SCREEN SOKUDO APPLIED MATERIALS

“Shooting for the 22nm Lithography Goal” with the

SOKUDO DUO

Coat / Develop Track

Three (3) different exposure options for 22nm:

- **MAPPER Lithography on E-Beam Maskless (ML2)**
- **ASML on EUV Lithography & M.P. Immersion ArF**
- **NIKON on Multiple Patterning Immersion ArF & EUVL**

One (1) in-line coat/develop track fits all scenarios:

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However, coat/develop track configuration varies significantly by photolithography technology …

- **Throughput (wph) Projections**

wph = wafers per hour
* Assumes E-Beam (ML2) Cluster Tool such as MAPPER Litho.

	2011	2012	2013	2014	2015
E-Beam	1 – 5	5 – 10	60 – 100*	100+*	120+*
EUV	30 – 60	60 – 100	80 – 125	125+	150+
Immersion	180 – 230	200 – 240	220 – 260	260+	280+

22NM VOLUME RAMP

NECESSARY FOR IMMERSION DOUBLE / MULTI-PATTERNING TO BE COST-EFFECTIVE

- **Resist Process Steps on Track**

	UL / Barc Coat	Resist Coat	Top Coat	Backside Clean	Bevel Clean	Post E. Rinse	Deve-lope
E-Beam	■	■	-	■	-	-	■
EUV	■	■	-	■	-	-	■
Immersion	■	■	▲	▲	■	■	■

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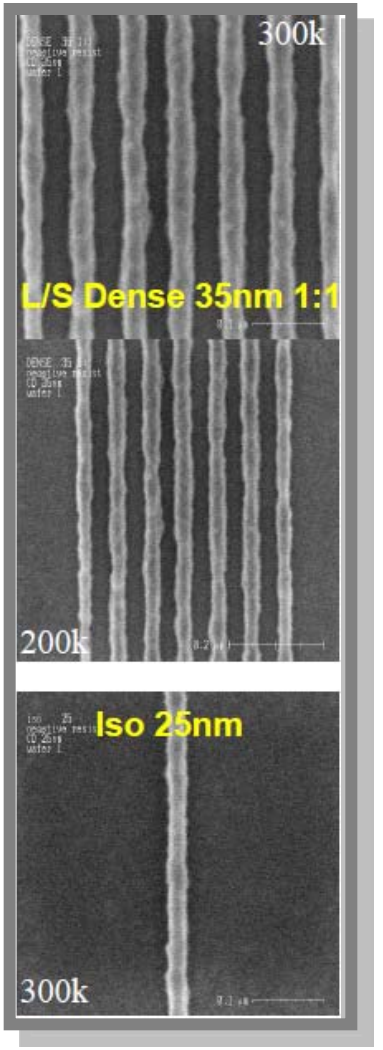
SOKUDO Coat/Develop Track 22nm Process Development

- imec Double Patterning LPLE
  - Materials & Process Benchmarking 32nm → 26nm
- Selete EUV Lithography Resist Qual.
  - New resist process evaluations @ SELETE
- cea leti E-Beam DW Qualification
  - MAPPER Lithography E-Beam Process R&D



SOKUDO RF3 track process E-Beam litho. exposures on Vistec SB3054DW at LETI

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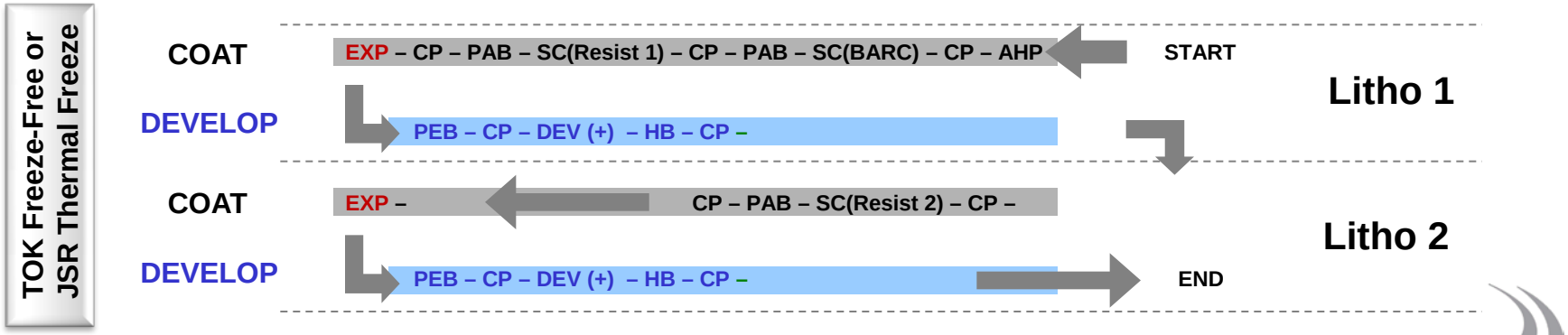
Immersion Lithography with SOKUDO

- **Immersion Resist Process Defectivity:** Microbridging & Resist Filtration
- **CoO Study for Double Patterning Lithography**
- **CDU optimization for immersion lithography & Double Patterning:**
  - JSR's litho-freeze-litho process (freeze coat, thermal freeze)
  - TOK's posi-posi process "Freeze-Free"

ASML XT:1900Gi + SOKUDO RF3S

“Photo” Double Patterning Resist Process on Track

	Freeze Coat chemical b/w 1st & 2nd Resist	Self-Freeze by 2nd Resist Coat & Bake	Thermal freeze bake
JSR	☻	--	☻
TOK	--	☻	--
Dow Elec. Mtrl.	○	○	
Shin-Etsu	--	○	
Sumitomo	--	○	



