



# Integrated Solution of Nikon Exposure, Metrology and Inspection

**Masahiro Morita**

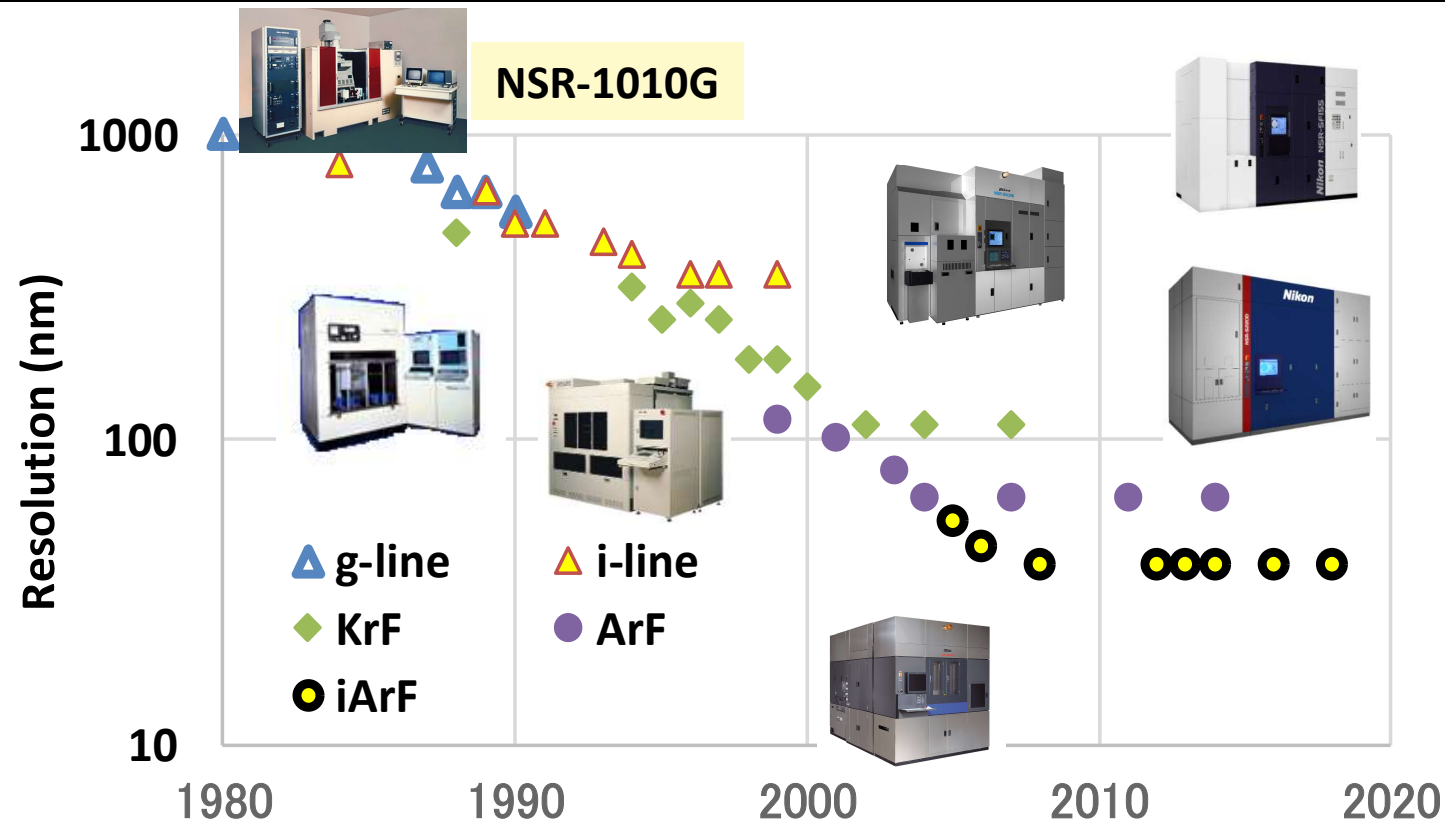
Sector Manager

Semiconductor Lithography Business Unit

NIKON CORPORATION



# NSR contribution for LSI innovation



**NSR-SF155**  
i-line  
