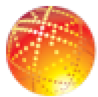
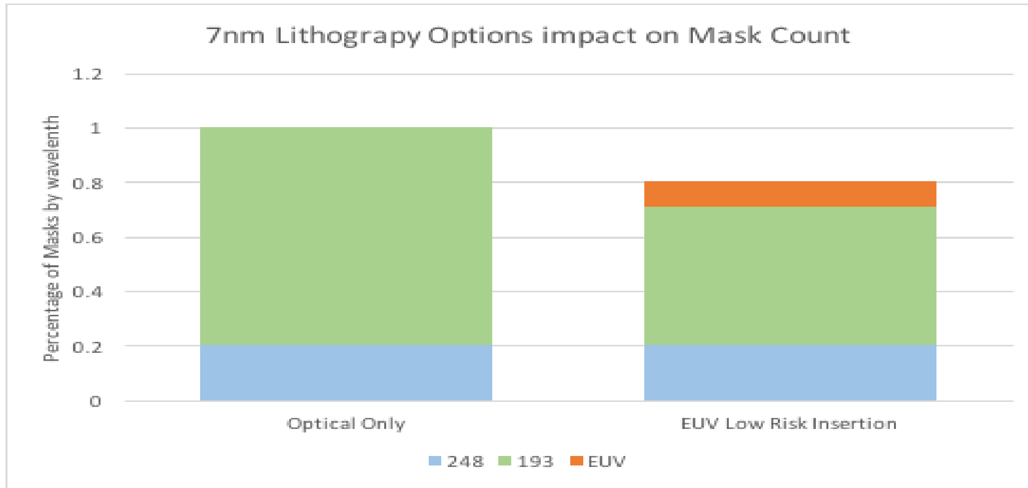
What's Different for EUV masks ?

GLOBALFOUNDRIES – Tom Faure, Jed Rankin


GLOBALFOUNDRIES

EUV Benefits GLOBALFOUNDRIES 7nm

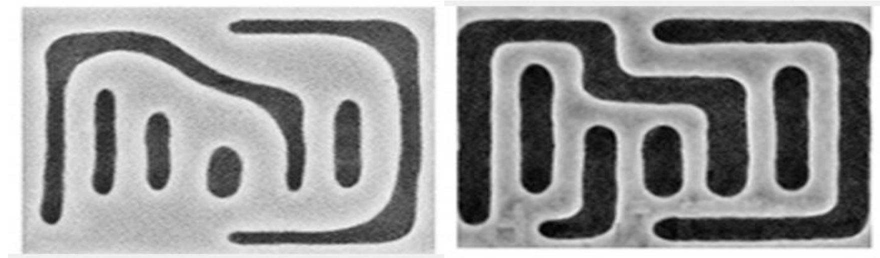


Multiple Fab Benefits:

- ❑ Lithographic Performance
  - →Device performance
- ❑ Wafer Cycle Time
  - →Faster Development
  - →Faster Prototyping
  - →Faster Production

7nm Cycle Time Impact:

- ❑ ~60 day reduction in development
- ❑ ~31 day reduction in production
- ❑ *Larger benefit at 5nm node with ~20 % more 193 levels required for optical-only solution*



193 Multipatterning EUV Single-exposure

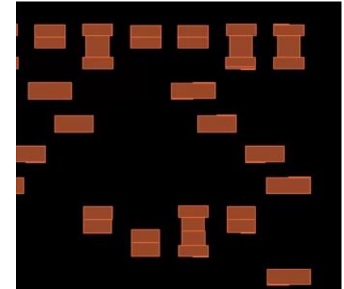
Samsung, VLSI 2017

7nm EUV vs. Optical Mask comparison

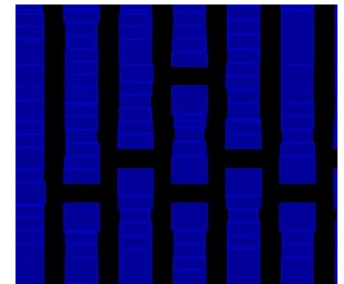
Physical Design Differences:

