The integrated EUV Mask Process at the Advanced Mask Technology Centre (AMTC) in Dresden

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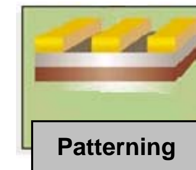
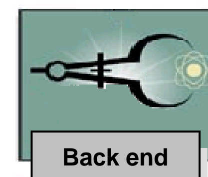
Outline

- History and motivation
- Integrated process flow
- Blank material
- Litho process
  - Resist inspection
  - Litho process performance
  - Resist thickness measurements

- Patterning
  - Absorber etch process
  - Buffer etch process
  - Patternprofiles
  - DUV degradation



- Back end
  - Defect inspection
  - Test mask performance



- Summary & outlook

History and motivation

Development scheme for candidate EUV mask processes

predevelopment in collaboration with IMS-Chips

Process A *FE @ IMS-Chips Stuttgart* *BE @ AMTC Dresden*

Process B *FE @ IMS-Chips Stuttgart* *BE @ AMTC Dresden*

Process C *FE @ IMS-Chips Stuttgart* *BE @ AMTC Dresden*

Various types of EUV masks for MET tool and ASML alpha demo tool

Process transfer & improvement at AMTC

Focus on:

- Lithographic process
- Absorber etch optimisation
- Buffer etch
- Metrology
- Inspection
- Repair
- Cleaning

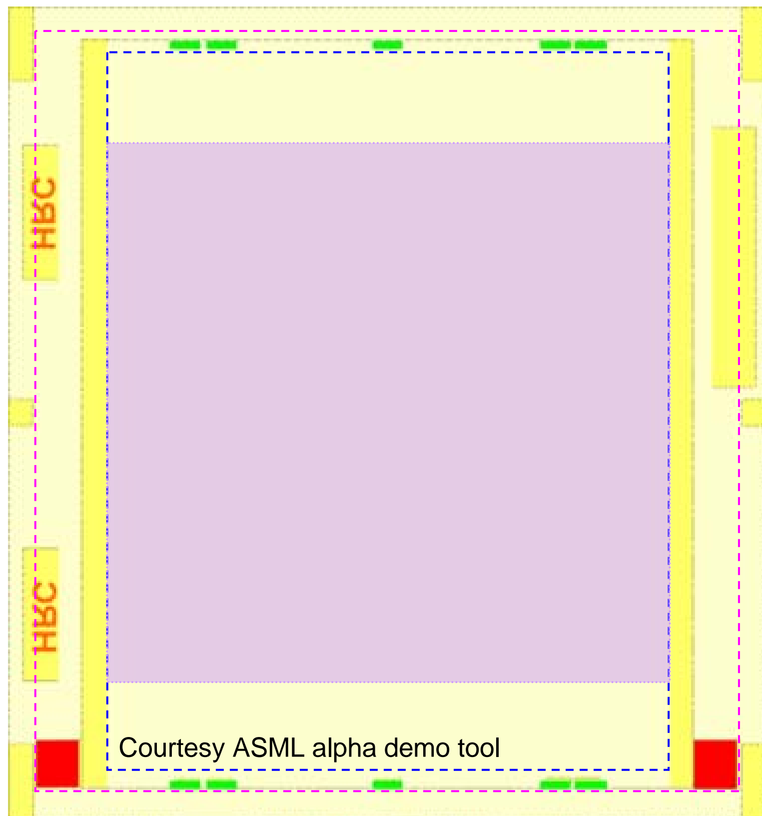
set-up of a pre-pilot EUV mask process

Process C *FE and BE @ AMTC Dresden*

History and motivation

- Target: High end EUV masks for the ASML alpha demo tool

Mask layout



ML / blank quality area
142mm x 142mm

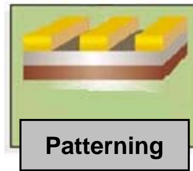
Full field printable area
104mm x 132mm

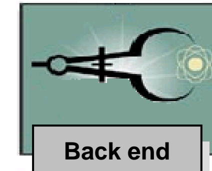
Alpha demo tool imaging area
104mm x 97mm (SEMI P40-1103)

