EUV Lithography Simulation for the 16 nm Node

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Outline

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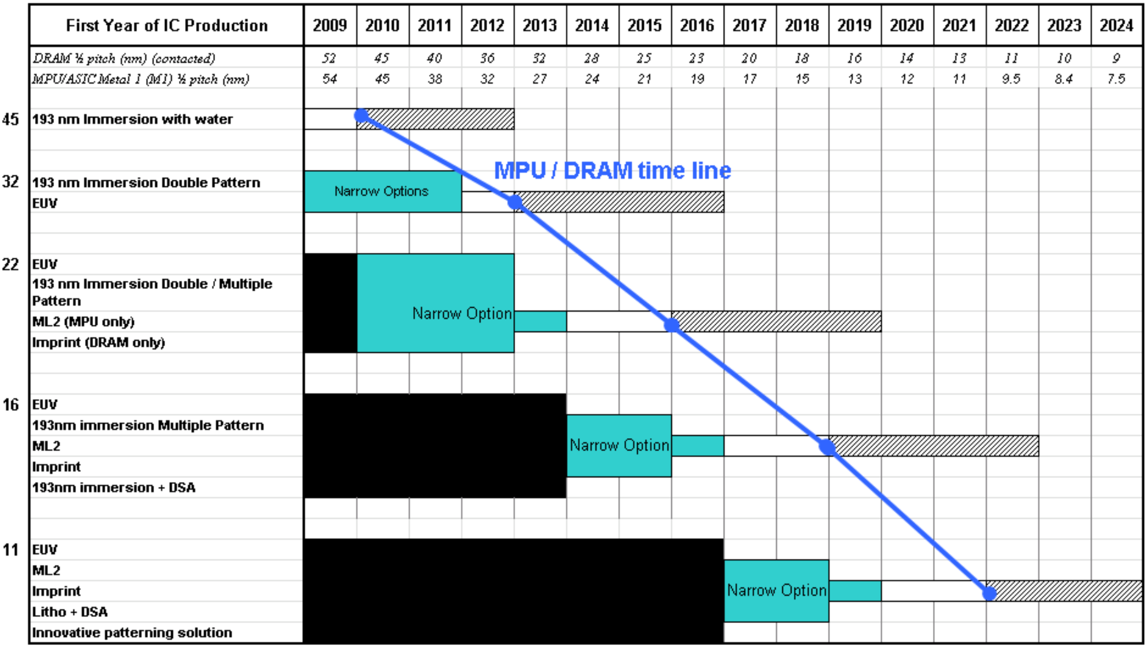
Motivation

- Over the years, extreme ultra-violet lithography (EUVL) has made a lot of progress.
- EUV is believed to be #1 candidate for the patterning of 22 nm node and below.
- Strong OAI with higher 8° oblique incidence might be needed on 16 nm node.

→ More shadow effect.



First Year of IC Production	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
DRAM ½ pitch (nm) (contacted)	52	45	40	36	32	28	25	23	20	18	16	14	13	11	10	9
MPU/ASIC Metal 1 (M1) ½ pitch (nm)	54	45	38	32	27	24	21	19	17	15	13	12	11	9.5	8.4	7.5

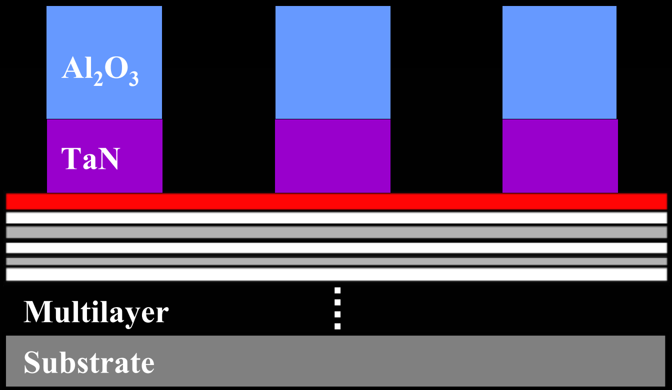
2010 International Technology Roadmap for Semiconductors (ITRS)

- This shadow effect will decrease the contrast of the aerial image, and resulting worse line width control.
- We studied some critical parameters that could determine the EUV process for 16 nm node with 22 nm node comparison .

Simulation Condition

❖ Exposure Condition

Exposure	Varied
Wavelength (nm)	13.5 nm
NA	0.25 (22 nm), 0.32 (16 nm)
Reduction	4 X
Incident angle	5°, 6°, 7°, 8°



❖ Material Condition

	Material	Thickness (nm)	*n*	*k*
Multilayer (Mo/Si)	Silicon	4.1	0.999	0.00183
	Mo	2.8	0.92388	0.00643
Capping Layer	Ru	1.8	0.88635	0.30171
Absorber	TaN	27.2	0.92599	0.04363
	Al_2O_3	20	0.96788	0.03899

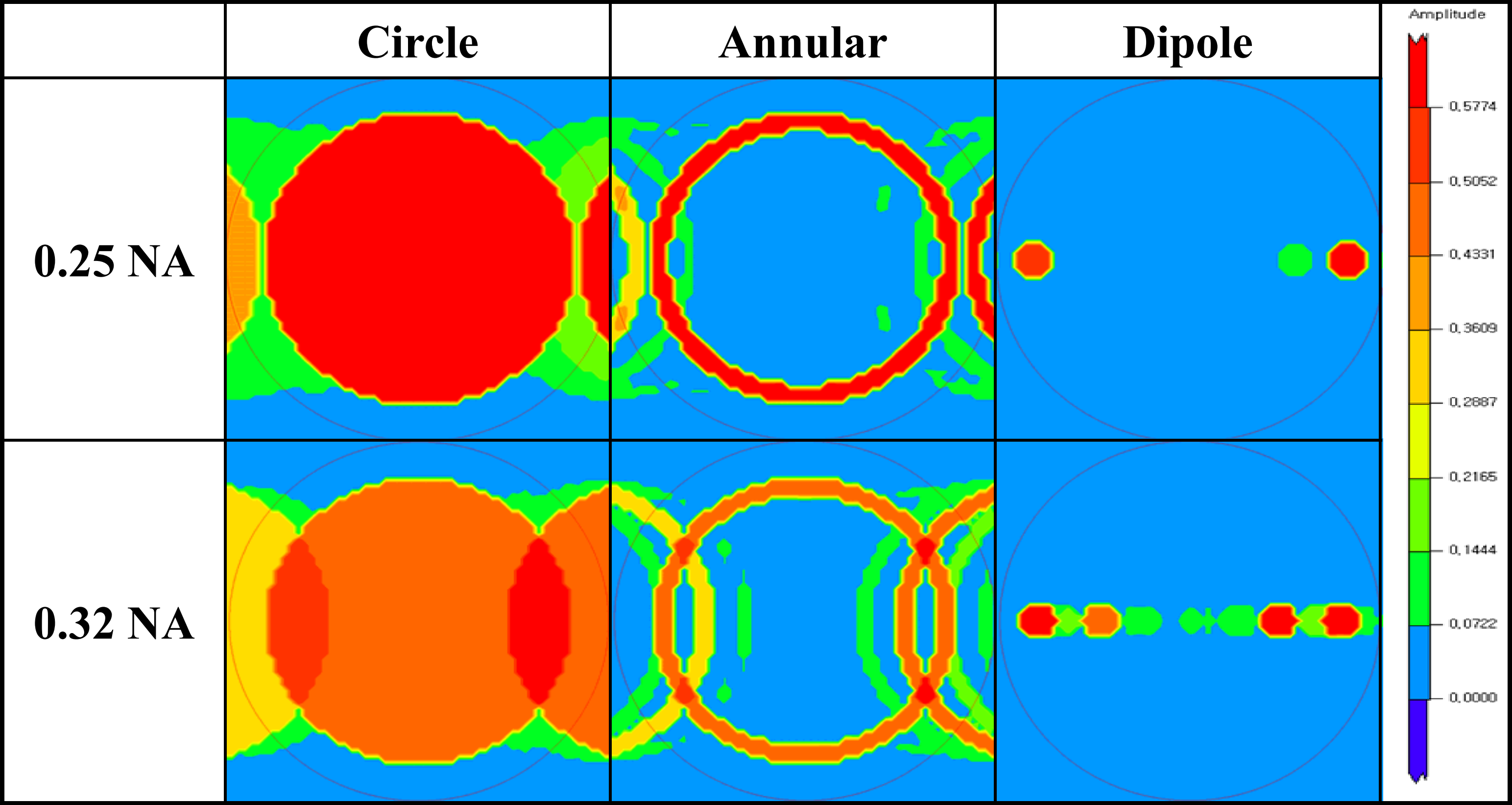
	Refractive Index	Dill A (1/μm)	Dill B (1/μm)	Dill C (cm^2/mJ)
EUV-2D	0.9765	0	5.1851	0.195

