



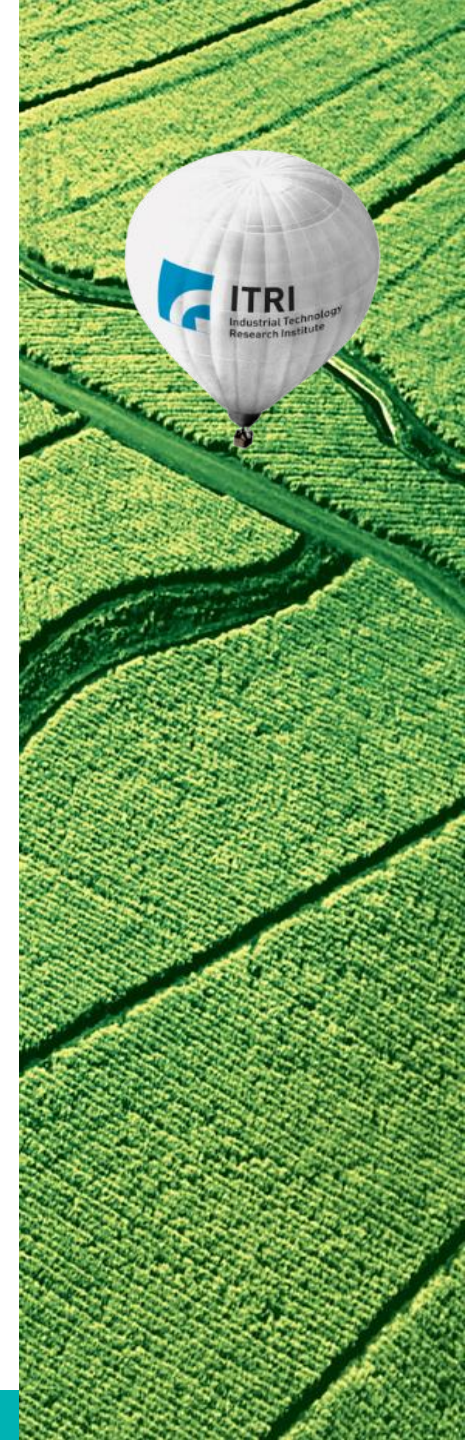
ITRI

Industrial Technology
Research Institute

2026 Taiwan AOIEA Forum & Show

FOUP式EUV劑量量測儀

工業技術研究院
量測技術發展中心
陳政憲



Outline

- 01** **About CMS / ITRI**
Measurement Standards and Physical Application Division
- 02** **EUV and EUV Lithography**
The EUV spectral range · exposure dose
- 03** **EUV Radiometry in CMS/ITRI**
Responsivity calibration · traceability · EUV sensor characterization
- 04** **Application: Transfer Standard for Industry**
Wafer-based & FOUP-type EUV dose measurement system
- 05** **Conclusion**



標準與物理計量技術應用組 技術簡介

精密儀器校正

國家度量衡標準實驗室：電、磁、微波、聲音、振動、溫度、濕度、光輻射 8 領域國際相互承認之一級校正

微波通訊量測技術

電場強度、微波功率、微波阻抗、低軌衛星天線量測

半導體製程參數量測與儀器

晶圓式 EUV 量測儀、
晶圓式溫度計、
EUV 光罩特性量測
EUV 元件缺陷檢測

軌道設施評估與診斷

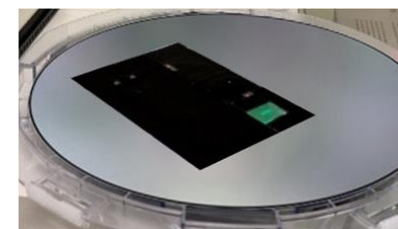
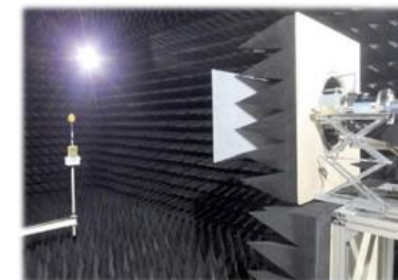
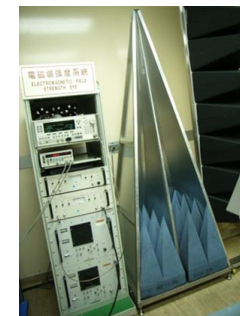
軌道環境電磁場與電磁相容性量測；
結構振動及噪音檢測；
乘坐舒適度評估

溫度與濕度量測技術

溫濕度感測器、輻射/接觸溫度、
IR 感測元件、自校型溫度感測器、
散熱設計

照明特性量測技術

CIE / IEC / ISO 照明標準量測；
道路照明; micro-LED 量測



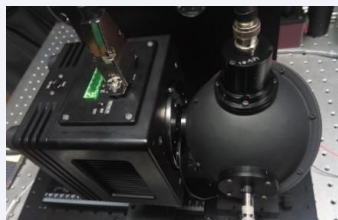
光電計量與感測技術研究室

● 光輻射量測技術

校正與量測

- 分光輻射
- 全光通量、分光輻射通量
- 色度、霧度、光散射

AI 分析技術：影像分析



● 光電量測與應用技術

顯示器特性量測

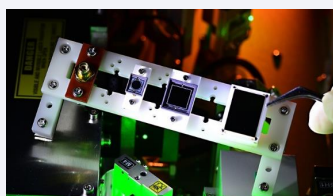
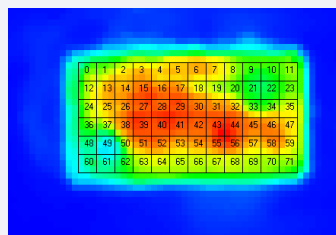
- SEMI/IEC 標準； μ LED、AR/VR

照明特性量測

- CIE/IEC/ISO 標準、道路照明應用

雷射應用

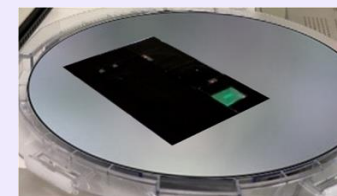
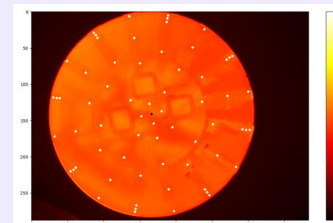
- 光通訊、測距、光達