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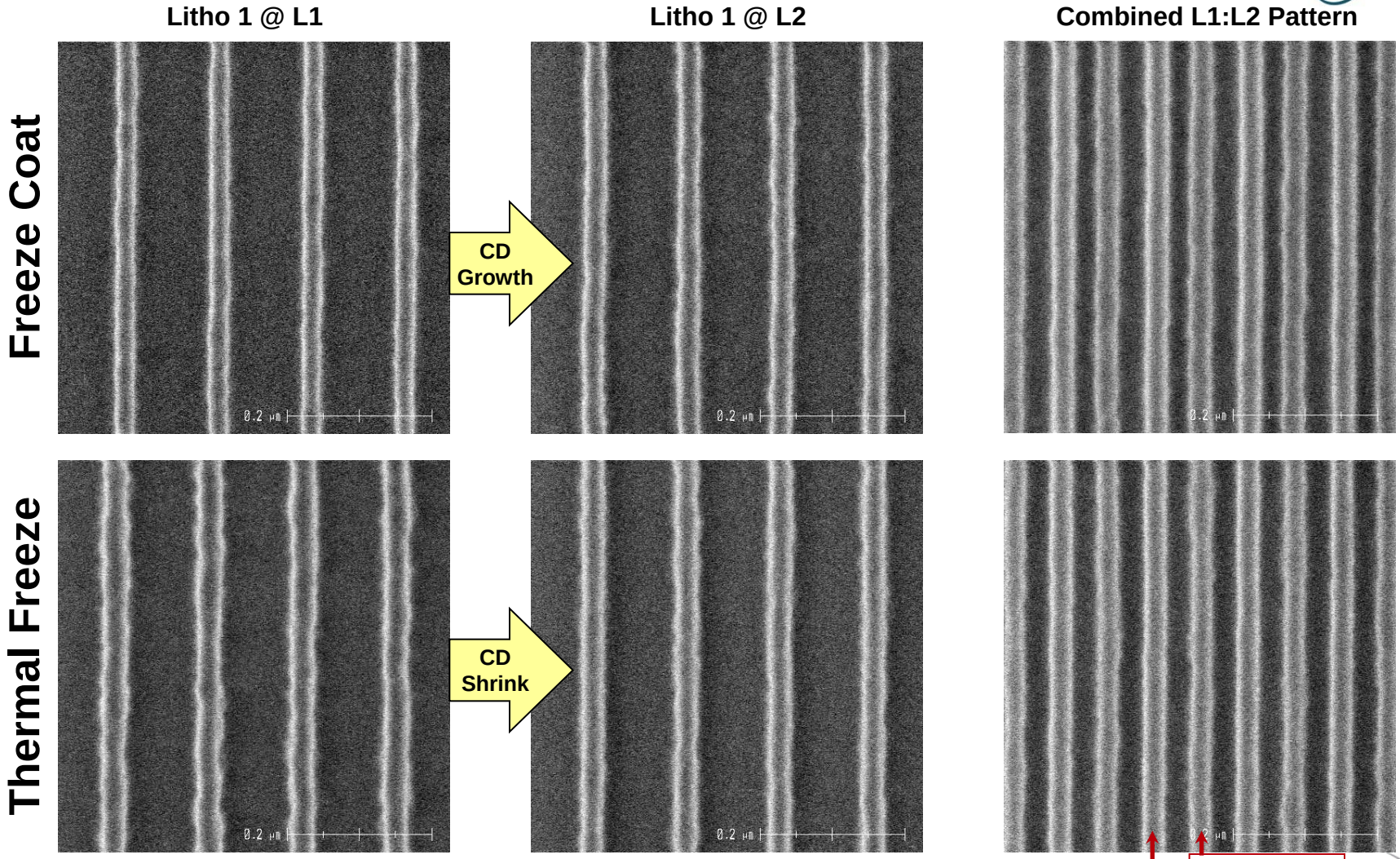
JSR Freeze Coat & Thermal Freeze Comparison
32nm Feature Target CD-SEM Images

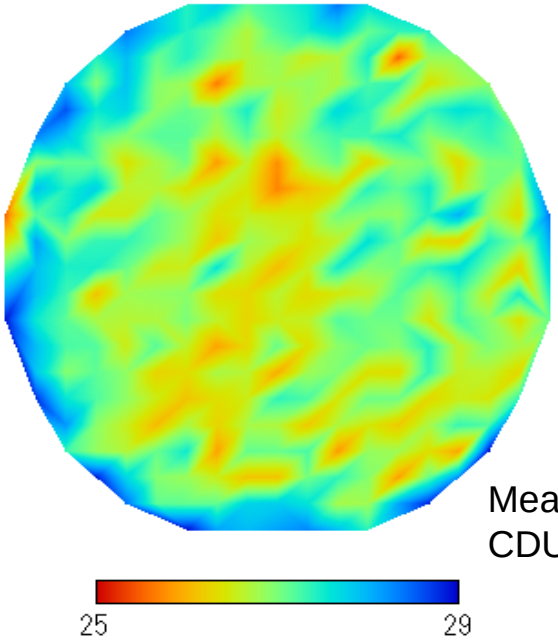


JSR Thermal-Freeze 26nm L/S Target CDU

SPIE 7639-81 Simplified “Litho-Cluster-Only” solution for double patterning ; JSR, ASML, SOKUDO

