

EUV mask cleaning: challenges and solutions

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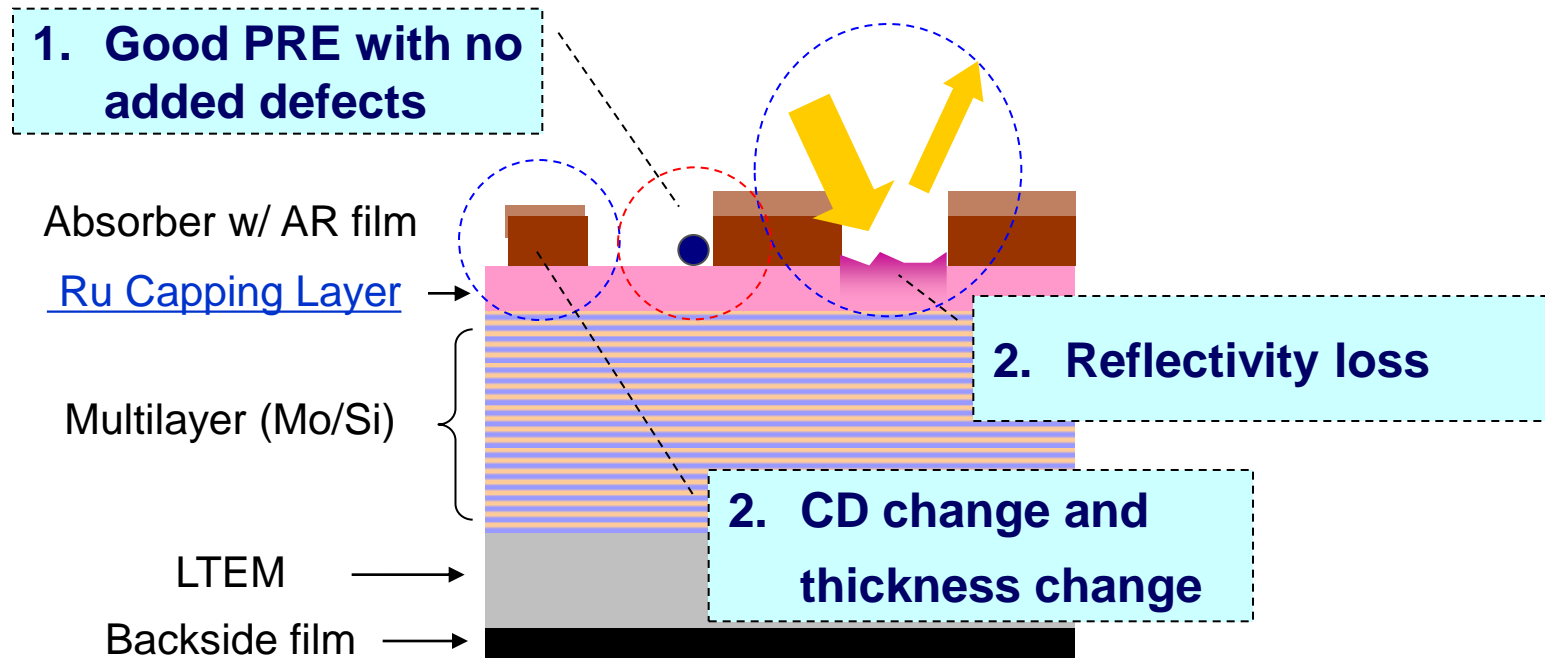
Dai Nippon Printing Co., Ltd.