Simulation Results

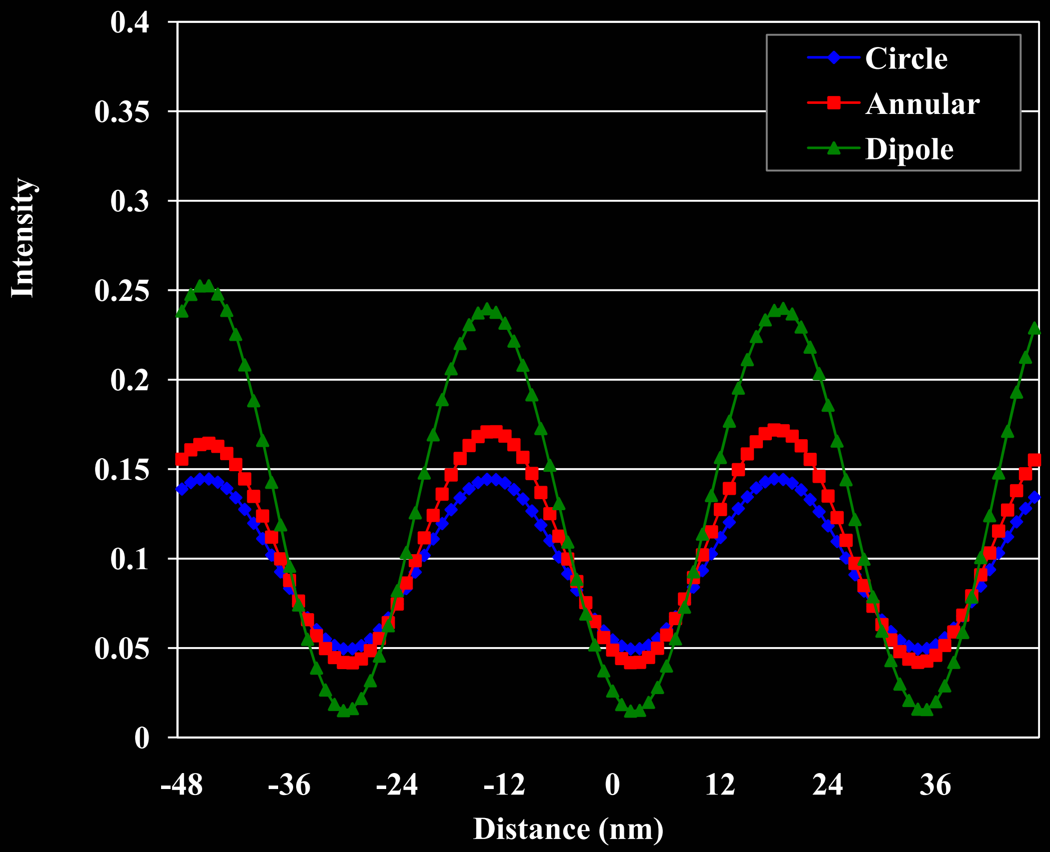
Illumination Condition

Amplitude distribution at pupil plane for 16 nm patterns

($\sigma = 0.8$)