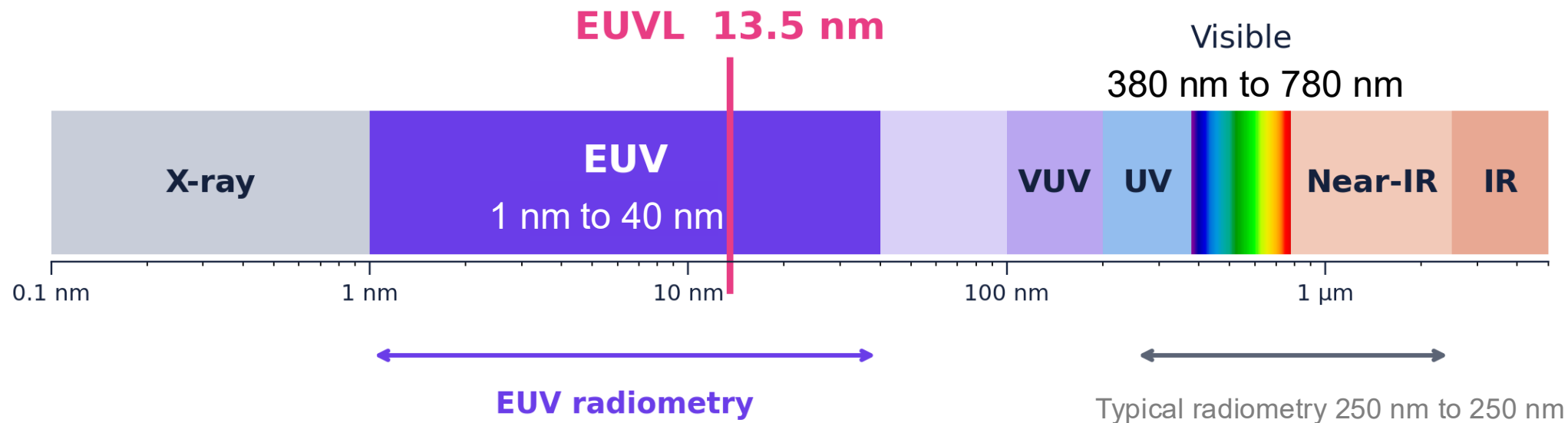
● 半導體量測技術

製程參數量測與儀器

- 晶圓式溫度計
- 晶圓式 EUV 光譜計
- EUV 光罩特性量測
- FOUP 式 EUV 劑量量測儀



The Wavelength Range of EUV Radiometry



Spectral position of EUV radiometry relative to UV, visible and IR radiometry.

13.5 nm

EUV lithography

**1 nm to
40 nm**

EUV radiometry

**100 nm to
200 nm**

Vacuum UV

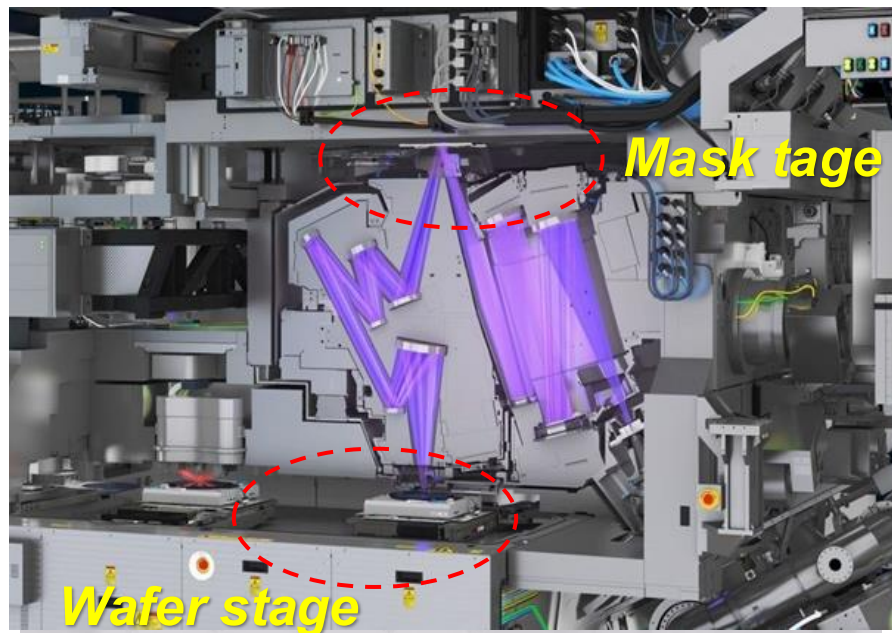
**380 nm to
780 nm**

Visible: photometry &
colorimetry

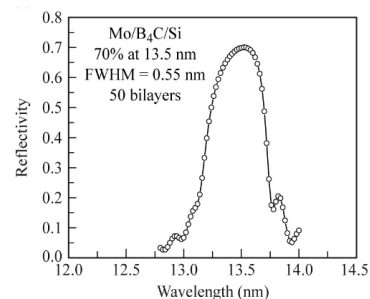
Extreme Ultraviolet (EUV) Lithography

Key technical challenges

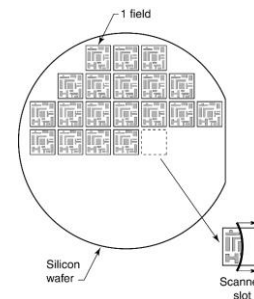
- DOF reduction
- Ultra-thin resist (< 16 nm)
- High-resolution resist
- Anamorphic mask
- Mask 3D effect (< 55 nm)
- Mask material
- Wafer topography control
- Variability control
- Edge placement error
- Image stitching (edge)



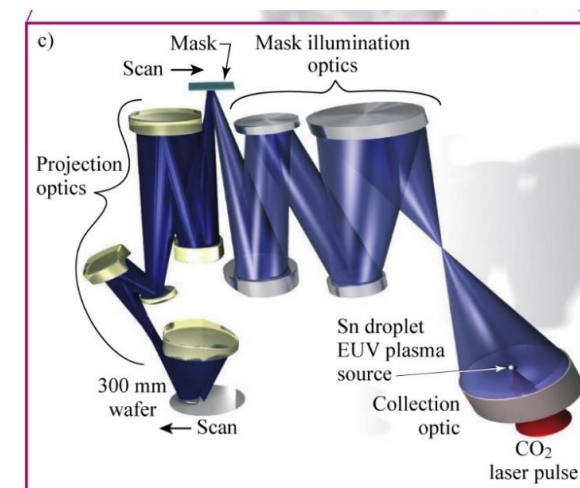
EUV scanner (ASML).