0.62 NA

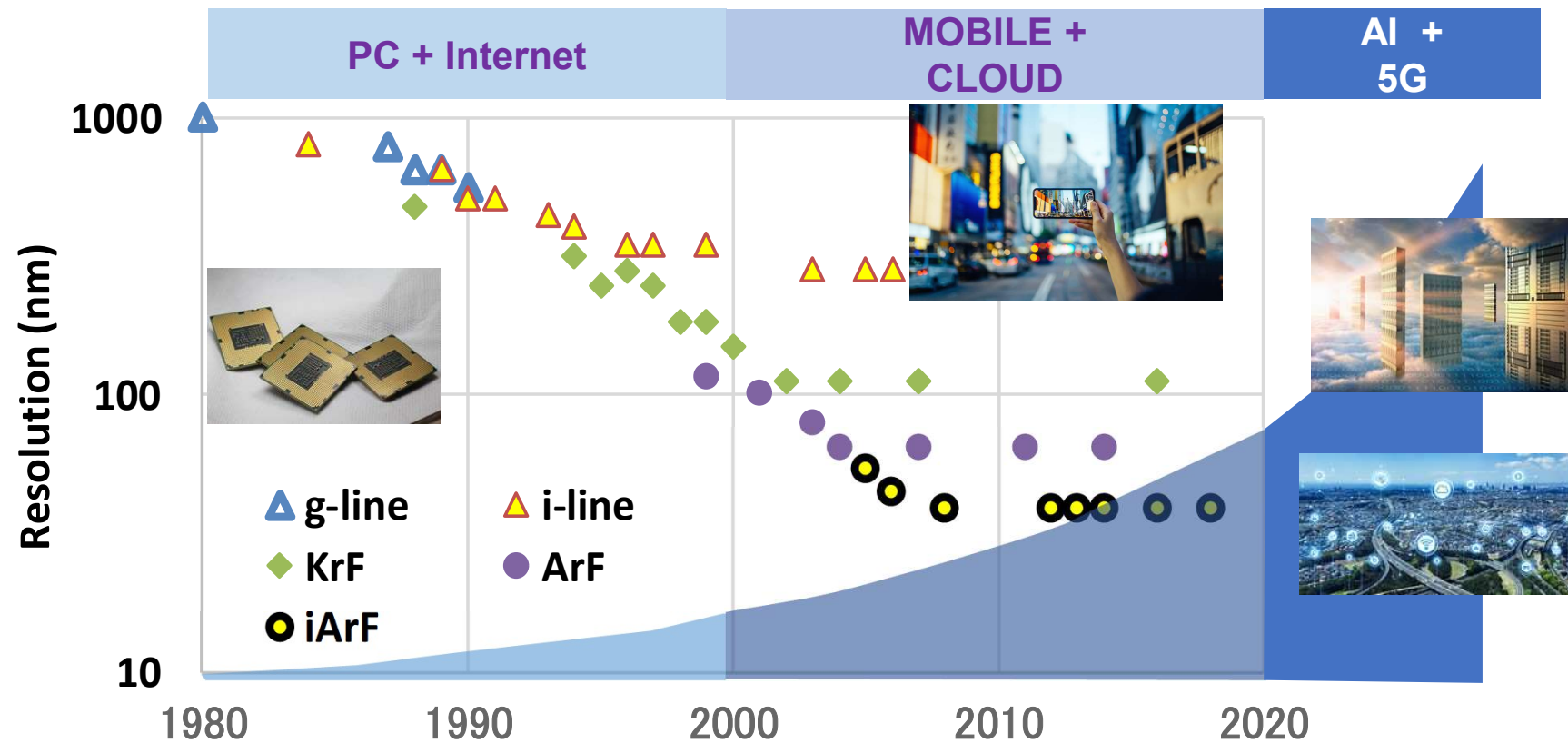
**NSR-S220D**  
KrF  
0.82 NA

**NSR-S322F**  
ArF Dry  
0.92 NA

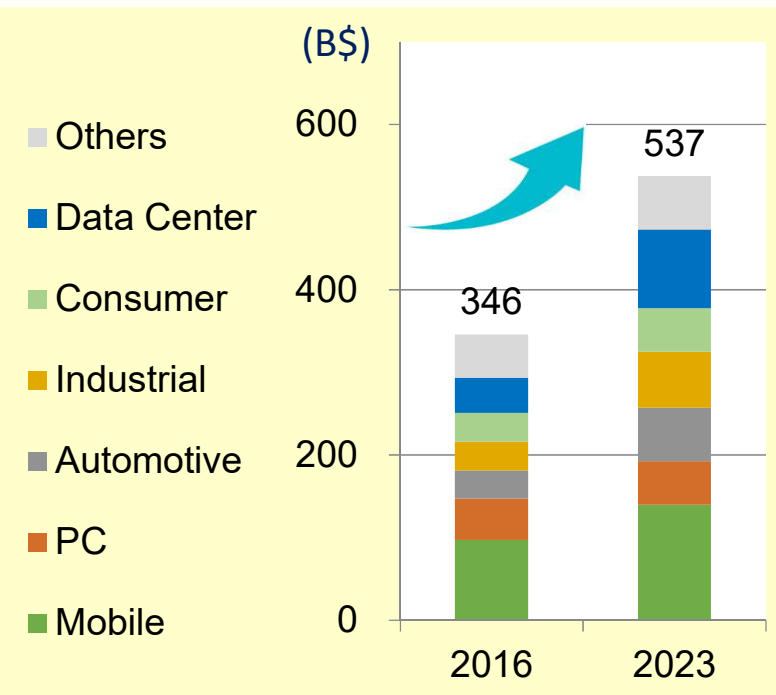
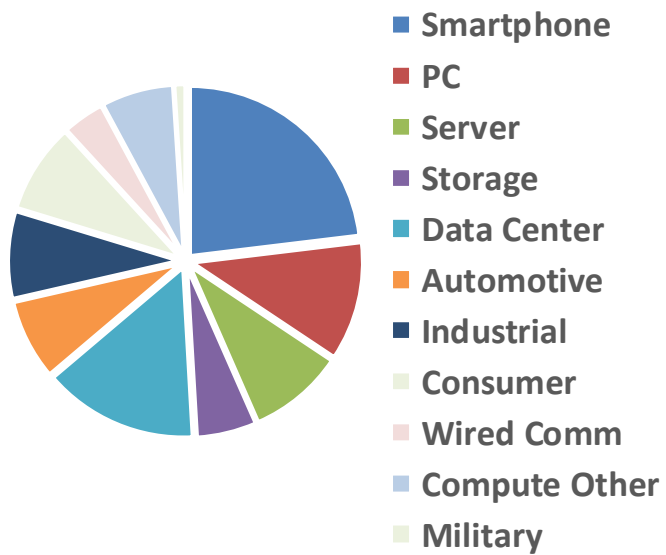
**NSR-S635E**  
Immersion  
1.35 NA