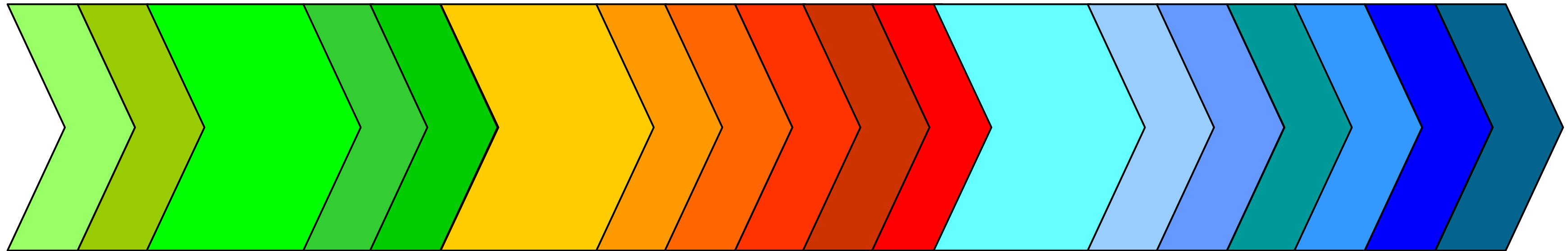
RPAS alignment mark

TIS alignment mark

Integrated process flow





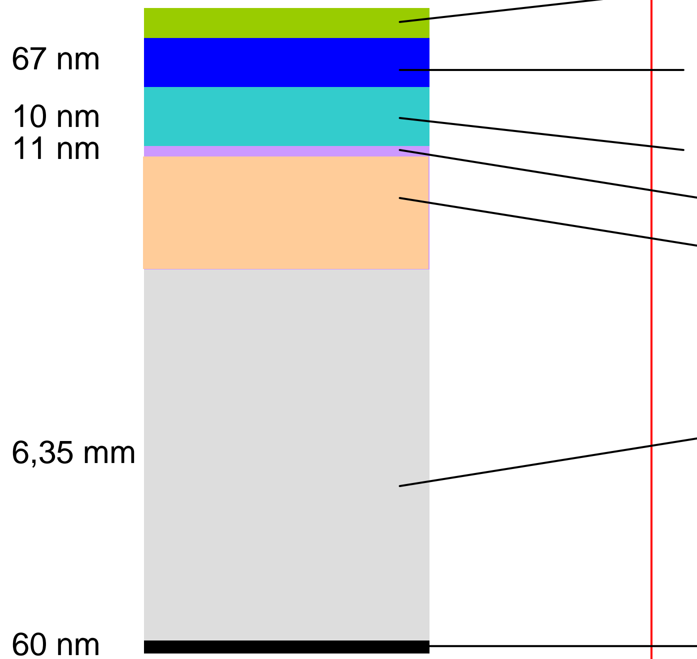


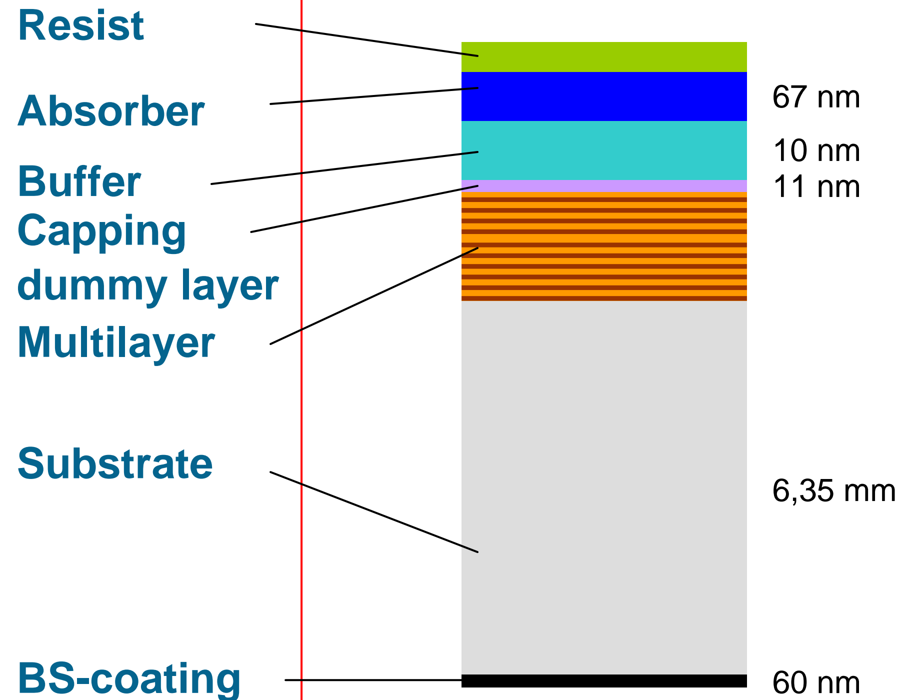
- **Resist inspection**
- **Resist thickness**
- **Litho EUV process based on 50keV e-beam writer**

- **Absorber etch process**
- **Buffer etch process**

- **Layer thickness metrology**
- **CD SEM metrology**
- **Registration metrology**
- **AFM metrology**
- **Mask inspection**
- **Repair**
- **Cleaning**

Blank material

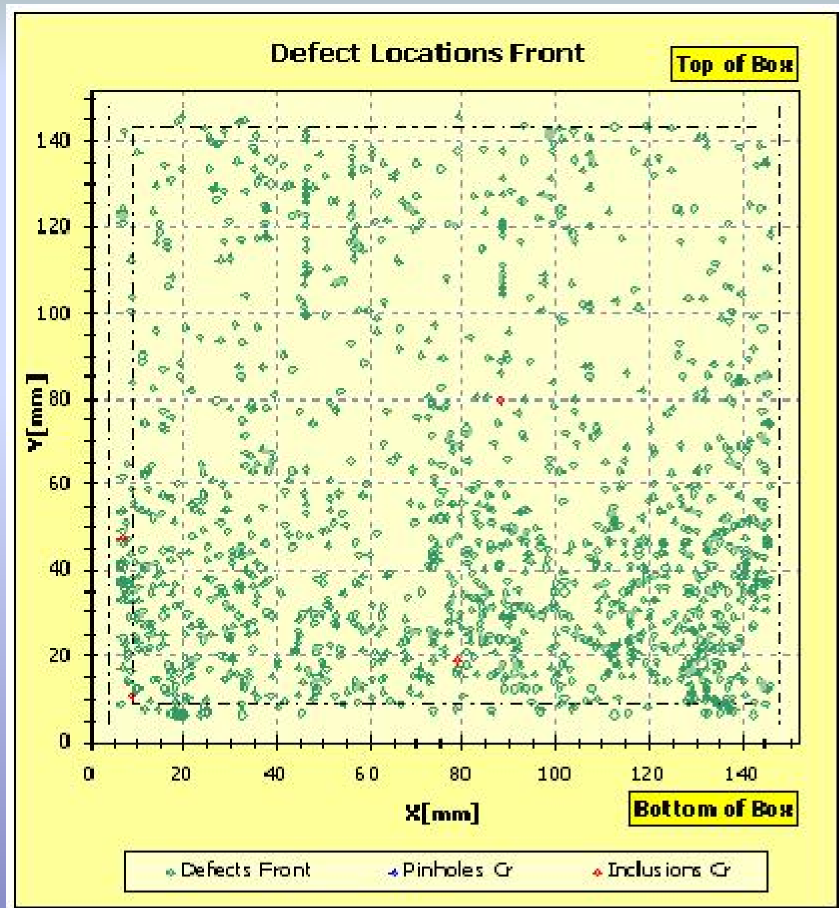




Blanks without resist coating from Schott Lithotec Meiningen Germany

Blank incoming inspection

Defect map for resist inspection



Detection limit of inspection tool: 80nm

EUV blanks of Schott Lithotec have been coated by a 3rd party and show too many defects

→AMTC is currently implementing with its partners a completely new resist coating process.