Mo/Si multilayer mirror.



Scanned field.



Reflective projection optics.

Reference: ASML

The Exposure Dose

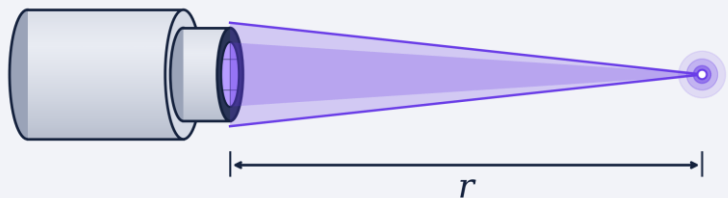


$$H = E \cdot t = \frac{\Phi}{A} \cdot t$$

Evaluating the exposure dose requires

- 1 Accurate irradiance $\rightarrow$ responsivity of the photodetector
- 2 Accurate exposure time

Calculation of Exposure Dose



Over-filled condition

Responsivity of irradiance

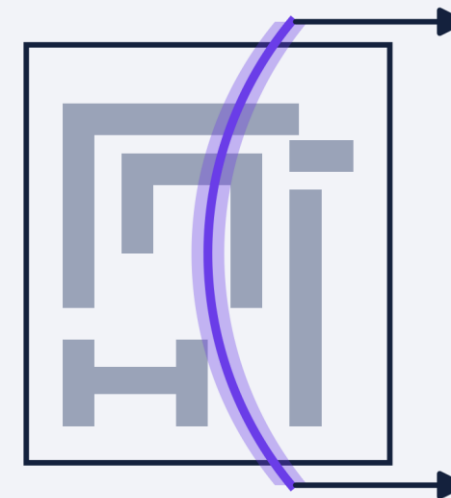
$$A / (W/m^2)$$



Under-filled condition

Responsivity of radiant flux

$$A / W$$



Scanned-slot exposure

Other contributors to dose uncertainty

Uniformity of detector
responsivity

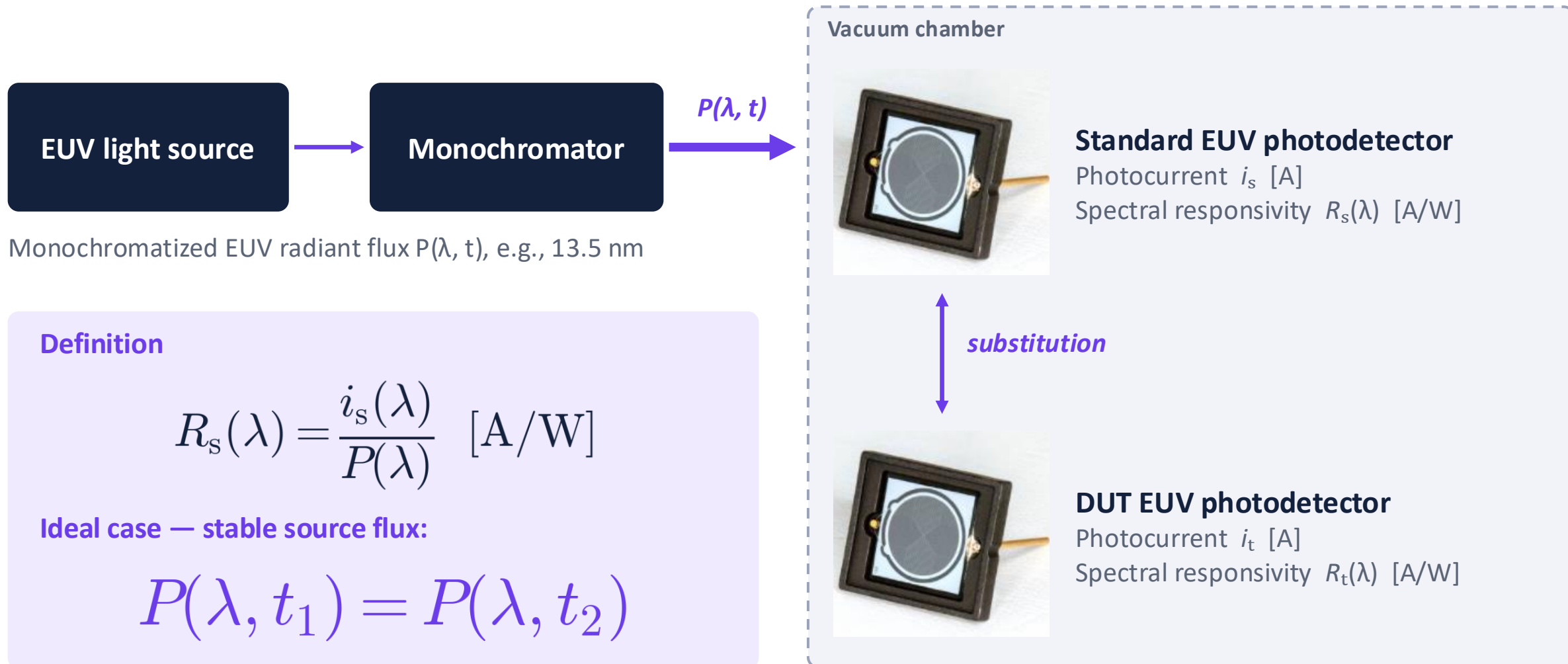
Spatial distribution of