# NSR contribution for LSI innovation

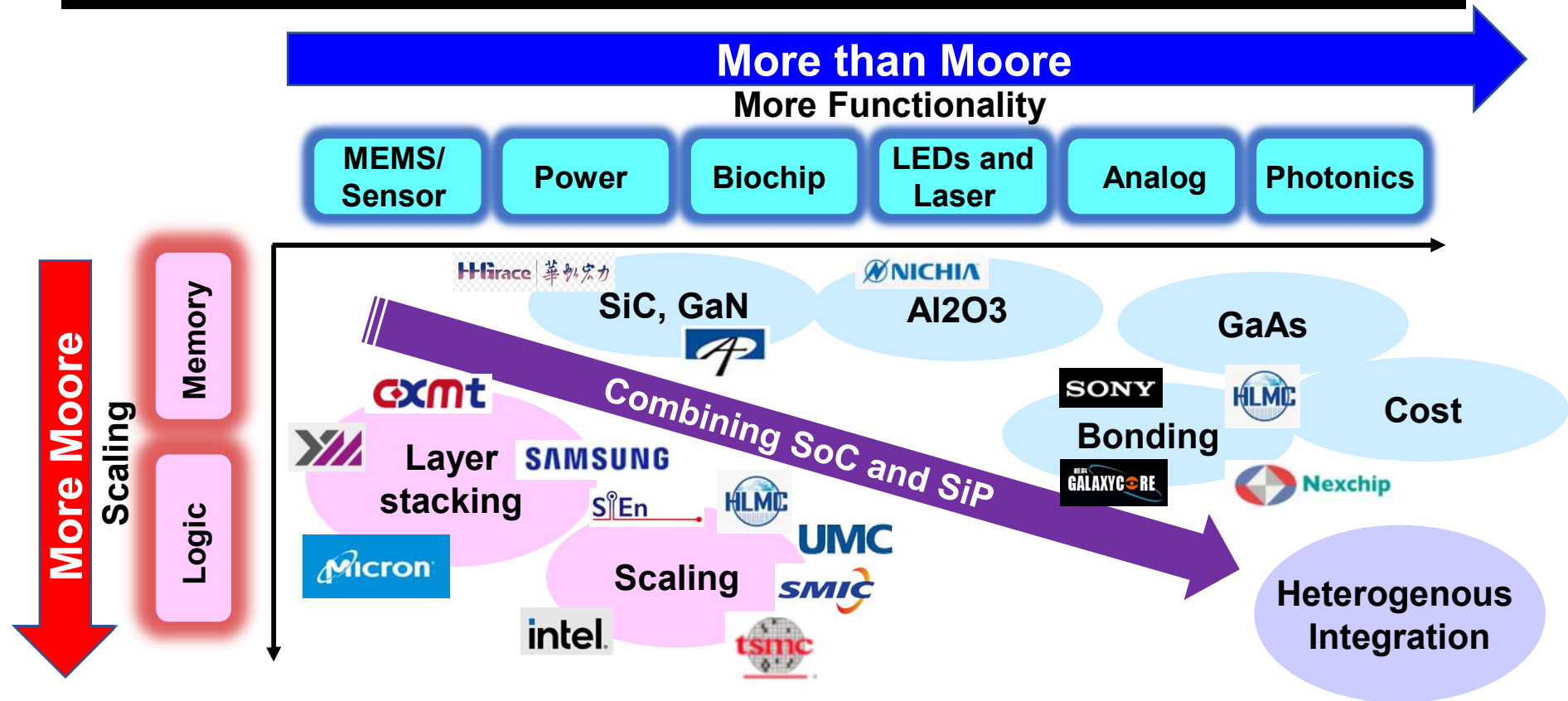


# Market trend

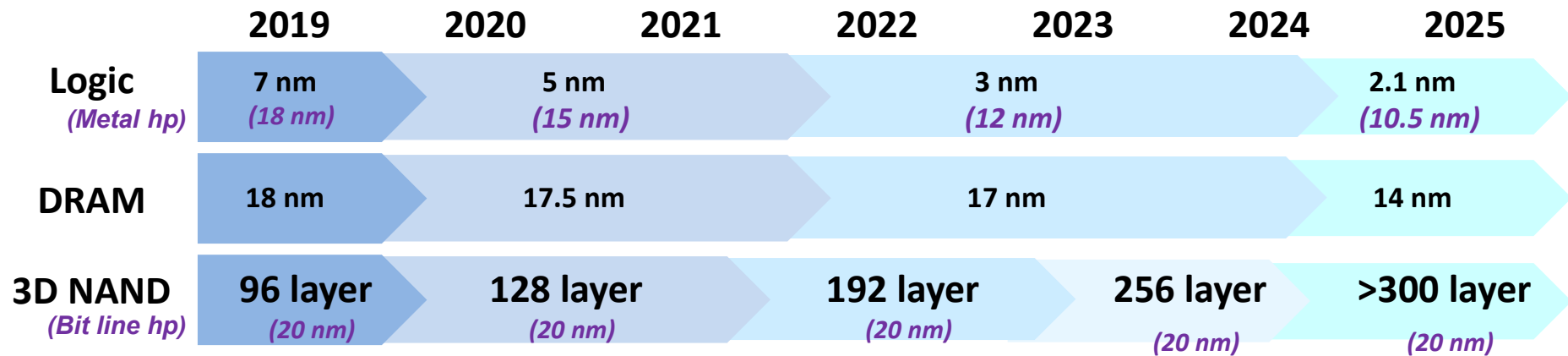


Source: Nikon estimation based on Gartner data

# Semiconductor products



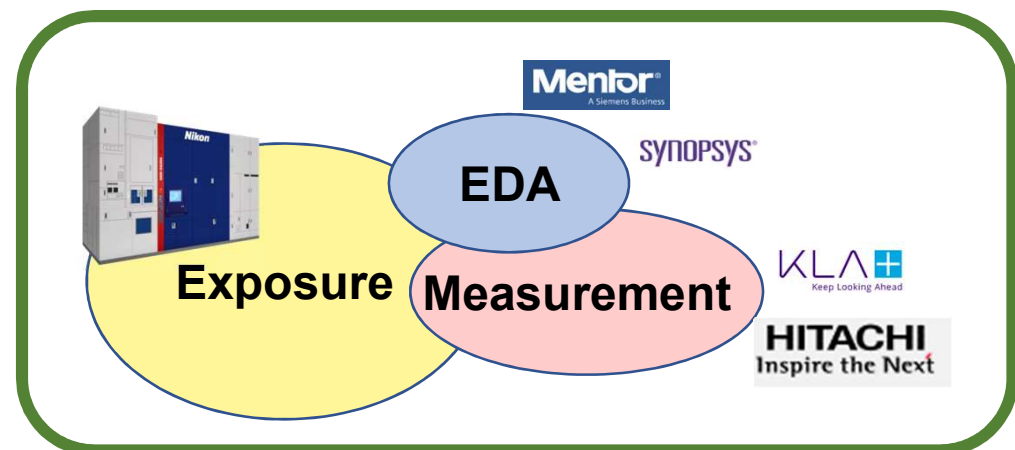
# More Moore



## Key technologies

- EUVL implementation at cutting edge
- EPE improvement on all devices  
(Overlay, OPC, measurment)

Source: IRDS roadmap 2020  
Nikon customer research



# On-Product Overlay (OPO) Key Factors



## *Logic/DRAM scaling*

Translation/Scale

Aberration Reduction

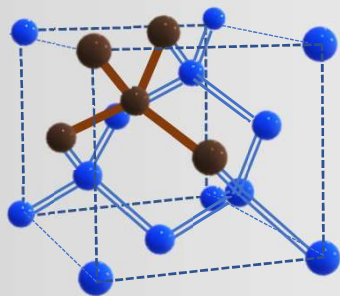
Distortion matching

Lens Heating  
Wafer heating

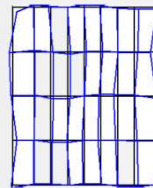
Process Impact

EUVL Matching

Pellicle Deformation



*Ultimate accuracy  
to Si atom level*



*Heterogenous  
integration*

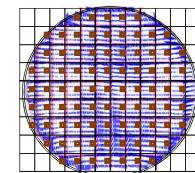
Wafer bonding  
deformation

*Functional  
CIS*

*3D NAND*

Layer stacking deformation

*Dense  
measurement w/o  
productivity loss*



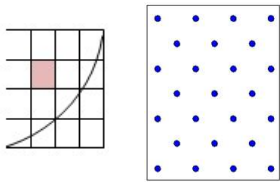
# Dense sampling for On-Product Overlay(OPO)