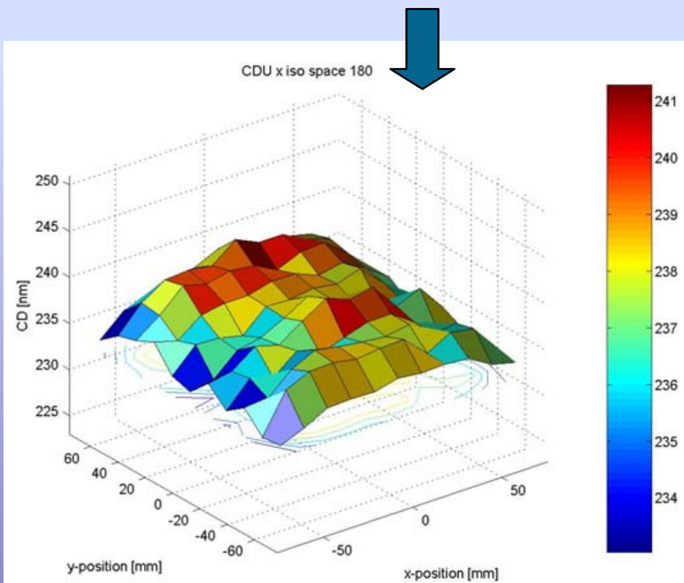
Litho process performance

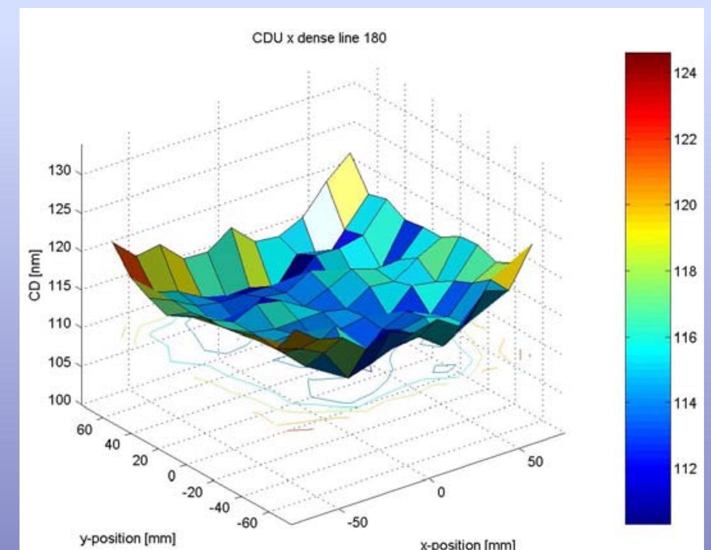
CD Uniformity after litho process for different structure types at 180 nm size, measured on area 132 x 132 mm²

Feature type	*Iso*	*Dense*	*Iso*	*Dense*
Contrast	*clear*	*clear*	*dark*	*dark*
CDU 3σ [nm]	5.6	9.5	16.5	8.6
CDU range [nm]	8.2	13.1	28.0	14.3

CD linearity after litho process for structure sizes in the range 180 - 1600 nm

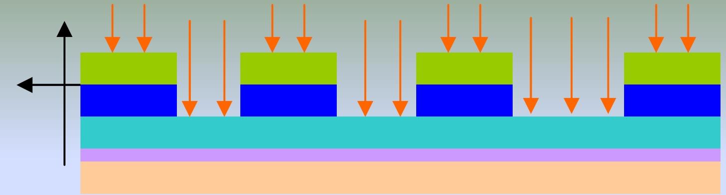
- < 5 nm for iso-clear, dense-clear & dense dark
- < 12 nm for iso-dark structure

