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Expanding The Lithography Process Window With CDC Technology

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Expanding The Lithography Process Window With CDC Technology

- Target of this paper
  - Test if the CD Control process (CDC) improves the litho process window in 65nm memory process
- Layout
  - Short introduction to CDC technology
  - Design Of Experiment (DOE)
  - Results
  - Summary and Conclusions

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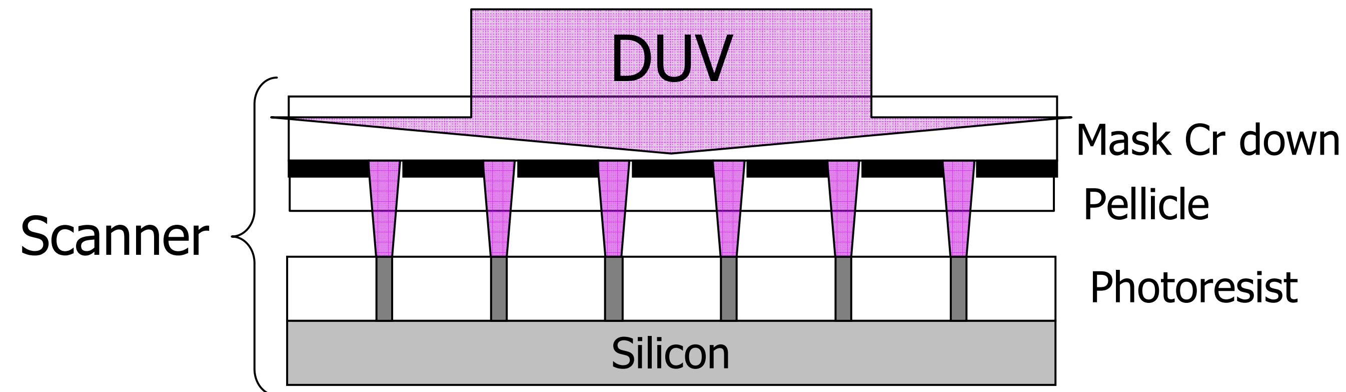
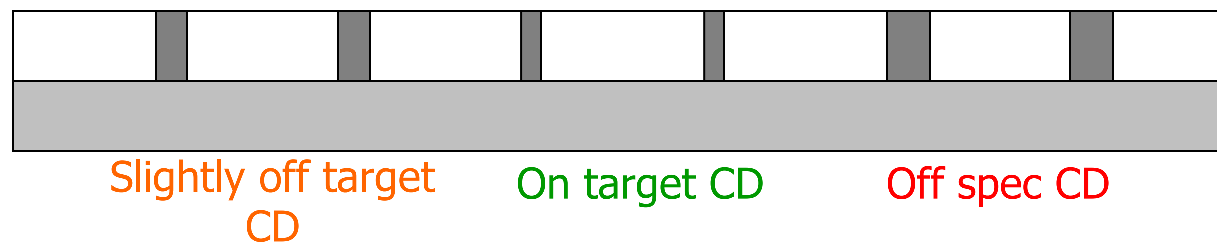
Introduction: Intrafield CDU problem