		7nm Optical	7nm EUV	5nm EUV
Contacts / Vias	Number of Masks per layer	2-4	1	1
	Tone	CP	CN	CN
	Primary Feature size on Mask (4x)	250nm	70nm	55nm
	SRAFs (4X)	50-60nm opaque	None *	30nm clear
Cuts / Metals Fin/Gate (5nm)	Number of Masks	3	1	1-2*
	Tone	CP/CN	CN	CN + CP
	Minimum Feature size on Mask (4x)	200nm	50 nm	45nm
	SRAFs	54nm opaque 60nm clear	None	24nm clear 30nm opaque

EUV Contact



EUV Metals



EUV allows design relaxation to Circa 32/28 nm

- ❑ Bidirectional Metals Allowed
- ❑ Relaxed local density (minimum SRAF)
- ❑ Simplified OPC (still requires MBOPC)

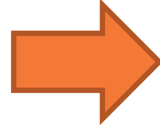
→*ILT not needed for 7nm EUV, but may be used*

Unique EUV mask requirements → MBMW

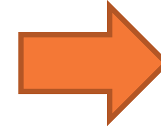
Benefit for 7nm, required for 5nm

Performance

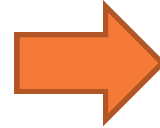
- Resolution (40nm → 24nm)
- Line Edge Roughness (4nm → 2nm)
- Local CDU (2.5nm → 1.5nm)
- Image Placement (2.5nm → 1.5nm)



Low Sensitivity Resists



Multibeam Writer



Long Write Times

Design

- Shot Count (ILT)
- Data Density (SRAF)

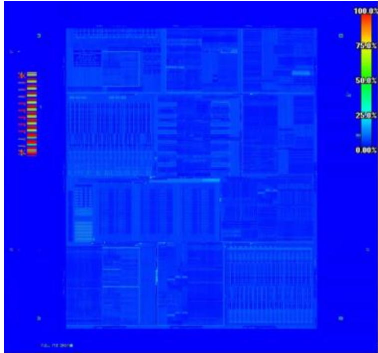
7nm Requirements
5nm Requirements

MBMW tools originally developed with expectations of high shot-count and data density

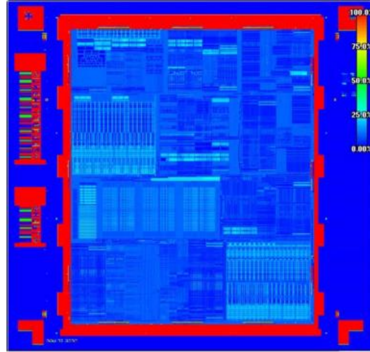
EUV allows relaxation of shot/vertex density ➔ Initial EUV layers will have no SRAF, less fill, no PRAF