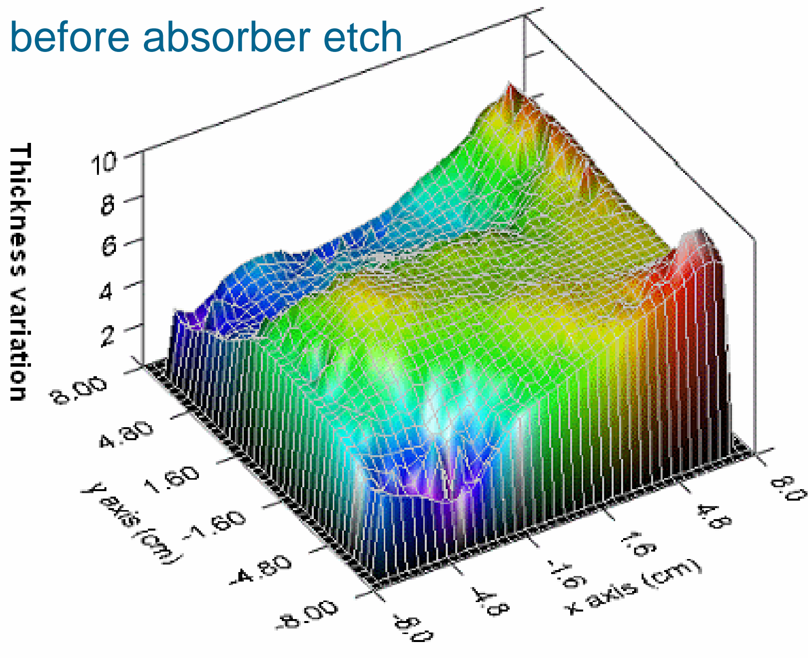


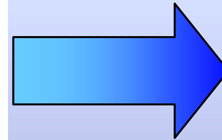


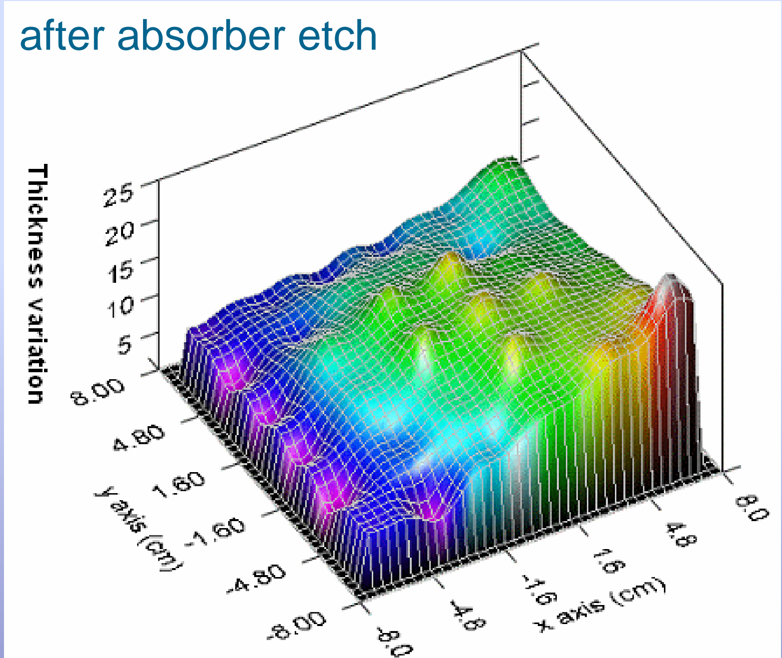
Resist thickness - absorber etch

Resist thickness degradation during TaN etch





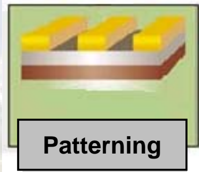




thickness variation
1σ = 2,1nm

Absorber etch has minimal impact on resist removal uniformity

thickness variation
1σ = 5,3nm



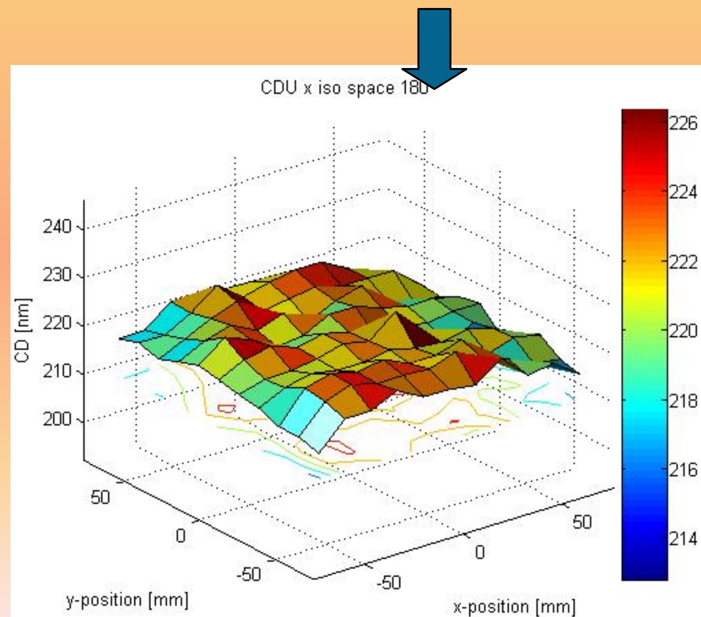
Absorber etch process

CD Uniformity of EUV mask after absorber etch

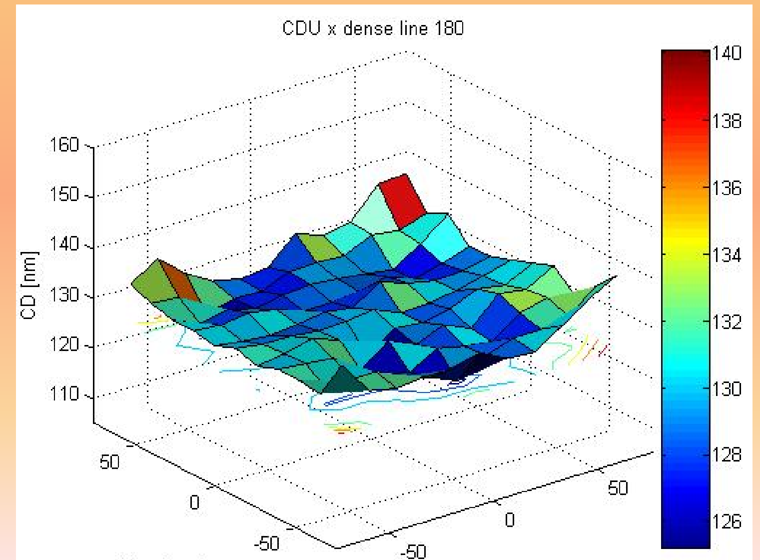
Feature type	*Iso*	*Dense*	*Iso*	*Dense*
Contrast	*clear*	*clear*	*dark*	*dark*
CDU 3σ [nm]	4.2	5.1	13.2	6.0
CDU range [nm]	6.3	7.4	24.5	11.0

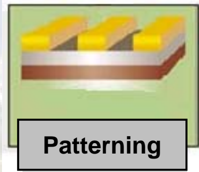
CD linearity after absorber etch process for structure size in the range 180 - 1600 nm

- < 10 nm for all structures



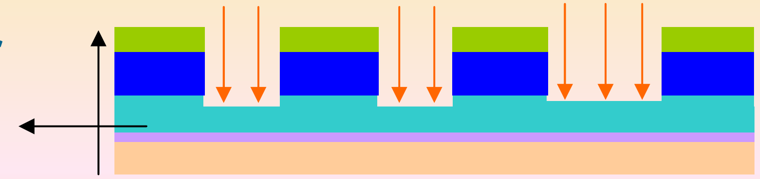
Center fast footprint at clear structures.



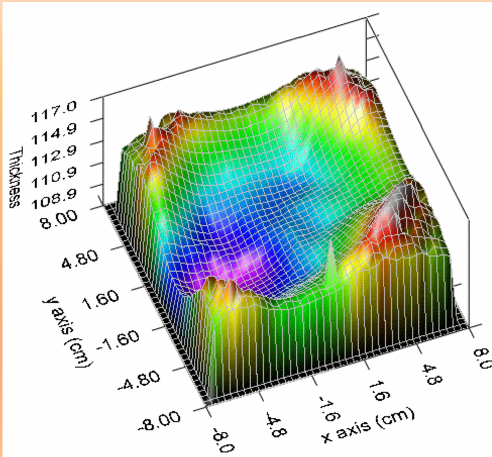


Buffer layer thickness after absorber etch

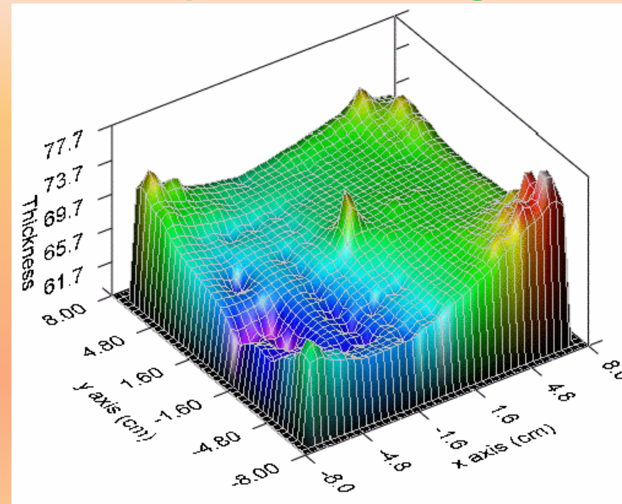
Adjusting etch depth uniformity for the buffer layer via TaN etch process conditions