Ideally Intra Field CDU should be perfectly uniform

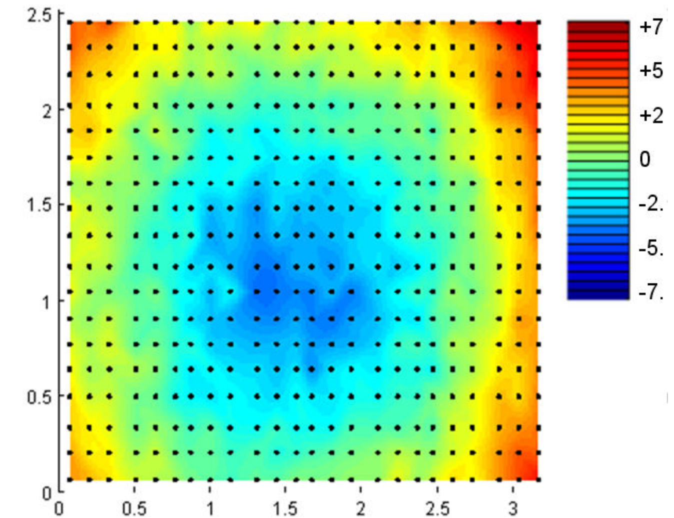


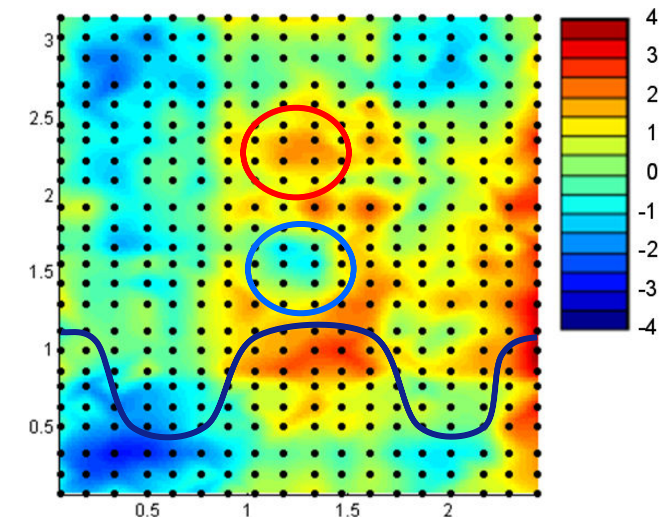
In practice CD varies over the field



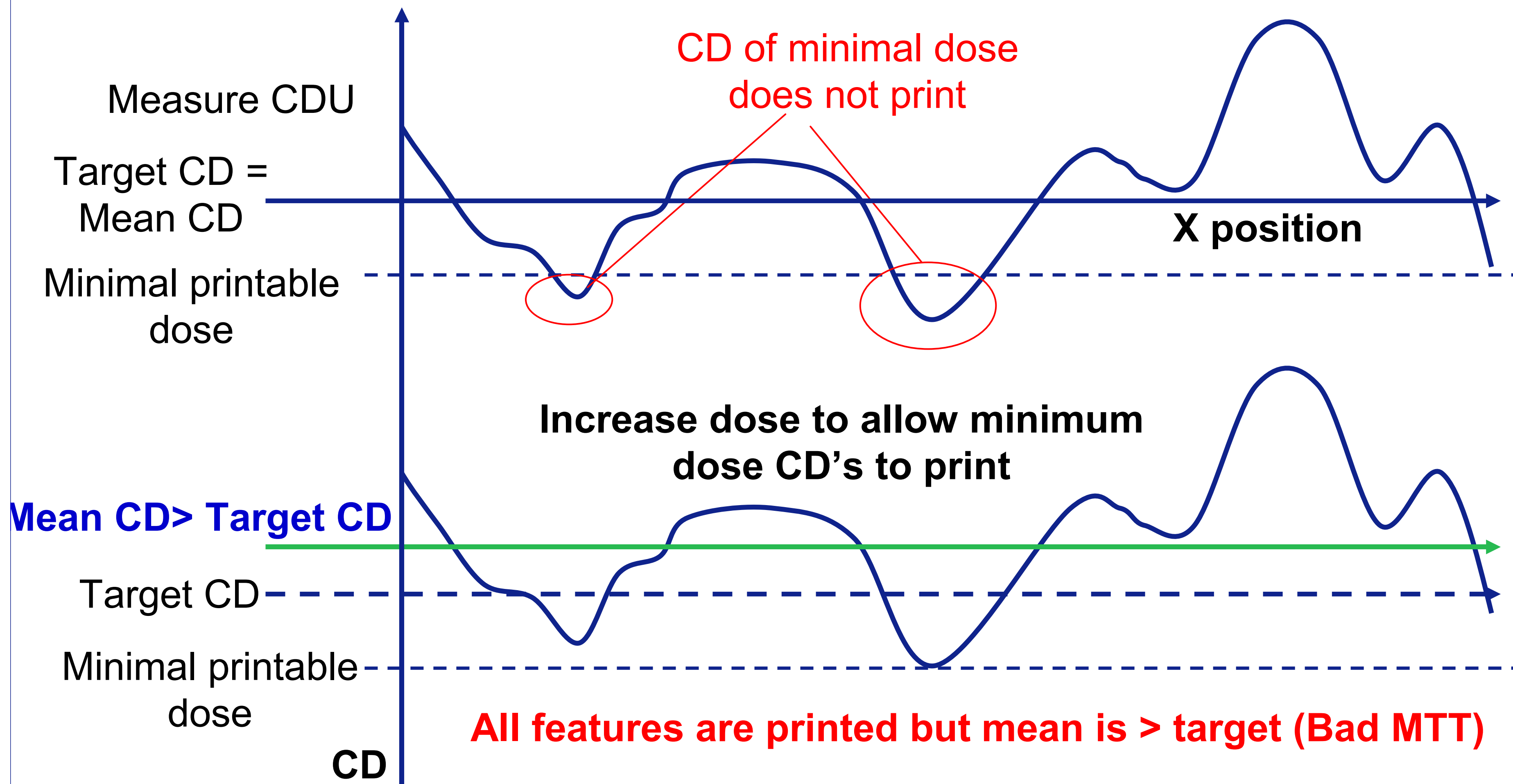
Introduction: Sources of CDU errors

- Mask manufacturing process
  - Quartz blank transmission non uniformity
  - Coating (Resist; MoSi; Cr) processes non uniformities
  - E-Beam writing drifts
  - Etching processes
  - Normally shows a radial effect with tilt
- Scanner non uniformities
  - Illumination non-uniformity
  - Projection lens aberrations
  - Across slit Tr variations
  - Scanner degradation over time
  - Normally shows along scan signature with hot and cold spots
- Mask deterioration through extended use
  - Haze
  - EFM