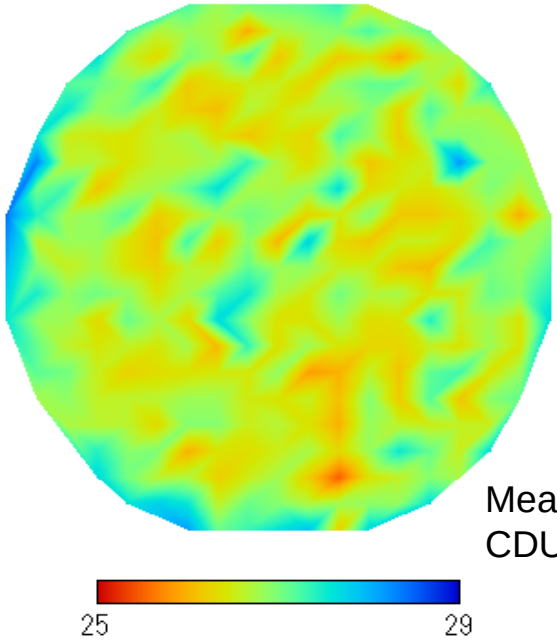
The CD uniformity data with the thermal freeze process comparable to traditional litho-etch-litho-etch and spacer double patterning CDU.

Layer 1



Mean : 27.00nm
CDU 3σ : 1.85nm

Layer 2



Mean : 26.75nm
CDU 3σ : 1.35nm

Substrate:ARC®29-SR (105nm)
Layer 1 : Non-TC thermal freeze resist (FT=60nm,130C/125C, SCA/RCA/ACA=90° /76° /94°)
Layer 2 : Non-TC normal resist (FT=50nm,100C/95C, SCA/RCA/ACA=92° /80° /95°),
Exposure : 39nmL96nmP with att-PSM, NA=1.35, Dipole40X, 0.747/0.626, Y-Polarization
Development : ECO Nozzle(OPD262/DIW)

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SOKUDO DUO integration for ASML NXE:3100 (EUV)

- **SOKUDO EUVL Coat/Develop Track Configurations ~120wph**
  - **Coat: Underlayer, Resist**
  - **Develop: TMAH / TBAH developers; various rinse approaches**
  - **Bake: Biased Hot Plate (QBH) for CDU control / tuning; "Q" Quick set-temperature change bake between lots**

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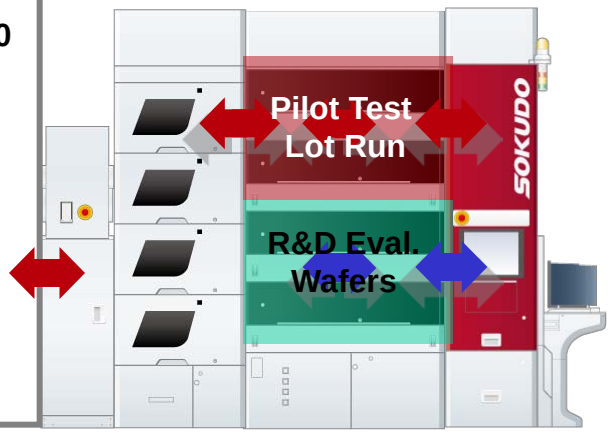
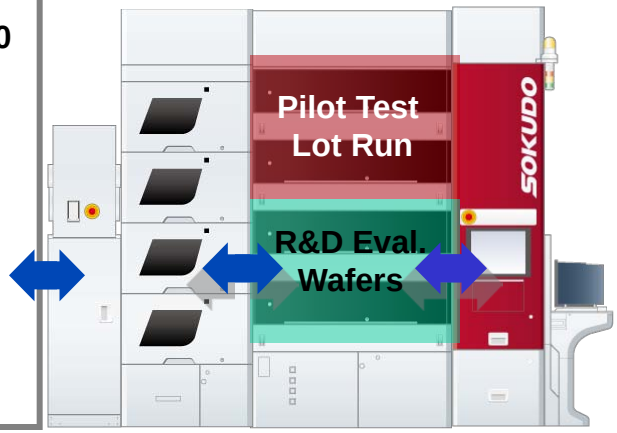
Maximize EUV Lithocell Utilization: Exposure Test Lot Run + R&D Eval. Wafers simultaneously

ASML NXE:3100



ASML NXE:3100



Always keep critical EUV scanner running when available!
KEY for R&D + Pilot Line Productivity!