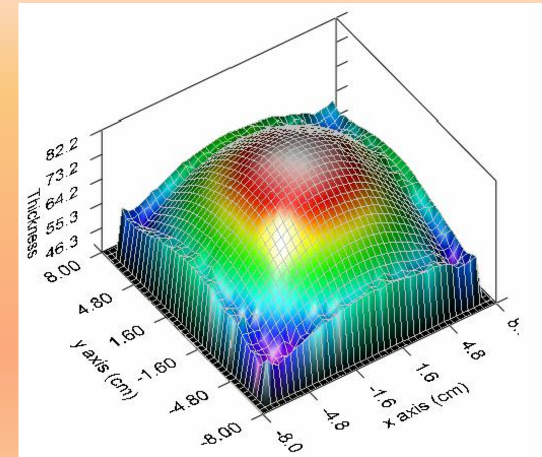
Center fast settings



Equalized settings



Center slow settings

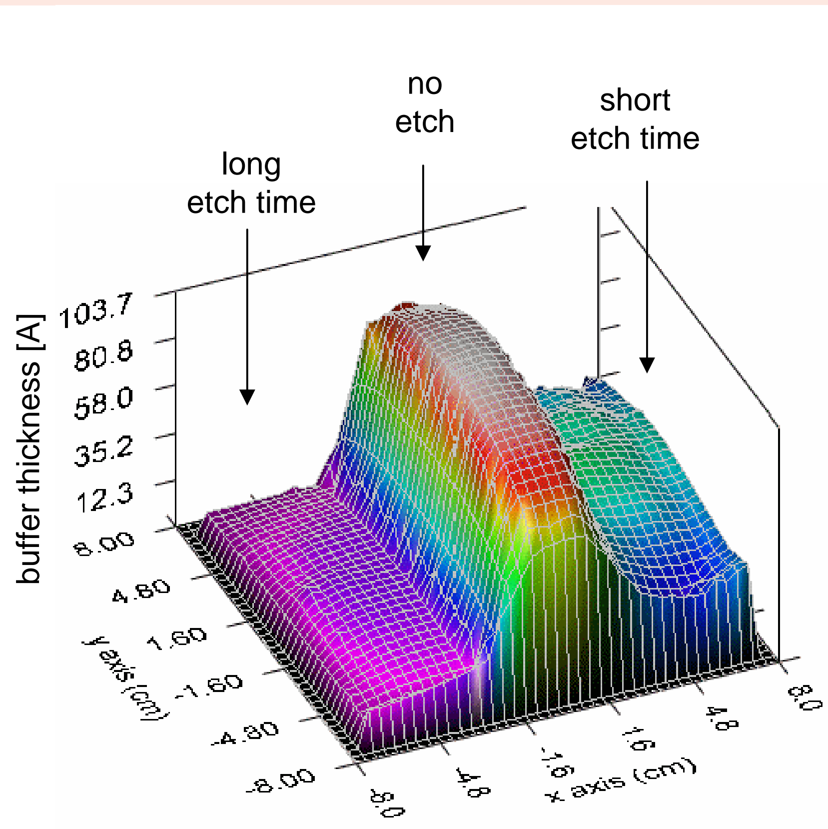


Min = 5,97 nm
Max = 7,90 nm
Mean = 6,79 nm
1s = 0,32 nm
Range = 1,93 nm

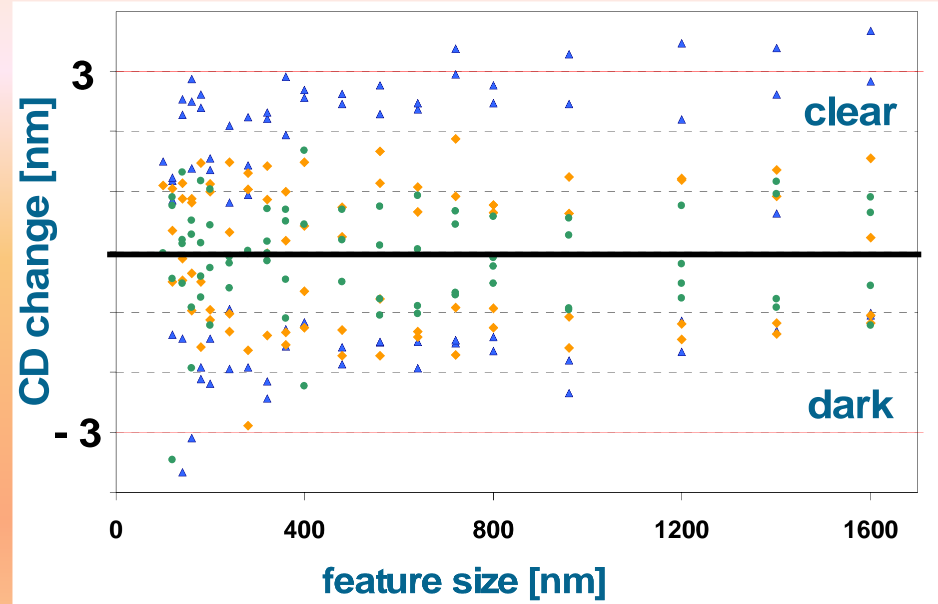
After TaN etch the buffer layer thickness is very uniform across the mask area.

Buffer etch process

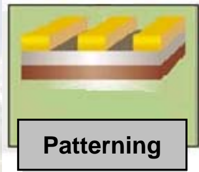
Wet etch experiment



Influence of buffer etch on CDU/CDO

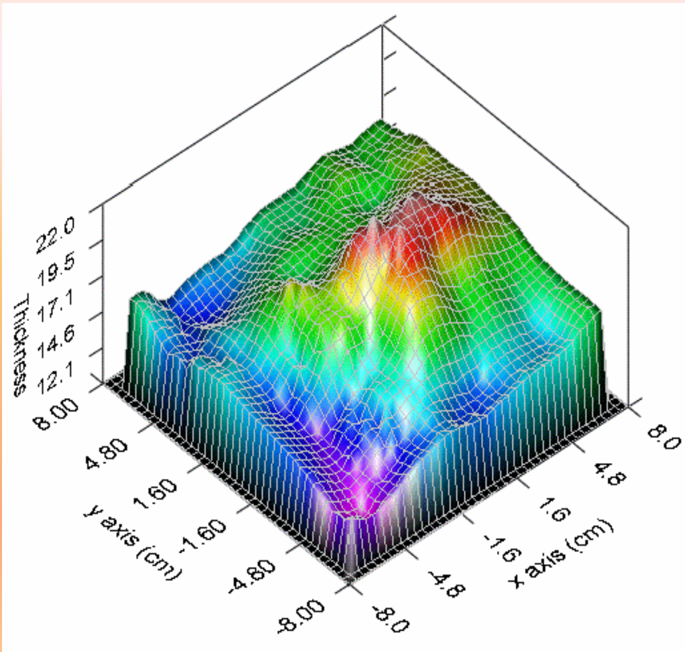


- Etch bias < 3nm (within CD-SEM repeatability limit)
- Change in CDU within repeatability limit of CD-SEM