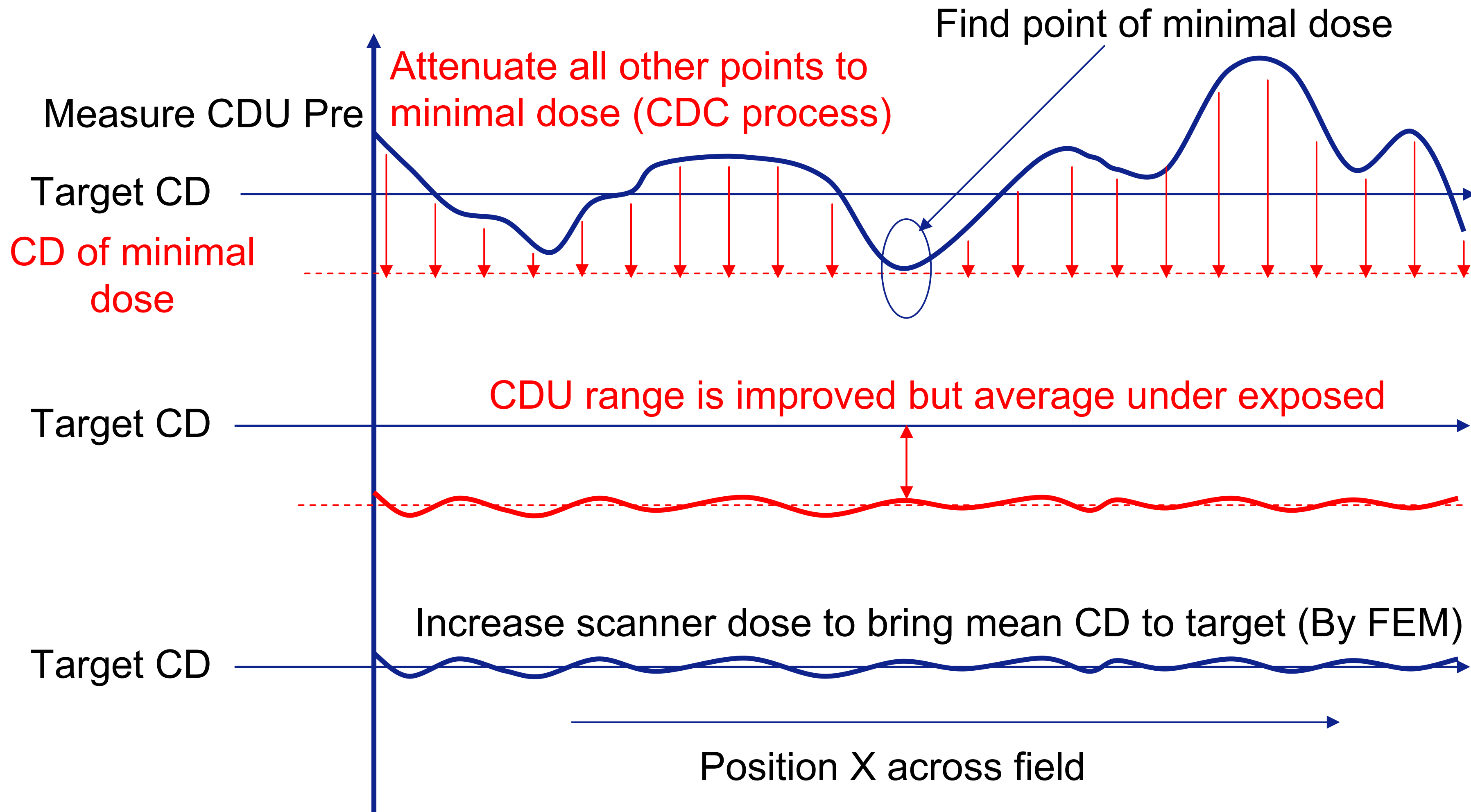


Introduction: CD Uniformity and Mean To Target (MTT)



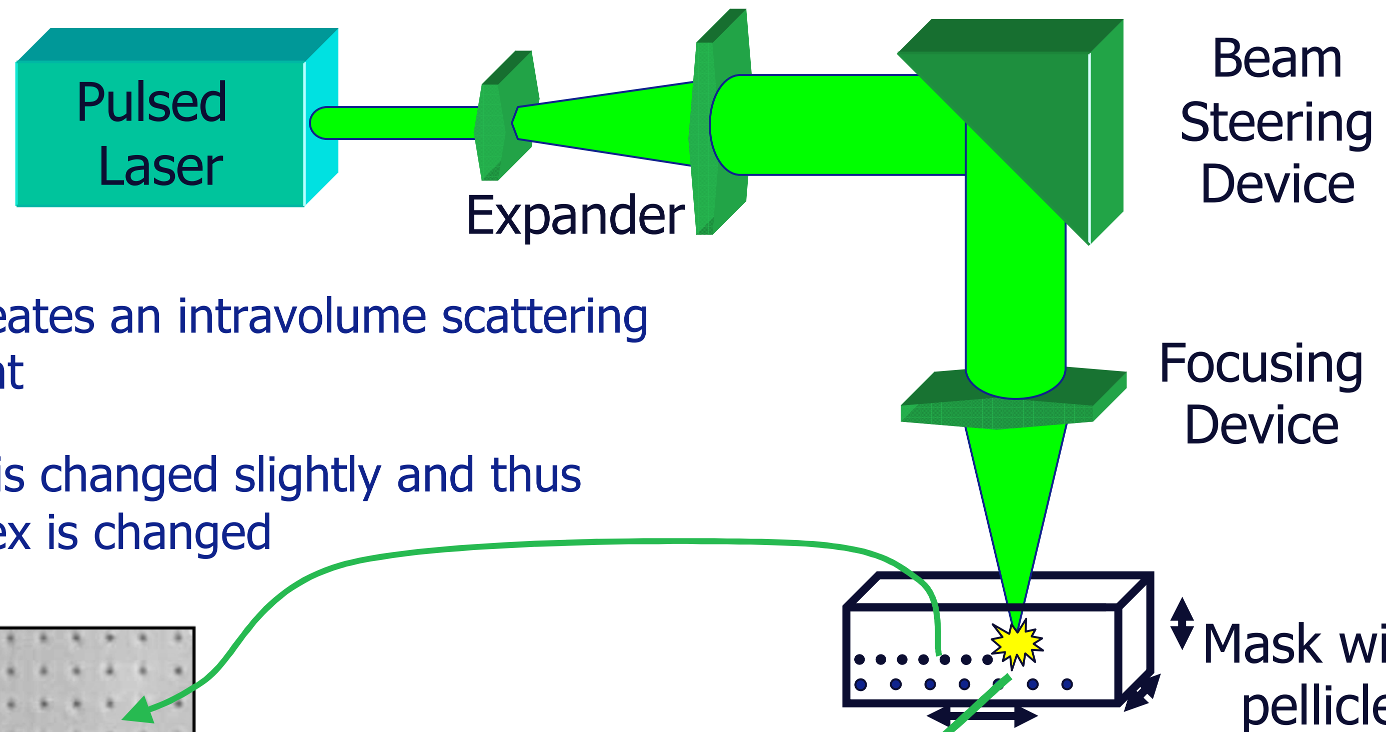
By adjusting dose alone (without CDC) it is sometimes possible to print all features and CD's, but CDU range and 3S are not improved and MTT is degraded

Introduction: Basic Principle of CDC

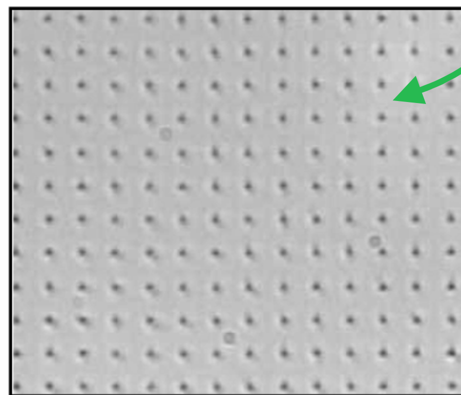


Finally Range, 3S and Mean To Target CD are all improved

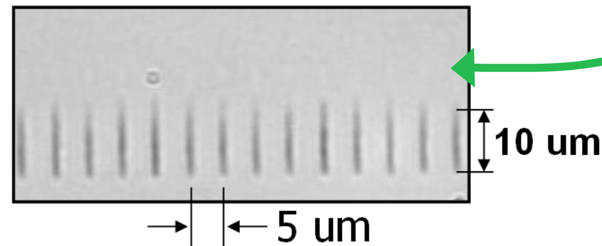
Introduction: Femtolaser Induced Optical Break Down



- Each pulse creates an intravolume scattering optical element
- Glass density is changed slightly and thus refraction index is changed