exposure light

Stability of scanning
speed

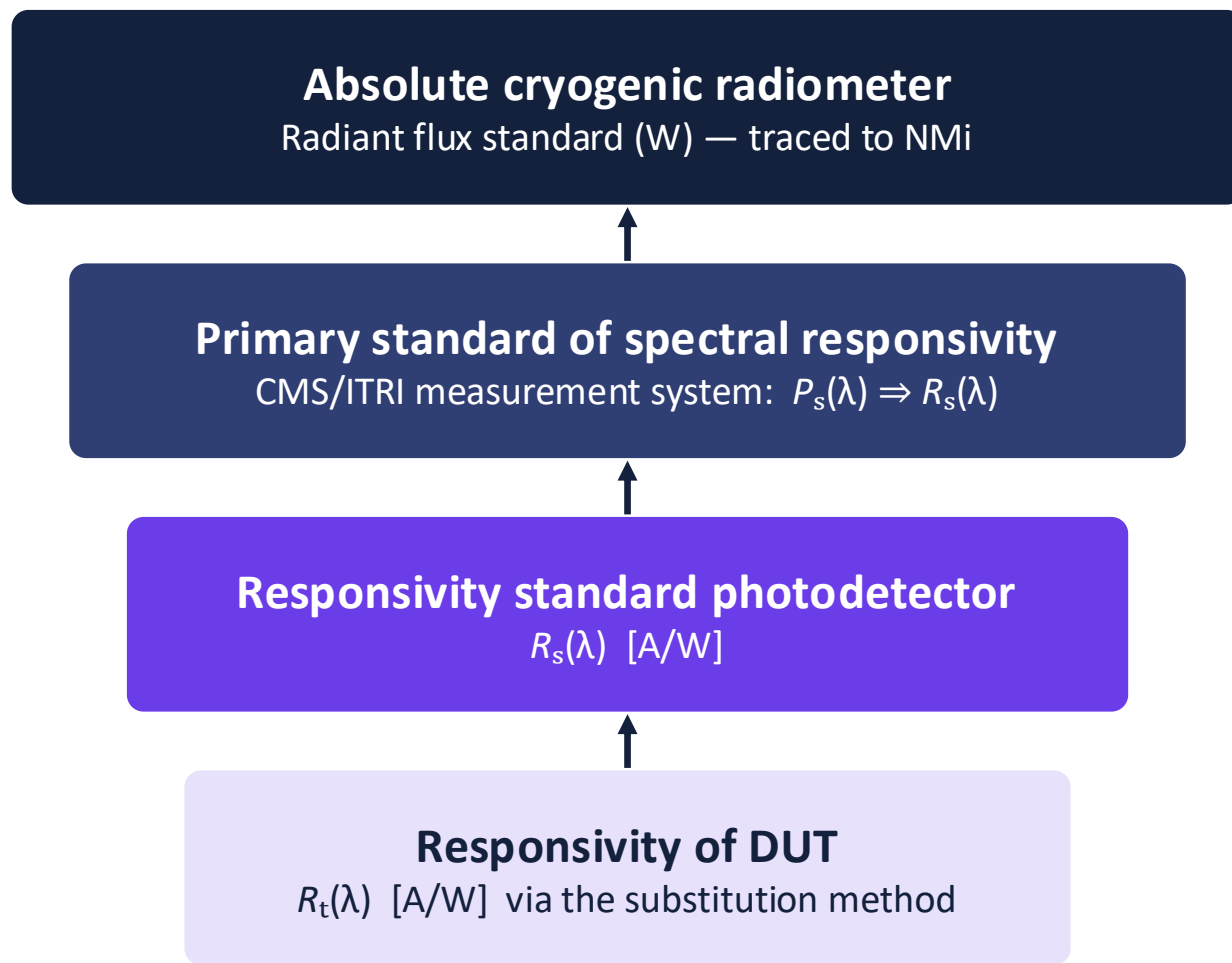
Accuracy of exposure
area

Stability & repeatability
of detector

Calibration of Spectral Responsivity of the Photodetector



Metrological Traceability Chain of the Responsivity Standard



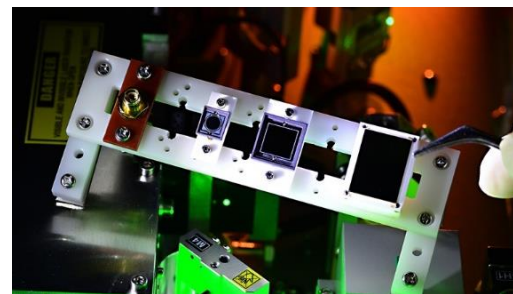
$$R_t(\lambda) = \frac{i_t(\lambda, t_2)}{i_s(\lambda, t_1)} \cdot R_s(\lambda)$$

$R_t(\lambda)$ spectral responsivity of DUT [A/W]

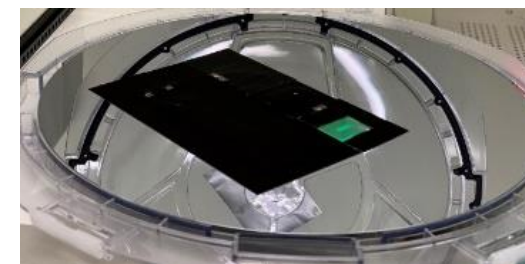
$R_s(\lambda)$ spectral responsivity of standard [A/W]

$i_t(\lambda, t_2)$ measured photocurrent of DUT [A]

$i_s(\lambda, t_1)$ photocurrent of standard [A]



Standard EUV sensors.



Wafer-type EUV meter.