Measure  
under layer distortion w/ high accuracy

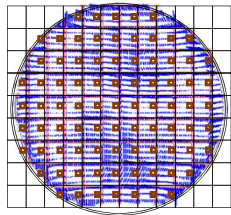


Reflect  
to overlay exposure correctly



Intra-Field dense sampling  
distorted intra-field layer

***Feed Forward  
Absolute data***

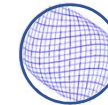


All shot grid sampling  
for large distorted layer



✓ Field by Field higher order  
Intra-field matching

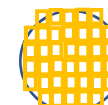
✓ Multi grid matching model



Polynomial Model



Edge Local Model



Die by Die Model

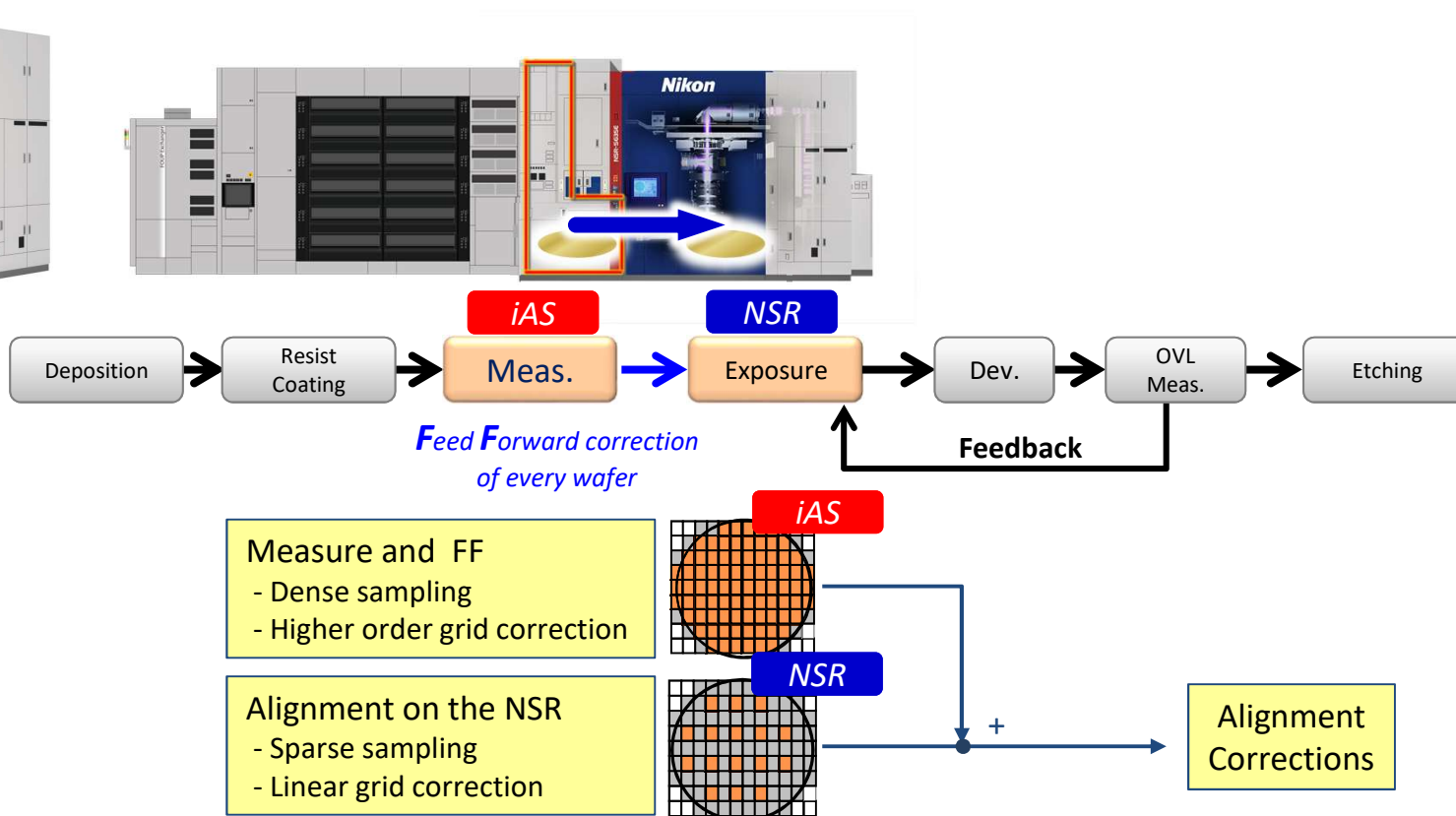
Dense sampling and FF is breakthrough for under layer matching

# Latest ArFi with iAS (inline Alignment Station)



**NSR-S635E**  
**ArFi**

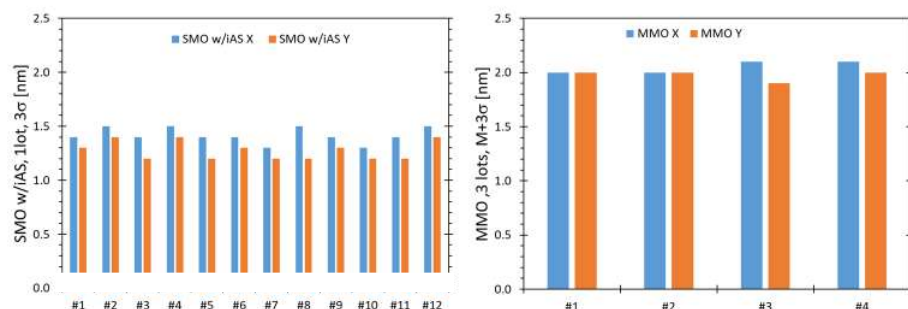
1.35 NA  
MMO <2.1 nm  
>275 wph



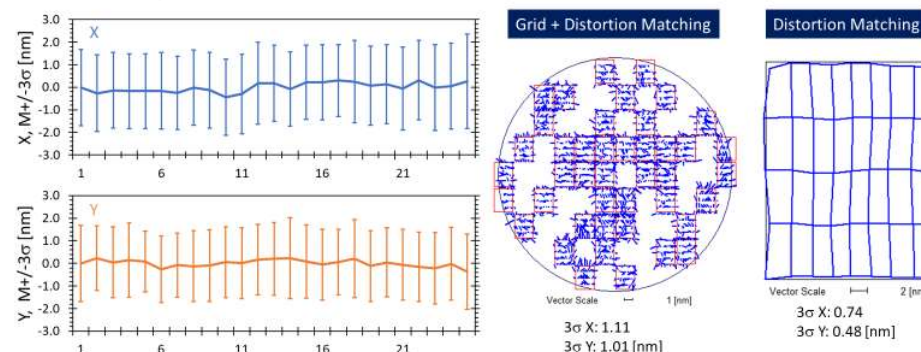
# S635E performance



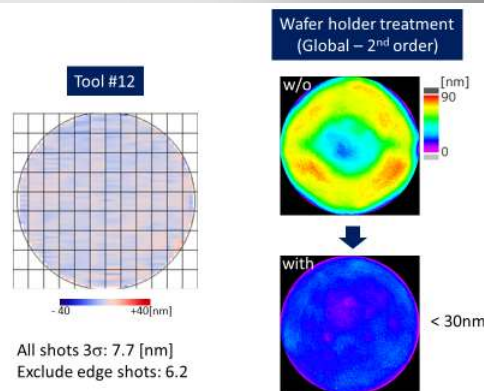
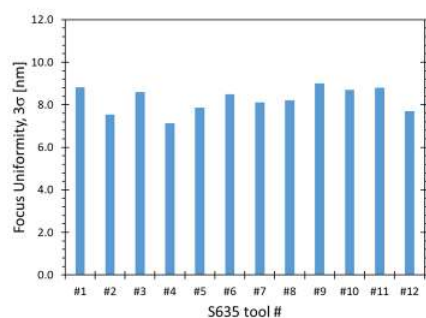
## SMO and MMO performance



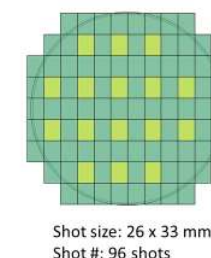
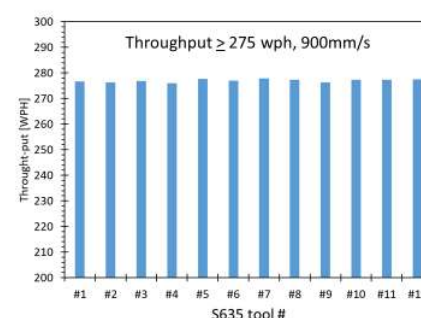
## MMO performance



## Focus uniformity control



## Throughput performances



S635E performed good performance for OVL / Focus / WPD

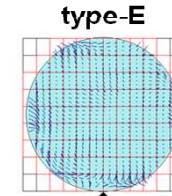
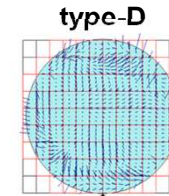
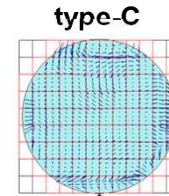
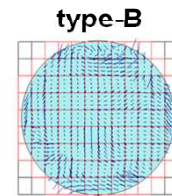
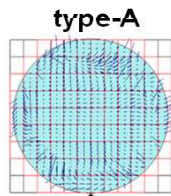
# OPO with proper dense alignment