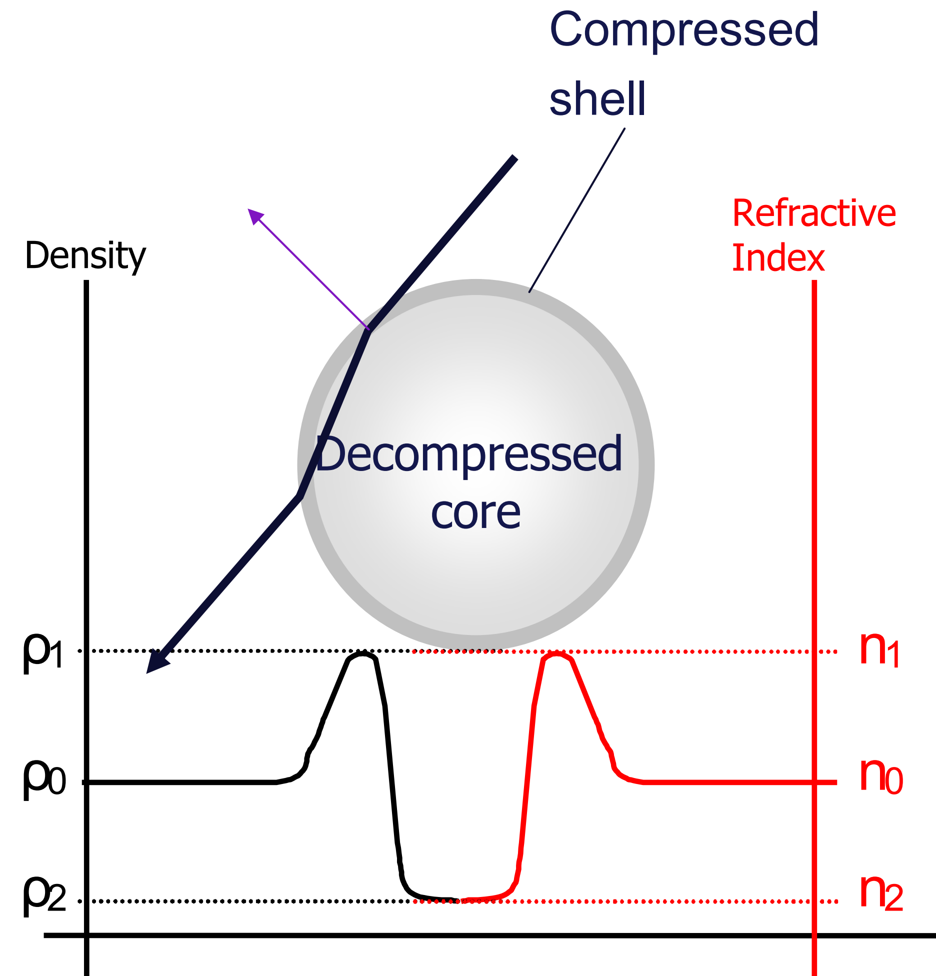
Top view of pixels



Side view of pixels

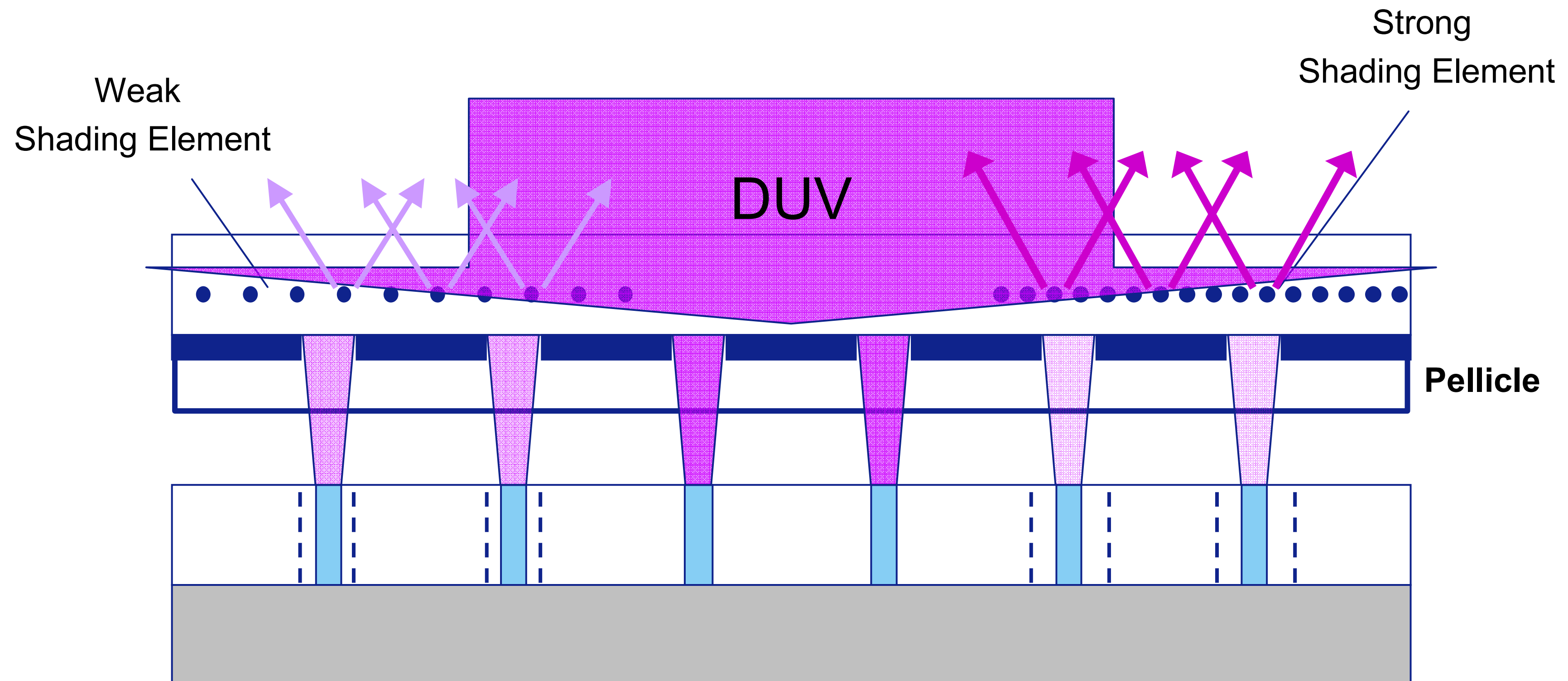
Introduction: Pixel Properties

- The pixel is combined of:
  - A compressed shell with high a density/refractive index
  - Decompressed core with a low density/refractive index
- When a light beam hits the pixel shell, a small portion of the energy is reflected
- Each pixel acts as a small scattering center due to a small Δn
- The pixel reduces the amount of light transmitted throughout the mask