Detector-Based EUV Radiometry in CMS/ITRI



Synchrotron (NSRRC)



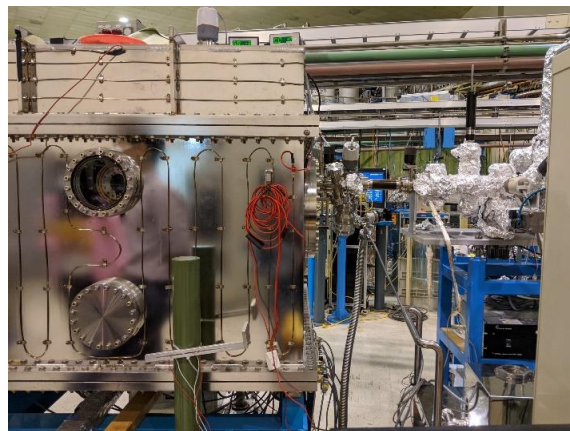
Monochromator



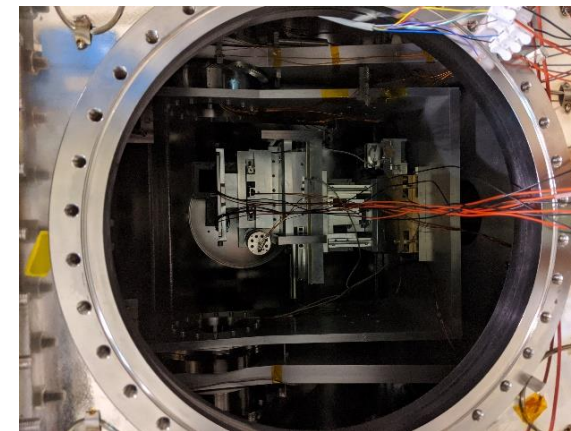
Standard detector ⇌ DUT



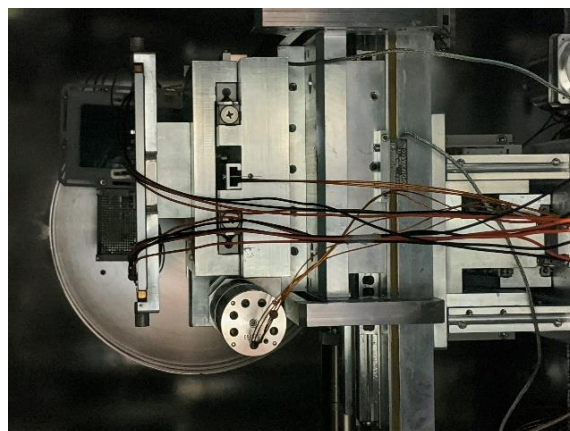
Vacuum chamber



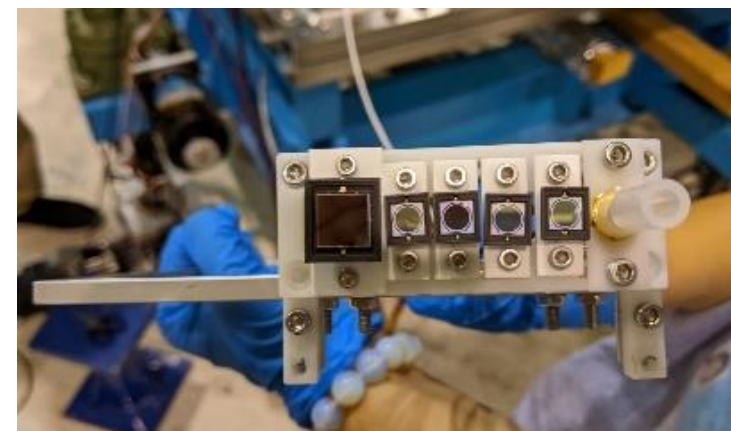
EUV beamline (Synchrotron).



Vacuum chamber.

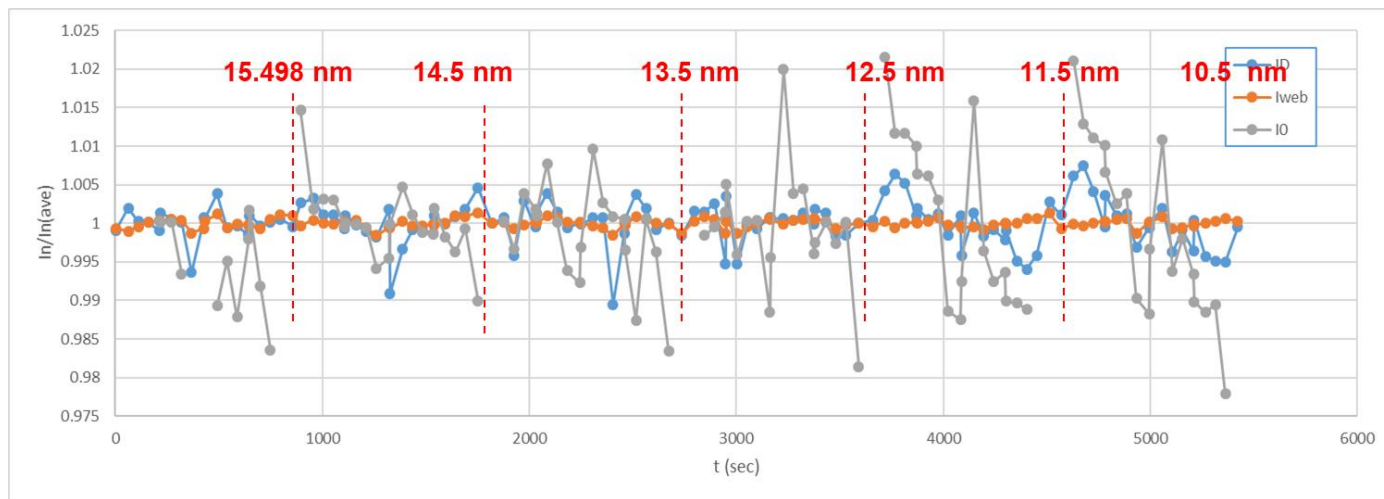


Multi-axes stage.



DUT and standard EUV photodetectors.