**1<sup>st</sup>  
Exposure  
Given grid**

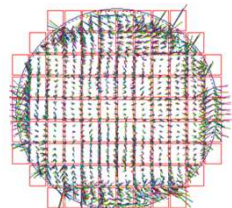
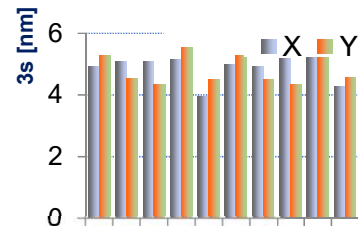
- 7<sup>th</sup> order error
- 5 error types
- 2 wafers each

Vector scale 20 nm



**2<sup>nd</sup>  
Exposure  
Overlay  
Result**

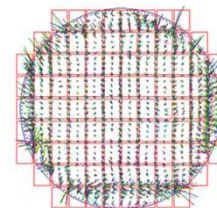
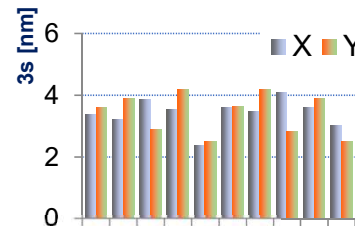
- ✓ 16 point EGA w/o iAS
- ✓ Linear correction



X: 4.59  
Y: 4.50

3s [nm]

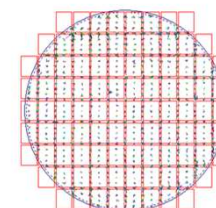
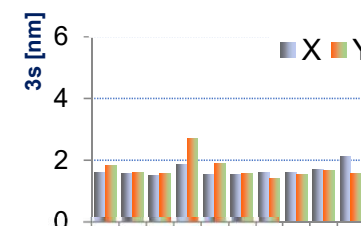
- ✓ 40 point EGA w/ iAS
- ✓ 5<sup>th</sup> order correction



X: 3.20  
Y: 3.36

3s [nm]

- ✓ 84 point EGA w/ iAS
- ✓ 7<sup>th</sup> order correction



X: 1.81  
Y: 1.83

3s [nm]

S635E improves OPO with dense sampling without THP drops

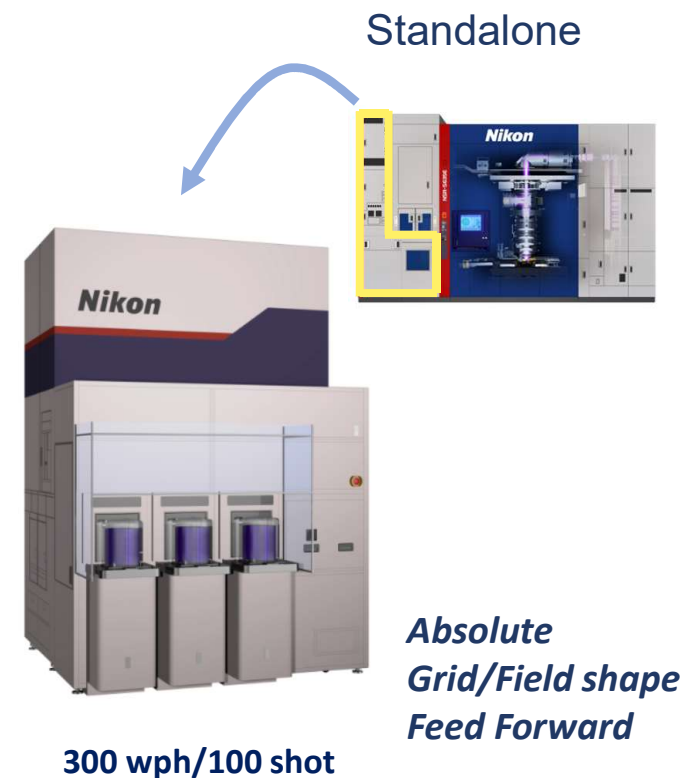
# Solution for overlay upgrade



At new fab is OK with the latest ArFi  
How about existing fab for enhancement ?  
Replacing to the latest scanner is too expensive

## ***Litho Booster (LB)***

- Standalone alignment station as same as scanner
- Feed forward by absolute measurement
  - ◆ Improvement for distorted wafer overlay
  - ◆ Scanner finger print correction
  - ◆ Solution for the unknown in overlay measurement
- Improvement for existing scanner system



# Fab enhancement with overlay improvement



- 65 nm logic → 55 nm logic
  - ✓ M1 pitch: 180 nm → 160 nm
  - ✓ Scanner : ArF dry → ArFi
    - but ArF dry has sufficient resolution
    - ArF dry + LB for dense meas.
- Back-illuminated CIS / 3-Layer stacked CIS
  - ✓ In-plane distortion by wafer bonding (Image sensor, logic, memory)
    - but same design rule (Needs of current tools usage)
    - Current Scanner + LB for dense measure
- NAND tiers
  - ✓ In-plane distortion by increasing stacking layers
    - but same design rule (Needs of current tools usage)
    - Current Scanner + LB for dense measure

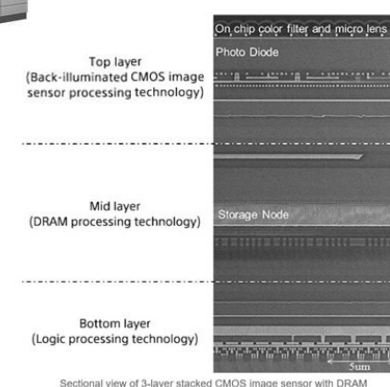


**NSR-S322F**

**0.92 NA**

**MMO < 5.0 nm**

**> 230 wph**



Source: 1/2.3in 20Mpixel 3-Layer Stacked CMOS Image Sensor with DRAM, ISSCC (2017)