Introduction: The CDC Solution

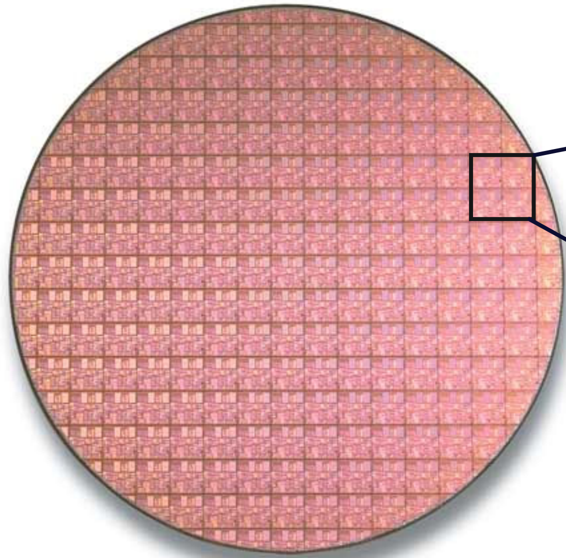
Controlling intra-field CD by locally attenuating the light transmitted through the mask:



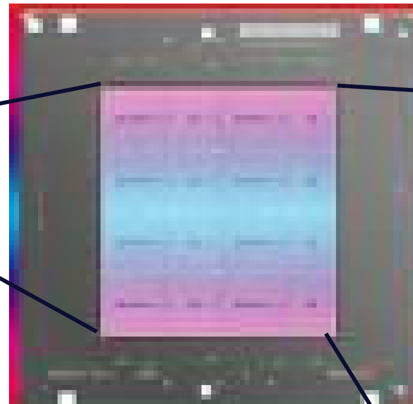
Finally Range, 3S and Mean To Target CD are all improved

Introduction: CDC writing logic

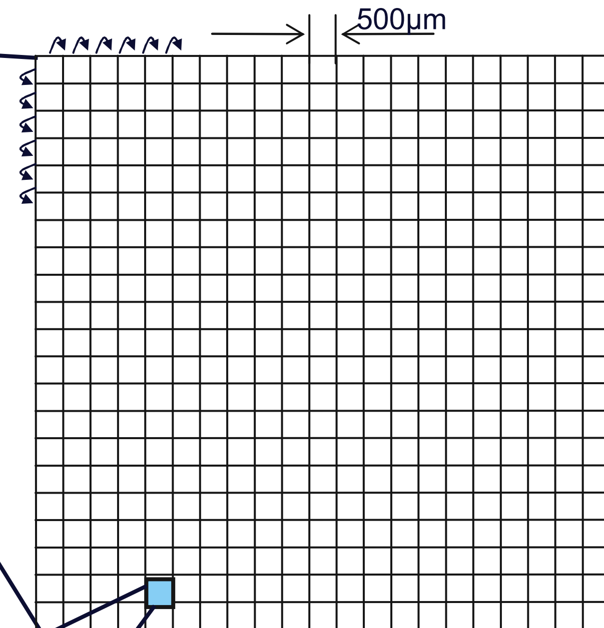
300 mm Wafer
Divided to fields of ~25 X30 mm



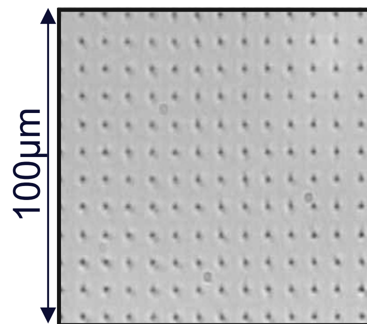
Mask exposure field
~100 X 120 mm



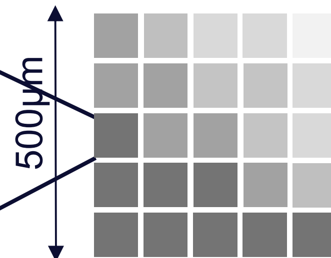
Exposure field divided to 40,000 CDC writing fields. Movement between fields is done by stage motion



Cluster
Discrete attenuation.
Constant pixel density



Writing Field
Field contains 25 clusters.
Each cluster has discrete attenuation value



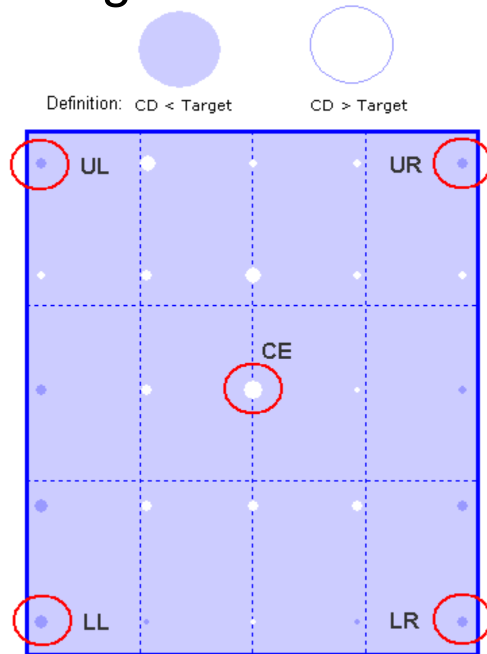
Design Of Experiment

Materials and equipment

1. Line/Space layer production memory mask (65 nm node) with out-of-spec CD uniformity (Rejected from production due to process window shrinking)
2. Wafer CD SEM type Hitachi 9380 working in Space Width mode for measuring wafer intra field CDU
3. Wafer defect inspector type KLA-Tencor ILM 2367 for process window qualification
4. Zeiss CDC200 tool for performing the CDC process