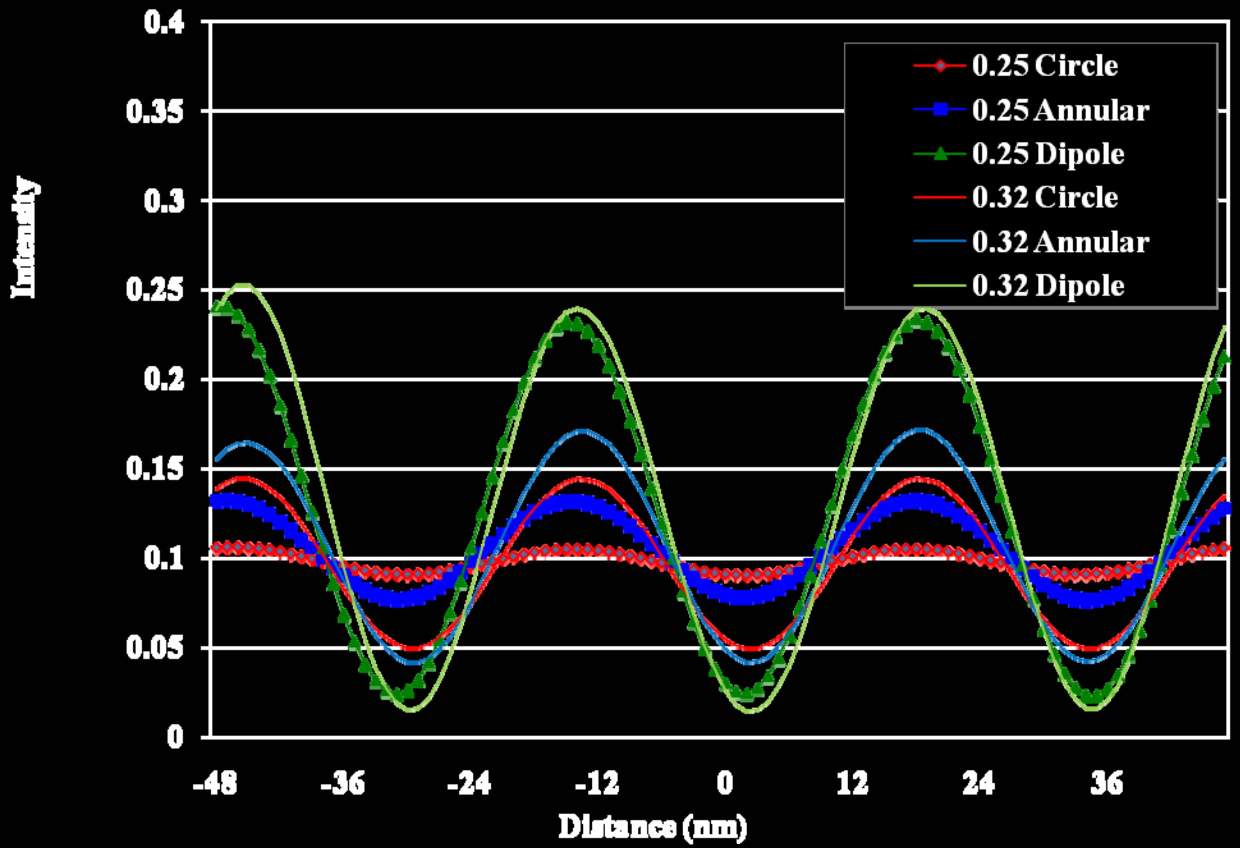


16 nm aerial images for different illuminations

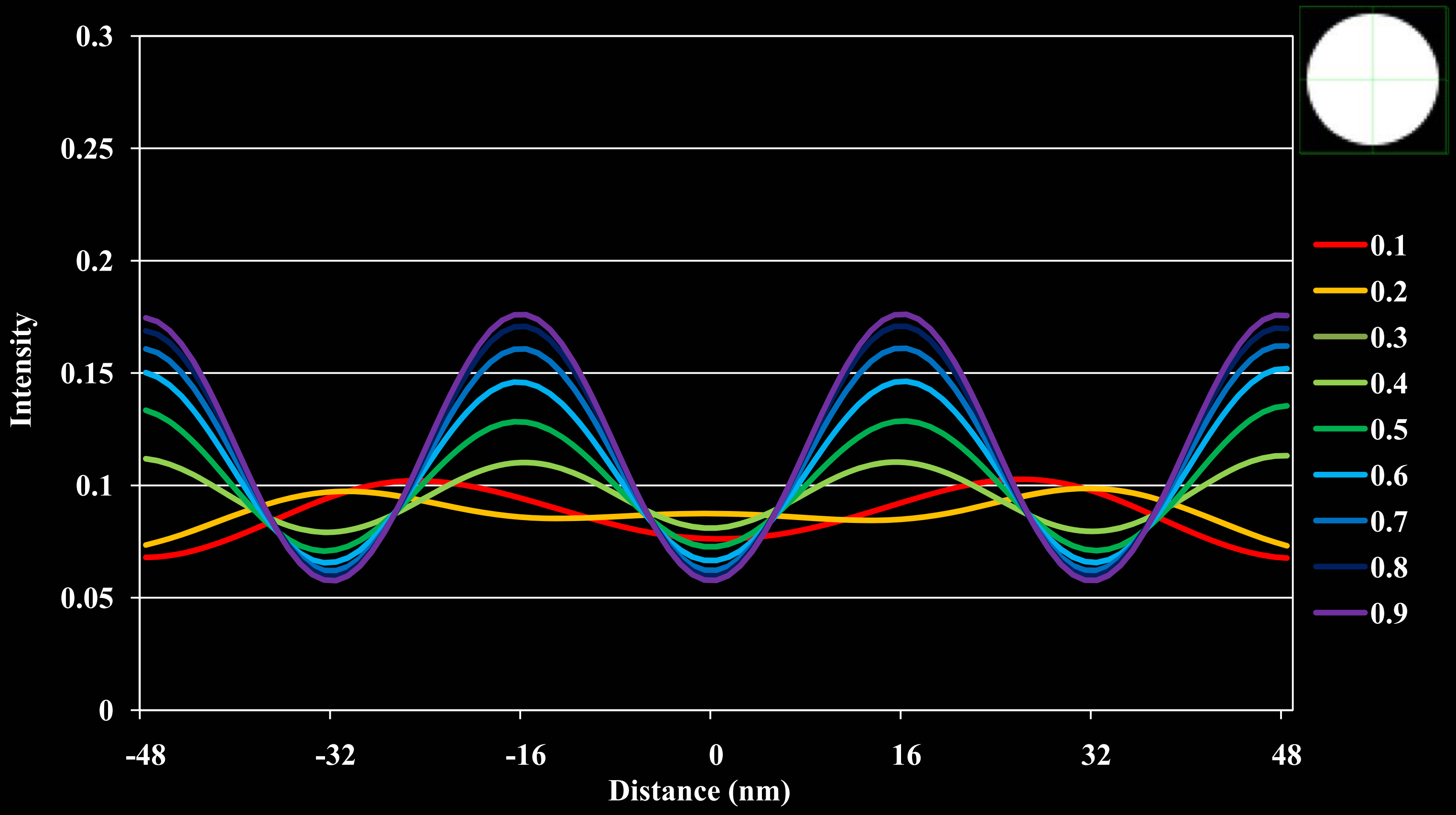


16 nm aerial images for different NA

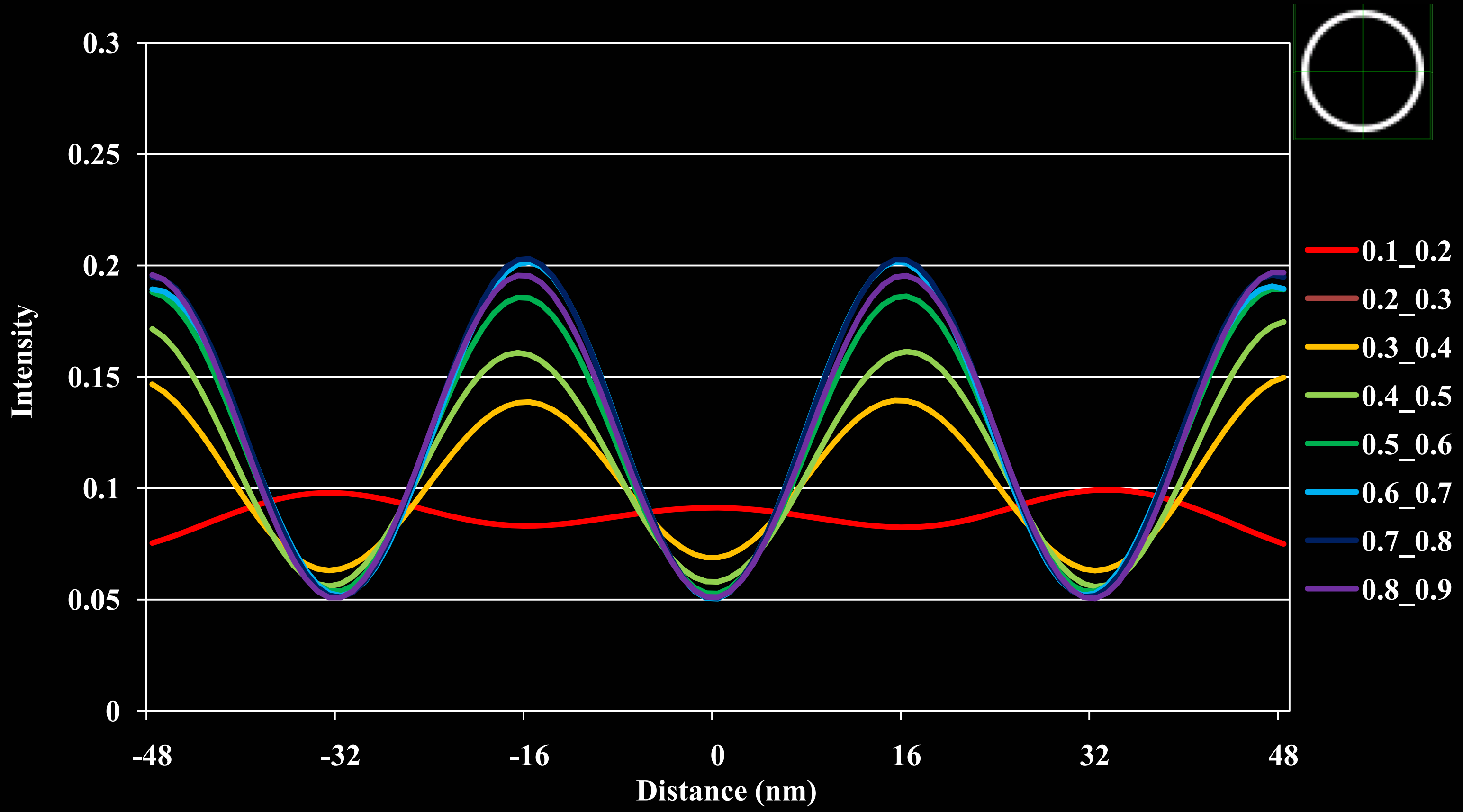
(Various illumination with same 0.8 σ)



