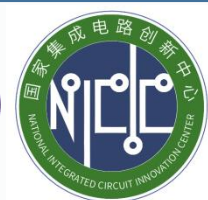

Impact of the Shrink of Photolithographic Design Rules by 10%

光刻设计规则缩小10%对光刻工艺产生的影响

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伍强*，李艳丽*，刘显和，王启
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国家集成电路创新中心

2023年10月

Outline

- A set of generic single exposure design rules under 193 nm immersion lithography
- Basic process conditions and process window performance
- The design rules with 10% shrink
- Process window performances with no process condition change
- An optimized process conditions and improved process window performance
- Conclusions and Outlook

A set of generic single exposure design rules under 193 nm immersion lithography

- 1D: Minimum pitch: 90 nm, Minimum ADI CD: 45 nm with Selective Sizing for larger pitches
- Restricted Design Rule (RDR): None
- Design Orientation: Bi-directional
- 2D: Minimum Tip-to-Tip ADI: 60 nm

*"Chinas integrated circuit development roadmap", National integrated circuit innovation center, 2019.

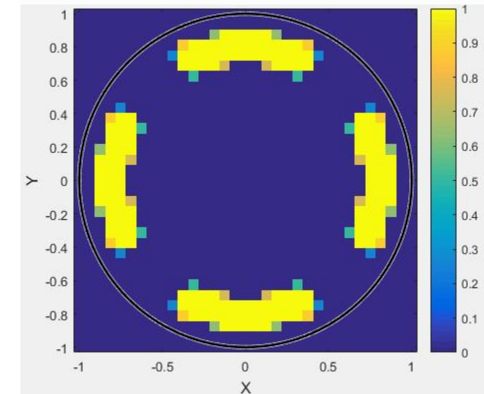
Basic process conditions and process window performance

Here is a list of the simulation conditions:

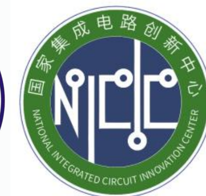
Imaging Conditions:
NA: 1.35NA
Partial Coherence: 0.9-0.7 Cross-Quadrupole 60°
Polarization: X/Y

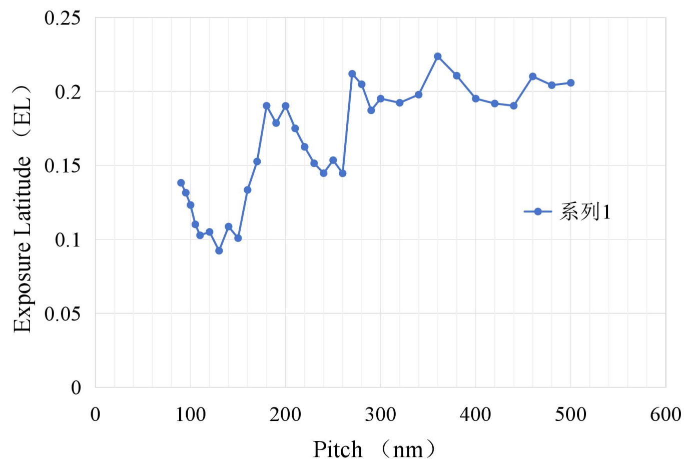
Photoresist:
Developing: Positive Toned Developing (PTD)
Effective Photoacid Diffusion Length: 5 nm
Thickness: 90 nm
n, k: 1.7, 0.02

Photomask:
6% Attenuated Phase Shifting Mask (Att-PSM)

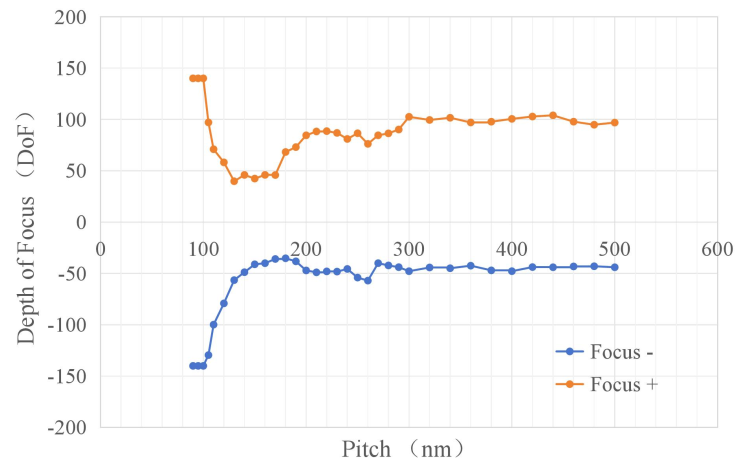


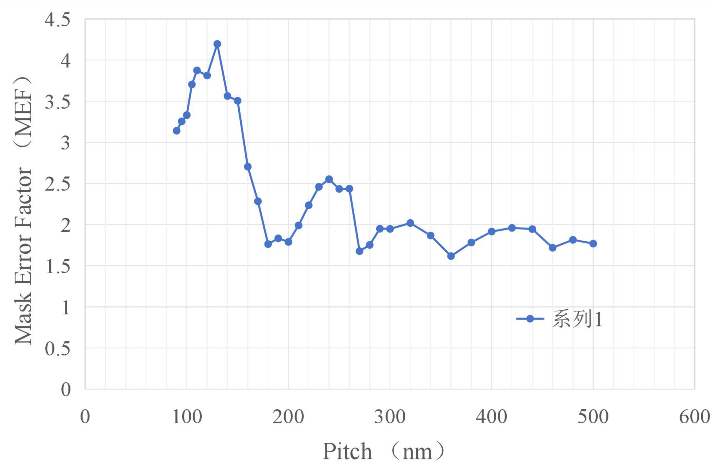
Basic process conditions and process window performance