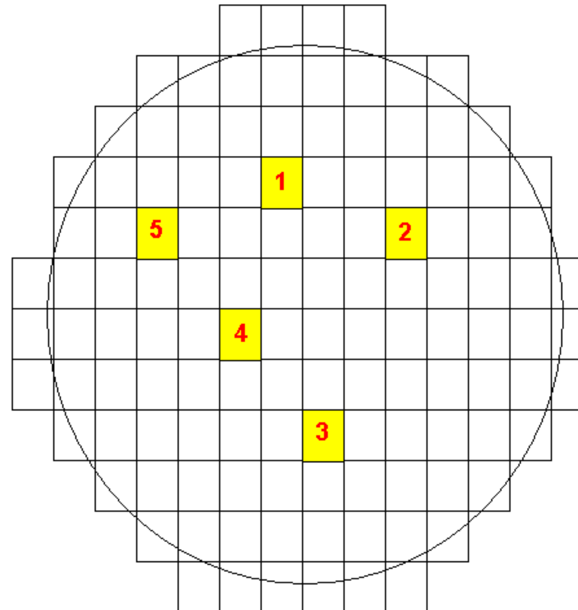
Design Of Experiment

Focus Exposure Matrix regions of interest



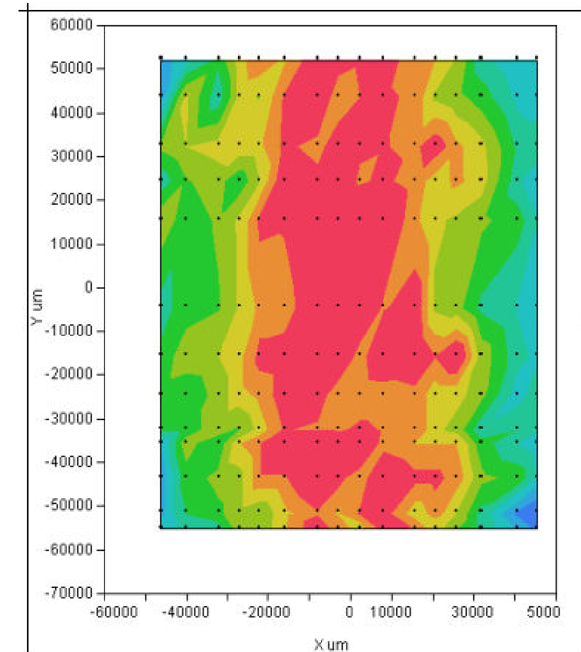
4 corners and center

CDU fields



5 wafer fields averaged for Intrafield CDU signature

Average intrafield CDU



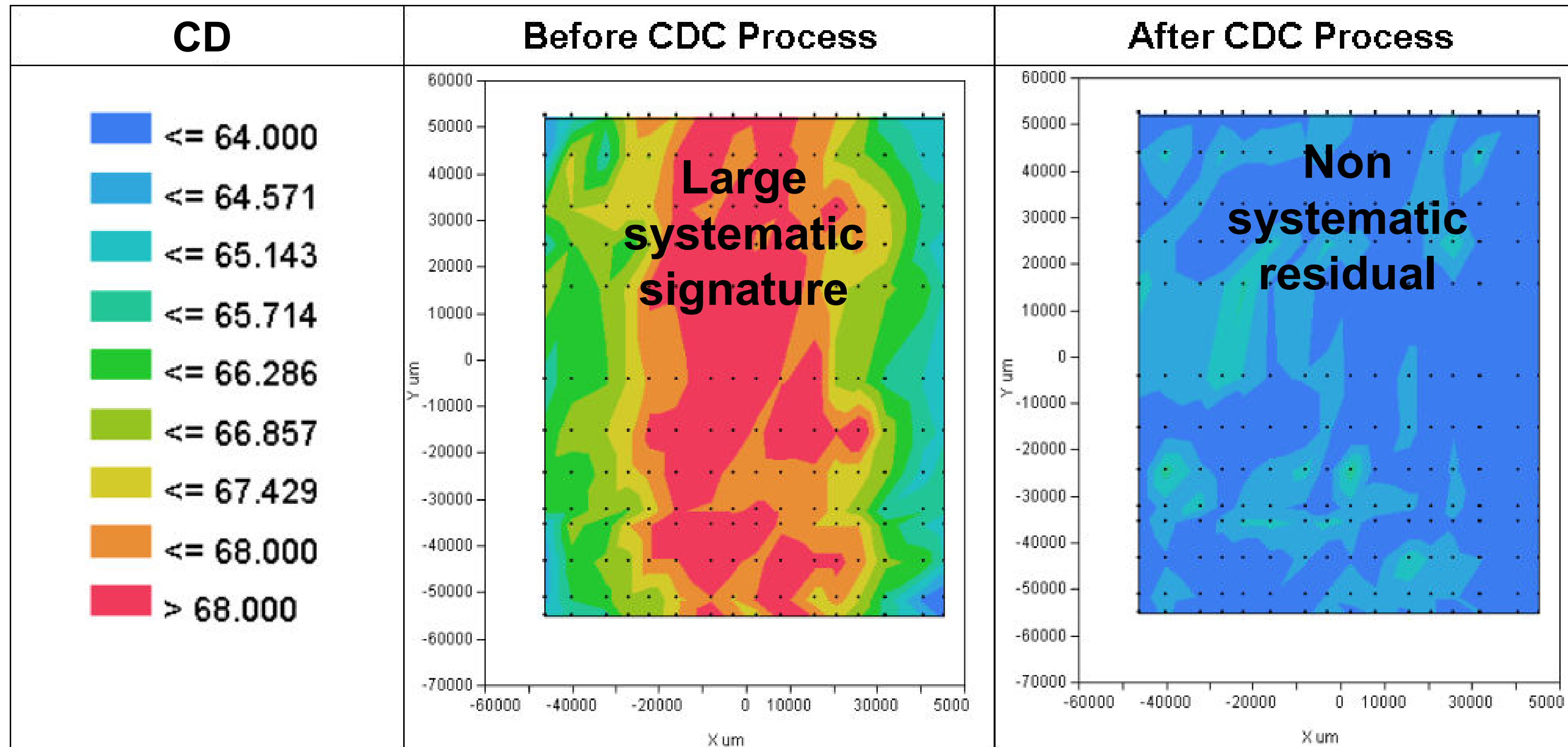
Wafer Intrafield CDU

Range 6.5nm

3S 3.95nm

Mask CDU out of spec!!