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 - EUV mask cleaning challenges
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EUV mask cleaning challenges



1. EUV mask cleaning required to remove all printable particles
 - ITRS: 25nm defect for 23nm NAND Flash Device
2. Minimum damage to absorber pattern, Ru surface and multilayer
3. Need more frequent cleaning due to lack of pellicle

EUV mask cleaning : SPM-SC1 recipe

- Cleaning performance
 - Particle removal efficiency
 - Added defects

- Damage
 - ARC layer
 - CD change
 - Ru capping layer

EUV mask cleaning : SPM-SC1 recipe

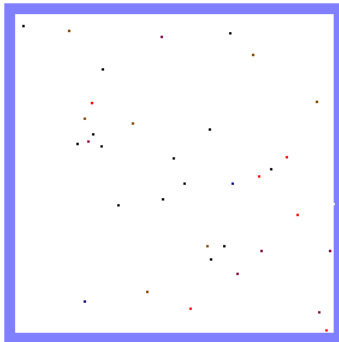
- Cleaning performance
 - Particle removal efficiency
 - Added defects

- Damage
 - ARC layer
 - CD change
 - Ru capping layer

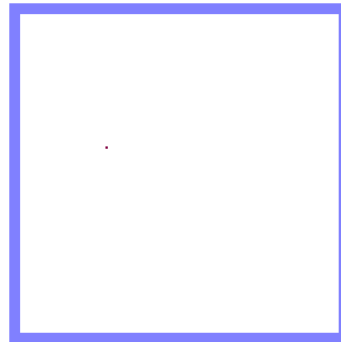
Particle removal

M1350

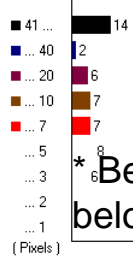
Added handling particles
(Before clean)



Remained handling particles
(After clean)



Pixel Histogram



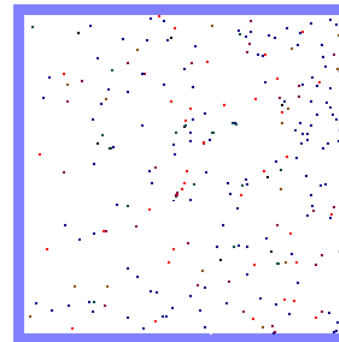
Pixel Histogram



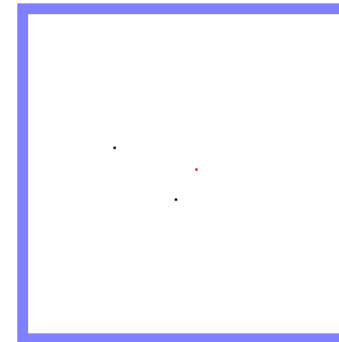
* Below pixel 6 are removed out due to below 100% capture rate

M7360

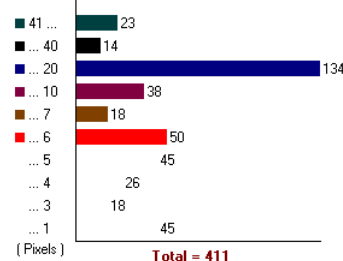
Added handling particles
(Before clean)



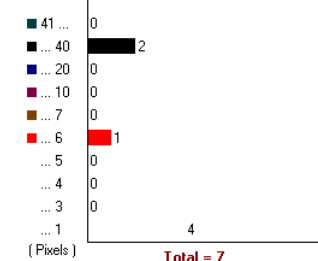
Remained handling particles
(After clean)



Pixel Histogram



Pixel Histogram



Almost all particles removed (>80 nm)

PRE = 97%

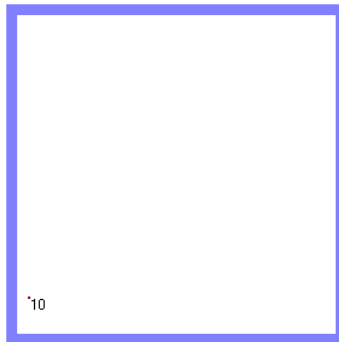
Almost all particles removed (> 50nm)