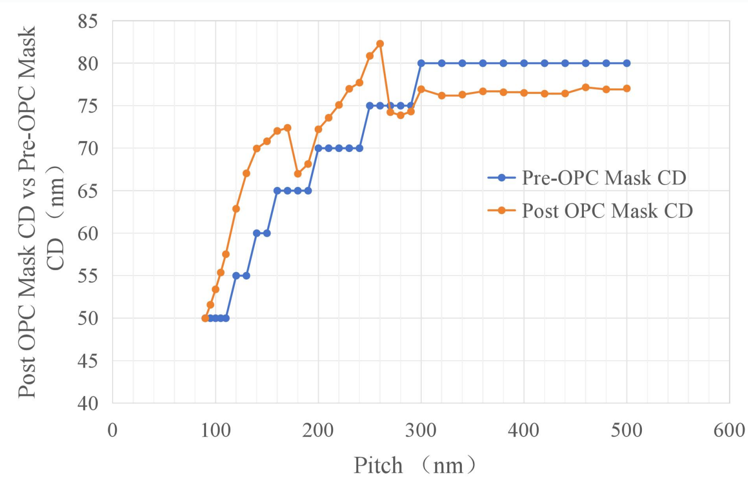




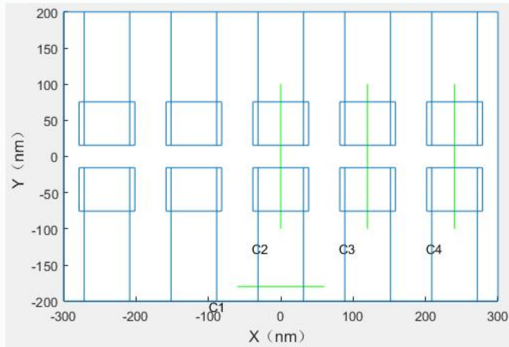
common DoF = 75 nm

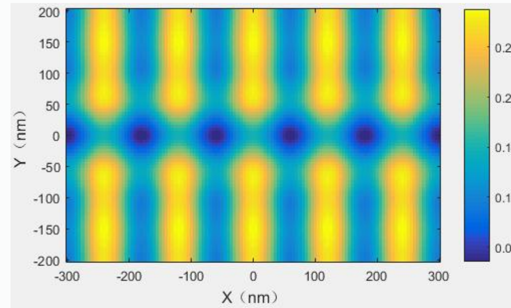


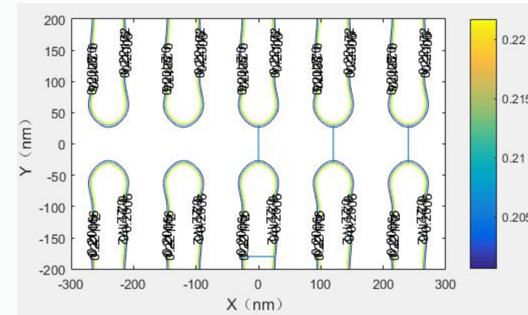




Basic process conditions and process window performance

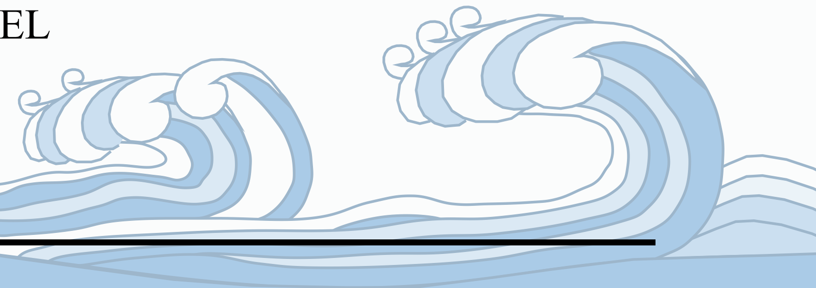






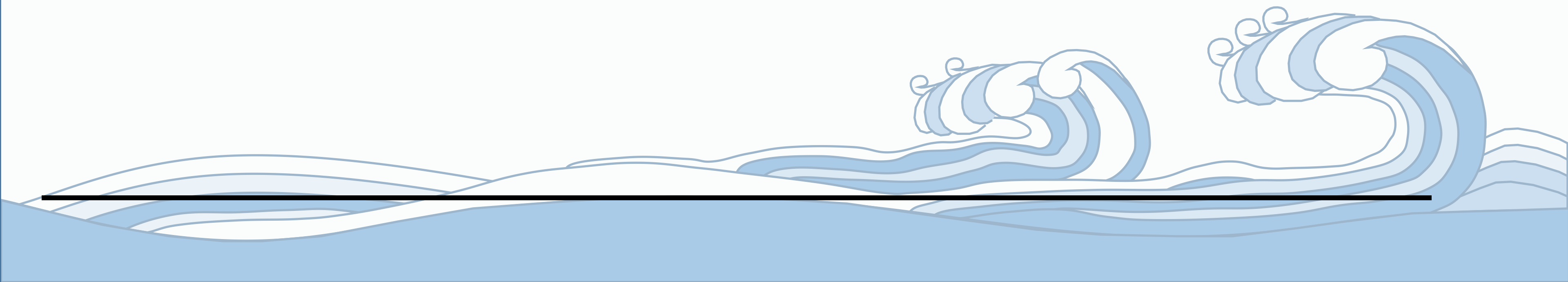
	CD	EL
Cut-1	50.0000	0.1068
Cut-2	59.8168	0.0926
Cut-3	59.8168	0.0926
Cut-4	59.8351	0.0926
Slice	0.2112	0