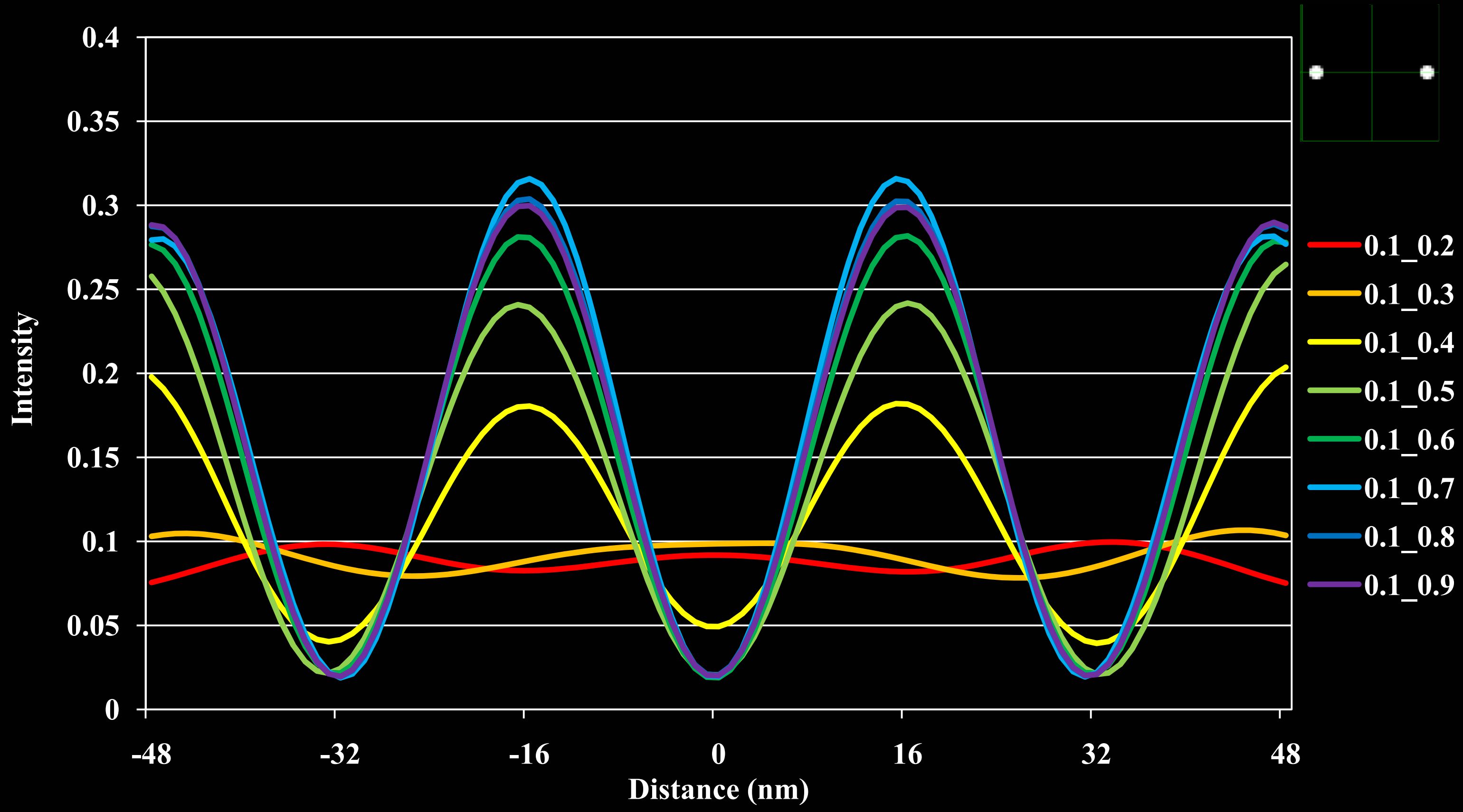
On-axis σ on 16 nm patterns



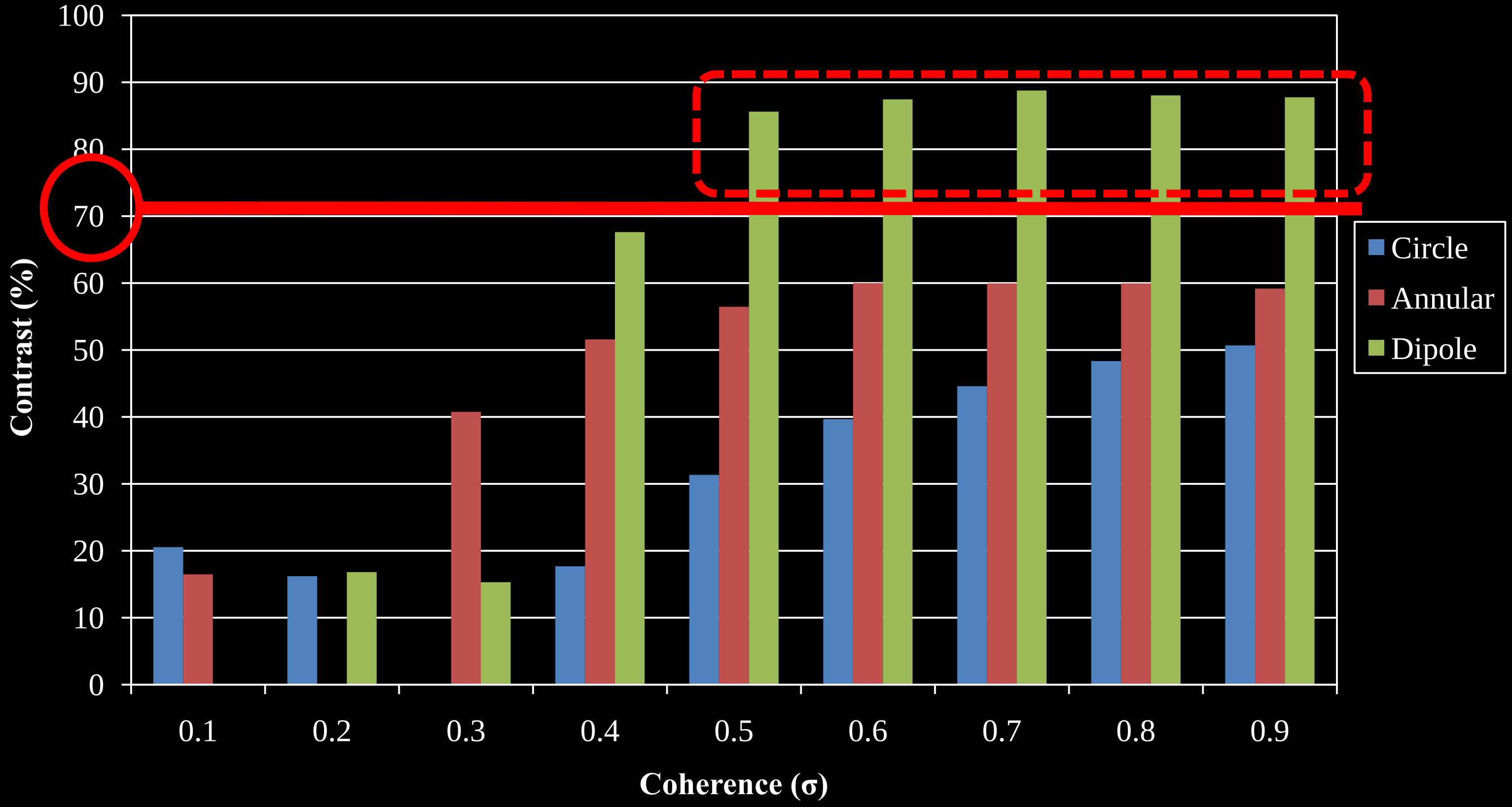
Annular illumination on 16 nm patterns



Dipole illumination on 16 nm patterns

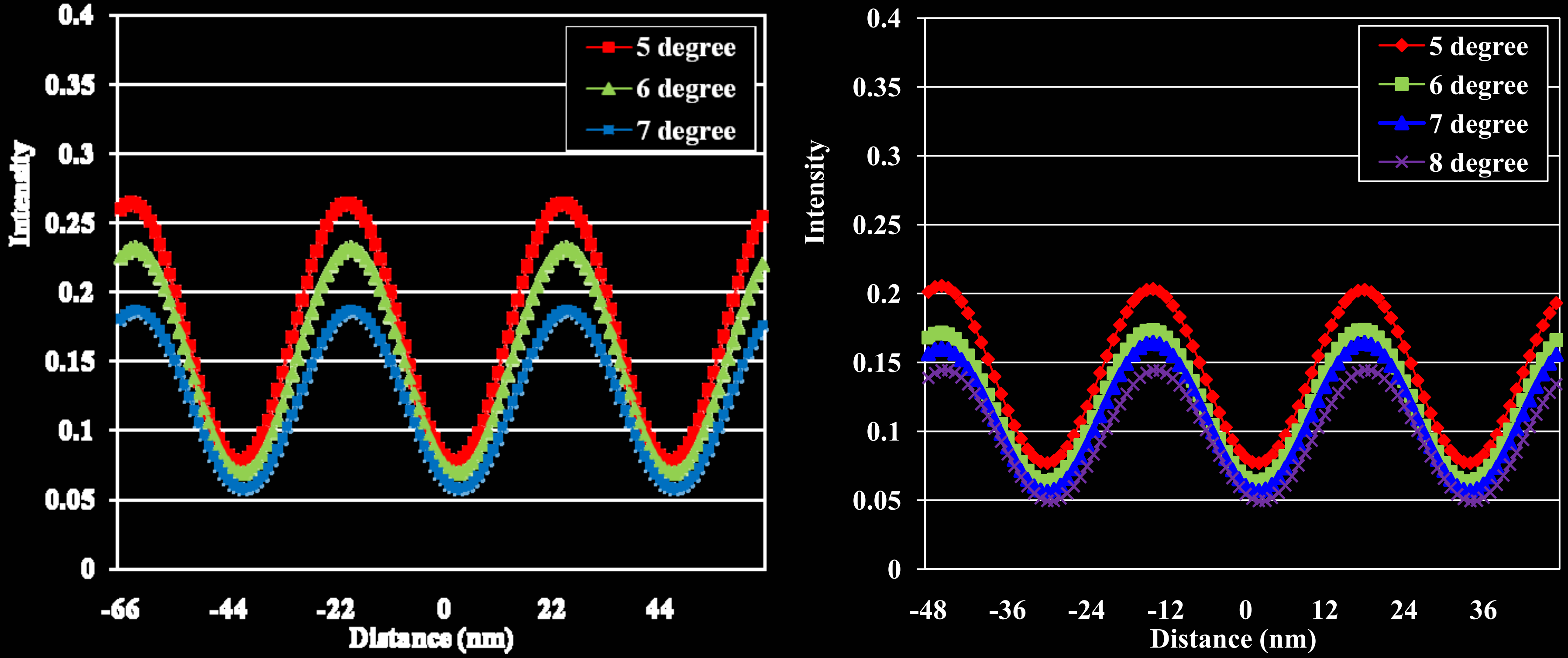


Contrast with different illumination on 16 nm pattern



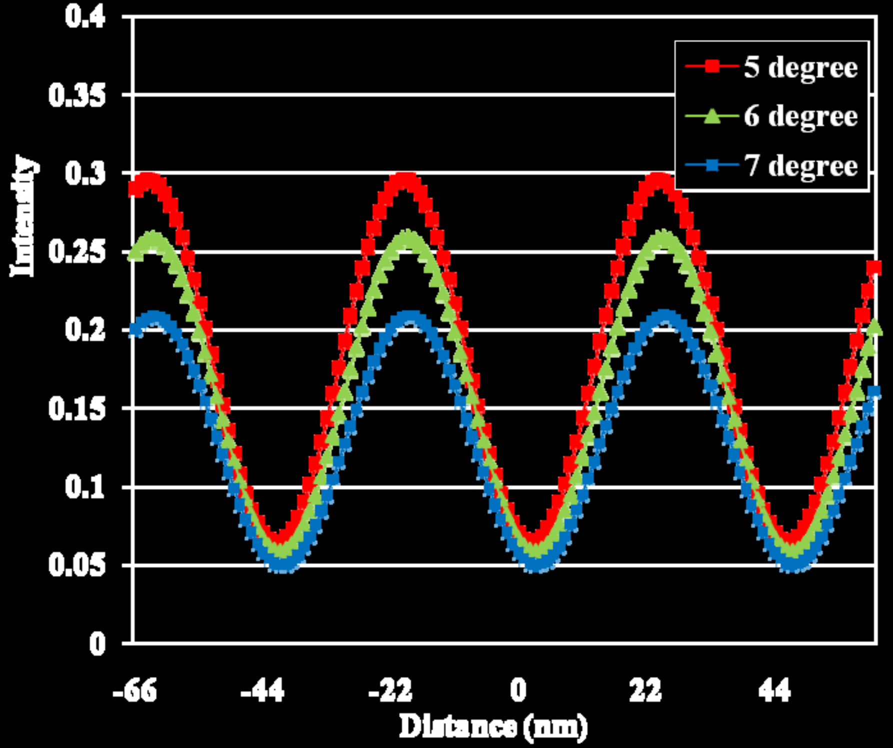
Incident Angle

Influence of incident angle for circular illumination

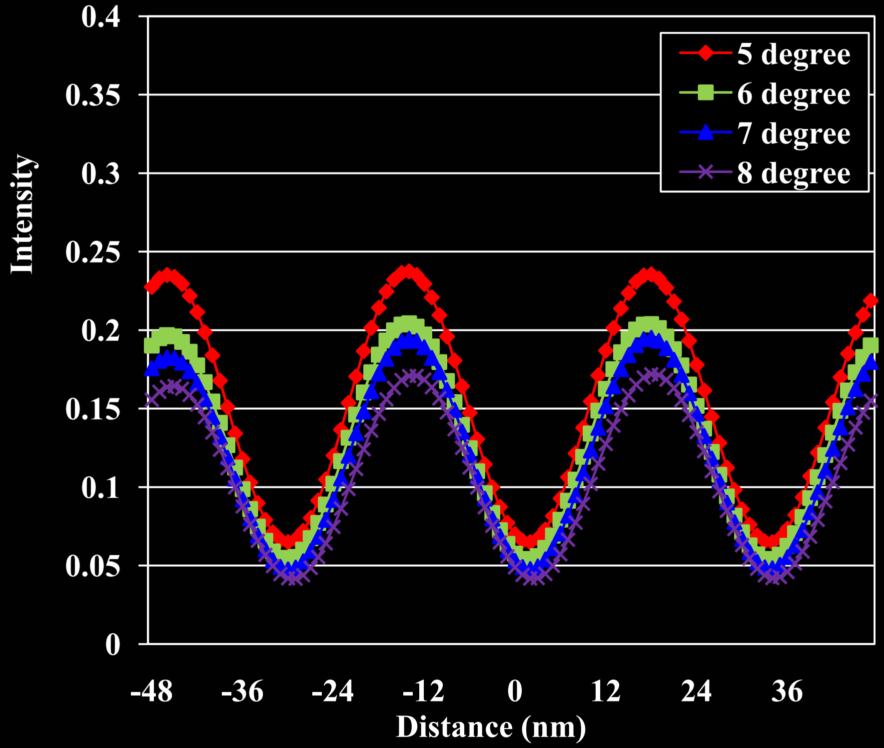