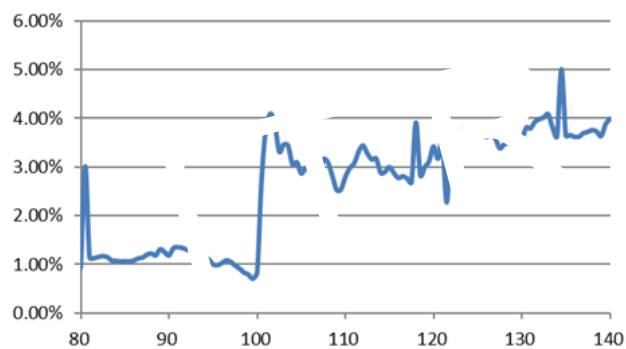
Stability of the EUV Radiometry Measurement System



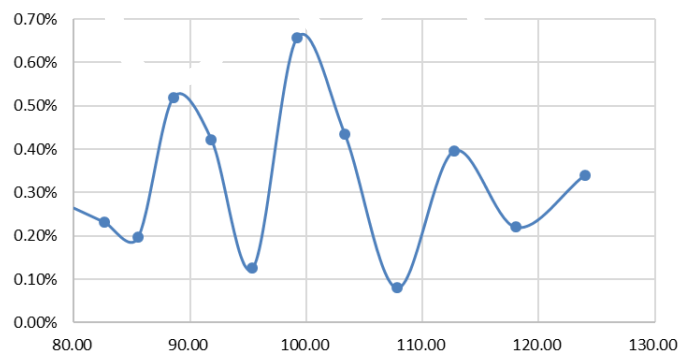
Long-term signal of gold-mesh I_0 and EUV sensors I_D across photon energies.



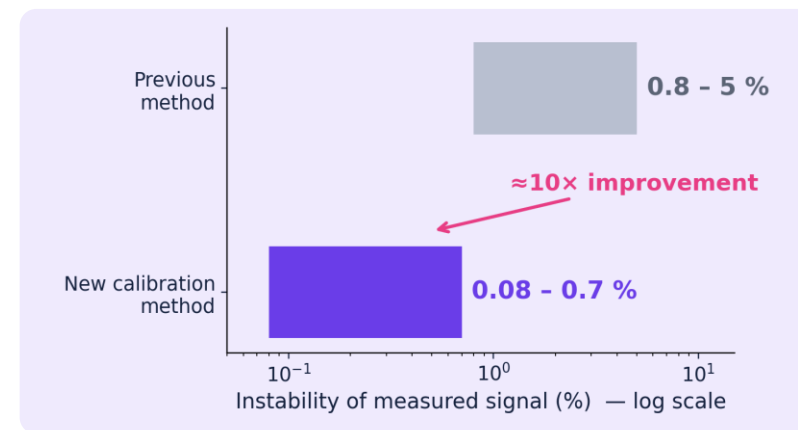
Test chamber.



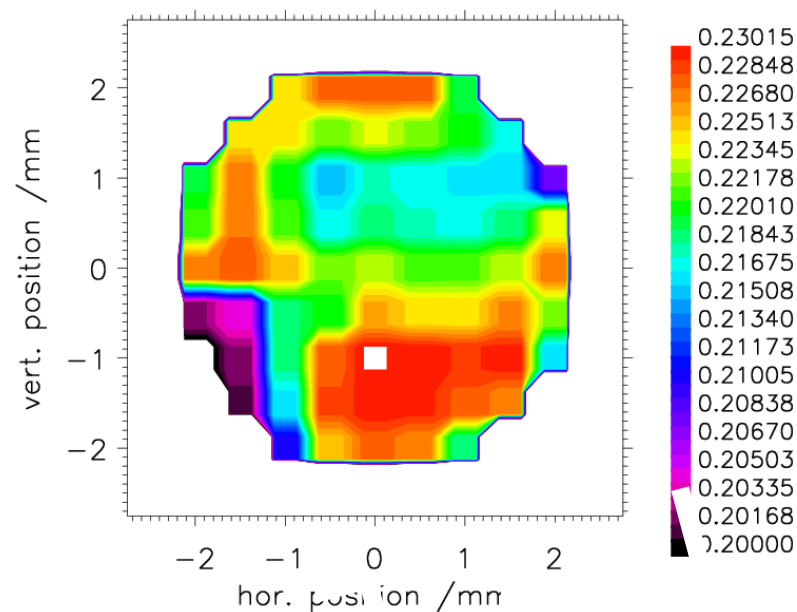
Previous: 0.8 % to 5 %.



New method: 0.08 % to 0.7 %.

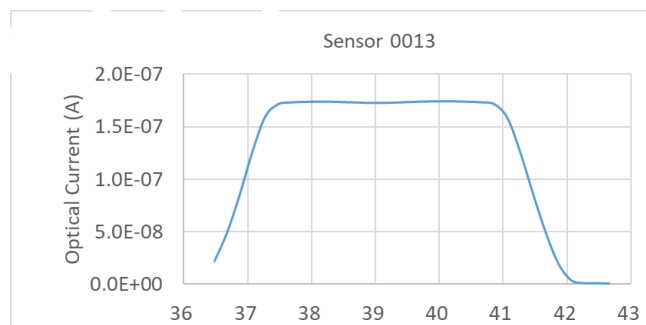


Responsivity Uniformity of the EUV Photodetector

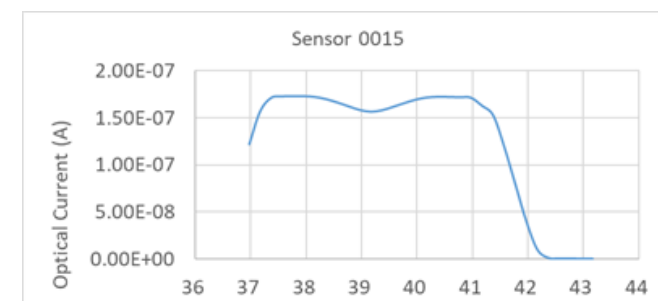


Measured 2-D responsivity map of an EUV photodetector.

- 1 **Why it matters** Responsivity uniformity directly limits the accuracy of EUV radiant-flux measurement.
- 2 **Impact** Non-uniformity combined with misalignment → measurement variation of up to 10 %.
- 3 **Root cause** Long-term EUV exposure causes oxidation and contamination, degrading uniformity.