- Minimum Tip-toTip ADI CD is around 60 nm with an EL around 10%

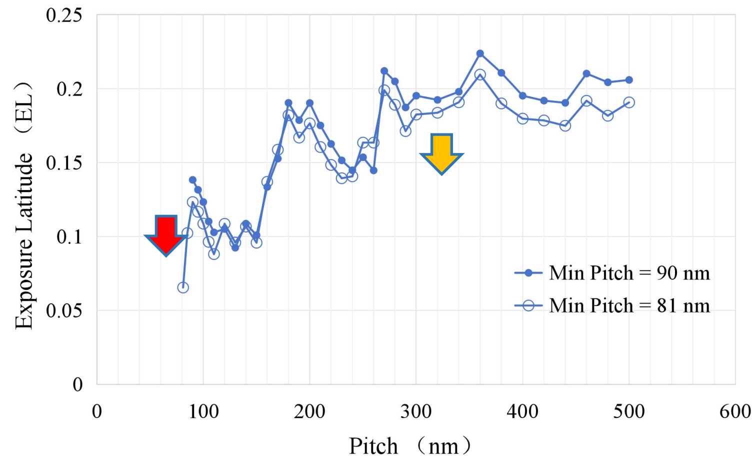


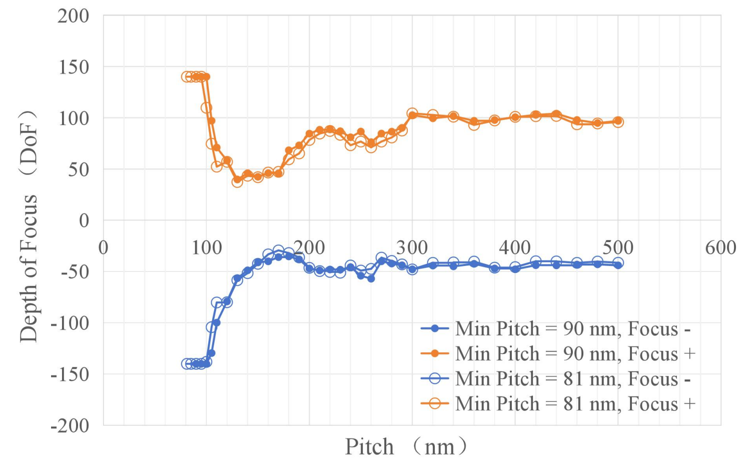
The design rules with 10% shrink

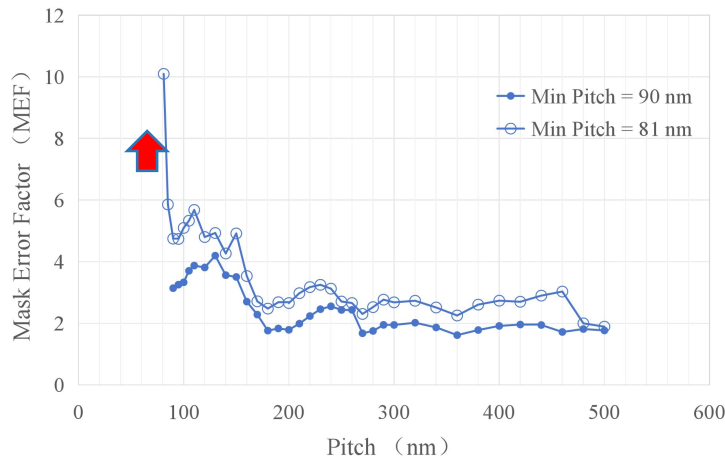
- 1D: Minimum pitch: 81 nm, Minimum ADI CD: 42 nm with Selective Sizing for larger pitches
- Restricted Design Rule (RDR): None
- Design Orientation: Uni-directional ?
- 2D: Minimum Tip-to-Tip ADI: ?