CA Mask Comparison

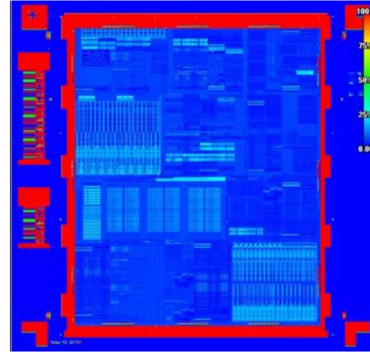
EUV CA: PCAR
4.9% Open Area



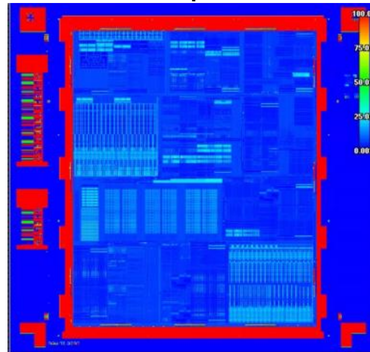
Opt CA-1 : NCAR
90% Open Area



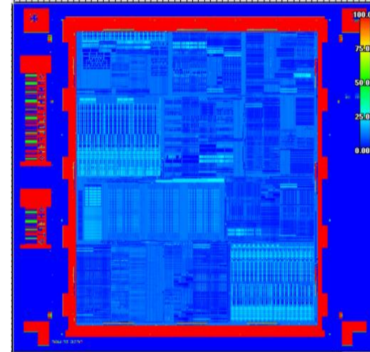
Opt CA-2 : NCAR
92% Open Area



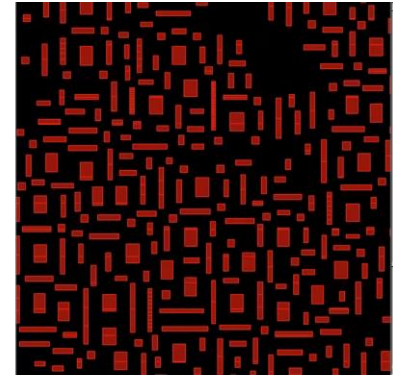
Opt CA-3 : NCAR
91% Open Area



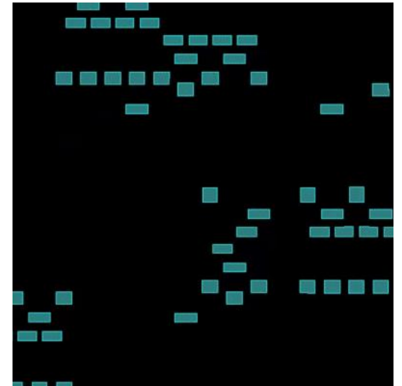
Opt CA-4: NCAR
85% Open Area



Optical Mask Design

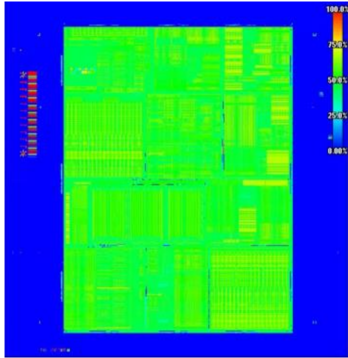


EUV Mask Design

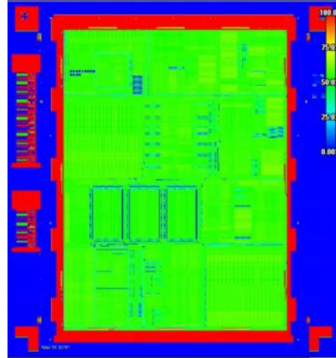


M1 Mask Comparison

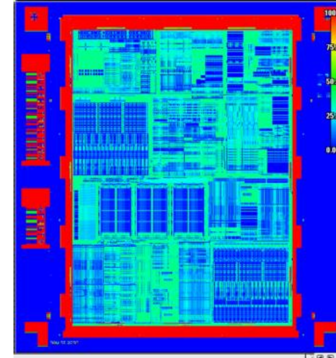
EUV M1: **PCAR (PTD)**
49% Open Area



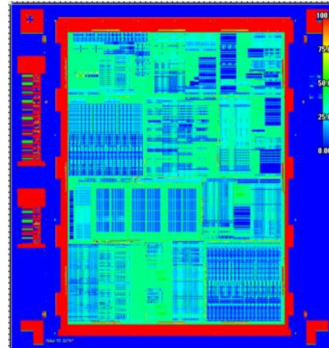
Opt M1-1:
NCAR (NTD)
45% Open Area



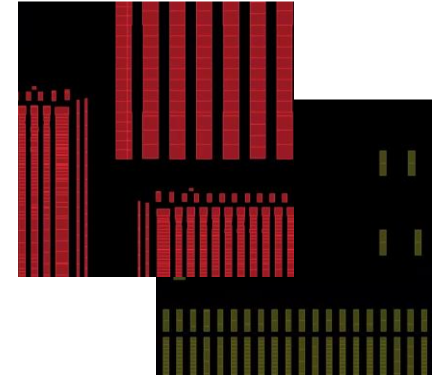
Opt M1-2:
NCAR
74% Open Area



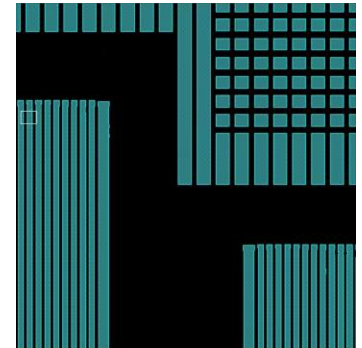
Opt M1-3: **NCAR**
69 % Open Area



Optical Mask Design



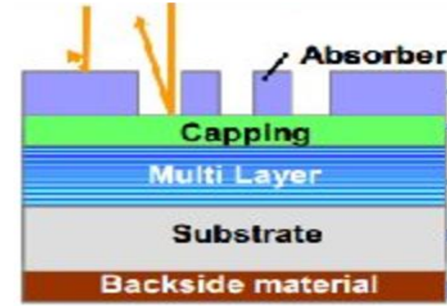
EUV Mask Design



EUV Specific Mask Challenges

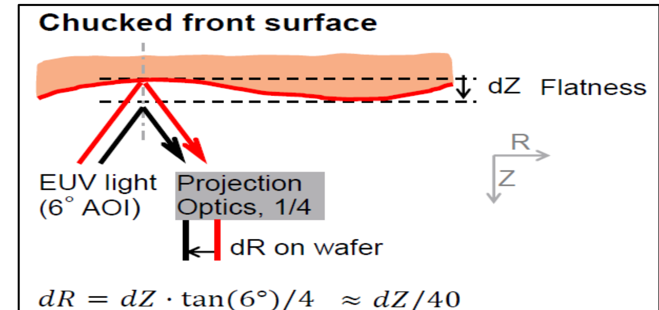
Materials & Structure:

- Importance of Blank defects (mirror)
- Introduction of Ta and Ru for RIE & repair
- Black-Border & Out-Of-Band suppression
- Backside and Cleanliness
- Flatness & Thickness requirements
- Lack of Pellicle at HVM introduction
- New (Thinner) absorbers (post 7nm)
  - →repair, integration and durability challenges



Equipment

- MBMW for CD, I/P, LER LCDU performance
- Use of Non-actinic inspection (DUV or SEM)
- Limited AIMS availability (lead time)
- Anamorphic Scaling (timing= beyond 5 nm)
  - →minimal impact expected (handled during fracture)
- Equipment extendability (Inspection, AIMS, writers, repair)

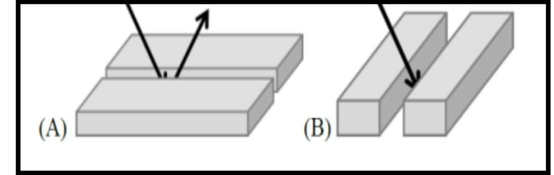


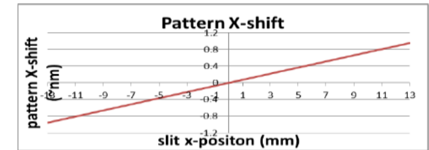
EUV Specific Mask Data Challenges

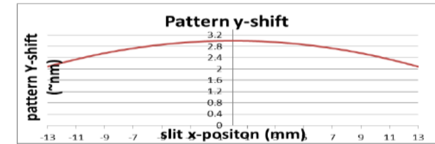
Current:

- ❑ Loss of Hierarchy / Jobdecking (Flare, Radial Azimuthal reflection)
- ❑ MPC (Dose modulation) for Resolution
- ❑ Blank Defectivity Management & Pattern-Shift for defect avoidance
- ❑ Unique e-beam corrections

