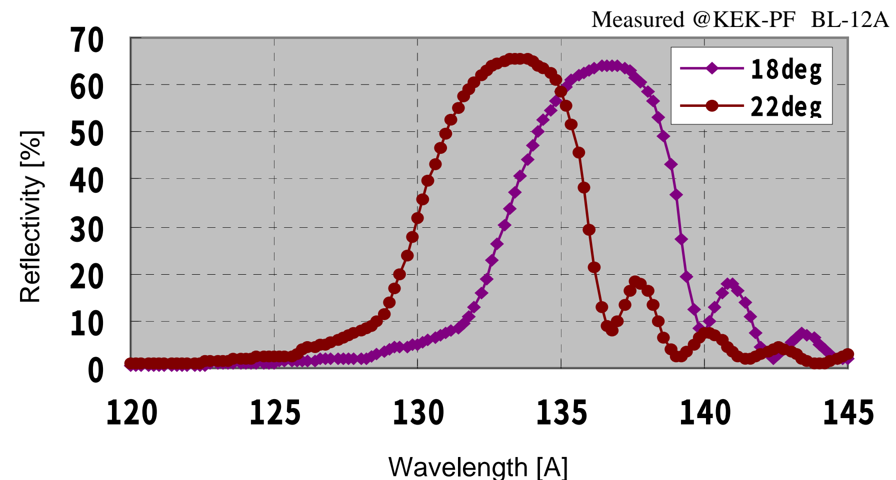
0.247 nm rms

0.139 nm rms

Multilayer coating system

- New low-pressure rotary magnet cathode (RMC) sputtering system installed.
- Max. substrate size: ϕ600mm
- 4-target system: capping layer and buffer layer available.
- Internal stress suppressed using stress compensation block.

Now in operation



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Aspheric mirror polishing for proto-type PO

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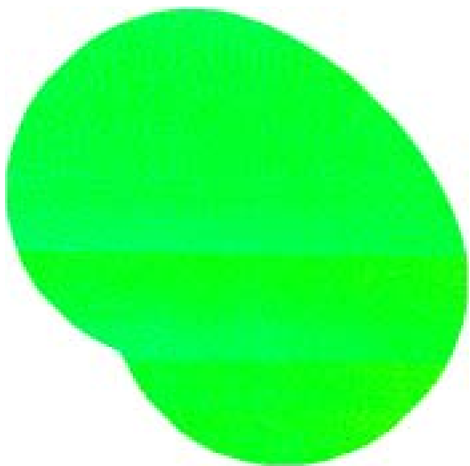
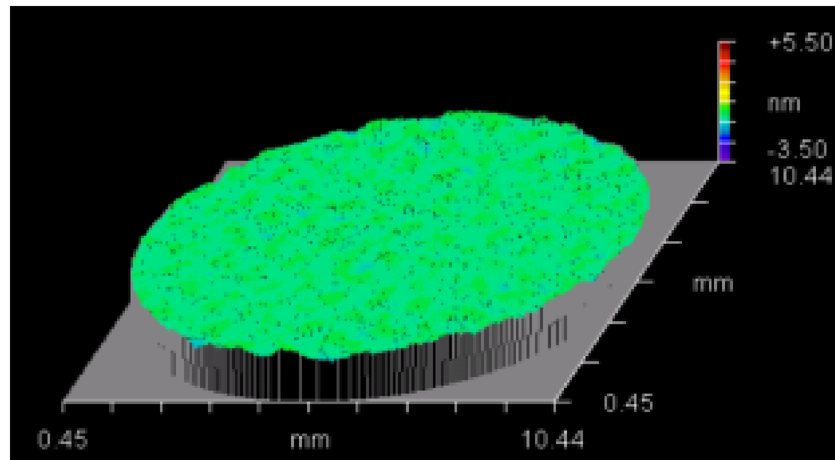
LSFR, MSFR and HSFR of polished LTEC material improved.

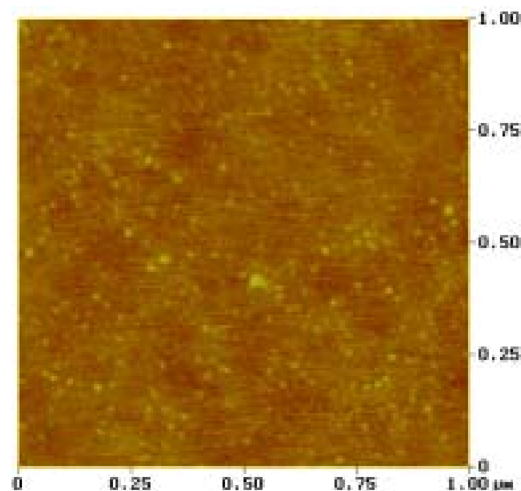




MSFR of M1：0.135nmRMS

Supported by NEDO

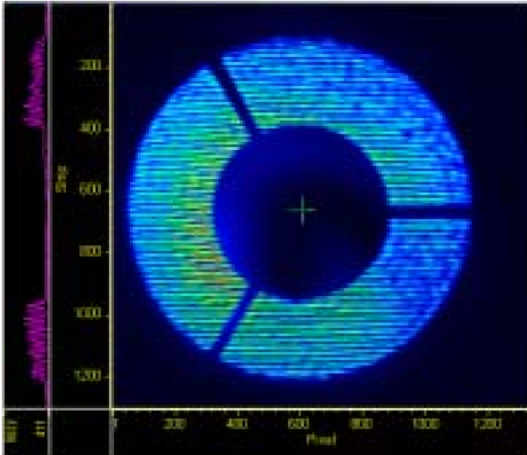
LSFR of M1：0.209nmRMS
(Raw data)