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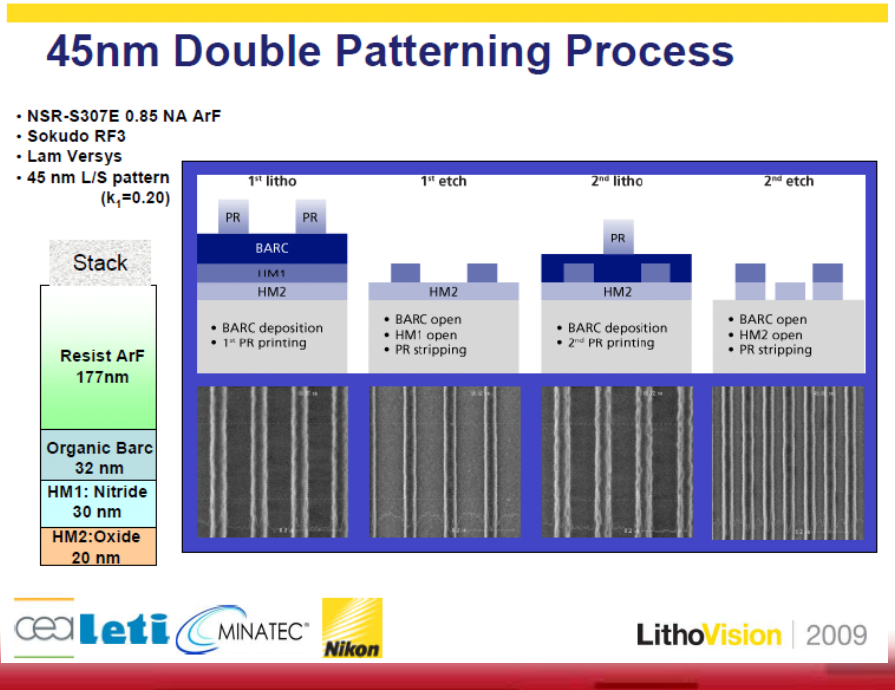
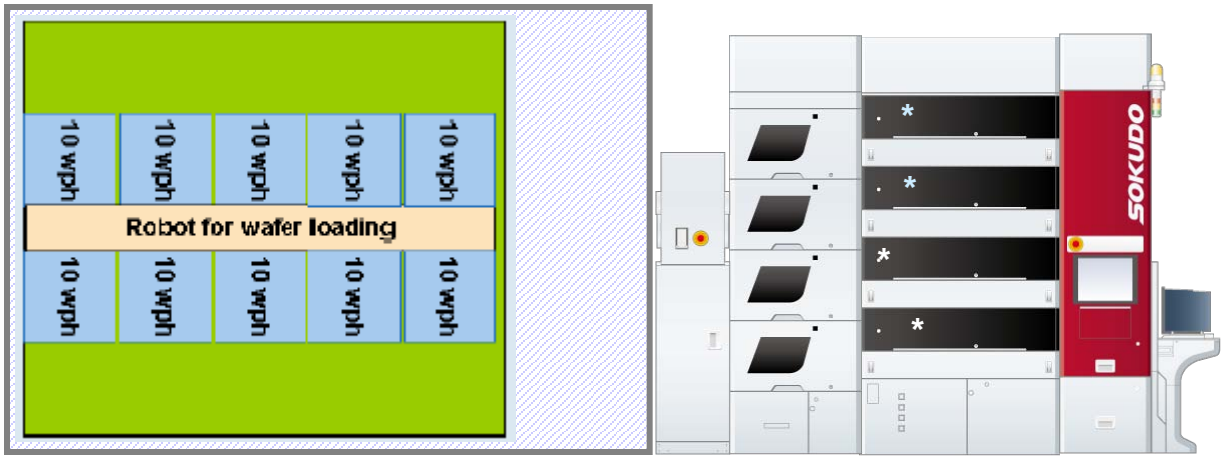
E-Beam Experience by SOKUDO

- **Advantest F-100 (Japan)**
  - **SOKUDO RF3 Coat, Developer in-line with E-Beam**
- **Vistec SB3054DW @ cea leti Grenoble (France)**
  - **SOKUDO RF3 off-line for E-Beam**
    - in-line with Nikon NSR-S307



The End Goal…

SOKUDO DUO E-Beam Coat/Develop Track in-line with MAPPER



MAPPER E-Beam Cluster

Target 100 WPH

SOKUDO DUO Track

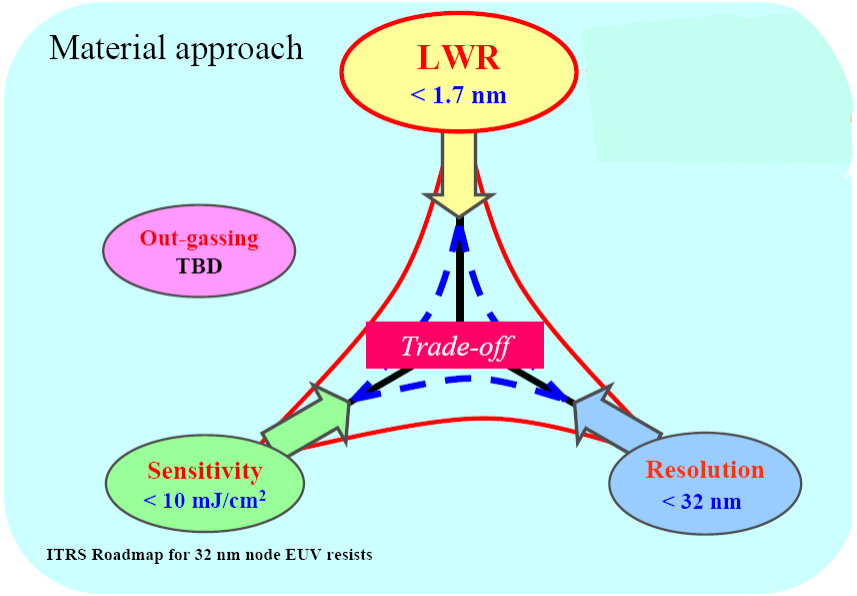
~100-120 WPH

*

2C = Underlayer
2C = RESIST
4D = DEVELOP
with Backside Scrub
+ E-Beam interface

EUV, E-Beam Common Resist Process Development Focus Points

- **Resist Manufacturers Continuously Reformulating for**
  - Line Width Roughness (LWR)
  - Sensitivity to Dose
  - Resolution 32 nm→ 22 nm
- **32 nm → 22 nm CD LWR, Pattern Collapse & Defectivity Track Process Studies:**
  - Develop methods, solutions
  - Rinse methods, solutions



Reference: SPIE 7636-27, February 2010, San Jose, CA USA

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SOKUDO EUVL Technical Papers History

SPIE Advanced Lithography 2009

7273-111 **Development of EUV resists at Selete**
SELETE (SOKUDO assignee, Koji Kaneyama)

7273-115 **EUV resist processing in vacuum**
SELETE, SOKUDO

International Symposium on EUVL 2009

Resist II **EUV resist materials and processing at Selete**
SELETE (SOKUDO assignee, Koji Kaneyama)