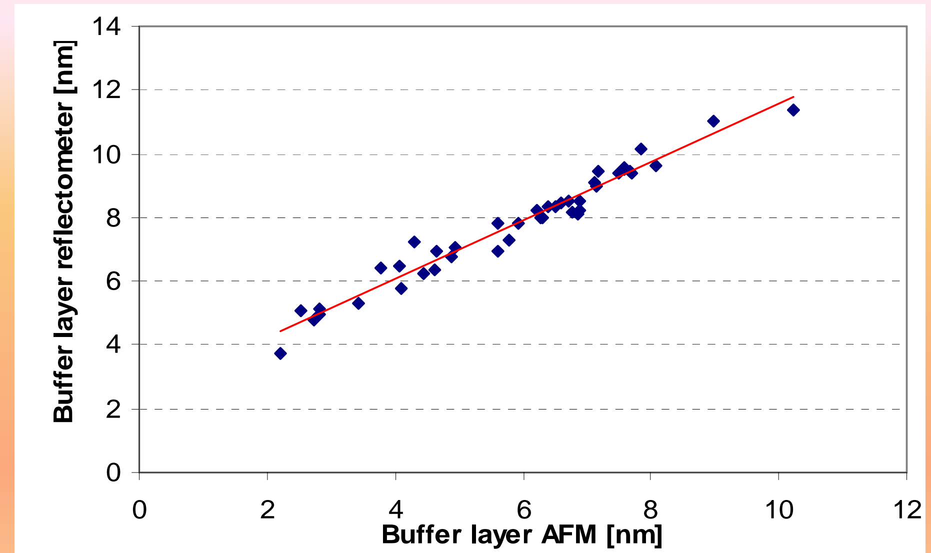
Buffer layer thickness after buffer etch

Buffer thickness after buffer etch



Min = 1,08 nm
Max = 2,28 nm
Mean = 1,60 nm ?
1s = 0,22 nm
Range = 1,20 nm

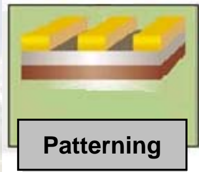
Correlation for buffer layer thickness AFM vs reflectometer tool



Correlation shows possible error in the layer model of the reflectometer measurement

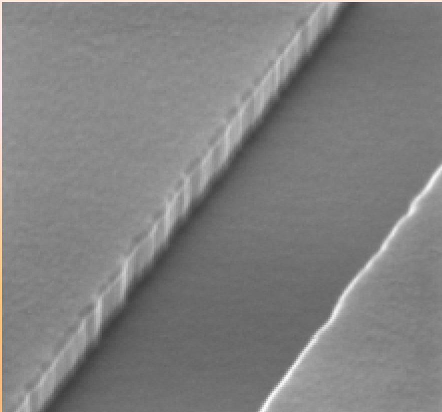
→ buffer layer thickness determined by reflectometer is 2.1 nm larger than AFM result

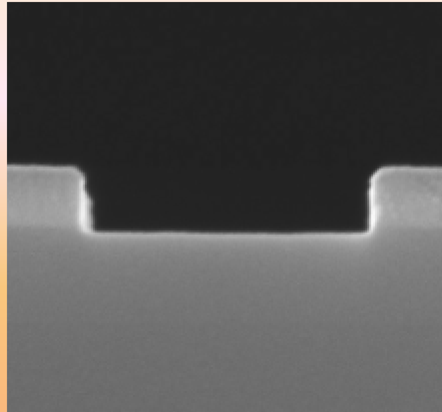
→ No indication for buffer material remnants found

