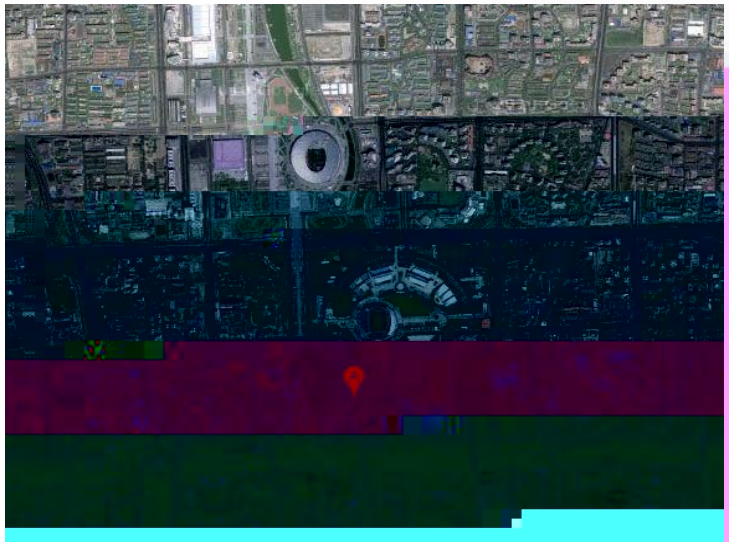
惟精惟一



“ 109( ) ”

“ ”

，

EDA

1000

500

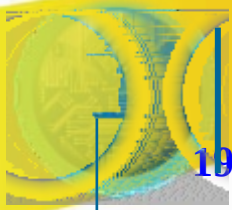
300

“ ”

109 1958-1986

1958 8
109

1960 “109 ”
12 14.5
1966 156
10
1967 “109 ”
7
1976 “013 ”
1977 “151 ”
STTL-E 75

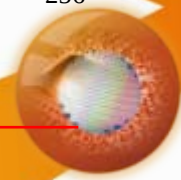


“109
” 1967-1975
14

1978 TTL-E ECL-D
TTL-F
“013 ” “109
” 109
1978-80 “757 ” 30
30 ECL TTL
1978 N MOS 256
MOSDRAM

1985 12 109

1986-2003



2003

“
” 2003 10
16 “
”

1986 64K DRAM
1989 CAE
1990 CMOS FD-2 RIE
1993 “ CAD ”
1997 “0.8 CMOS ”
1999

2003 “20 CMOS ”
2006 “ 30 CMOS ”
2007 “ ”
2008 “90 —65 ”
2009 “100nm ”

“ ”