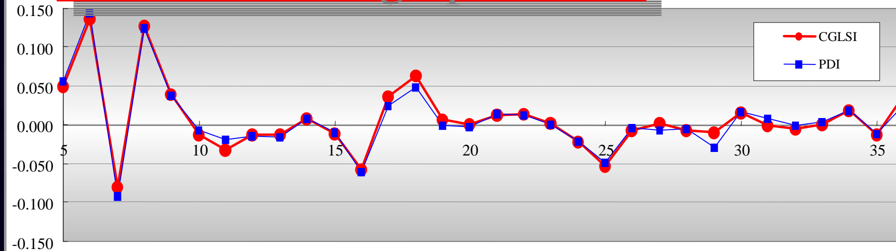
HSFR on flat surface: 0.097nmRMS

PoC study of EUV WF metrology

Supported by NEDO

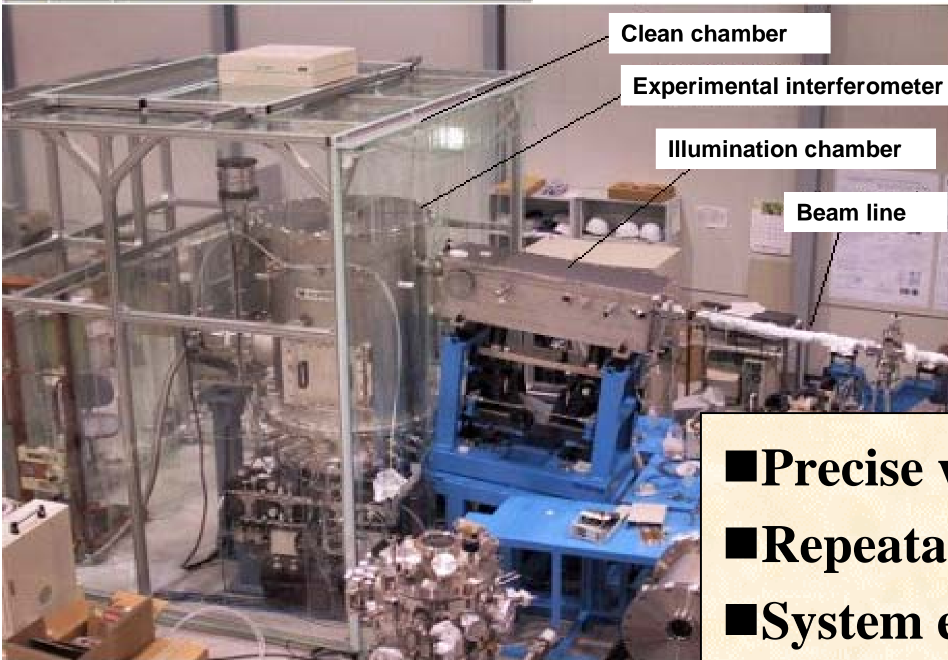


Confirmed high precision



Wavefront Aberration RMS

CGLSI	PDI
1.24nm	1.26nm



- Precise wavefornt metrology was confirmed.
- Repeatability of 0.045nm RMS
- System error of less than 0.086nm RMS

EUV WF Sensor for Full-field Projection Optics

Supported by NEDO

Under construction

■Actinic wavefront sensor for 6-mirror PO is under construction.
■It will be installed at New Subaru synchrotron facility of Univ. Hyogo in this November.