(a) 22 nm node

(b) 16 nm node

Influence of incident angle for annular illumination

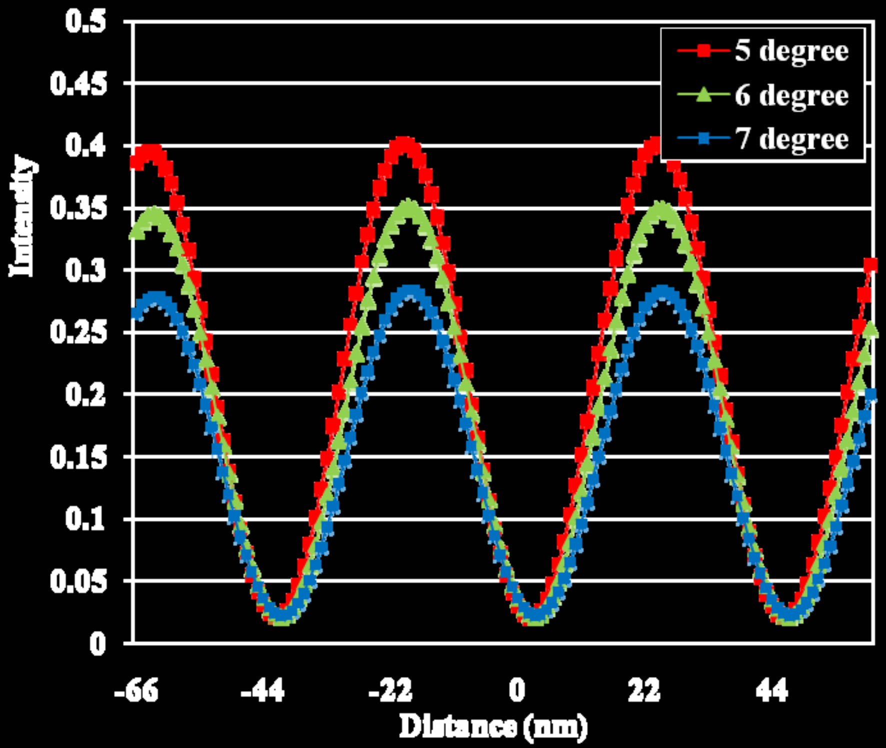


(a) 22 nm node

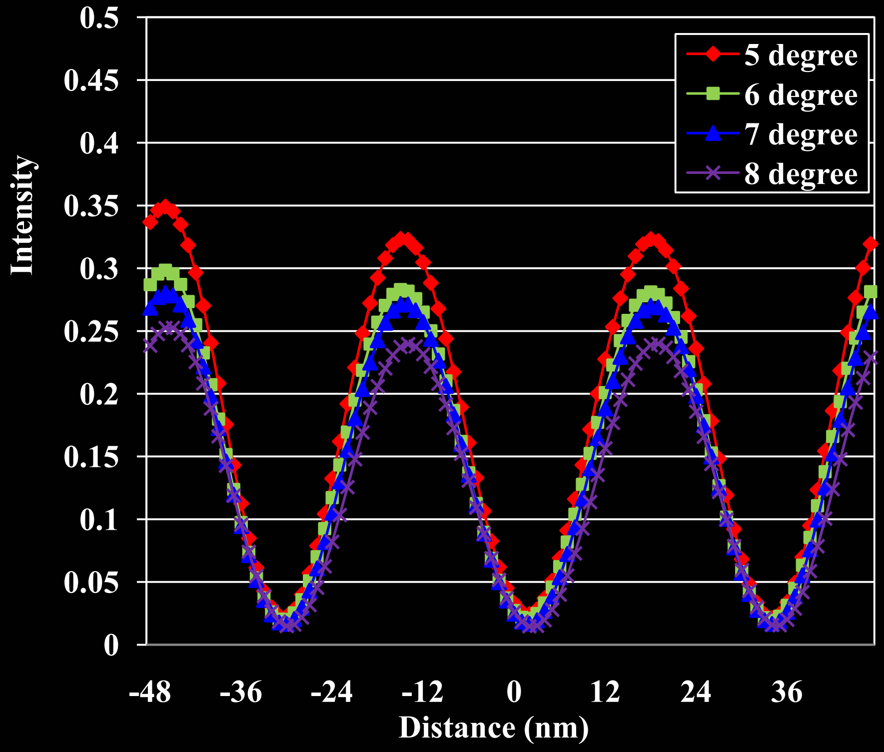


(b) 16 nm node

Influence of incident angle for dipole illumination



(a) 22 nm node

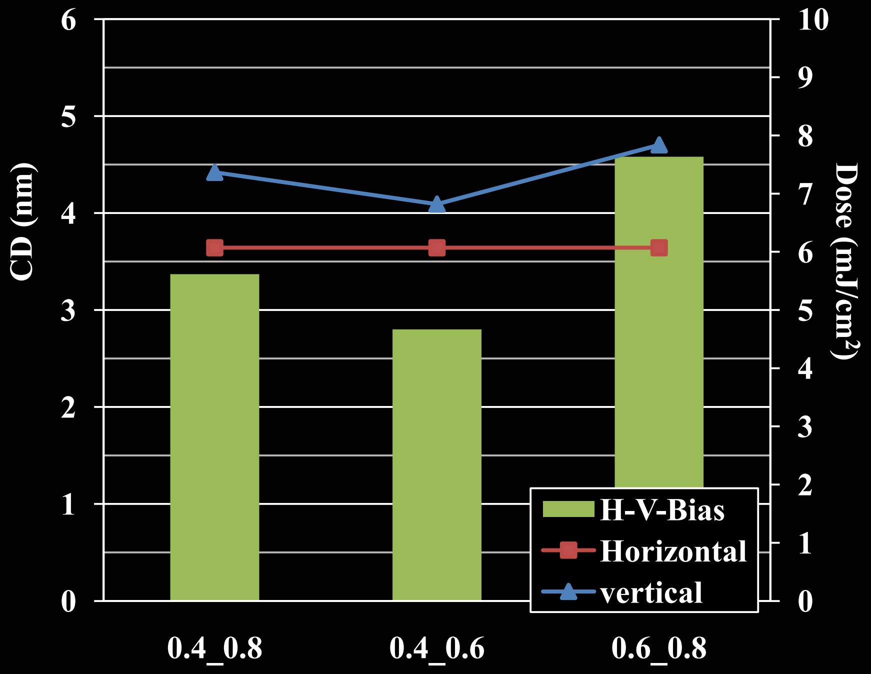


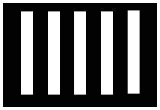
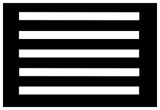
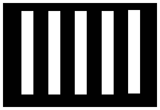