Poster 94 **Study of post-develop defect on typical EUV resist**
SOKUDO

SPIE Advanced Lithography 2010

7636-111 **Study of post-develop defect on typical EUV resist**
SOKUDO

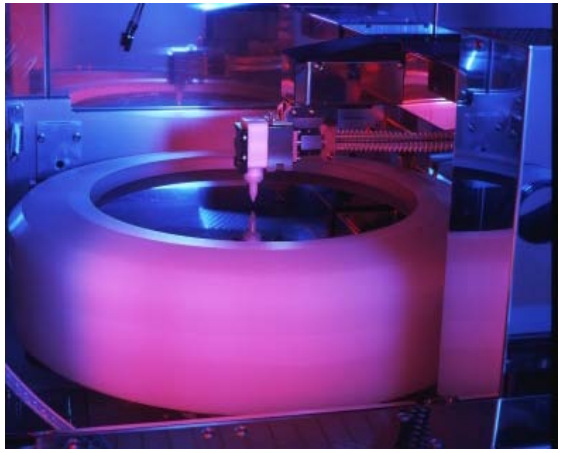
7636-115 **Alternative resist processes for LWR reduction in EUVL**
SELETE (SOKUDO assignee, Koji Kaneyama)

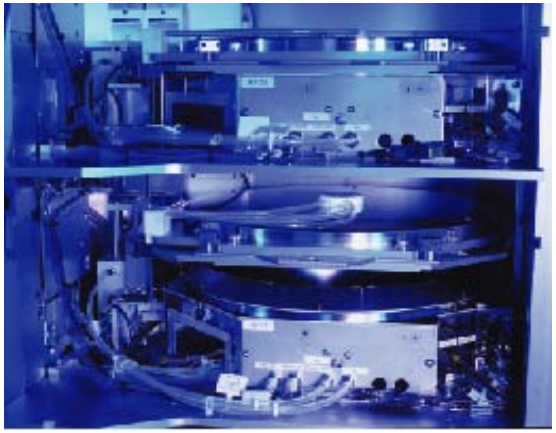
7639-26 **Development of EUV-resists based on various new materials**
SELETE (SOKUDO assignee, Koji Kaneyama)

7636-27 **Development of resist material process for hp 2x nm devices using EUV lithography**
SELETE (SOKUDO assignee, Koji Kaneyama)

Coat, Bake & Develop Track Process Knobs

for EUV / E-Beam resist development





SPIN COAT

- Dispense Chemistries:
  - Underlayer +
  - Photo Resist
- Thin-film coating recipe

  40-60nm thickness

BAKE & CHILL

- Post-Expose (PEB) for

  CD Uniformity control
- High Temp. (PAB, BARC)

DEVELOP

- Defect Control Approach
  - Wafer Rinse & Dry
  - Surfactant Rinse
- Developer Chemistries:

  TMAH, TBAH(?)

  Negative Develop(?)

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PEB in vacuum vs. atmosphere

Selete

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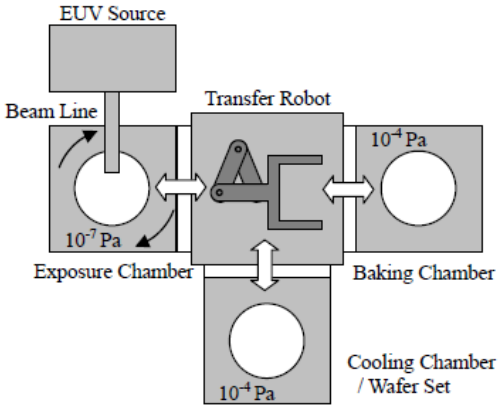
Custom built Vacuum PEB "Baking Chamber" & "Cooling Chamber"



(b) detailed description

Table 3. The lithographic performance of MET-2D with PEB in vacuum and atmosphere

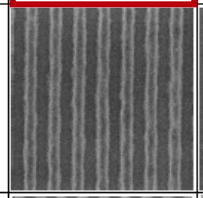
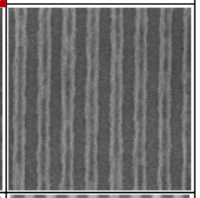
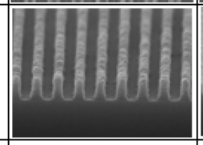
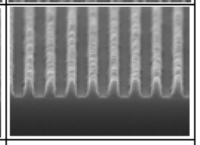
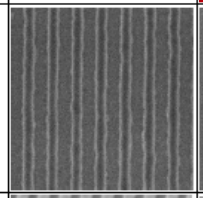
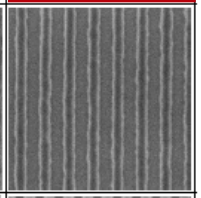
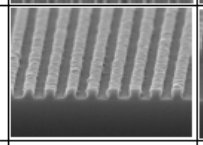
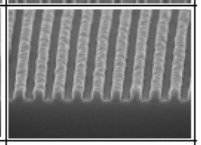
Item	in Vacuum		in Atmosphere
EUV Resist Type: MET-2D			
Top-view SEM Image @45nmLS (1:1)			
Cross-section SEM Image			
Esize@45nmLS [mJ/cm^2]	14.1	=	13.7
Resolution limit [nm]	40	=	40
LWR [nm]	6.1	<	7.8

Table 4. The lithographic performance of SSR3 with PEB in vacuum and atmosphere.