PRE = 99%

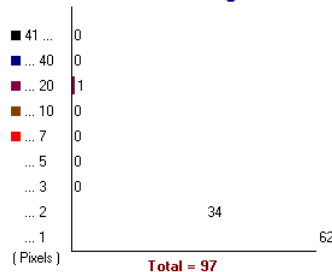
Added defects from cleaning

M1350

Adder map



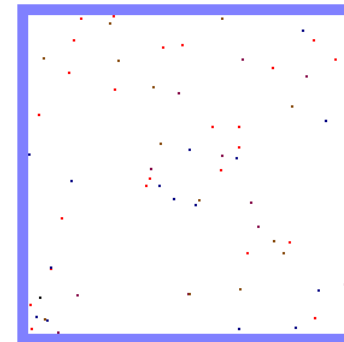
Pixel Histogram



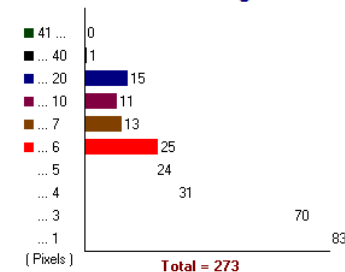
1 adder (> 80nm)

M7360

Adder map



Pixel Histogram



65 adders (> 50nm)

2 types of added defects

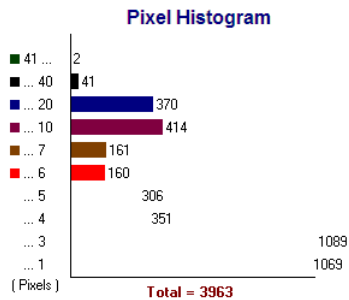
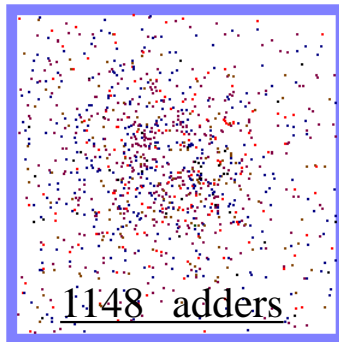
- Added defects
 - Particles type defects
 - Filtration of chemicals
 - Clean chemical

 - Pit type defects
 - Megasonic optimization

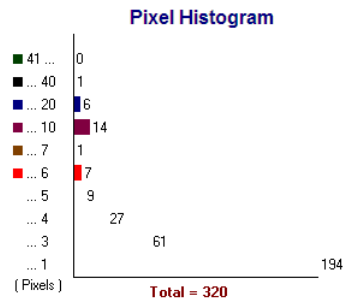
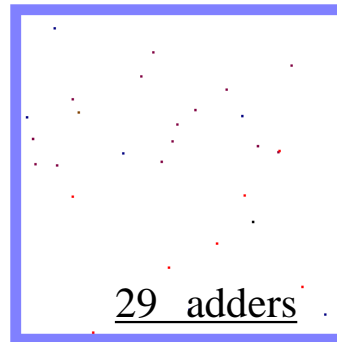
Particle type adders

Adder maps from each chemical steps

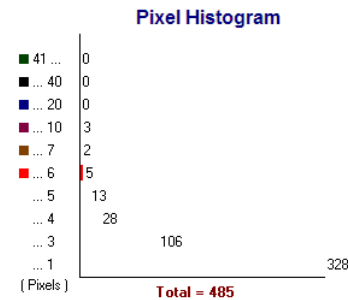
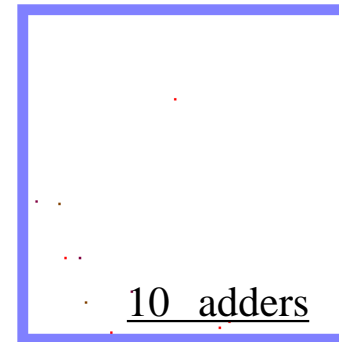
SPM step