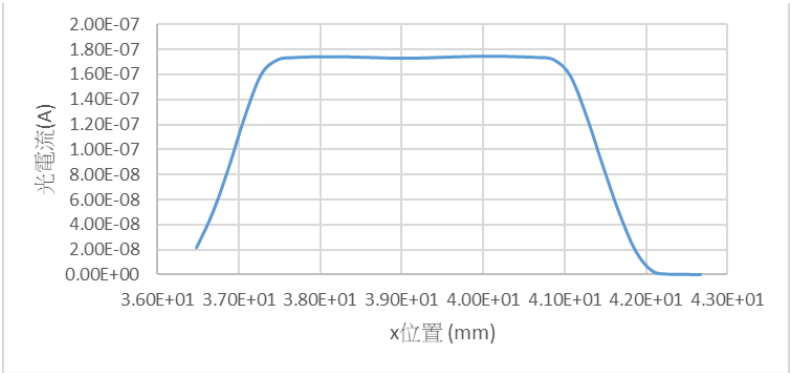
Ideal: uniform responsivity.



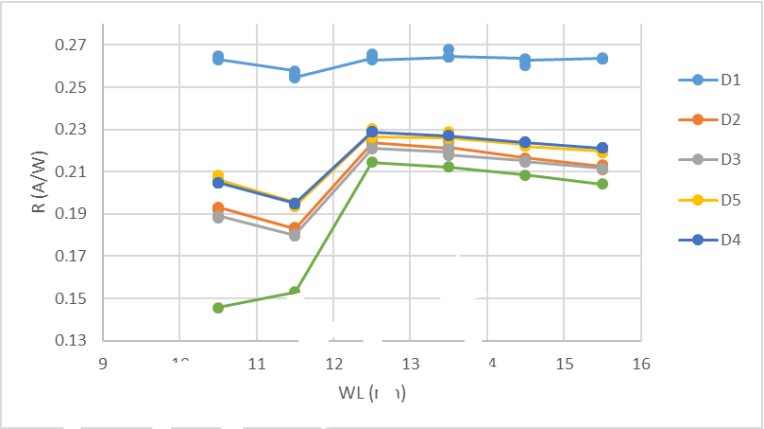
After long-term exposure.

Characterization of EUV Transfer Standards

> 98 %
Uniformity of active area

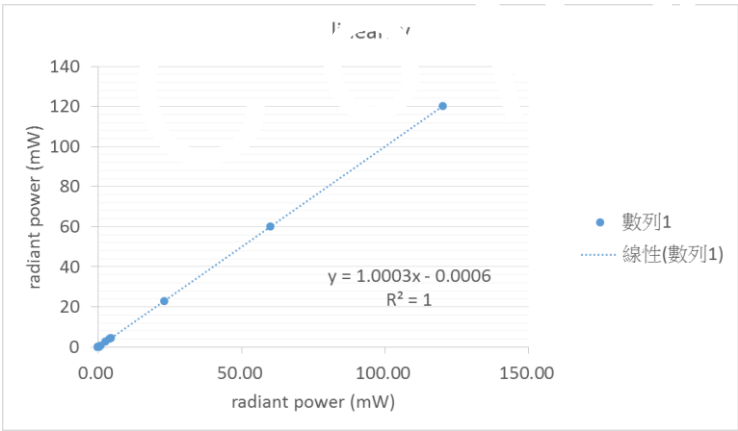


Uniformity of active area.

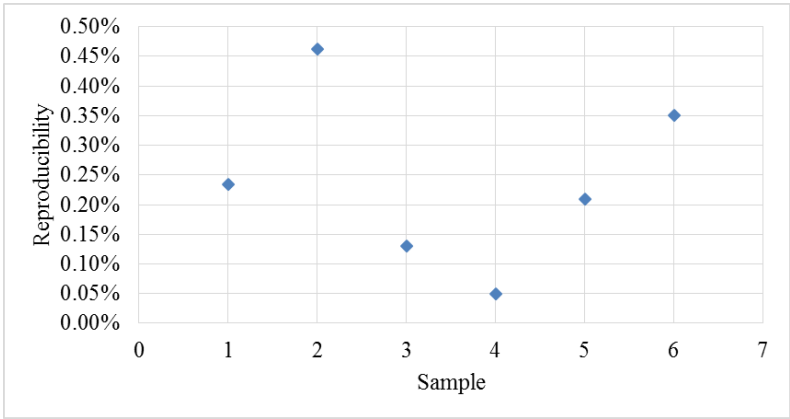


Spectral responsivity.

99.6 %
Linearity



Linearity.



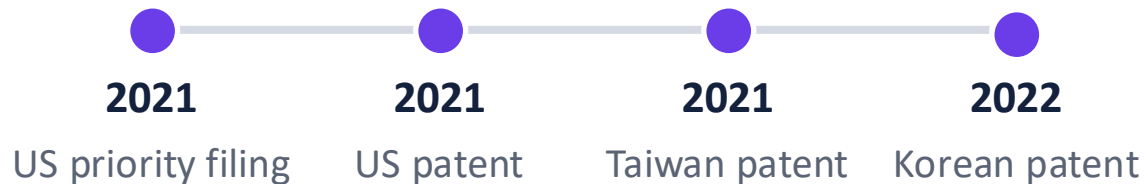
Reproducibility.

< 0.46 %
Reproducibility deviation

FOUP-Type EUV Meter: Proprietary Patented Technology

- 1 FOUP-type form factor**
Compatible with the EUV tool — no equipment modification
- 2 Assess source status in < 3 min**
In-process, without resist coating or etching
- 3 Non-destructive measurement**
Fast, clear, root-cause-oriented insight

Patent portfolio



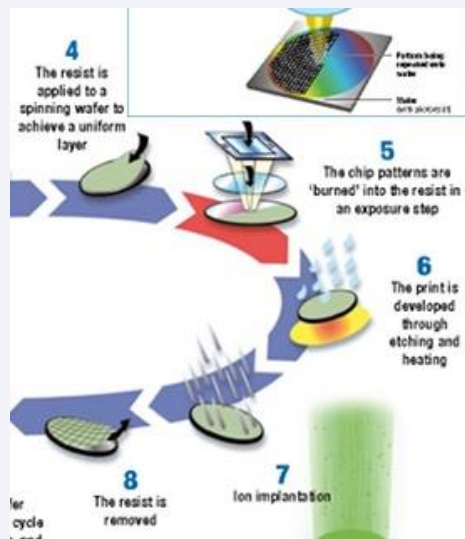
FOUP-type EUV meter.