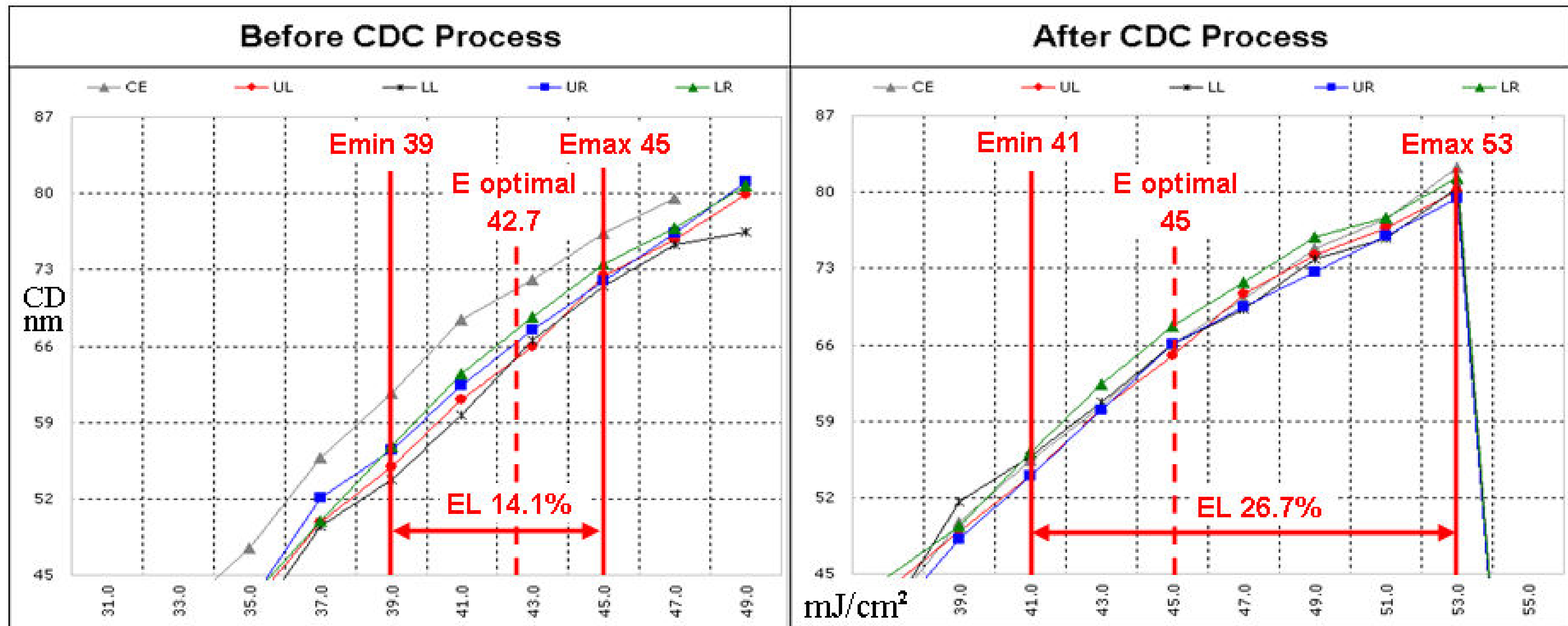
Results: CDU



CD	Unit	Pre CDC	Post CDC	Improvement
Range	nm	6.5	3.8	42%
3S	nm	3.95	1.94	51%

Results: Litho Process Window Evaluation

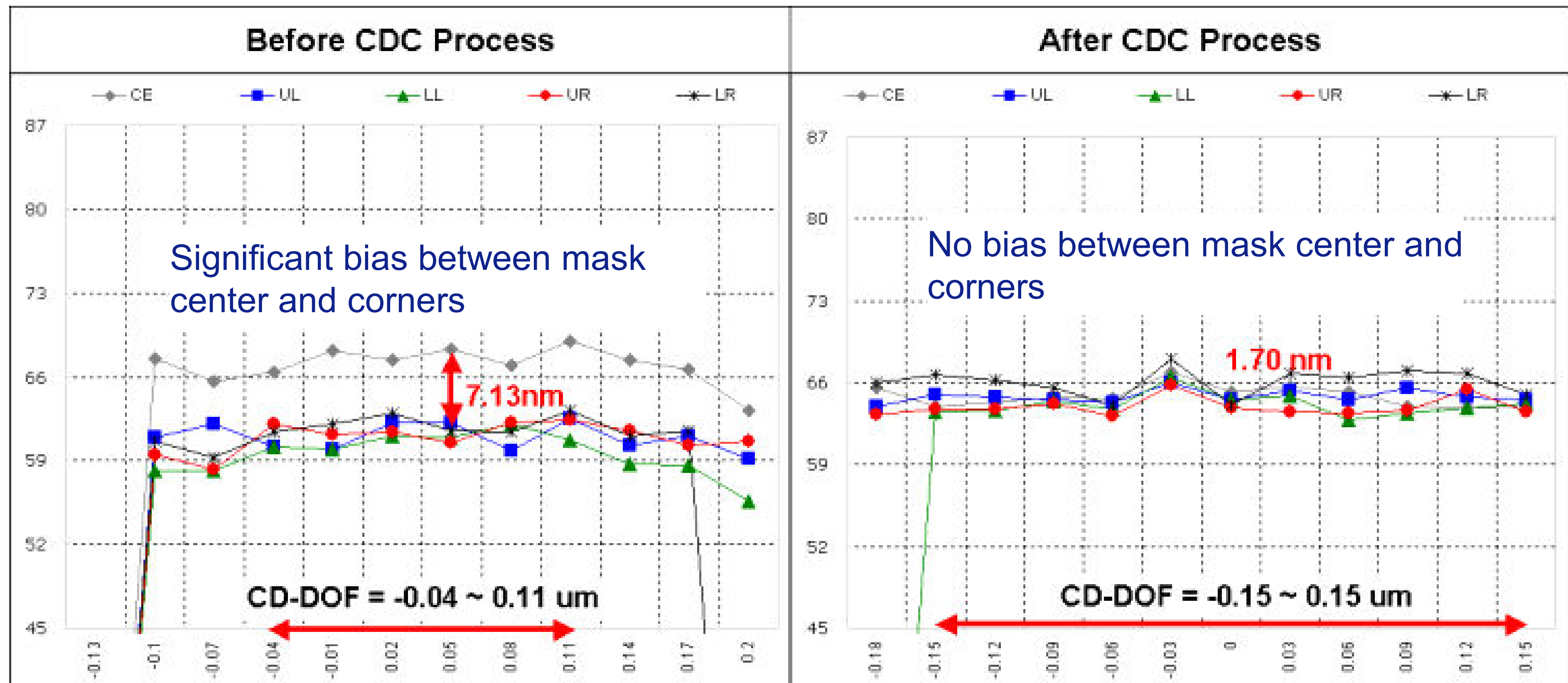
Exposure Latitude After Development (ADI) test