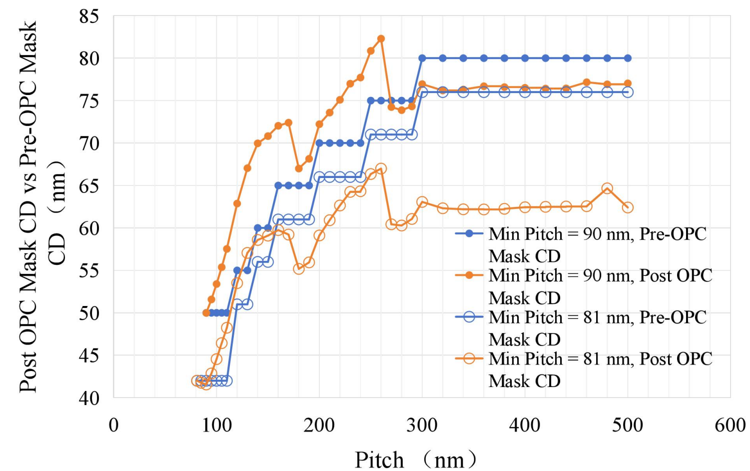


Process window performances with no process condition change



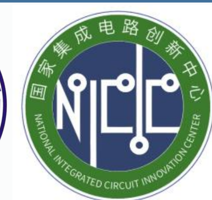


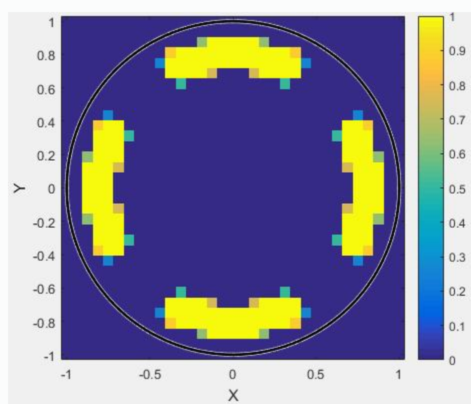


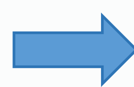


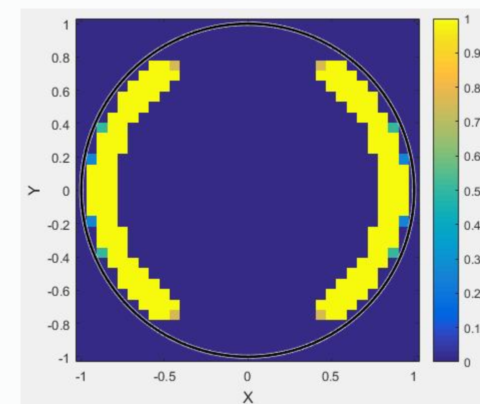
- If the exposure condition does not change, EL around the minimum pitches drops drastically and MEF sharply increases

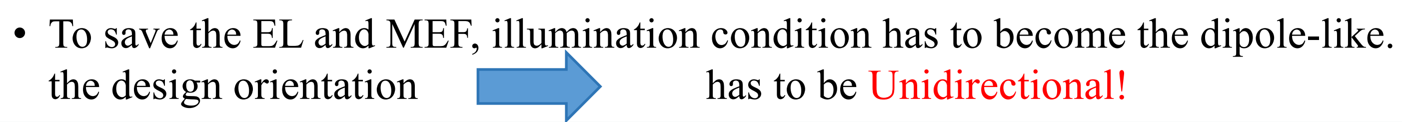
An optimized process conditions and improved process window performance



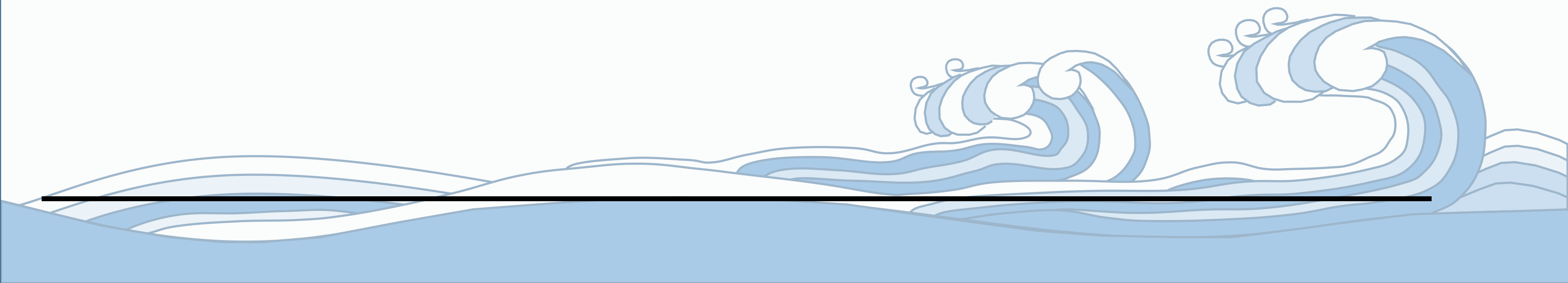




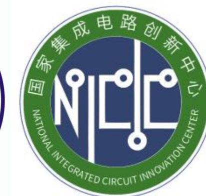




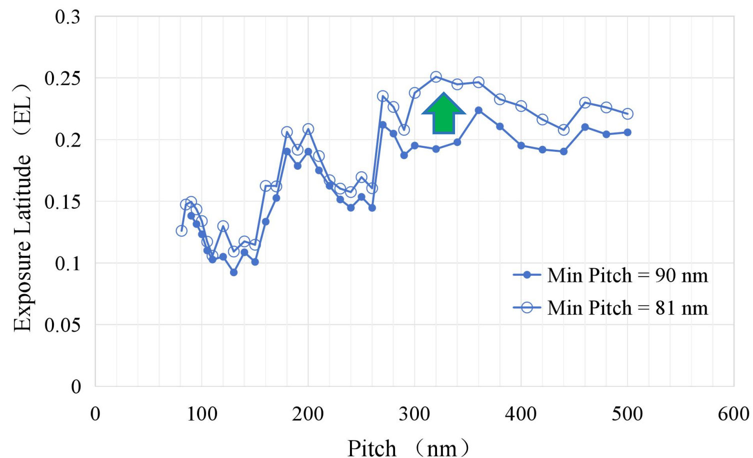
- To save the EL and MEF, illumination condition has to become the dipole-like. the design orientation ➡ has to be Unidirectional!