Item	in Vacuum		in Atmosphere
EUV Resist Type: SSR3			
Top-view SEM Image @45nmLS (1:1)			
Cross-section SEM Image			
Esize@45nmLS [mJ/cm^2]	16.0	>	11.2
Resolution limit [nm]	30	>	25
LWR [nm]	6.2	>	4.9

Summary: Results depend on resist, PEB in Vacuum may be low value-added

Reference: EUV resist processing in vacuum, Koji Kaneyama, Shinji Kobayashi, Toshiro Itani; Proc. SPIE 7273-115 (2009)

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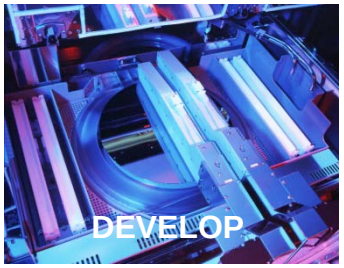
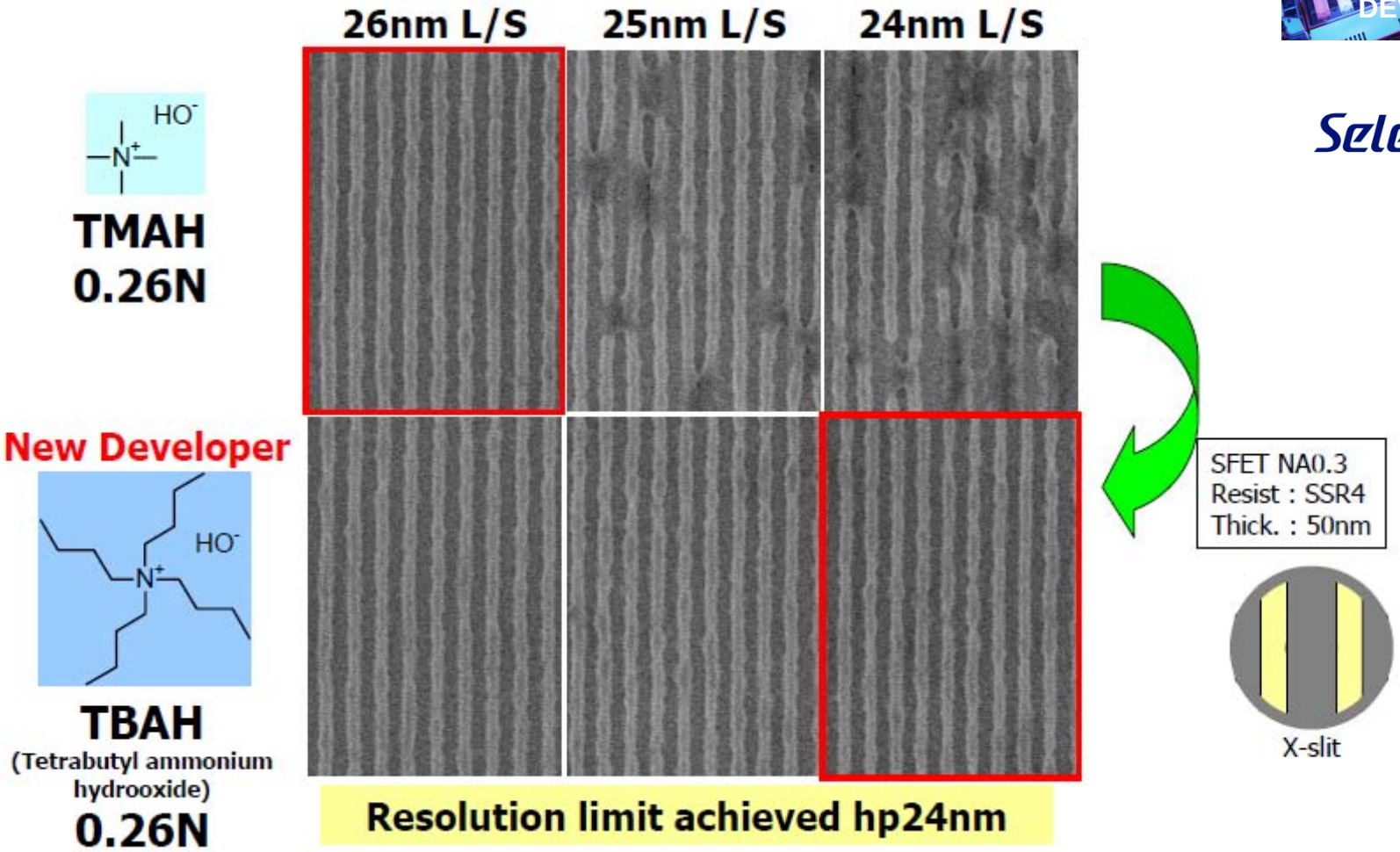
TBAH Developer extends CD capability, reduces pattern collapse



Selete



Reference: EUV resist materials and processing at Selete, K. Matsunaga, et.al., International Symposium on EUV Lithography, October 2009, Prague

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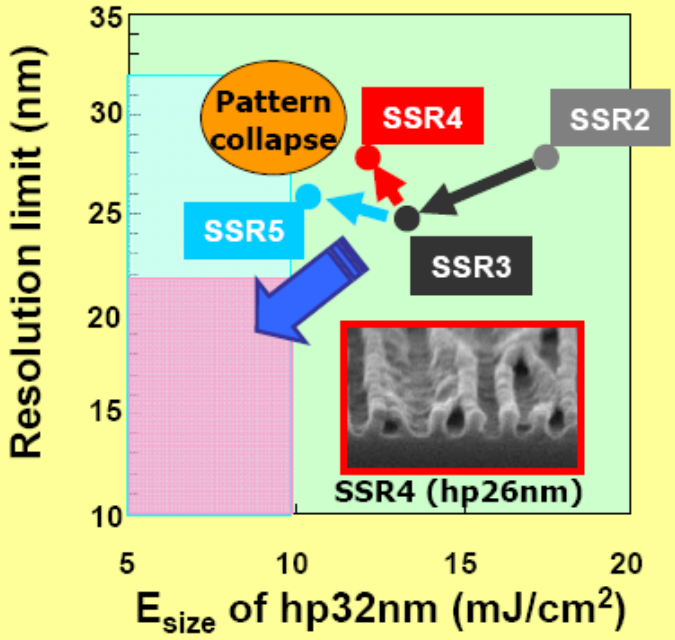
Pattern Collapse limiting EUV resist resolution