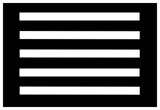
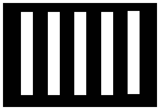
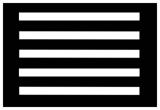
(b) 16 nm node

Shadow Effect

Horizontal-Vertical CD bias for annular illumination

< 22 nm pattern >

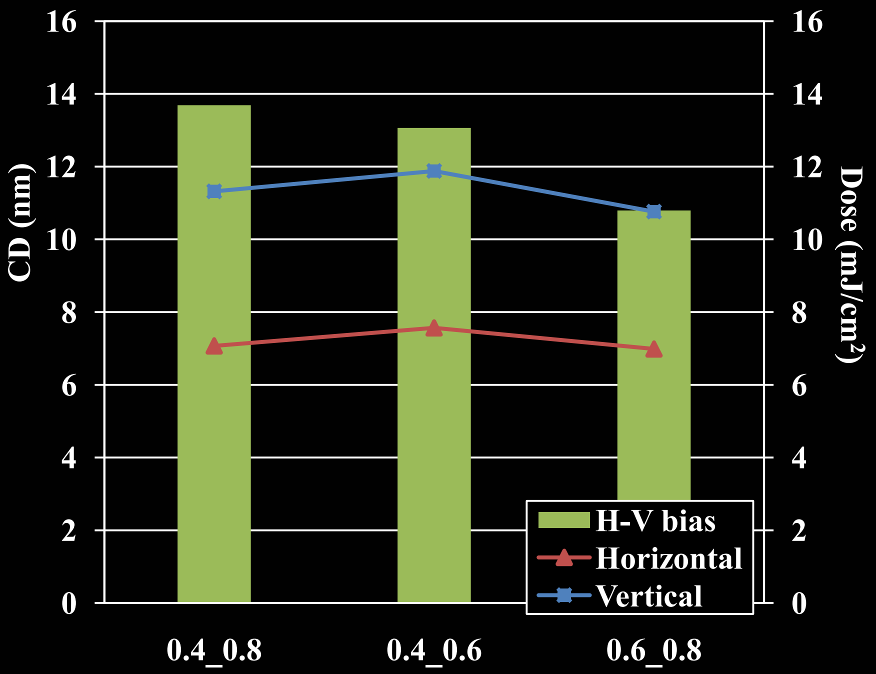


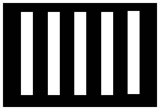
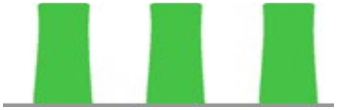
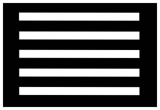
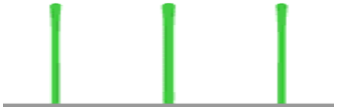
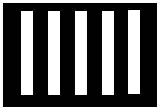
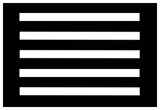
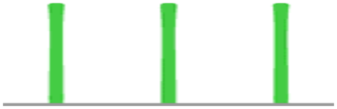
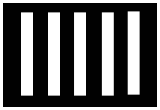
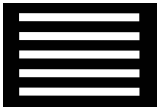
Coherence (σ)	Pattern shape	Resist profile	CD(nm)
0.4_0.8			21.90
			18.53
0.4_0.6			19.87
			17.07
0.6_0.8			24.46
			19.88

- Horizontal-vertical (H-V) critical dimension (CD) difference with different annular illumination