Contamination Control

■Tool vacuum system design

- ➢Proper partial pressures of H_2O and Hydrocarbon inside critical areas

■Mitigation

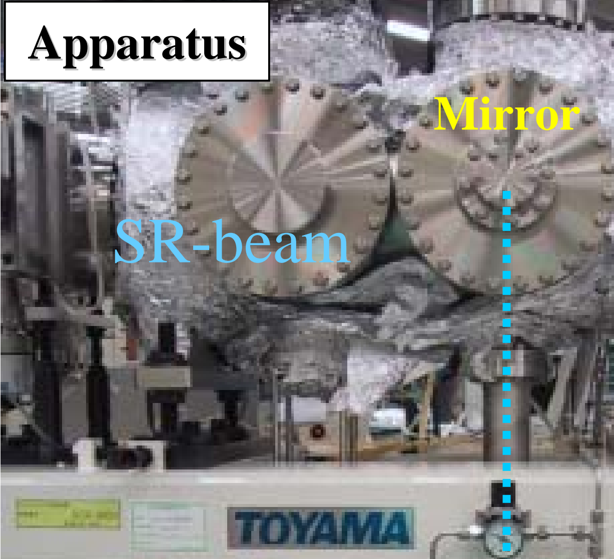
- ➢Proceeding mitigation experiments

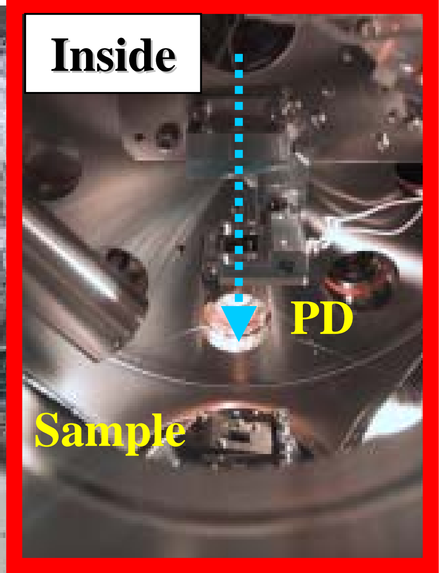
■Status

- ➢Experiment of contamination test tool in Super-ALIS (NTT)
- ➢Study for H_2O dependence on carbon/oxidation in New Subaru (UoH)
- ➢Experiment of UV+O_2 cleaning

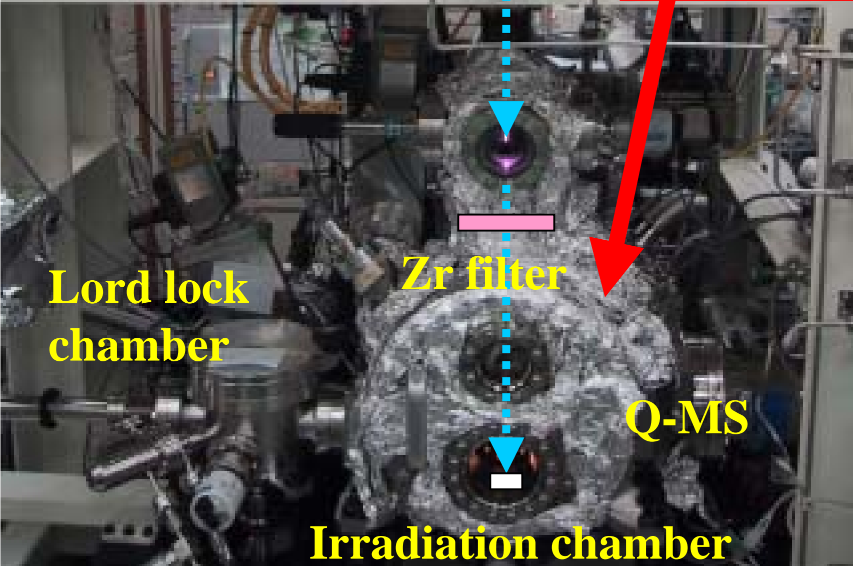
Contamination study using Super ALIS synchrotron source at NTT Atsugi

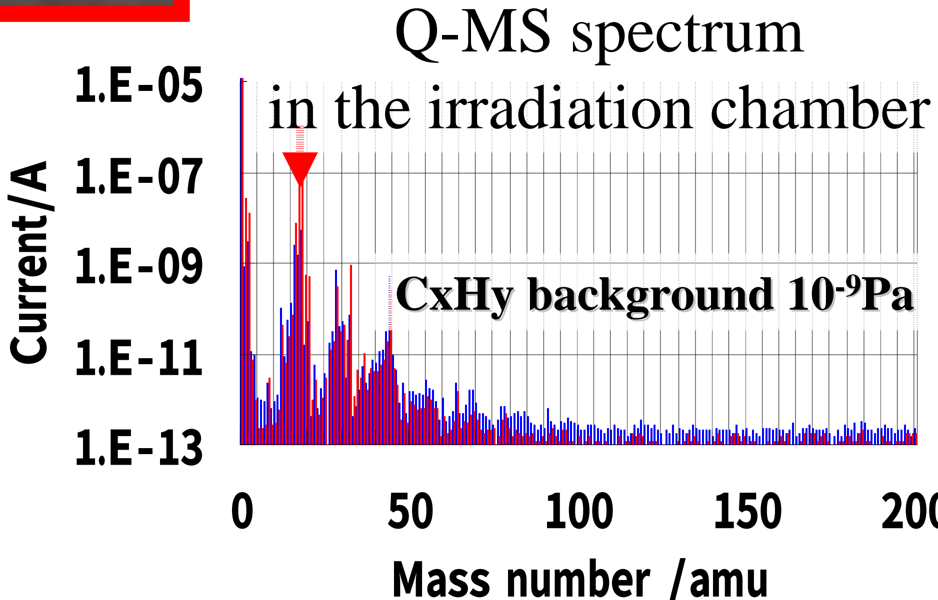
EUVA Supported by NEDO





SR-beam:**Super-ALIS**
Light intensity:**16mW/mm^2**
Beam size:**1*1.5mm**
Background pressure:**5e-7Pa**
H_2O,O_2 pressure:BG~**1e-2Pa**
In-situ reflectance measurement