Hot water step

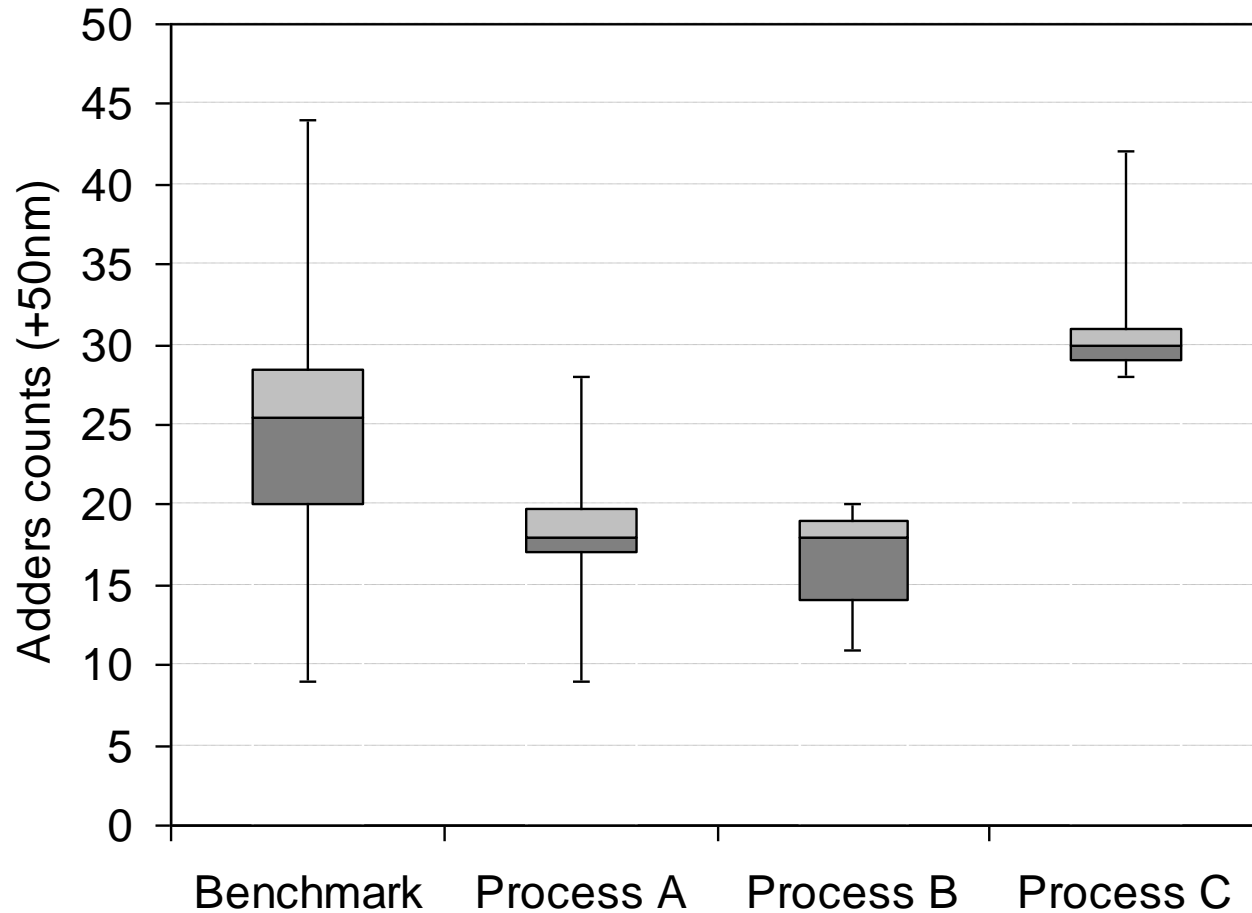


SC1 step



SPM chemical is likely main source of particle type adders