Source:  
<https://www.techinsights.com/>



# Integrated Solution of Metrology and Exposure

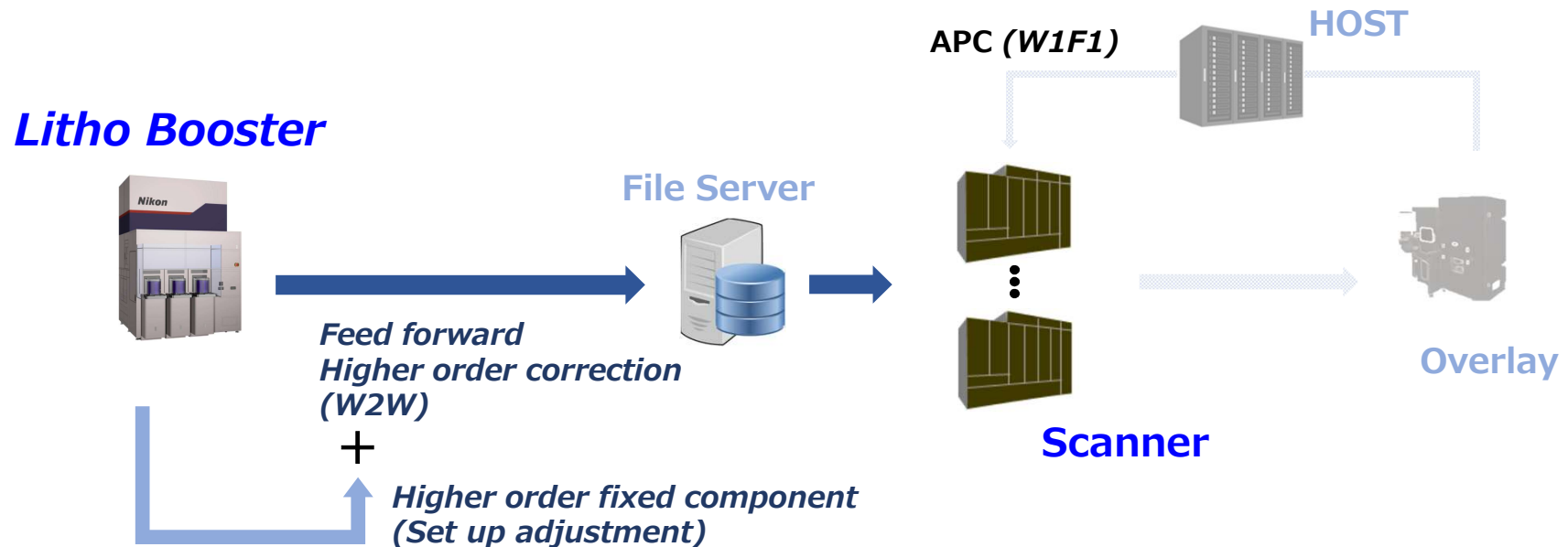


Can be coupled with any scanner



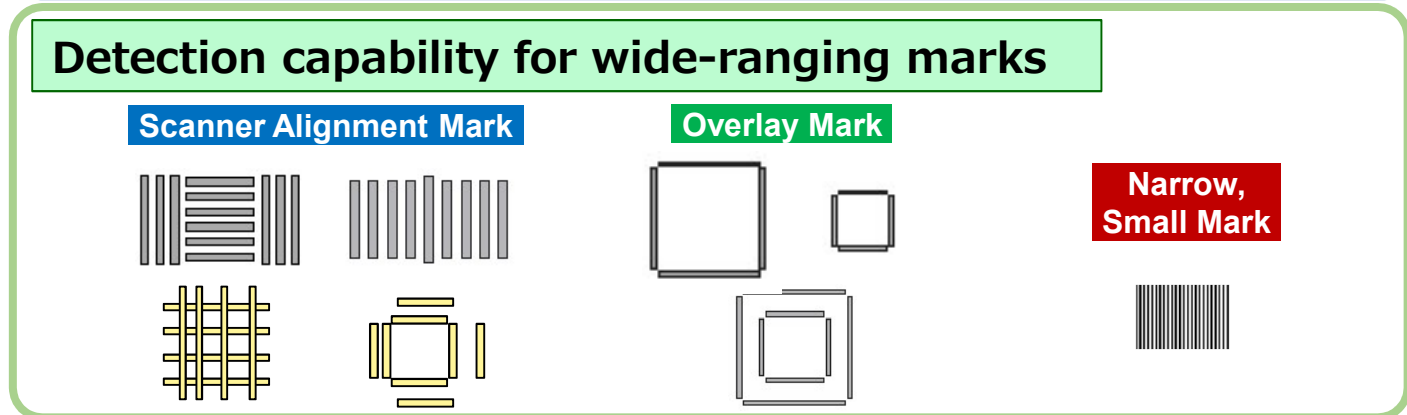
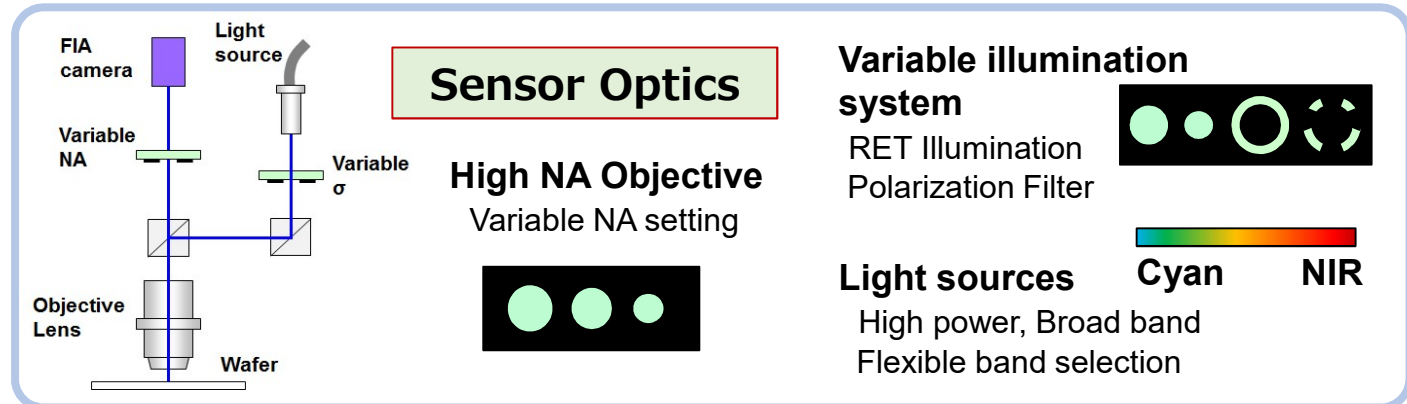
LB measurement result can be fed forward to any scanner

# Use case of standalone alignment station



- APC                      liner correction
- Litho Booser          higher order correction
- *Feed forward correction doesn't impact to APC*

# High accuracy imaging sensor: iFIA



High performance optics enable to measure several marks

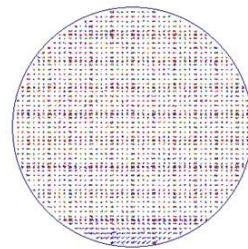
# Alignment Accuracy: Repeatability & Reproducibility



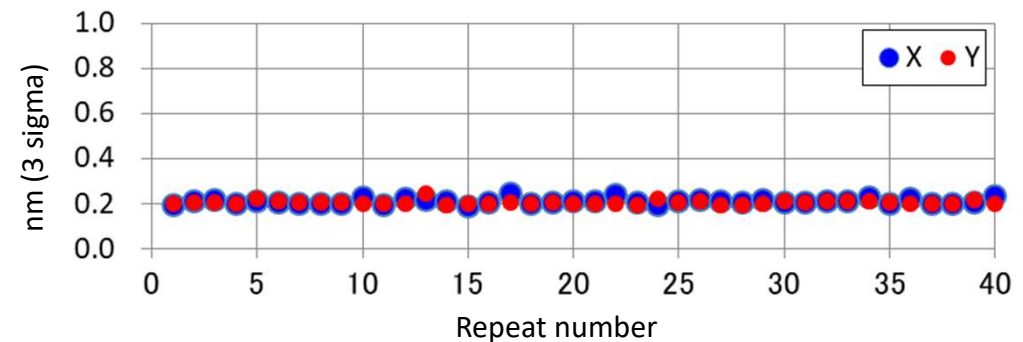
## Measurement repeatability (3 sigma), 40 times