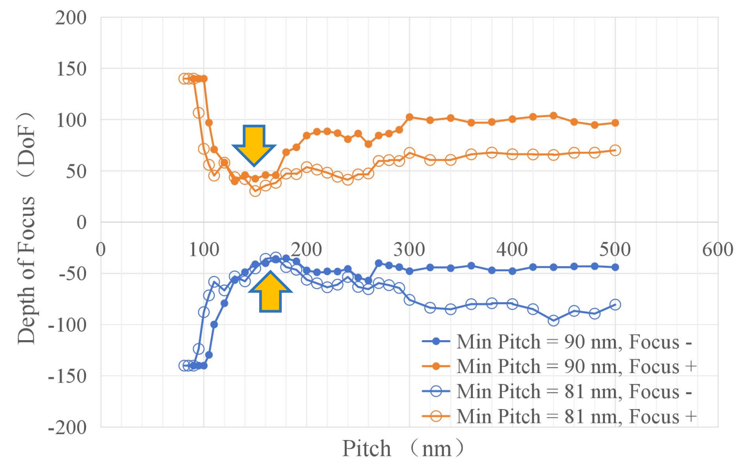


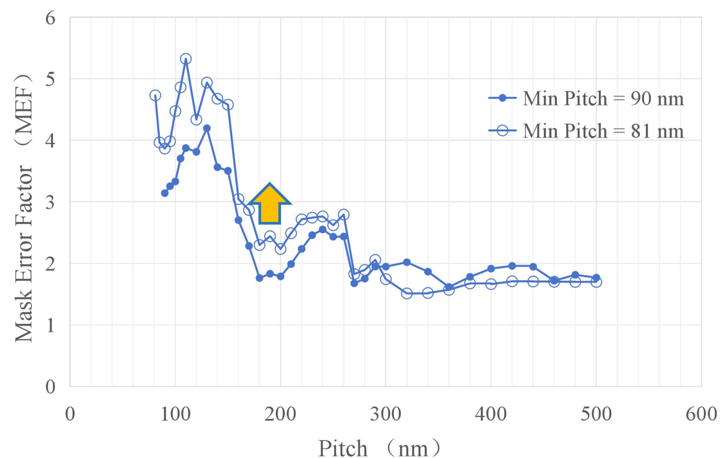
An optimized process conditions and improved process window performance

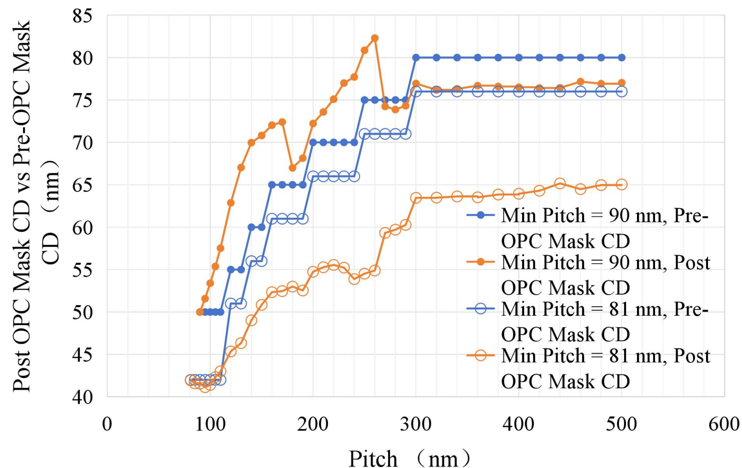


common DoF = 75 nm (P90), 64.8 nm (P81)

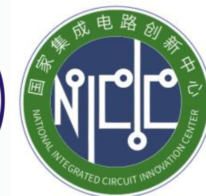




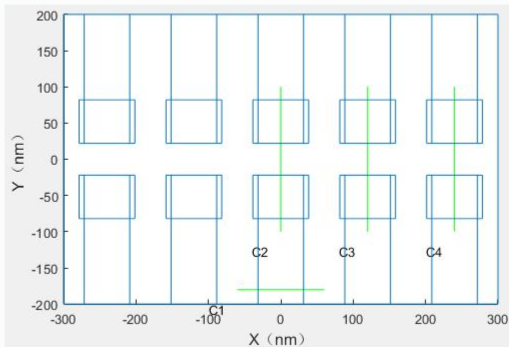


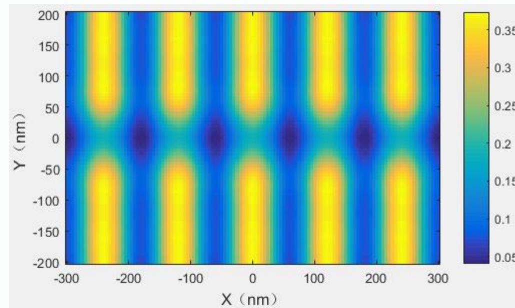


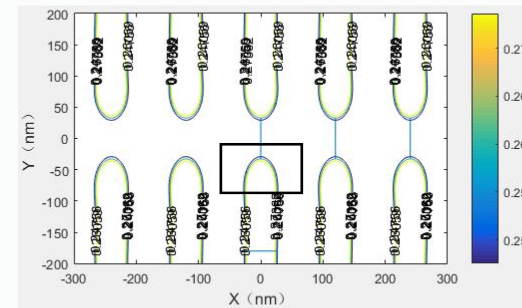
- with dipole-like illumination, the EL and MEF is much improved.
- EL now is acceptable, but MEF is still high.