FOUP-Type EUV Meter: Proprietary Patented Technology



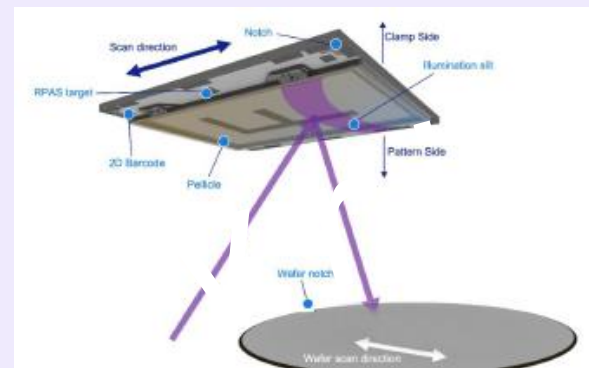
Wafer-Based EUV Dose Measurement System

AS-IS Destructive measurement



- Complex steps: coating → lithography → resist removal & etching
- Time-consuming process
- Hard to trace root causes objectively

TO-BE Non-destructive measurement



- High-resolution EUV intensity, uniformity & spectrum
- Tool-to-tool and fab-to-fab matching

In-process

High-resolution, direct process monitoring

Multi-function

Intensity, uniformity & spectrum on one wafer

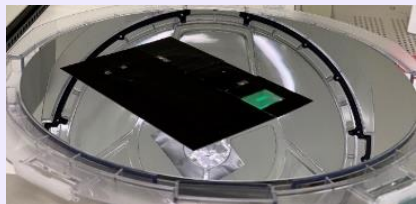
Non-destructive

Fast, clear, root-cause-oriented insight

Cross-fab matching

High stability & repeatability across tools

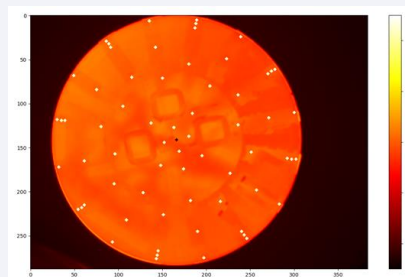
Wafer-Based Meter Family and Applications



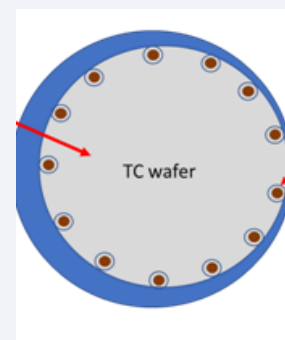
EUV dose meter



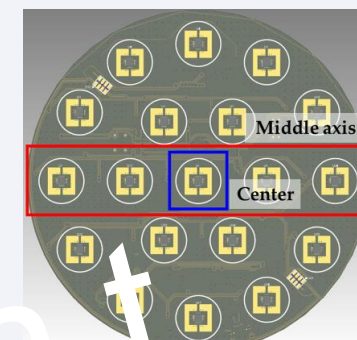
EUV uniformity meter



Multi-temperature meter

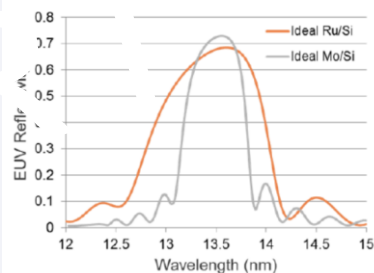
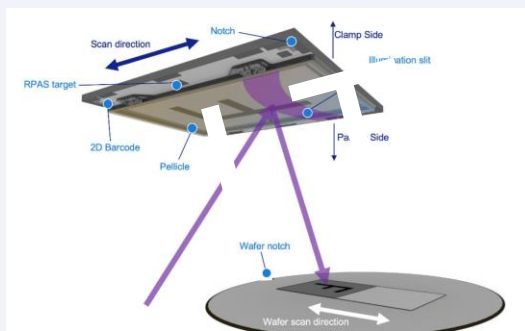


Position meter

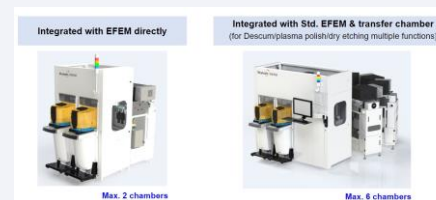
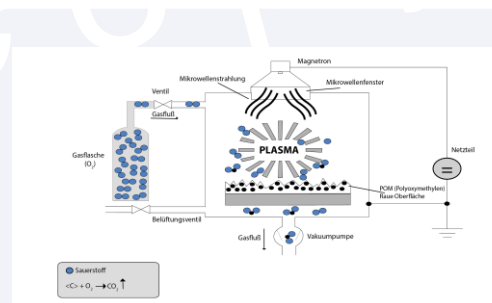


Multi-plasma meter

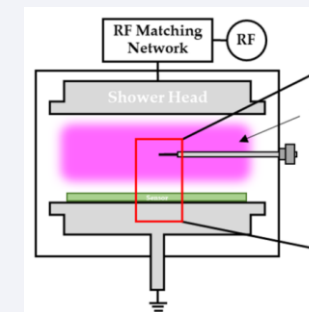
Applications



EUV lithography



Etching process (plasma)



Conclusion

1 EUV radiometry & traceability

- Spectral responsivity calibration of EUV sensors, 10 nm to 20 nm
- Traceable to an absolute cryogenic radiometer
- System stability improved to 0.08 % to 0.7 %
- Transfer standard: uniformity > 98 %, linearity 99.6 %

2 Wafer-/FOUP-based dose meter

- First non-destructive, in-process EUV dose measurement
- Evaluation time cut from > 12 h to < 3 min
- Radiant dose accuracy 1 nJ/cm² (@ EUV dose 150 mJ/cm²)
- Tool-to-tool and fab-to-fab matching

3 Industrial impact

- Compatible with EUV scanners — no tool modification
- Extends to temperature, position and plasma meters
- Patents granted in US, TW and KR

Thank you for your attention

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