**Alignment repeatability**  
2740 marks / wafer  
(35 marks / field)

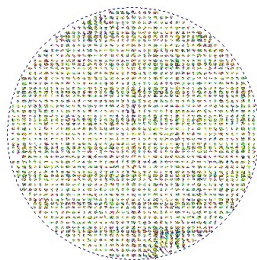
without  
chuck / de-chuck



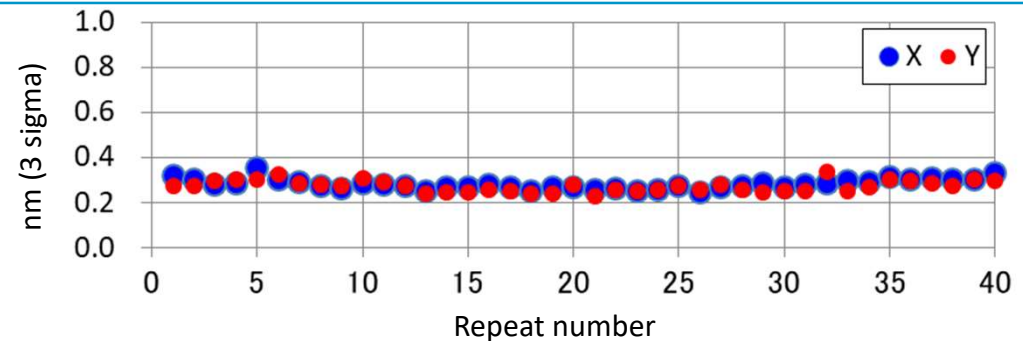
0.21 nm, 0.21 nm



**Chucking  
reproducibility**  
2740 marks / wafer  
(35 marks / field)



0.28 nm, 0.27 nm



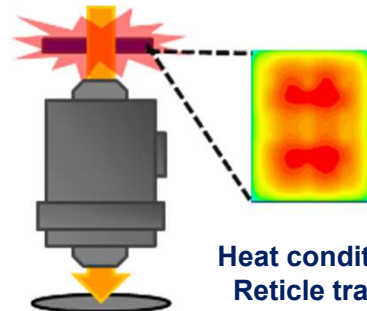
Excellent measurement accuracy with dense sampling

# Scanner finger print correction

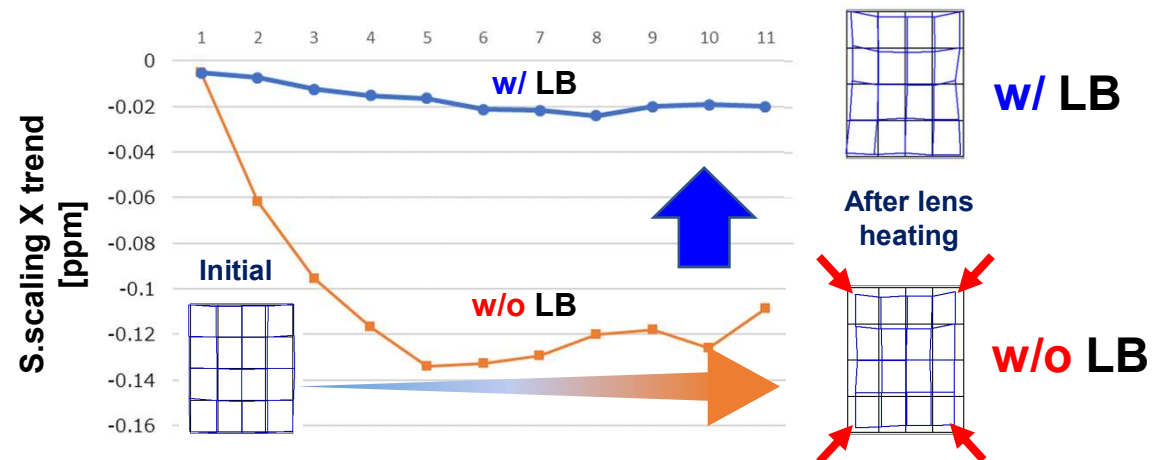


- Various scanners have own finger print  
(grid, distortion, optics heating, reticle heating, wafer heating, pericle deformation)

## Reticle heating error



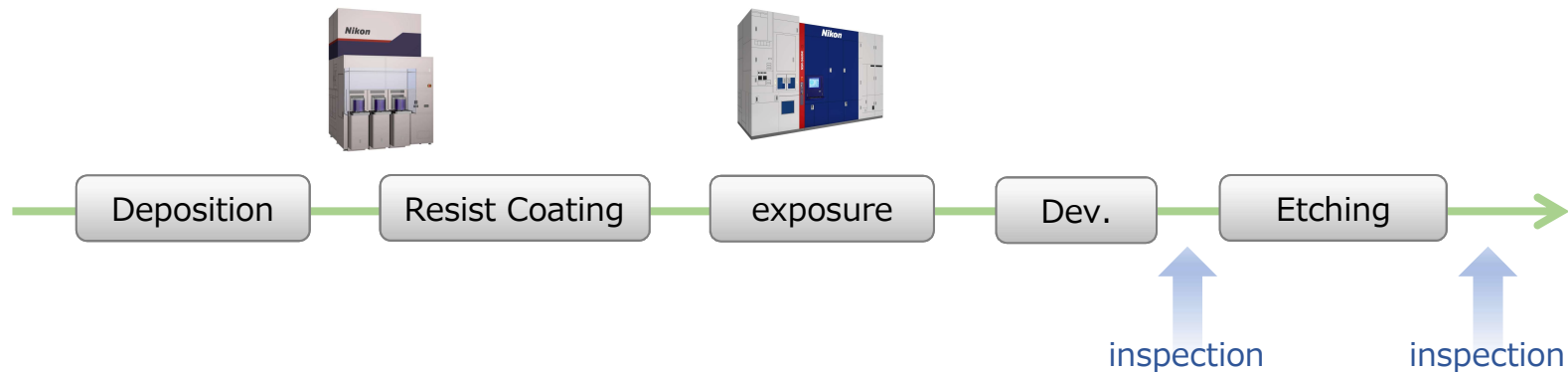
Heat conditions  
Reticle transmittance : 5 %  
Dose : 30 mJ/cm2