An optimized process conditions and improved process window performance







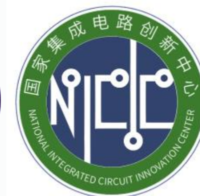
	CD	EL
Cut-1	50.0000	0.1430
Cut-2	65.0674	0.0926
Cut-3	65.0674	0.0926
Cut-4	65.0701	0.0926
Slice	0.2606	0

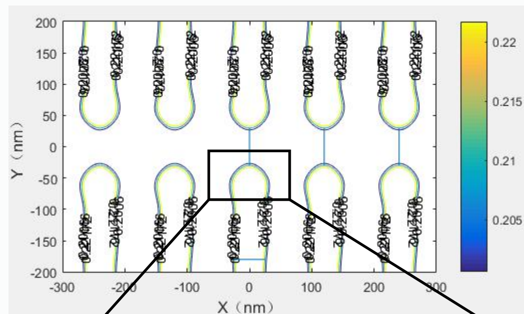
original result for comparison

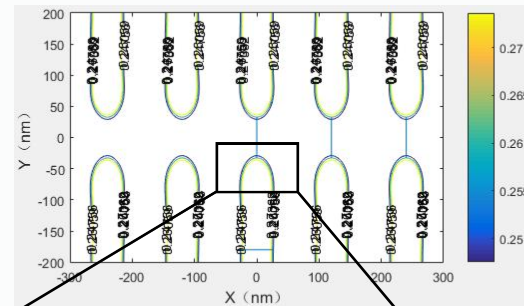
	CD	EL
Cut-1	50.0000	0.1068
Cut-2	59.8168	0.0926
Cut-3	59.8168	0.0926
Cut-4	59.8351	0.0926
Slice	0.2112	0

- Minimum Tip-toTip ADI CD is around 65 nm with an EL around 10%. Just 5 nm more? Oh, No! it may be more → After Etch, the AEI Tip-toTip may become much larger than that of P90.

An optimized process conditions and improved process window performance



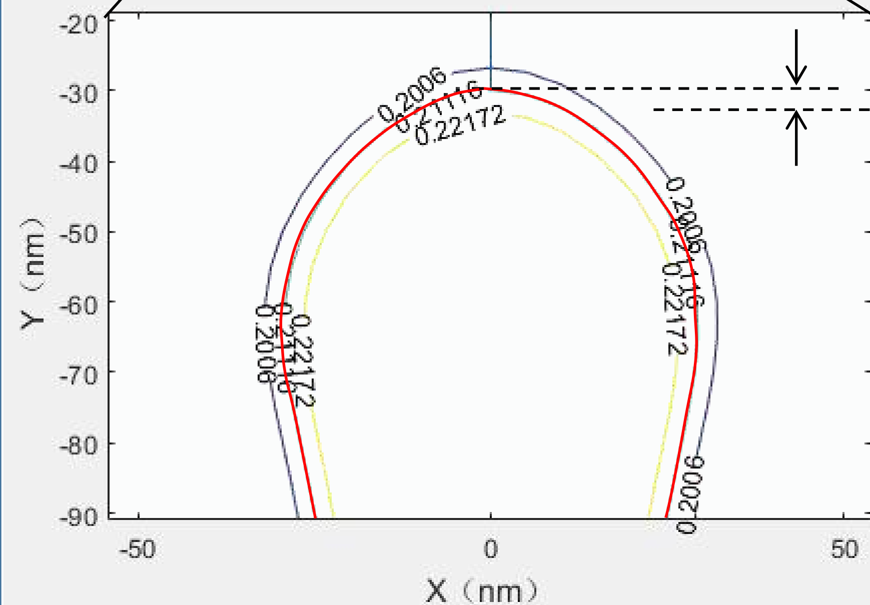


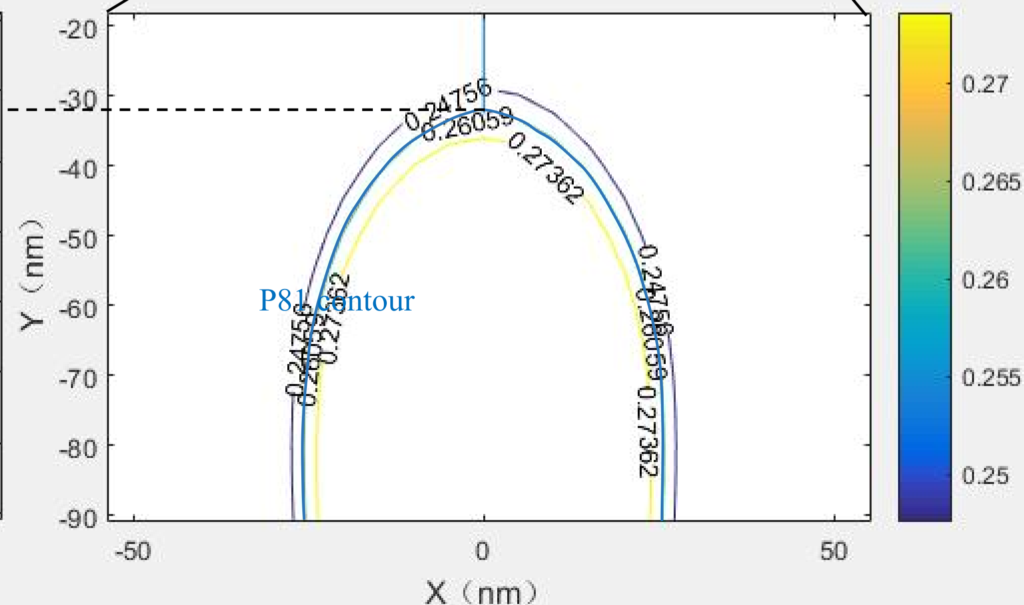


P90 contour

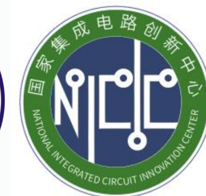
2.5 nm
(/edge)