Radial X-Y Corrections

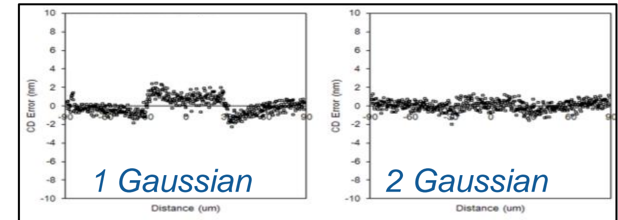




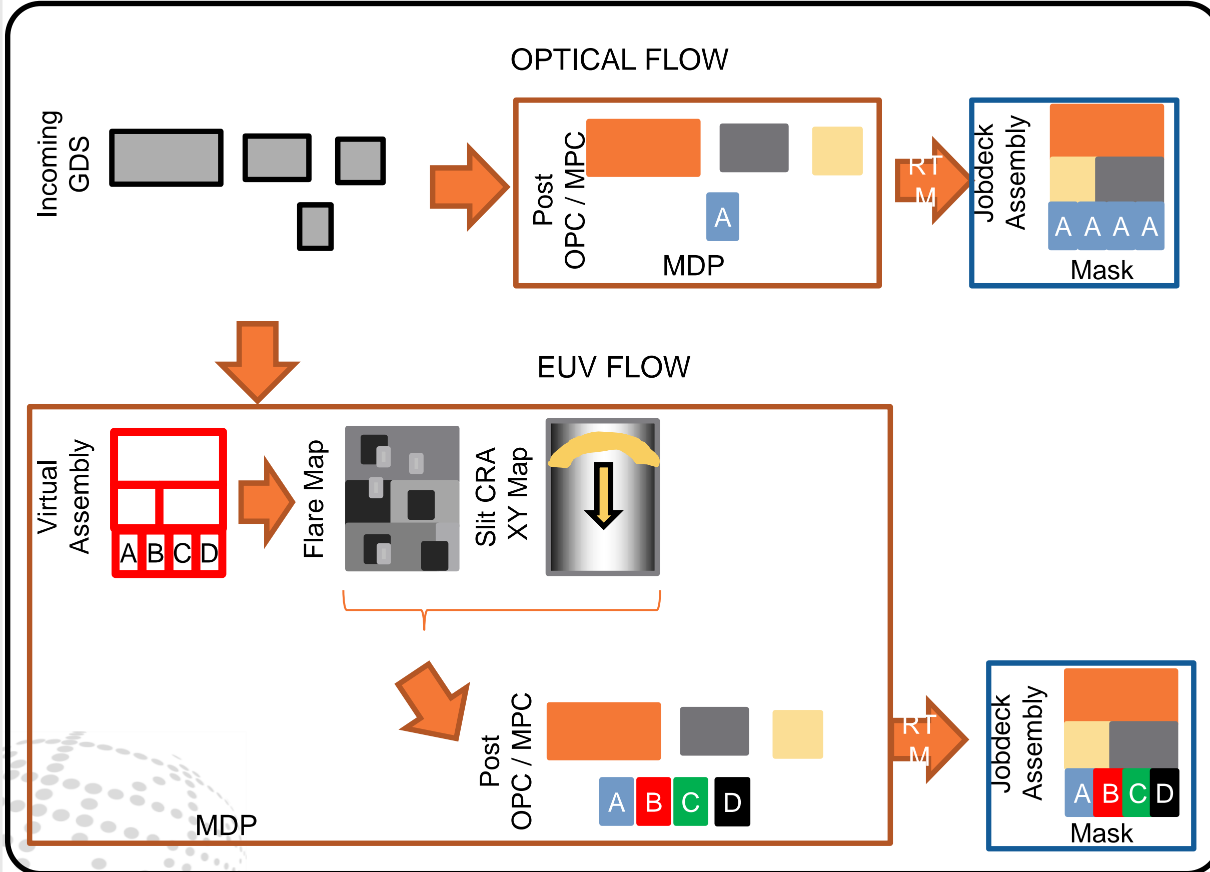


- Future:
  - ❑ Data Density
  - ❑ Fracture / prep for MBMW or advanced writers
    - → Increased off-board correction (MPC, CD & I/P e-beam corrections)
  - ❑ Migration toward ILT and curvilinear designs
    - → Because we can (data and writers) not because it's needed (yet)

E-beam Density Effect Corrections



MDP Flow comparison & Complexity



Positional dependence within EUV field:

- EUV flare
- Radial exposure slit
- Reflective Mask

Unique Data challenges:

- Additional MDP complexity
  - ❑ Creation of Flare Map
  - ❑ Positional awareness (X-Y)
  - ❑ Requires concurrent data
- Loss of hierarchy
- No repeated die (jobdeck)
- Future - Anamorphic

Summary

- EUV is real:
  - ❑ Benefits are real: *Imaging quality, Cycle Time*
  - ❑ Challenges are real: *Scanner-throughput ,Mask–defectivity, EPE, Resist-stochastics*

- Changes to Data Infrastructure and processing are required
  - ❑ OPC, MPC, Jobdecking, Pattern-shifting (defects), Image shifting, fracture, anamorphic scaling….

➔ Solutions exist. Data will not limit EUV's success.