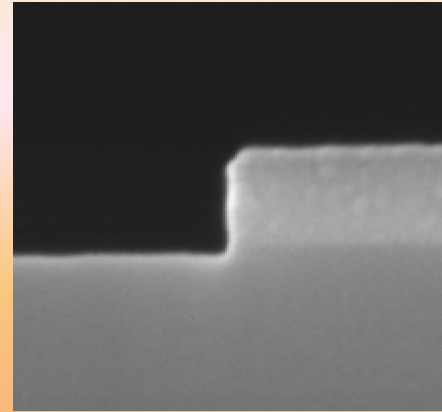


Pattern profiles from absorber DoE

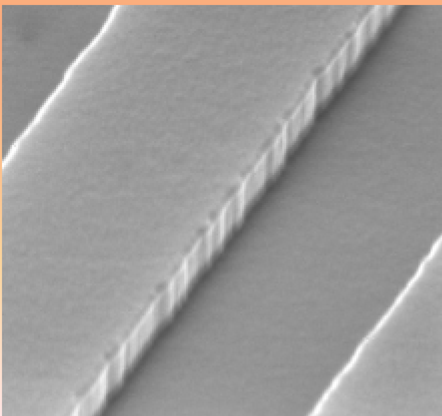
Isolated trench

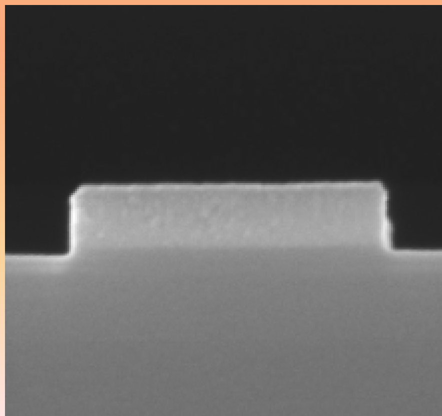


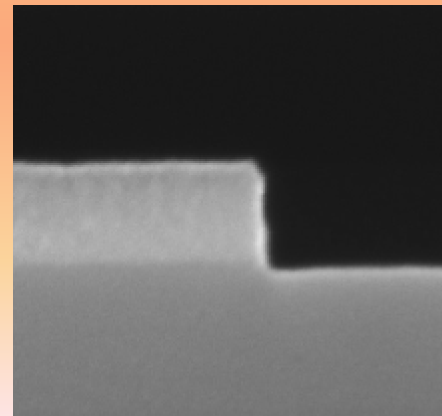




Isolated line

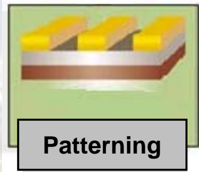






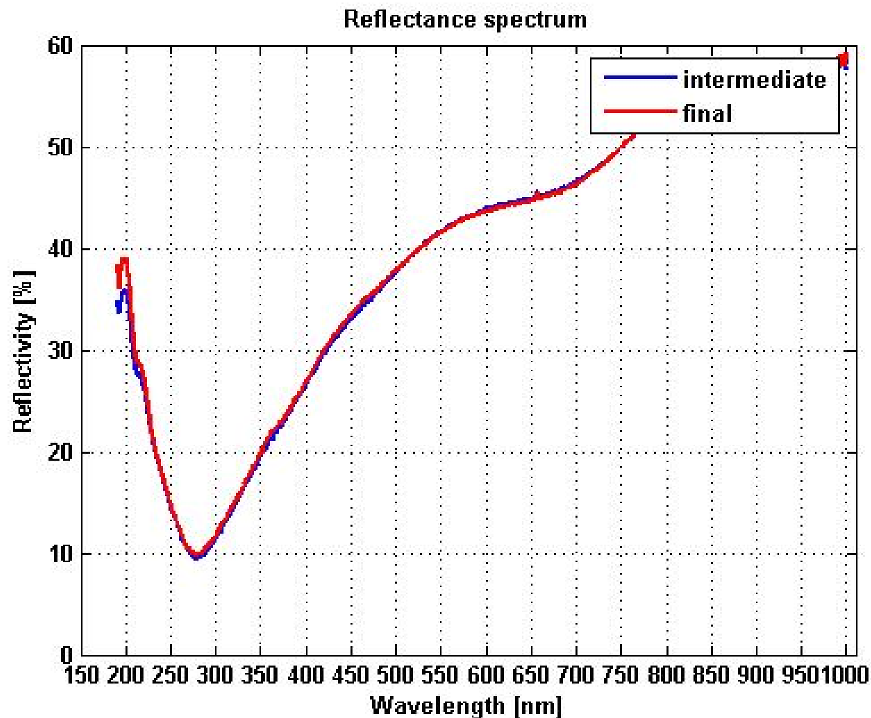
Absorber and buffer etch process done

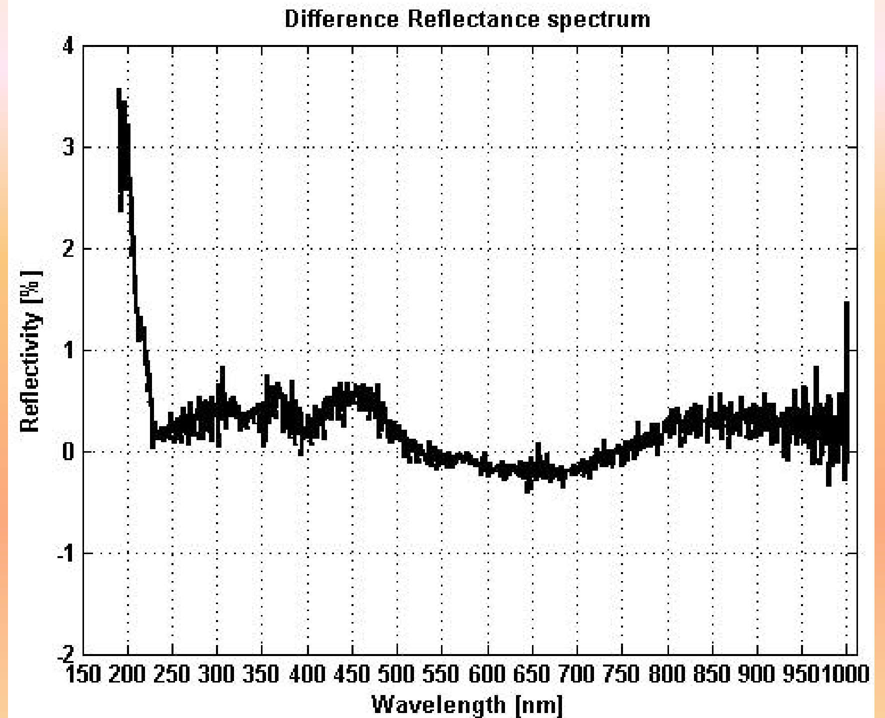
- **Rectangular sidewalls**
- **No undercut seen**