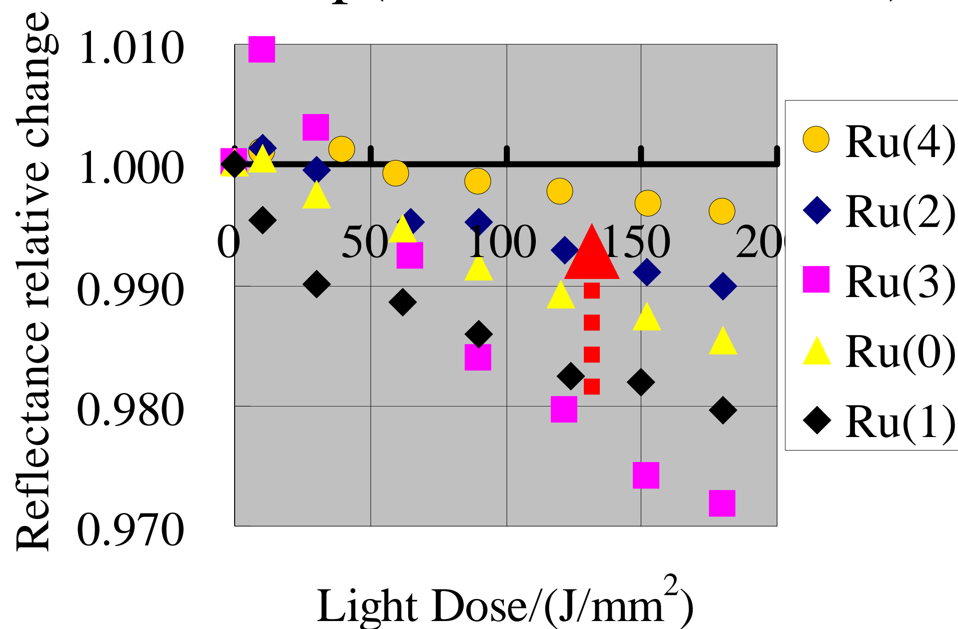




Durability to oxidation of Ru capping layer

Supported by NEDO

Condition; H_2O:1e-4Pa EUV:180J/mm^2 16mW/mm^2

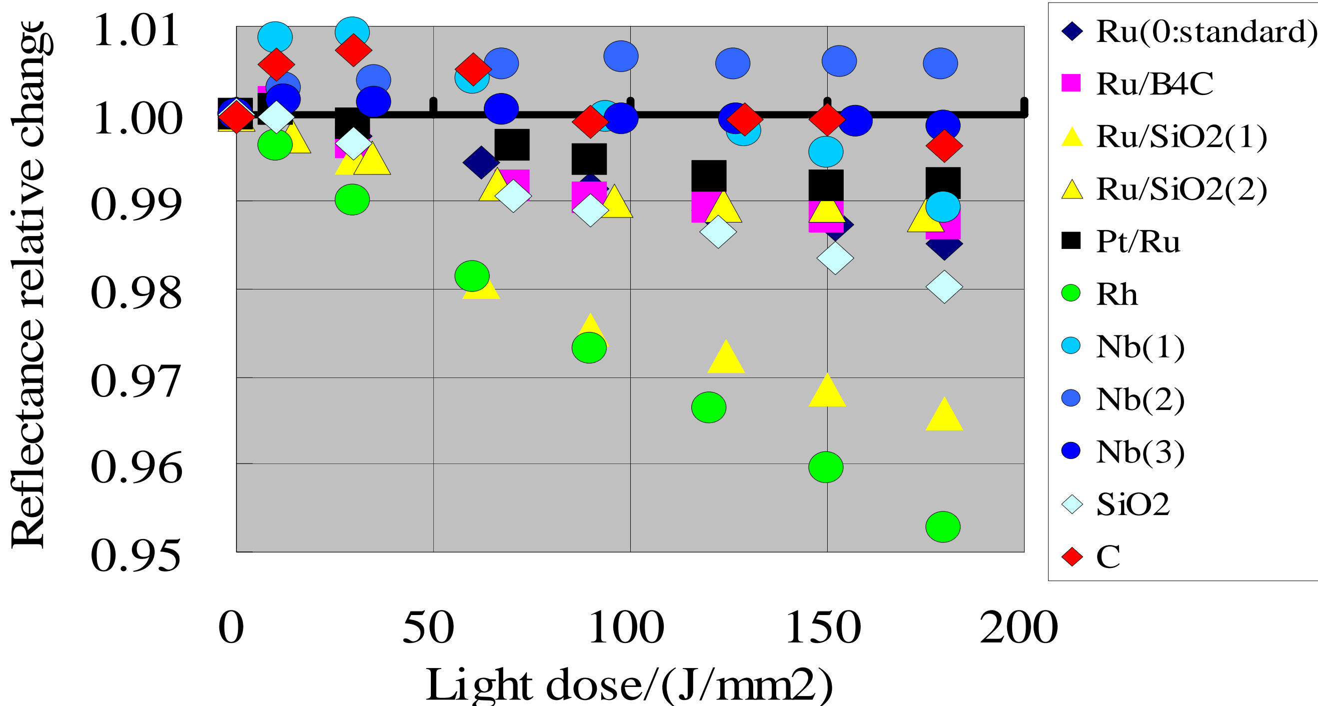


■Ru-cap was improved by the deposition condition optimization.