Sensitivity – Resolution



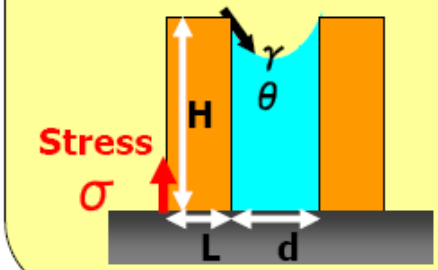
32nm
22nm

Targets: Sensitivity (E_{size}) : 10mJ/cm^2
Short-range LWR : hp x 10%

Condition: SFET NA0.3, Illum. Annular (0.7/0.3), Thick: 60nm

Model of pattern collapse and improvement by process

Tensile stress



Stress $\sigma = \frac{6\gamma\cos\theta}{d}\left(\frac{H}{L}\right)^2$

H.Namatsu, Appl. Phys. Lett. 66 (20), 1995

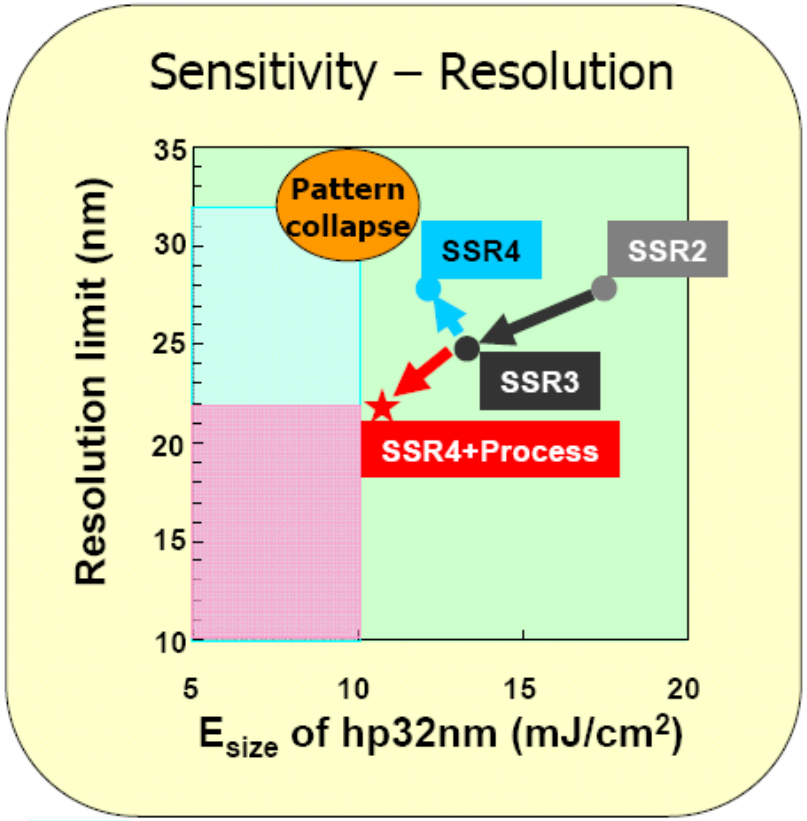
- Thinner resist thickness
- Rinse solution
- Additional under layer