Pits type adders



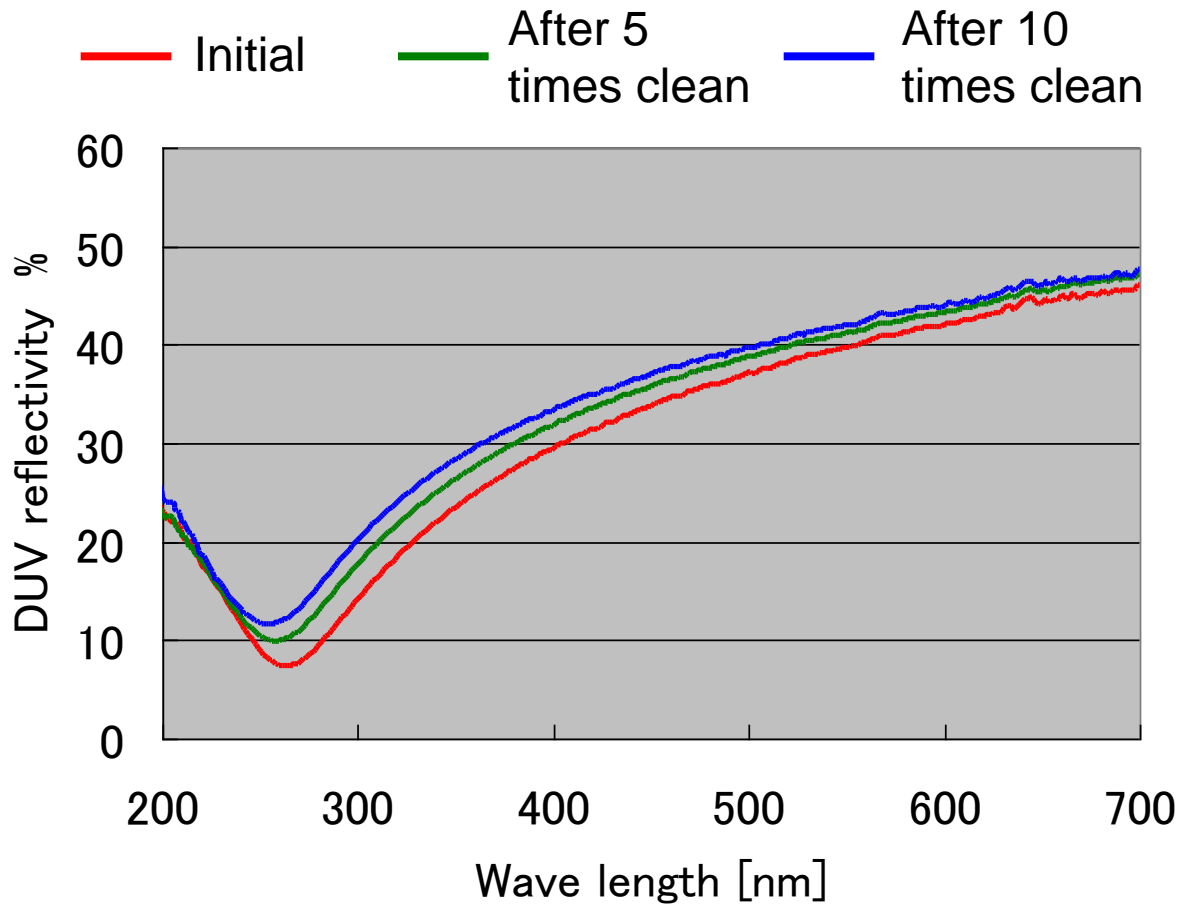
Lower megasonic power and higher frequency