# Yield management

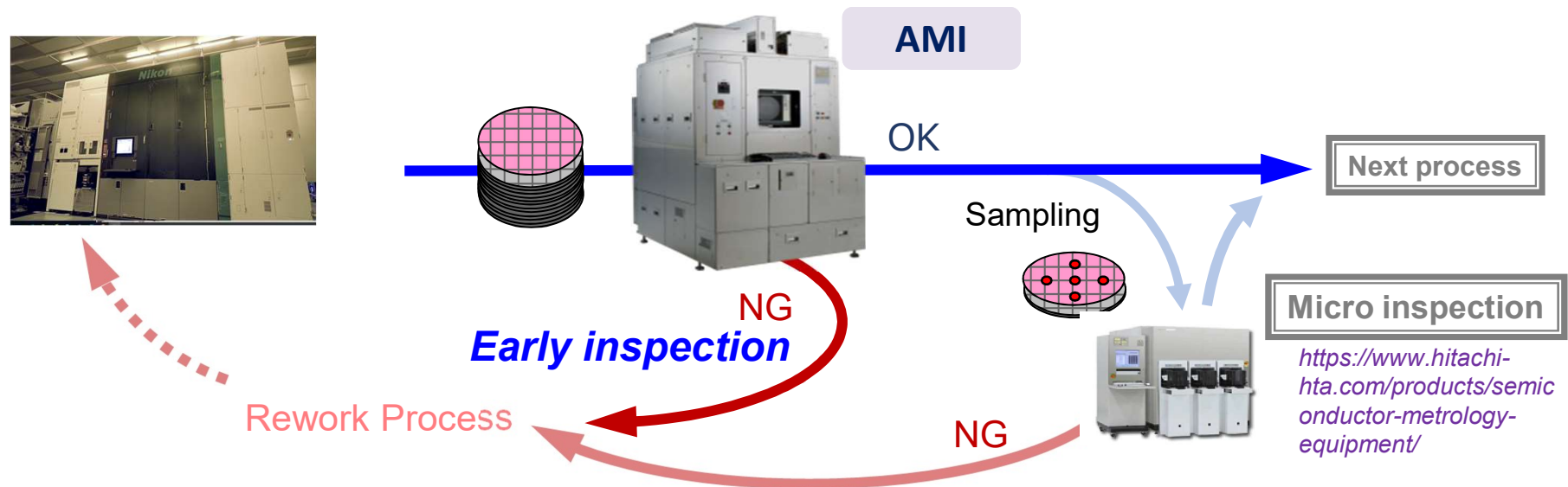


- iAS and Litho Booster enhance OPO by feedforward correction with dense sampling, and as the result contributes to the improvement of yield.
- From the viewpoint of yield, it is very important to maintain and improve production process by finding abnormalities in each production process.



- The important thing is that each inspection should not impact productivity.

# Auto Macro Inspection



- Higher sensitivity imaging system
- Whole wafer detection system
- 170 wph
- Focus and dose inspection for Litho.
- Litho. coating inspection
- Particle & scratch inspection for wafer handling

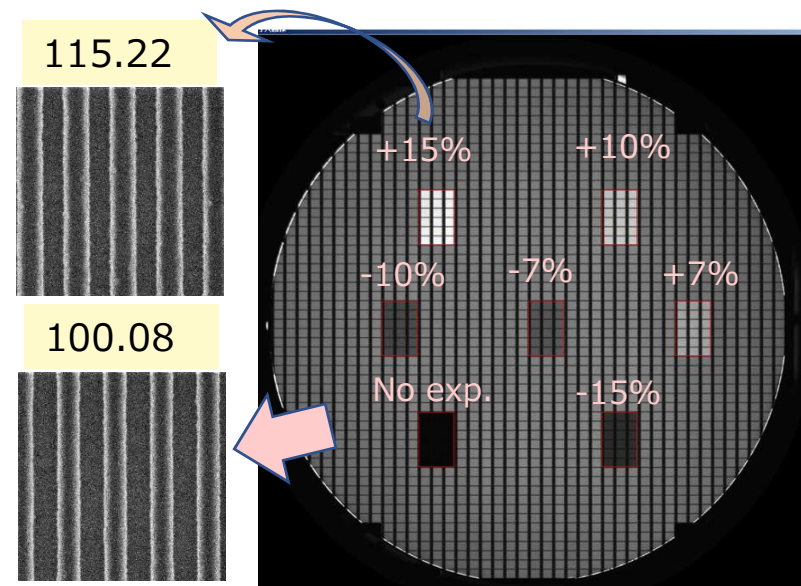
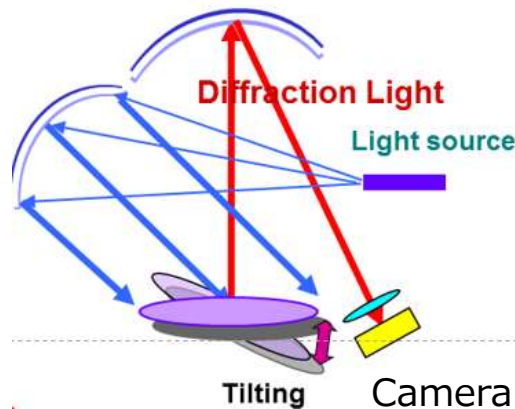
Early inspection will be important for the yield management

# Higher sensitivity : Pattern dimension



## Bright field for wafer pattern

Diffraction detection system



Abnormal pattern dimension (100 nm L/S)  
→  $\pm 15\%$  dimension change can be detected

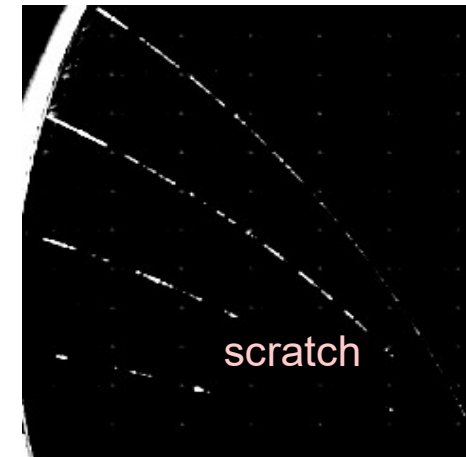
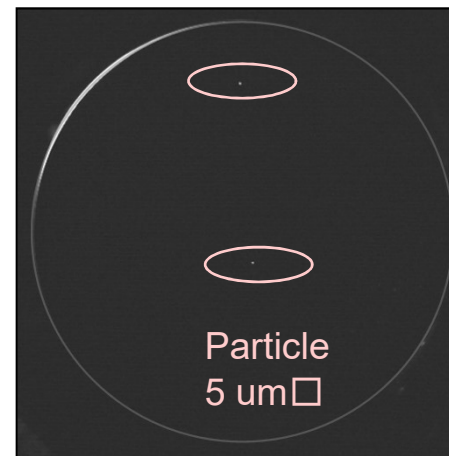
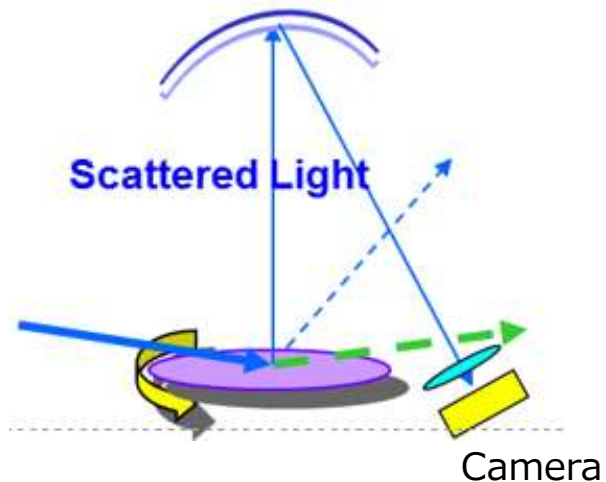
AMI can detect abnormal pattern dimension with higher throughput

# Higher sensitivity : Particle detect



## *Dark field for particle/scratch*

Scattering detection system



AMI enable yield management without productivity loss due to higher throughput by whole wafer surface observation

# Summary

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- Today, most important subject for IC manufacturing is On-product overlay improvement, corresponding to the scaling of devices, and wafer distortion of 3D structures.
- iAS and Litho Booster enhance On-product overlay by various correction with dense sampling and feed-forward alignment
- AMI enables more efficient process yield management with higher productivity





NIKON CORPORATION