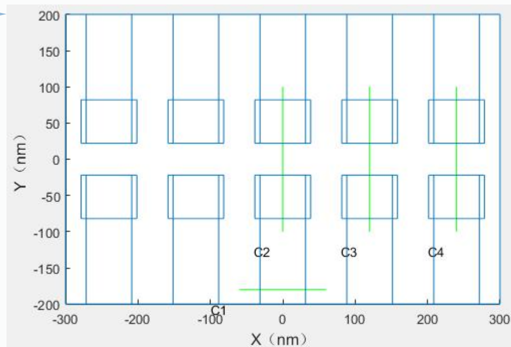
P81 contour

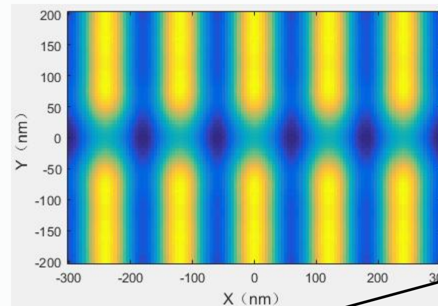


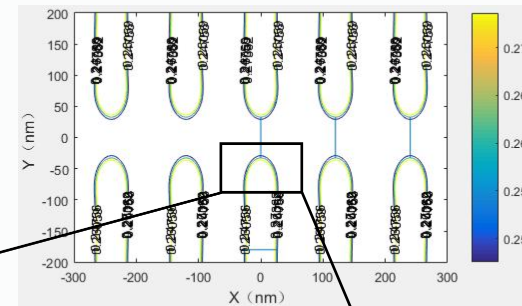


An optimized process conditions and improved process window performance

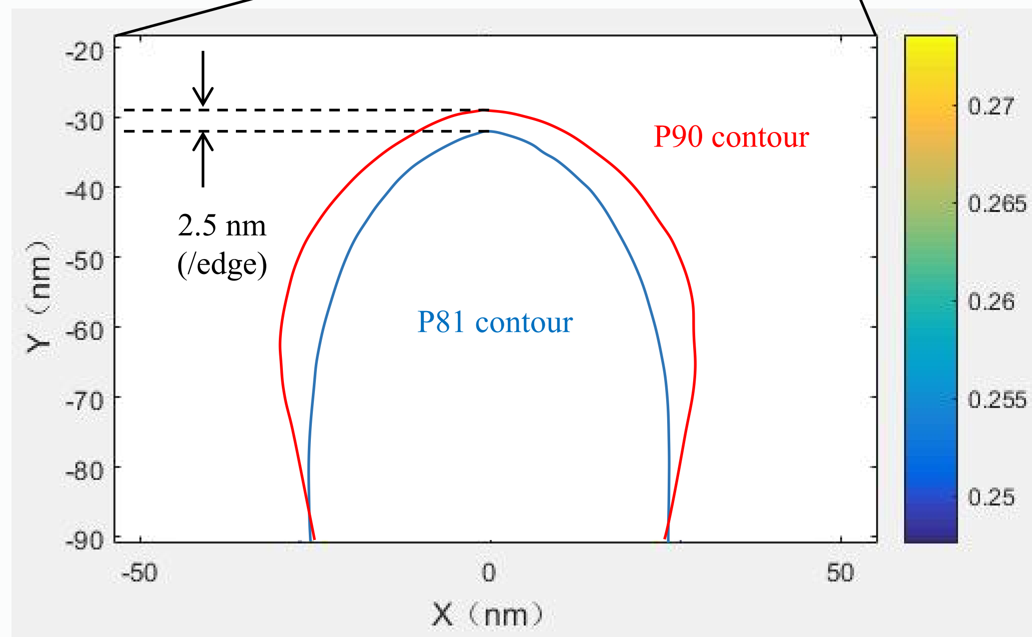






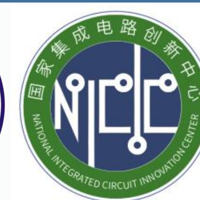


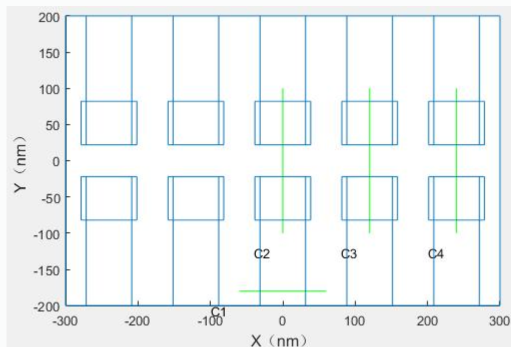
	CD	EL
Cut-1	50.0000	0.1430
Cut-2	65.0674	0.0926
Cut-3	65.0674	0.0926
Cut-4	65.0701	0.0926
Slice	0.2606	0

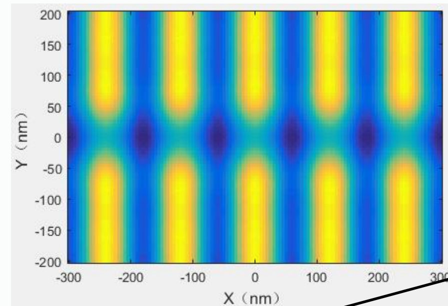


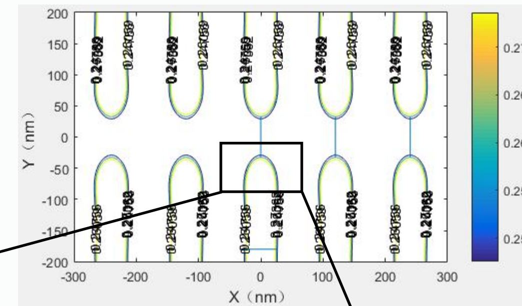
- With dipole-like illumination, the line end becomes more pointy, which will cause bigger etch bias!