EUV mask cleaning : SPM-SC1 recipe

- Cleaning performance
 - Particle removal efficiency
 - Added defects

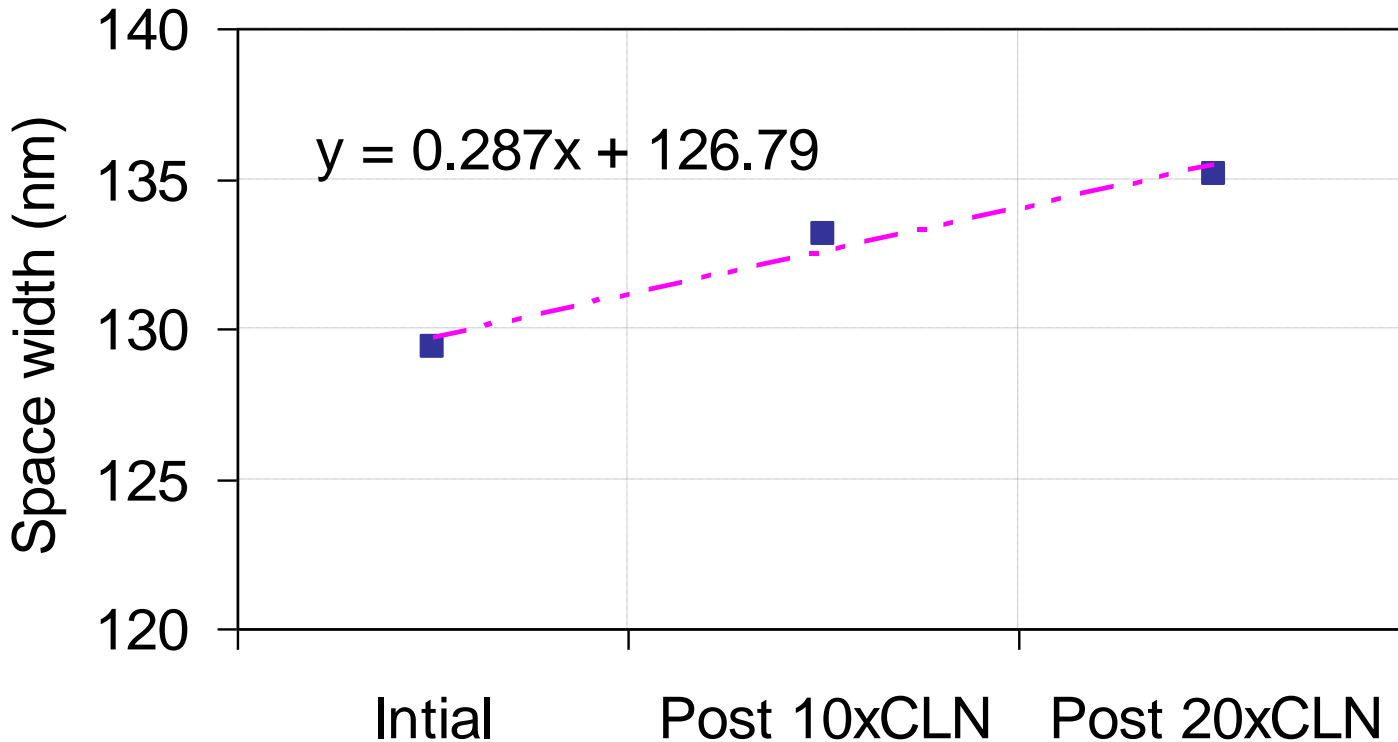
- Damage
 - ARC layer
 - CD change
 - Ru capping layer

ARC damage (Thickness change)



Estimated TaBO damage is 0.25nm /clean

Absorber damage (CD change)

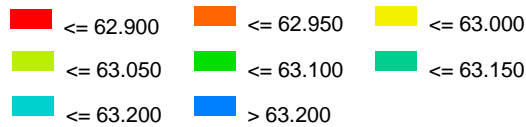
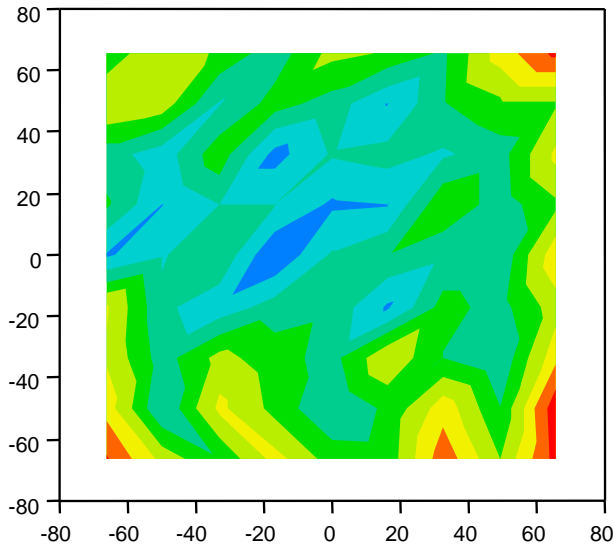