Horizontal-Vertical CD bias for annular illumination

< 16 nm pattern >

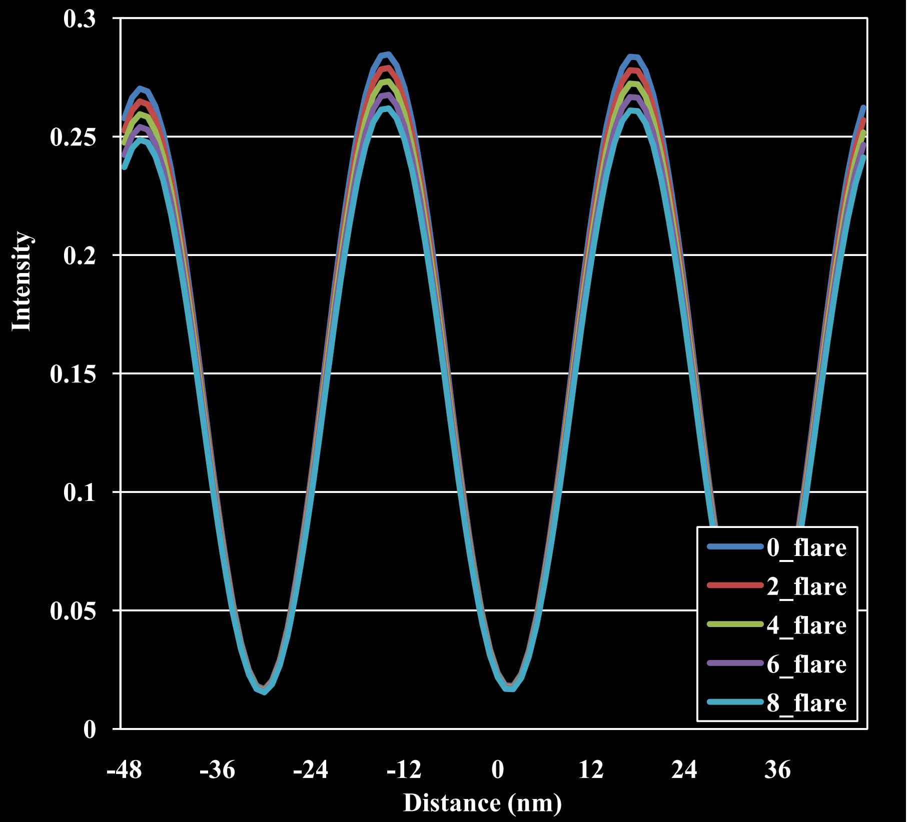


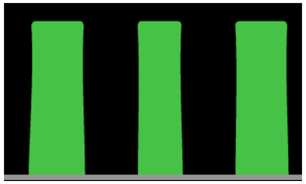
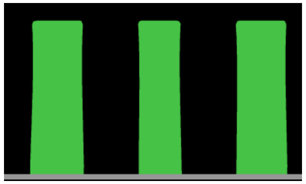
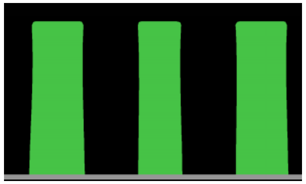
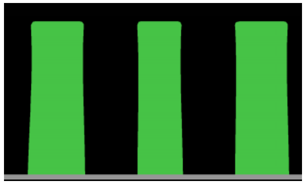
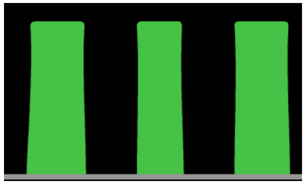
Coherence (σ)	Pattern shape	Resist profile	CD(nm)
0.4_0.8			15.99
			2.30
0.4_0.6			17.05
			3.99
0.6_0.8			15.99
			5.21

- Horizontal-vertical (H-V) critical dimension (CD) difference with different annular illumination

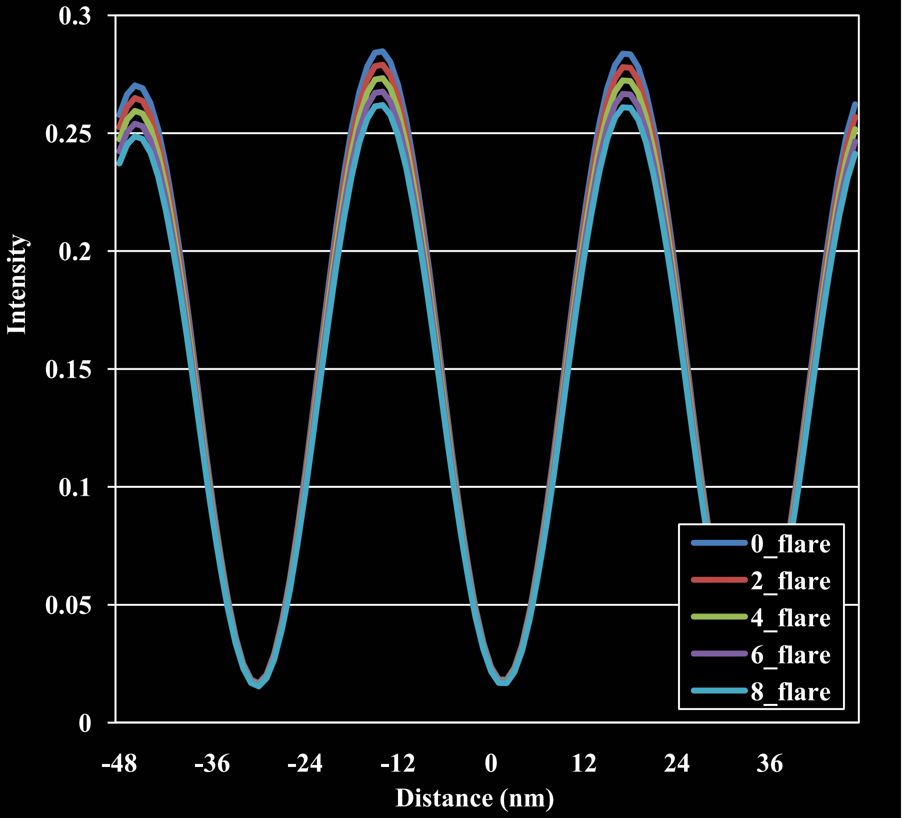
Flare

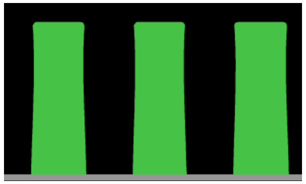
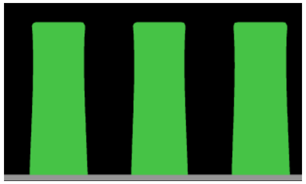
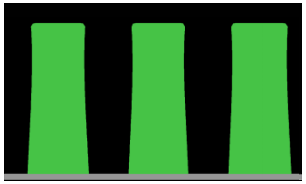
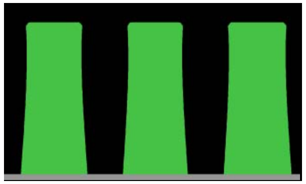
Flare dependency on 22 nm node



		0% Flare	2% Flare
Resist Profile	Side view		
	CD (nm)	22.0	22.58
	Angle (°)	89.21	89.11
		4% Flare	6% Flare
	Side view		
	CD (nm)	23.21	23.91
	Angle (°)	89.0	88.89
		8% Flare	
	Side view		Optimized for 0% Flare
	CD (nm)	24.68	
	Angle (°)	88.76	

Flare dependency on 16 nm node



		0% Flare	2% Flare
Resist Profile	Side view		
	CD (nm)	16.72	17.44
	Angle (°)	88.99	88.71
		4% Flare	6% Flare
	Side view		
	CD (nm)	18.31	19.39
	Angle (°)	88.32	87.73
		8% Flare	
	Side view		Optimized for 0% Flare
	CD (nm)	20.8	
	Angle (°)	86.94	

Conclusion

- 22 nm node with EUV can be realized soon, how about 16 nm node?
- We studied some of the optimized EUV parameters for 16 nm node with some comparison to 22 nm node.
  - As expected, higher NA gives better aerial image.
  - Strong off-axis like dipole and higher σ can make better 16 nm patterns.
  - The aerial image went worse if the incident angle is increased with higher σ of the off-axis illumination.
  - Strong off-axis causes more shadow effect on 16 nm and shows much larger H-V bias.
  - Less than 4 % flare is needed on 16 nm pattern, even though 8 % flare might be alright for 22 nm patterns.
  - We need more complex optical proximity correction in EUV to make 16 nm.

Thank

you!!