An optimized process conditions and improved process window performance

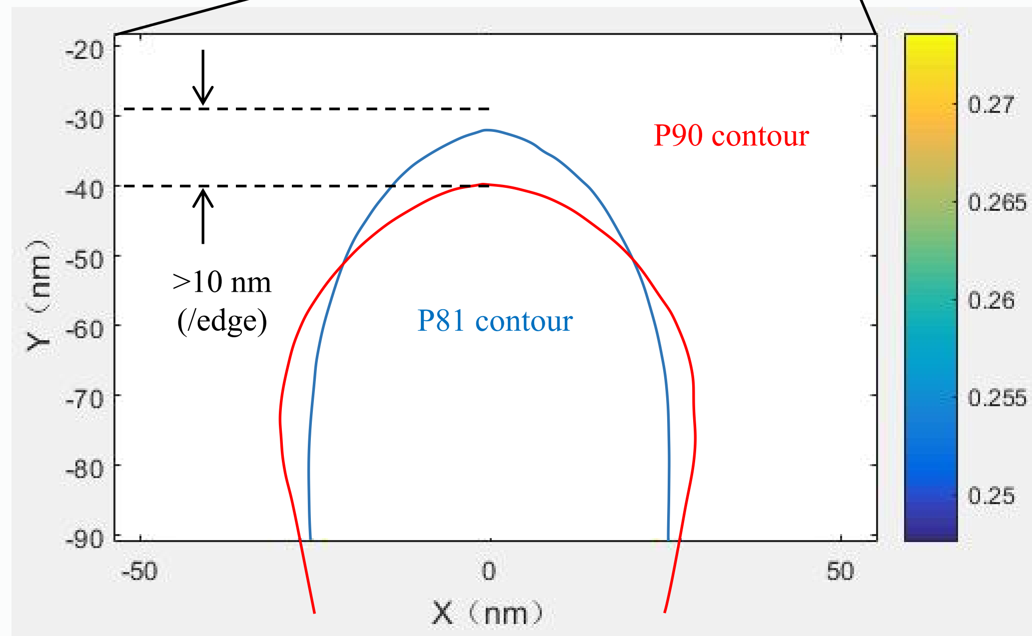








- Minimum Tip-toTip ADI CD is around 65 nm with an EL around 10%.
- But, After Etch, the AEI Tip-toTip may become much larger than that of P90.
- The AEI equivalent Tip-to-Tip may be 10 nm/edge, or 20 nm larger!



Conclusions and Outlook

- We have done a study of the lithographic process window change if the design rule with a minimum pitch of 90 nm shrinks by about 10%.

- The conclusion is that with the adjustment of lithographic conditions, we can achieve the same EL at the minimum pitch but
  - with a significantly higher MEF(25~50% increase)
  - a 10 nm shrink of DoF from an original 75 nm (13% reduction).
  - In 2D, an 5 nm increase in Tip-to-Tip distance from an original 60 nm (8.3% increase), and may be much higher after etch due to shape becoming “sharper”, which can be 20 nm increase, or a 33% increase!

- if the minimum pitch becomes significantly smaller than 90 nm, the design rule may need to be Unidirectional.

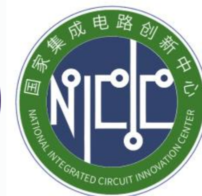
- A shrink of the design rule by 10% along one direction may result in the design rule relaxation along the perpendicular direction due to the Tip-to-Tip distance increase and higher challenge in CDU due a big MEF increase and significant DoF reduction.

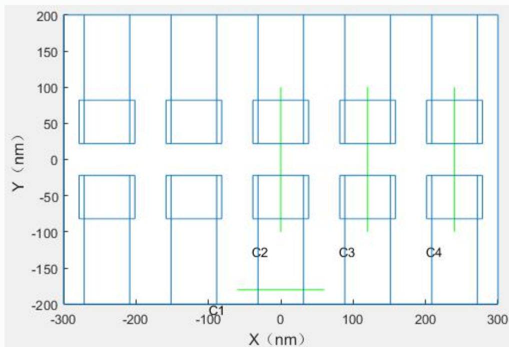
Thank You！

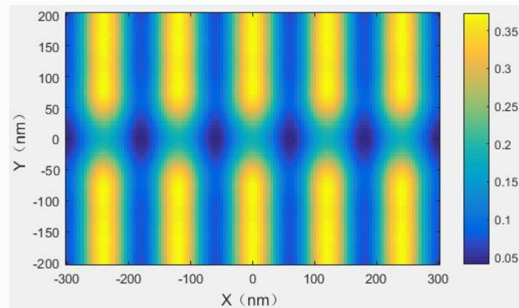
谢谢！

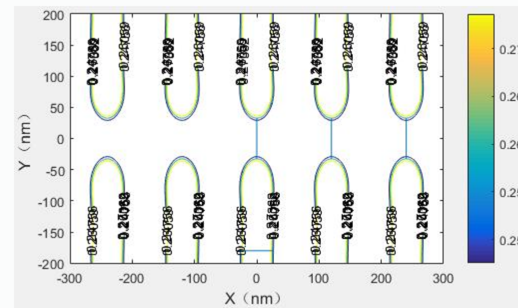
我们的目标是星辰大海，诗和远方。。。。。。

An optimized process conditions and improved process window performance









	CD	EL
Cut-1	50.0000	0.1
Cut-2	65.0674	0.0
Cut-3	65.0674	0.0
Cut-4	65.0701	0.0
Slice	0.2606