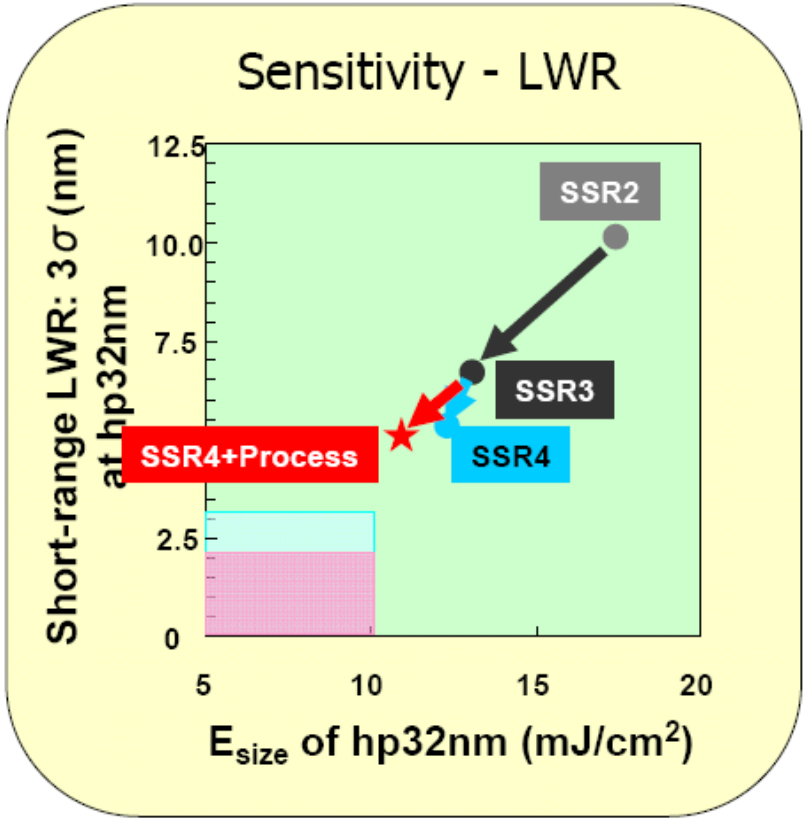
Swelling

- Developer concentration
- Developer with surfactant
- Bulky developer solution

Reference: SPIE 7636-27, February 2010, San Jose, CA USA

EUV resists improving with each new generation: Resolution, LWR, Sensitivity





32nm
22nm

Targets: Sensitivity (E_{size}) : 10mJ/cm²
Short-range LWR : hp x 10%

SSR# = Selete Standard Resist #

Reference: SPIE 7636-27, February 2010, San Jose, CA USA

Selete

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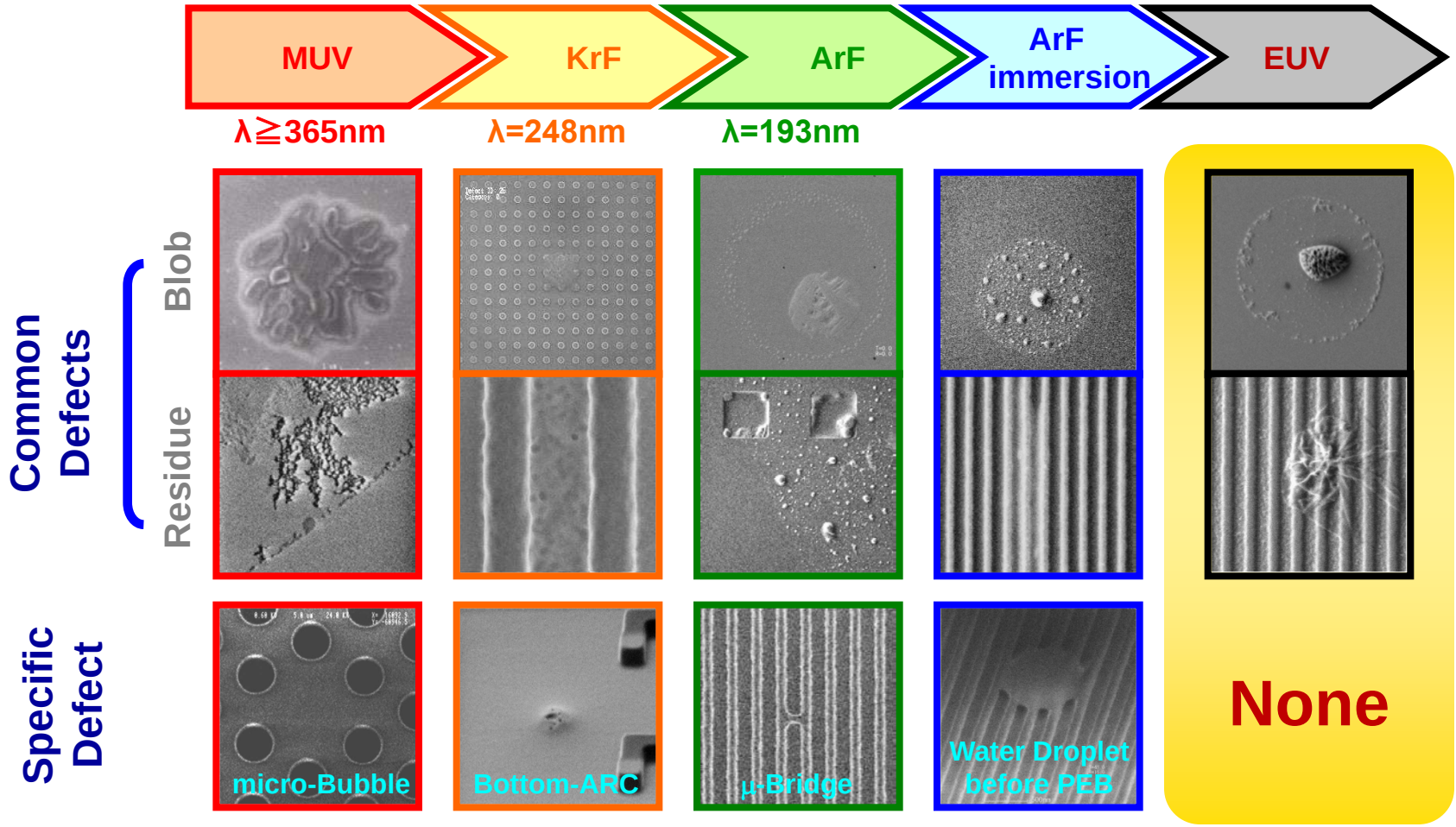
Common / specific defect history; EUV study started



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EUV & E-Beam …

- **Although EUV may be leading the march towards 22 nm, E-Beam can close gap with (MAPPER) throughput plans for improvement towards 2012+**

- **SOKUDO participating in EUV and E-Beam collaborations**
  - **EUVL consortia resist evaluations and characterization** Selete
  - **E-Beam IMAGINE project resist process qualification** cea leti

- **EUV and E-Beam resists following similar trends and challenges:**
  - **In parallel transitioning from 32nm → 22 nm process development**
  - **Both resist systems largely based on reformulating i/KrF generation blends**
  - **Resist trending to thinner coatings: 40-60 nm target thickness**
  - **Resolution – LWR – Sensitivity (RLS) all common issues**

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"Shooting for the 22nm Lithography Goal" with the

SOKUDO DUO

Coat / Develop Track