Candidates of better capping layer material

Supported by NEDO

Condition; H_2O:1×10^{-4}Pa EUV:180J/mm^2 16mW/mm^2



☺ **C-Cap,Nb-Cap,Pt/Ru-Cap**

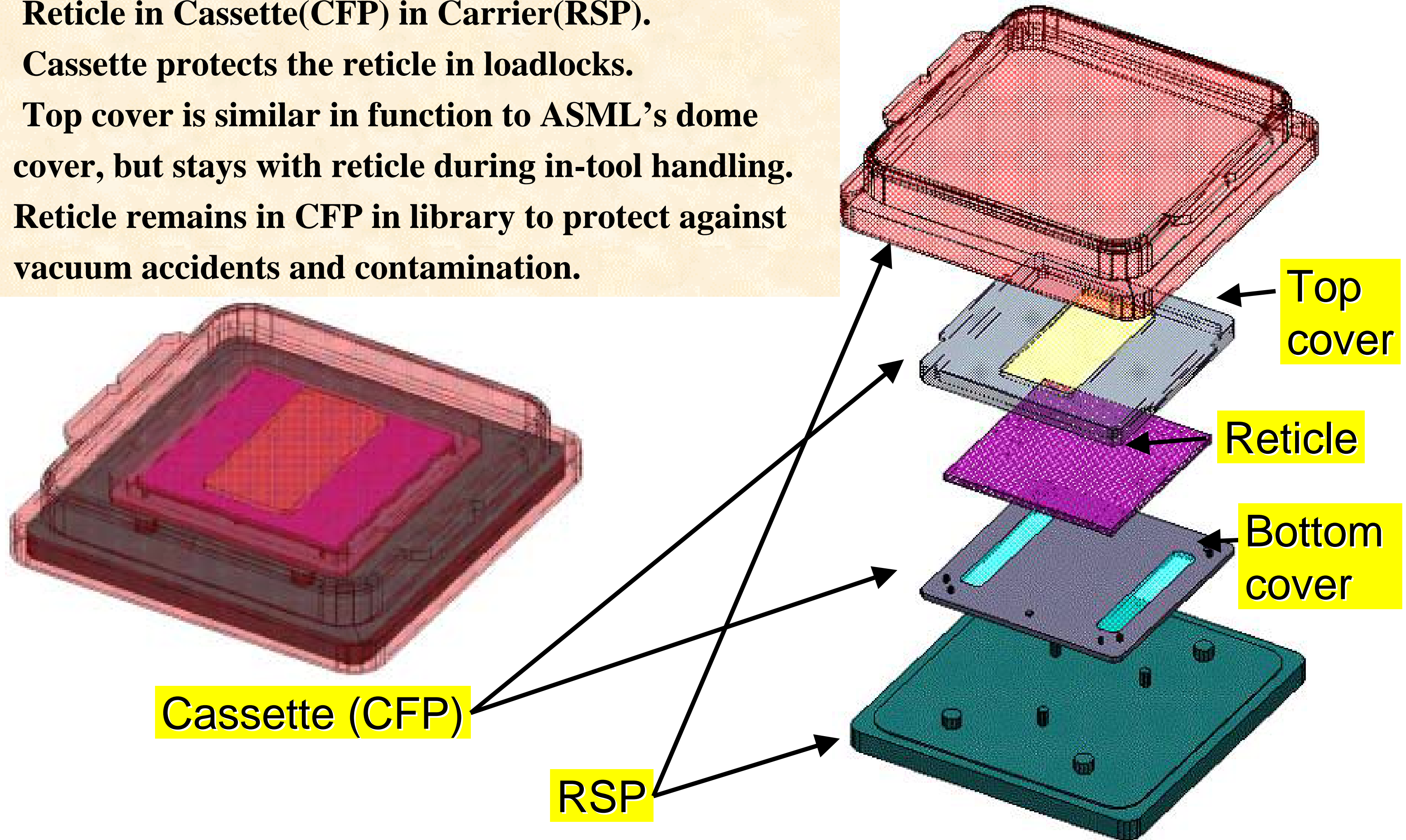
😐 Ru/B_4C-Cap, Ru/SiO_2(2)-Cap

☹ Ru/SiO_2(1)-Cap, SiO_2-Cap, Rh-Cap

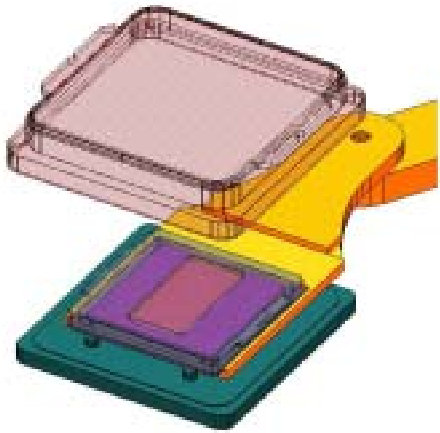
Reticle Protection

✧ *Dual Pod Concept by Canon and Nikon*

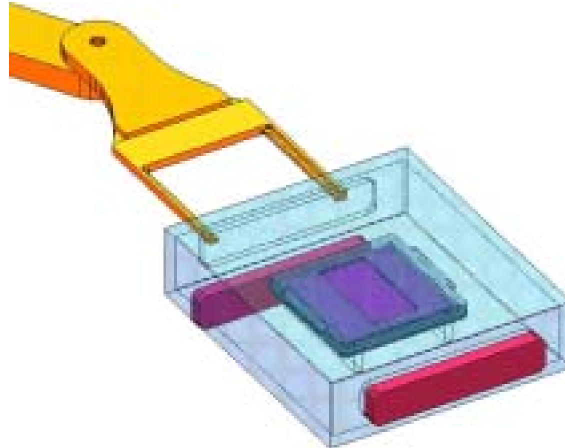
1. Reticle in Cassette(CFP) in Carrier(RSP).