CD change

0.29nm/clean

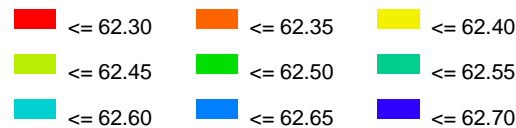
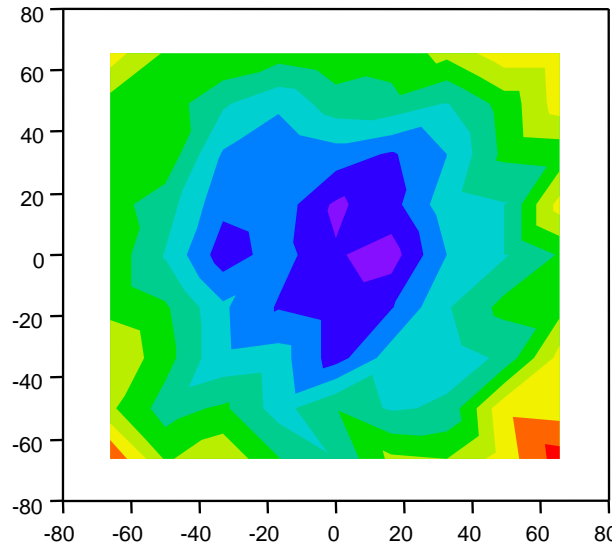
Ru damage (EUVR change)

Initial



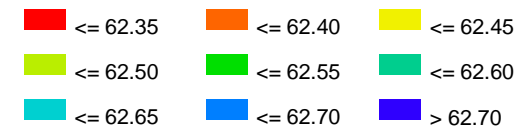
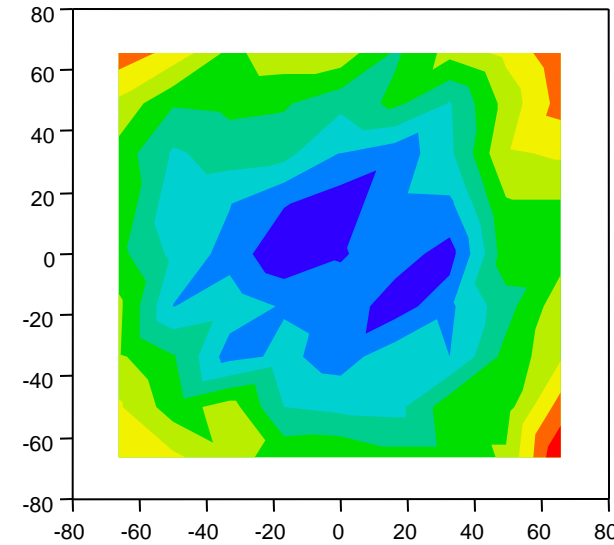
Average 63.08%
Range 0.39%
3sigma 0.25%

After 10 times clean



Average 62.52%
Range 0.45%
3sigma 0.30%

After 20 times clean



Average 62.55%
Range 0.44%
3sigma 0.29%

Summary

	SPM-SC1	DIO3-SC1	New cleaning
PRE (50nm)	99%	NA	Under evaluation
Adders (50nm)	<20	NA	Under evaluation
CD change	0.29nm/clean	NA	<0.1nm/clean
ARC Thickness change	0.25nm/clean	NA	<0.1nm/clean
EUVR change	No change	1.0%/clean*	Under evaluation

Acknowledgements

- Ted Liang in Intel for our collaboration works
- Arun John and Andy Ma in SEMATECH for pits reduction works
- DNP EUV mask team members for their supports