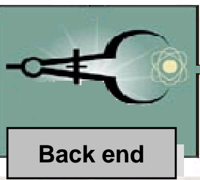
Absorber degradation

Degradation of absorber reflectance by EUV mask process



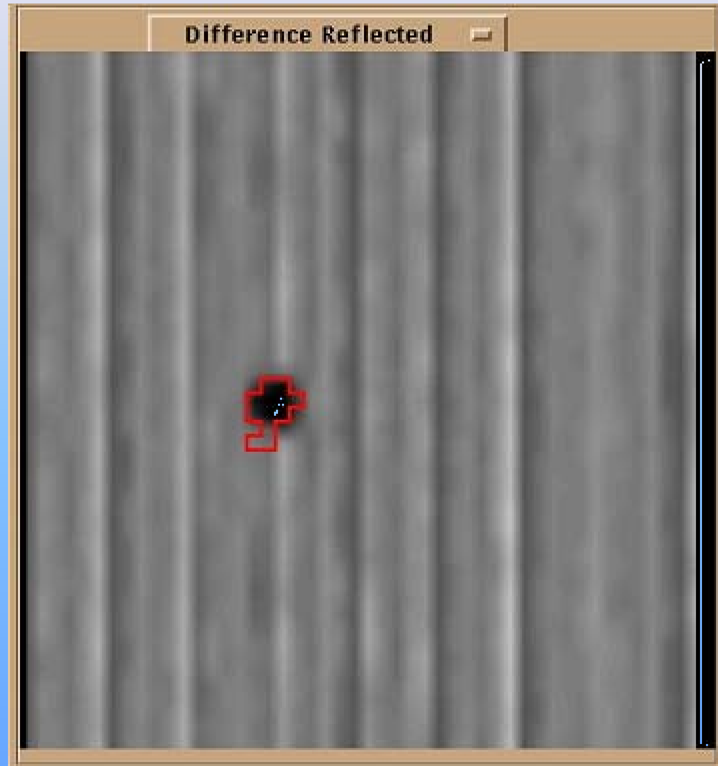


EUV mask process shows negligible impact on absorber DUV reflectance

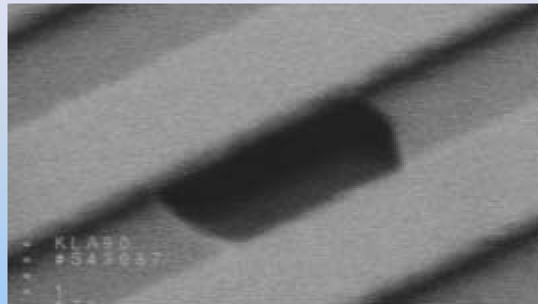


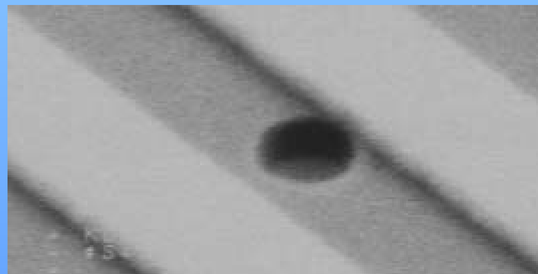
Defect inspection

D2D inspection

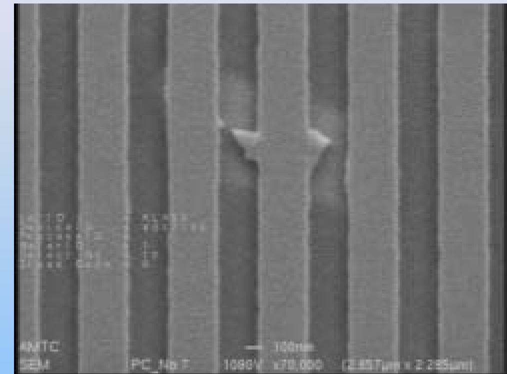


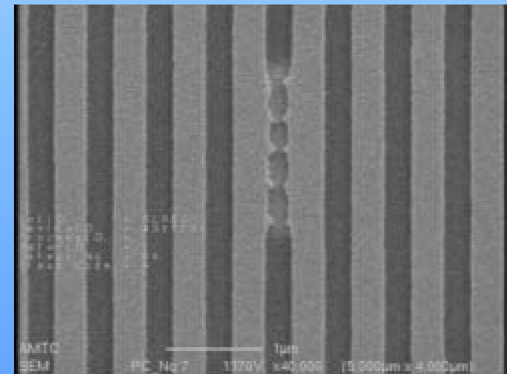
Material defects

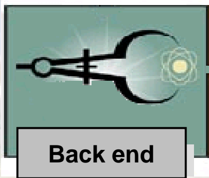




Mask defects caused by resist impurities

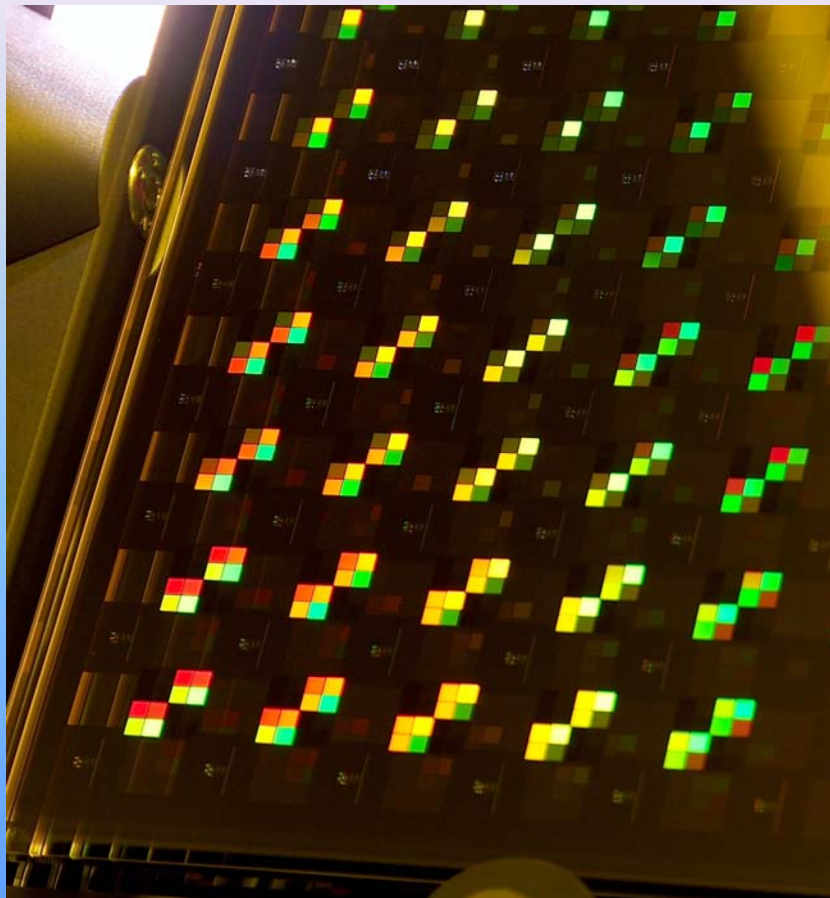






Test mask performance

Test mask



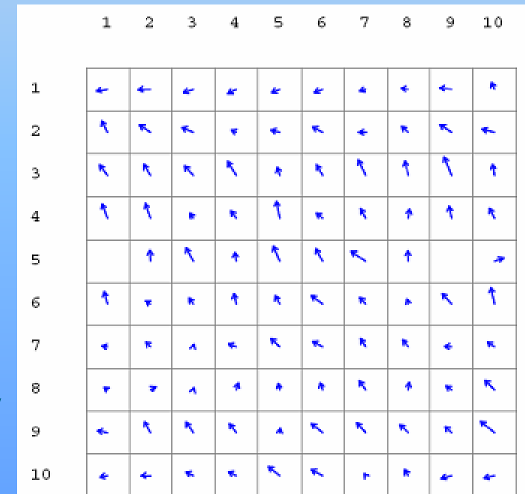
CDU on 104mm x 132mm area

Nominal CD	iso line CDU 3σ [nm]	dense line CDU 3σ [nm]
400	6,2	6,4
200	5,8	5,5
180	7,9	4,1
160	8,8	7,1

Registration on area 119mm x 119mm

X max 3σ: 6,22 nm
Y max 3σ: 7,71 nm

- Scale and ortho corrections applied.
- PG process not fully adjusted



Summary & Outlook

AMTC has established an integrated EUV mask process based on dummy EUV material

Major achievements:

- **DOE optimized absorber etch process**
- **Uniform buffer etch process**
- **Layer thickness model**
- **Blank and mask inspection**

Next steps:

- **Change of resist coating process**
- **Further litho process improvement**
- **Evaluation of multilayer material**

Acknowledgement

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GEFÖRDERT VOM