- Exposure Latitude increased from 6 mJ/cm^2 (14.1%) to 12 mJ/cm^2 (26.7%)
- Almost 90% improvement in exposure latitude!!

Results: Litho Process Window Evaluation

Through Focus test



- Depth Of Focus increased from 0.15µm to 0.30µm
- 100% improvement in DOF!!

Results: Litho Process Window Evaluation

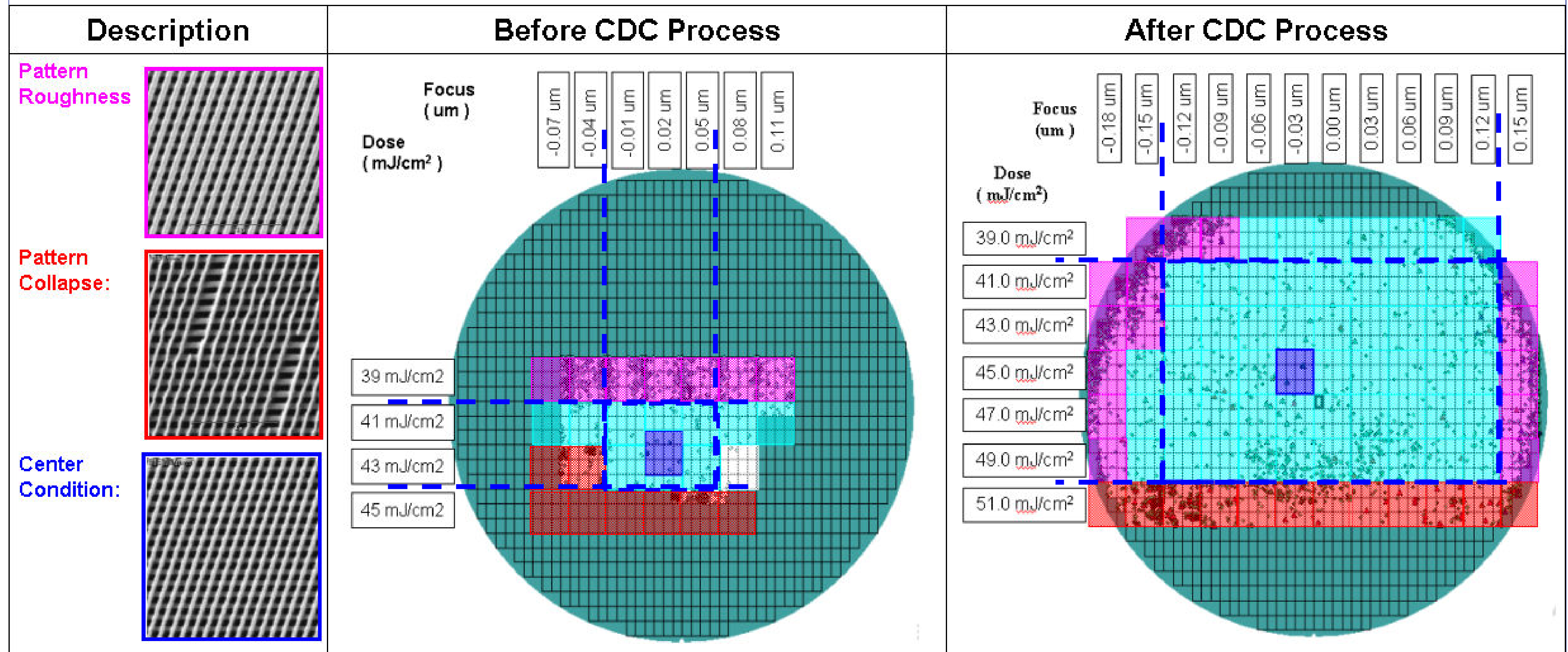
Summary table

Parameter	Units	Pre CDC	Post CDC	Improvement
E optimal	mJ/cm^2	43	45	
Best Focus	µm	0.02	-0.03	
CD-DOF	µm	0.15	0.30	100%
Exposure Latitude ADI	%	14.1	26.7	89%
CD Range	nm	7.13	1.70	76%

- These results show that the CDC process can both significantly enlarge the process window and improve CDU

Results: Litho Process Window Verification

After Etch Inspection (AEI)



Pre CDC
DOF 0.06µm
Dose Range 2mJ/cm²

Post CDC
DOF 0.24µm
Dose Range 8mJ/cm²

Results: Litho Process Window Verification

After Etch Inspection Summary

Margin	Unit	Pre CDC	Post CDC	Improvement
Dose Range	mJ/cm^2	2	8	300%
Focus Range	µm	0.06	0.24	300%
AEI EL	%	4.7	17.8	279%

- Post etch inspection confirms very significant expansion of the process window

Summary and Conclusions

- The CDC process was performed on a 65nm L/S memory mask from PSC fab. The mask was rejected from production due to bad CDU and too small Process Window.
- The CDC process managed to improve the CDU Range and 3S by ~50%
- ADI Exposure Latitude and Depth of Focus were improved by 90-100%
- After Etch Dose and Focus range were improved 300%
- After Etch Exposure Latitude was improved 280%
- **The CDC process brought the mask into spec for production.**
- **Conclusions**
  1. **The CDC process can bring an out of spec mask into spec and save the cost of a new mask**
  2. **The CDC process can increase the wafer chip yield and binning by providing a larger process window and tighter CDU**

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Thank You for Your Attenuation !

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