2. Cassette protects the reticle in loadlocks.
3. Top cover is similar in function to ASML's dome cover, but stays with reticle during in-tool handling.
4. Reticle remains in CFP in library to protect against vacuum accidents and contamination.



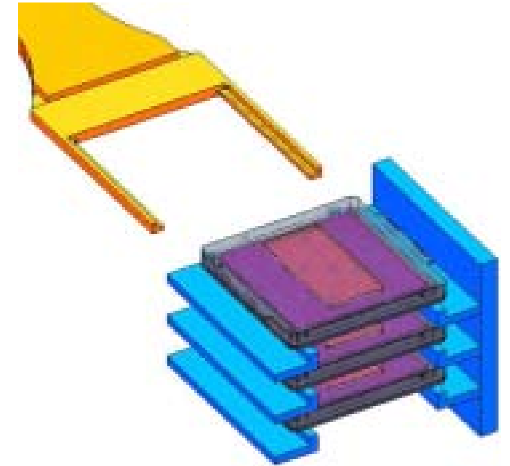
Handling sequence of Dual Pod Concept



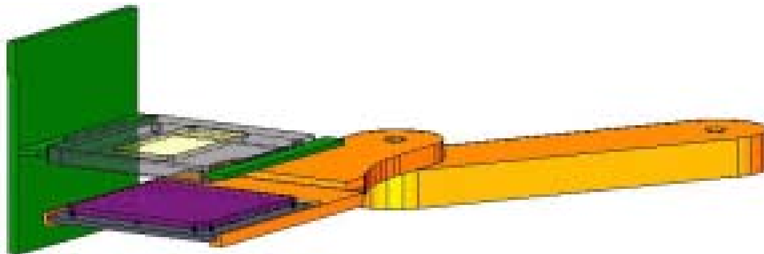
(1) Open the Carrier and take out the Cassette



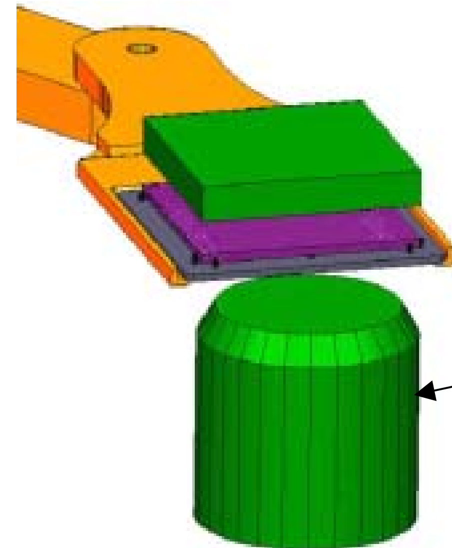
(2) In a loadlock



(3) Library in vacuum



(4) Prior to loading, remove the top cover

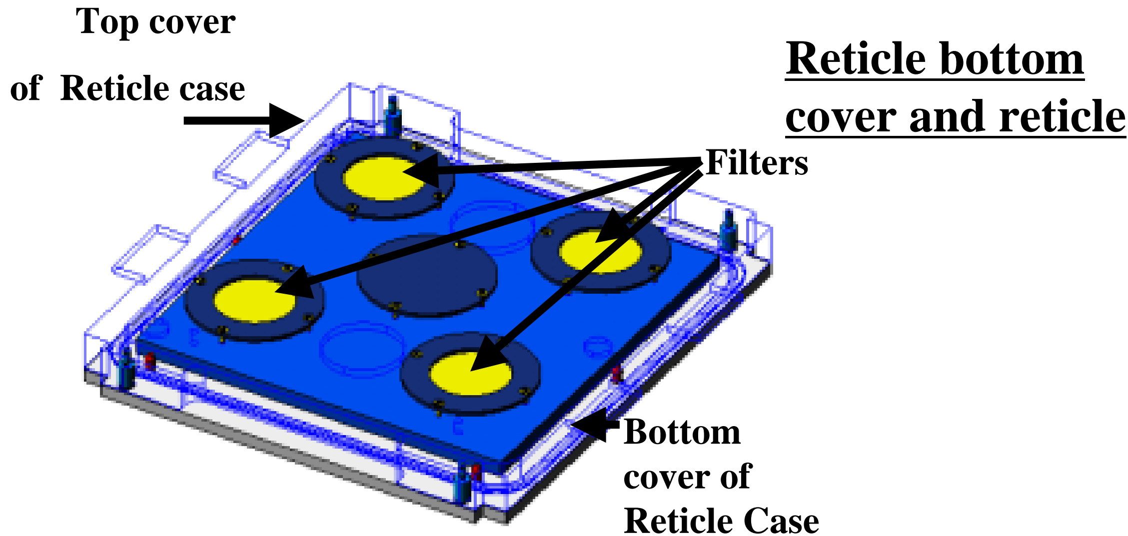


(5) Chuck the reticle

Reticle Protection

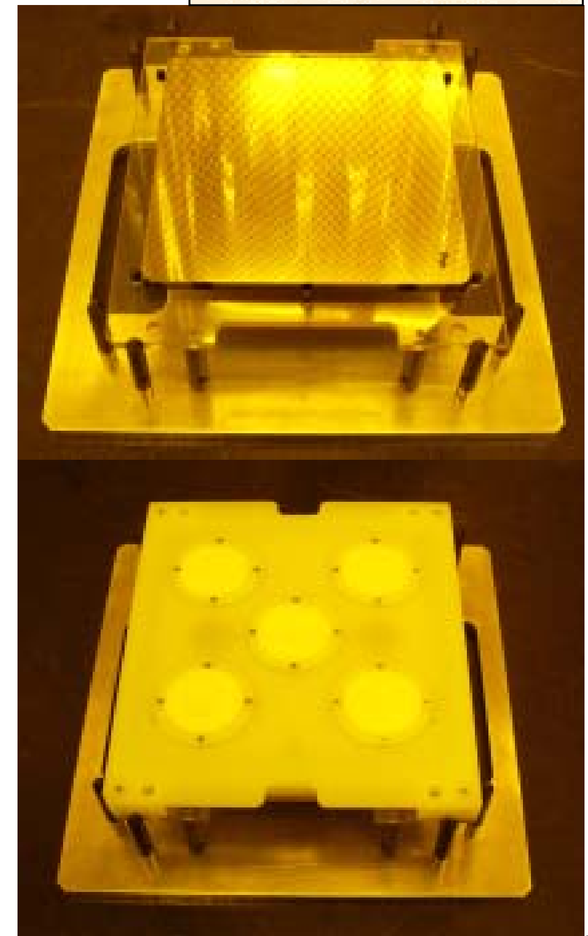
□ Reticle Case development based on the Dual pod concept

➢Proto-type Reticle Case has been completed and particle experiments are on going.



Preliminary design of Reticle Case

Proto-Type Reticle Case



Reticle bottom cover and reticle

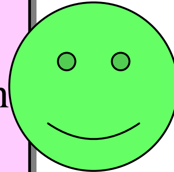
Reticle cover

Status of Critical Issues and Challenges

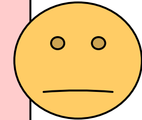
EUVL tool development is ready along with infrastructure development.

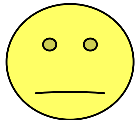
No

Reflective Optics
- Aspherical mirror fabrication
- Reflectivity
- Wavefront error
- Flare

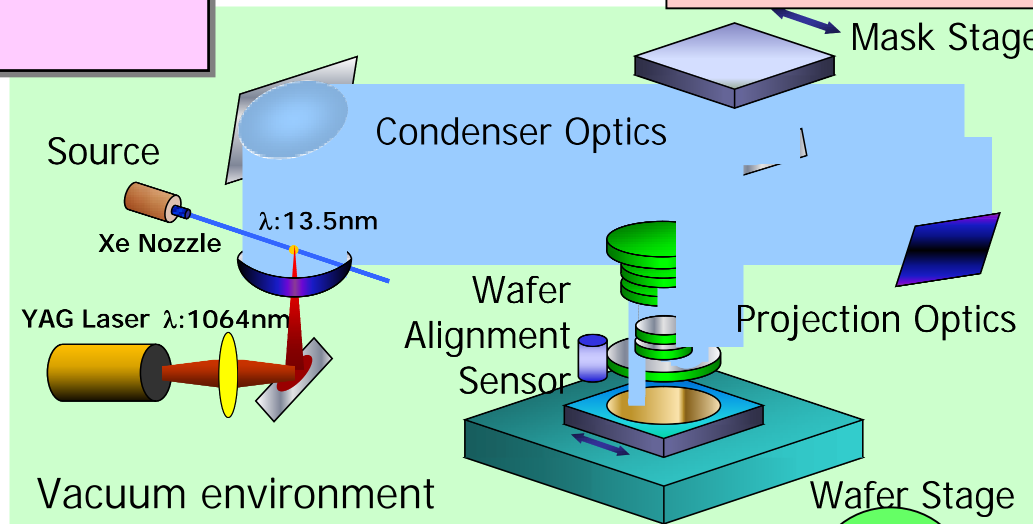


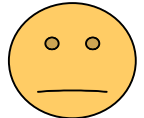
Reflective Mask
- Reflectivity
- Defect
- Flatness



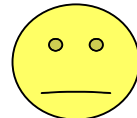


EUV Source
- Power
- Debris
- Lifetime





EUV resist
- Sensitivity
- LER/LWR



Contamination Control
- Vacuum Quality
- Optics Lifetime
- Reticle particle protection

Vacuum Compatible Body/Stages
- Synchronization accuracy
- Electrostatic Chuck
- Vacuum

EUV1 Tool Specifications (tentative)

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

Specification Item	EUV1
Field size (mm^2)	26 x 33
NA and Magnification	0.25, x1/4
Resolution (nm)	Dense line: 45 @hp Isolated line: 25 (Target 32 @hp)
Flare (%)	10
Overlay (nm)	15
Wafer size (diameter, mm)	300
Throughput (WPH) (10W& 5mj/cm^2)	5-10

Overall Development Status Summary

- EUV1 tool system and module detailed design have been completed by utilizing Nikon's own technologies such as EPL technology and other key basic development results supported by government programs.
- EUV1 tool fabrication has already started.
- P.O. proto-typing has been proceeding on schedule and production P.O. fabrication has started.
  - NA=0.25 Magnification=1/4 Field=26x33mm
- High reflective Mo/Si coating with low stress was achieved.
- Irradiation tests using SR have been conducted.
- Metrology tools have been almost completed and ready for P.O. production.
- DPP source has been chosen and expected Source power at IF is 10W and THP is around 5-10 WPH.

➢ EUV1 tool development program has been proceeding along with mask, resist and other infrastructure developments.

➢ EUV1 will be delivered in 1H/2007 for process development.

Nikon Presentation information in EUVL Symposium

Nikon Presentation		Oral/Poster	Date
Lifetime estimation and improvement of capping layer on multi-layer mirror for EUV Lithography in EUVA	S. Matsunari, T. Aoki (EUVA/Nikon) Y. Gomei, H. Takase, S. Terashima (EUVA/Canon).	O	Nov. 9
Systematic error evaluation of EUV wavefront metrology system	M. Okada, K. Ohtaki, K. Sugisaki, Y. Zhu, J. Saito, K. Murakami (EUVA/Nikon) C. Ohuchi, M. Hasegawa, S. Kato, T. Hasegawa, A. Suzuki, H. Yokota (EUVA/Canon) M. Niibe (Univ. Hyogo).	P	Nov. 7
Nikon Co-presentation			
Optimisation of Optical Design in Grazing Incidence Collector for EUVL DPP Sources	Enrico Buratti1(Media Lario), Valentino Rigato1,2, Fabio E. Zocchi1*, Hiroyuki Kondo3, Hideki Komatsuda3, Jürgen Kleinschmidt4, Guido Schriever4, Jesko Brudermann4, Imtiaz Ahmad4, Denis Bolshukhin4	O	Nov. 7
Lifetime Improvement of Projection Mirror with Ru Capping Layer for EUVL by Irradiation Atmosphere	Y. Kakutani, M. Niibe (Univ. Hyogo) Y. Fukuda, Y. Gomei, H. Takase, S. Terashima (EUVA/Canon) S. Matsunari, T. Aoki (EUVA/Nikon).	O	Nov. 9
A new contamination evaluation system for EUVL projection mirrors in New SUBARU	M. Niibe, Y. Kakutani (Univ. Hyogo) Y. Fukuda, Y. Gomei, H. Takase, S. Terashima (EUVA/Canon) S. Matsunari, T. Aoki (EUVA/Nikon).	P	Nov. 7
EUV wavefront metrology system in EUVA	T. Hasegawa, S. Kato, C. Ouchi, M. Hasegawa, H. Yokota (EUVA/Canon) K. Sugisaki, M. Okada, J. Kawakami, K. Murakami, Y. Zhu, K. Ohtaki, Z. Liu, J. Saito (EUVA/Nikon) M. Niibe (Univ. Hyogo) M. Takeda (Univ. Electro-Communications)	P	Nov. 7
Nikon contribution			
Patterning Performance of Molecular Resists from the ASET-HINA	H. Oizumi (ASET), et al.	O	Nov. 8
Prinrability of contact-hole patterns in EUVL using 0.3-NA HiNA Optics	Y. Tanaka (ASET), et al.	P	Nov. 7

Acknowledgements

■A part of this work was conducted under EUVA project.

■EUVA project has been supported by NEDO.

Nikon gratefully acknowledges METI and NEDO for their support.