109

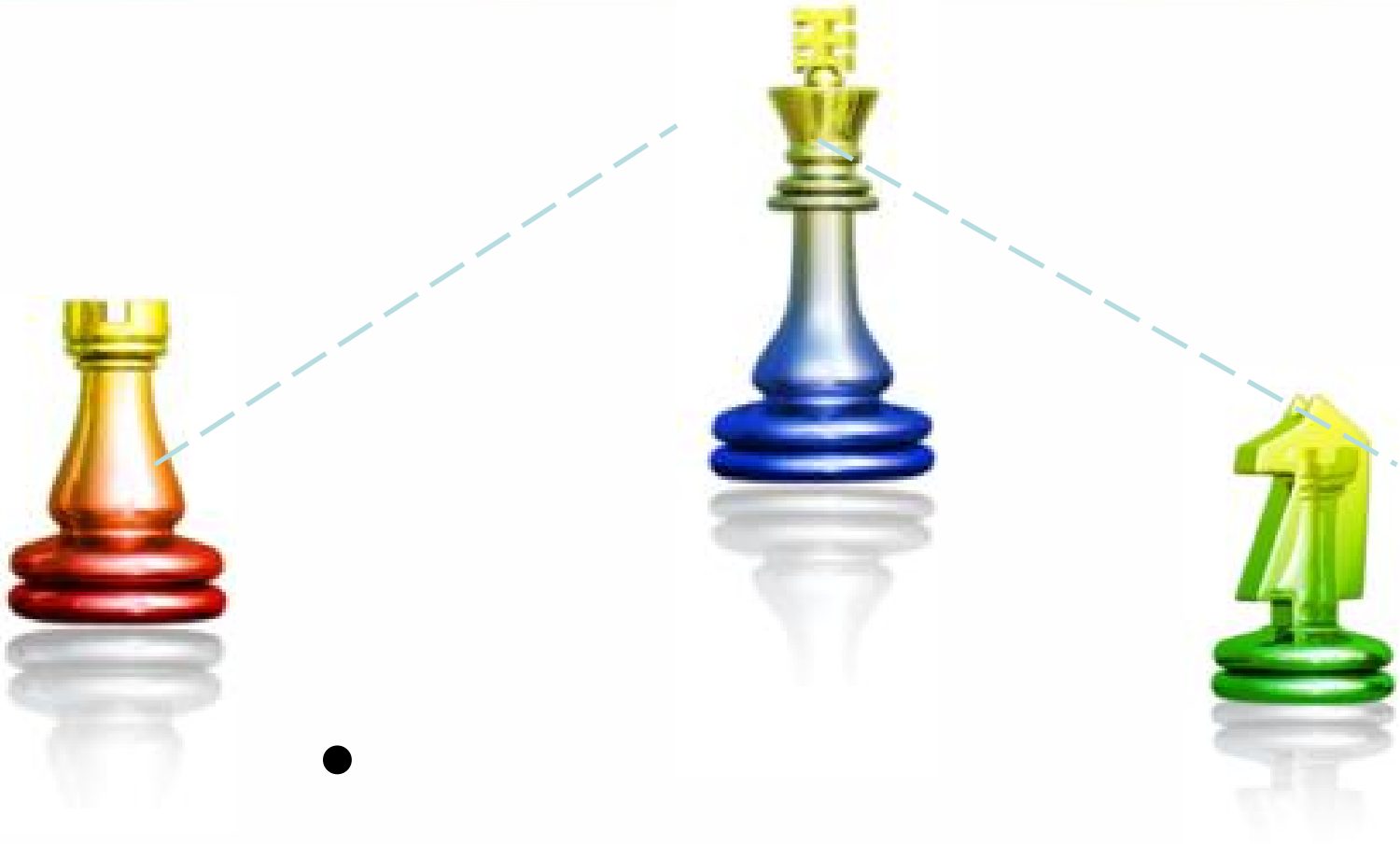
109

1985 5 25

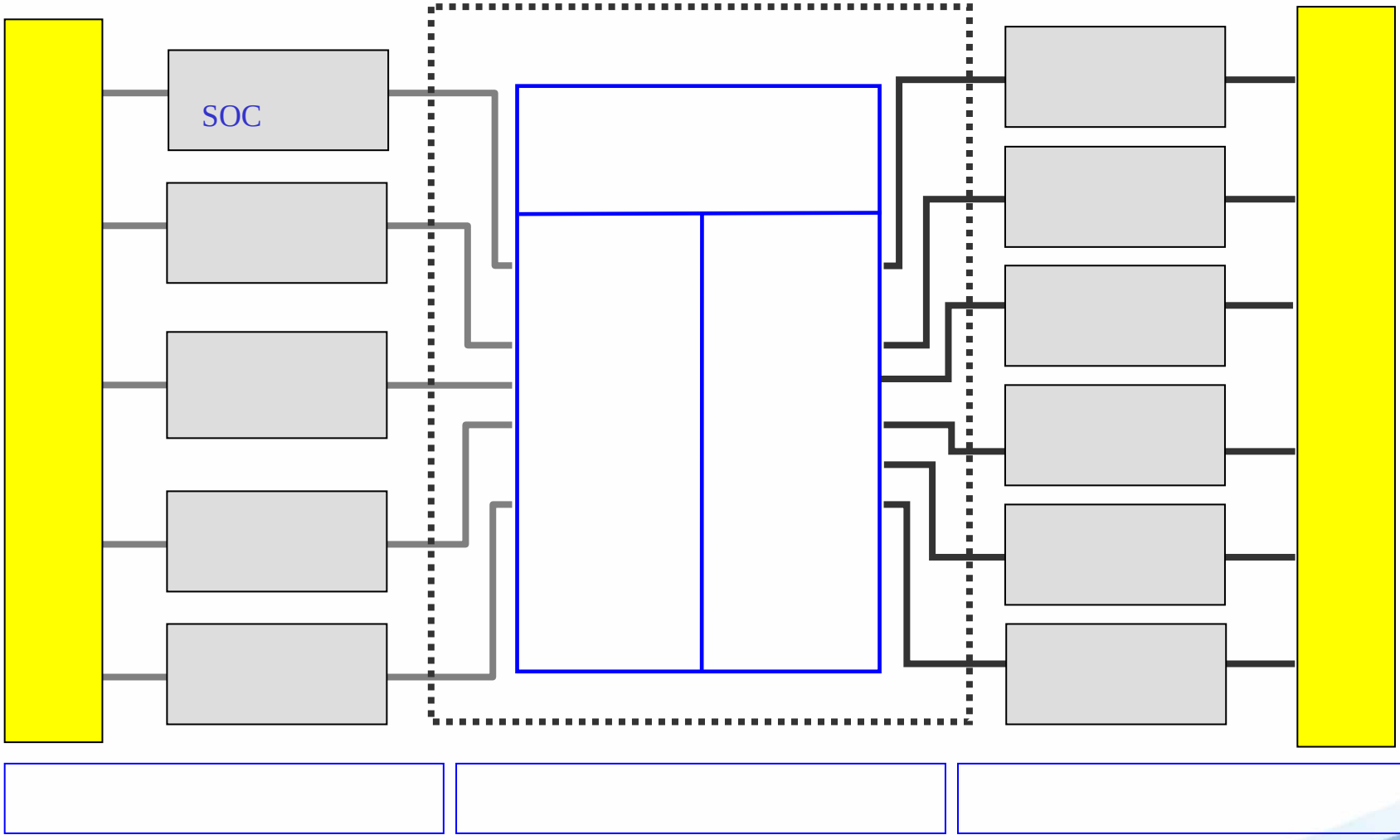
1986
109

1993 3 11

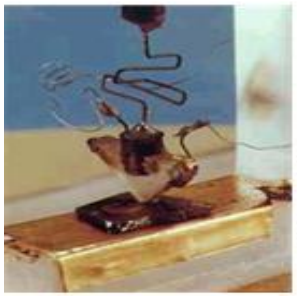
“ ”



“ ”

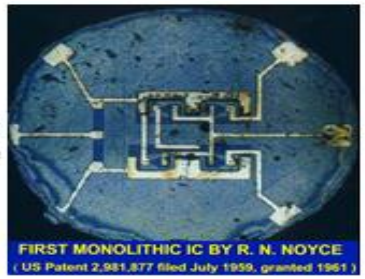

SOC

Top-down



First Transistor
By
J. Bardeen and
W.Brattain

First Monolithic
IC by R.N.Noyce

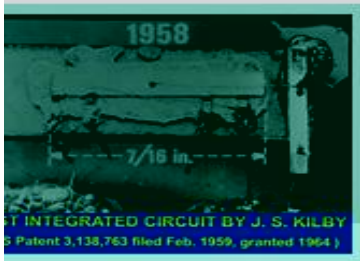


Power5 uP 2005 IBM

MOSFET(1960)
CMOS (1961)

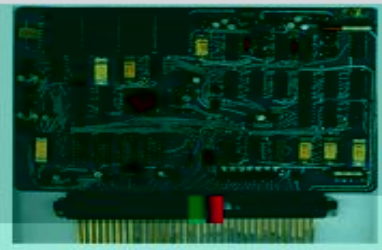
VLSI era

1940 1950 1960 1970 1980 1990 2000



Planar
Process(1960)

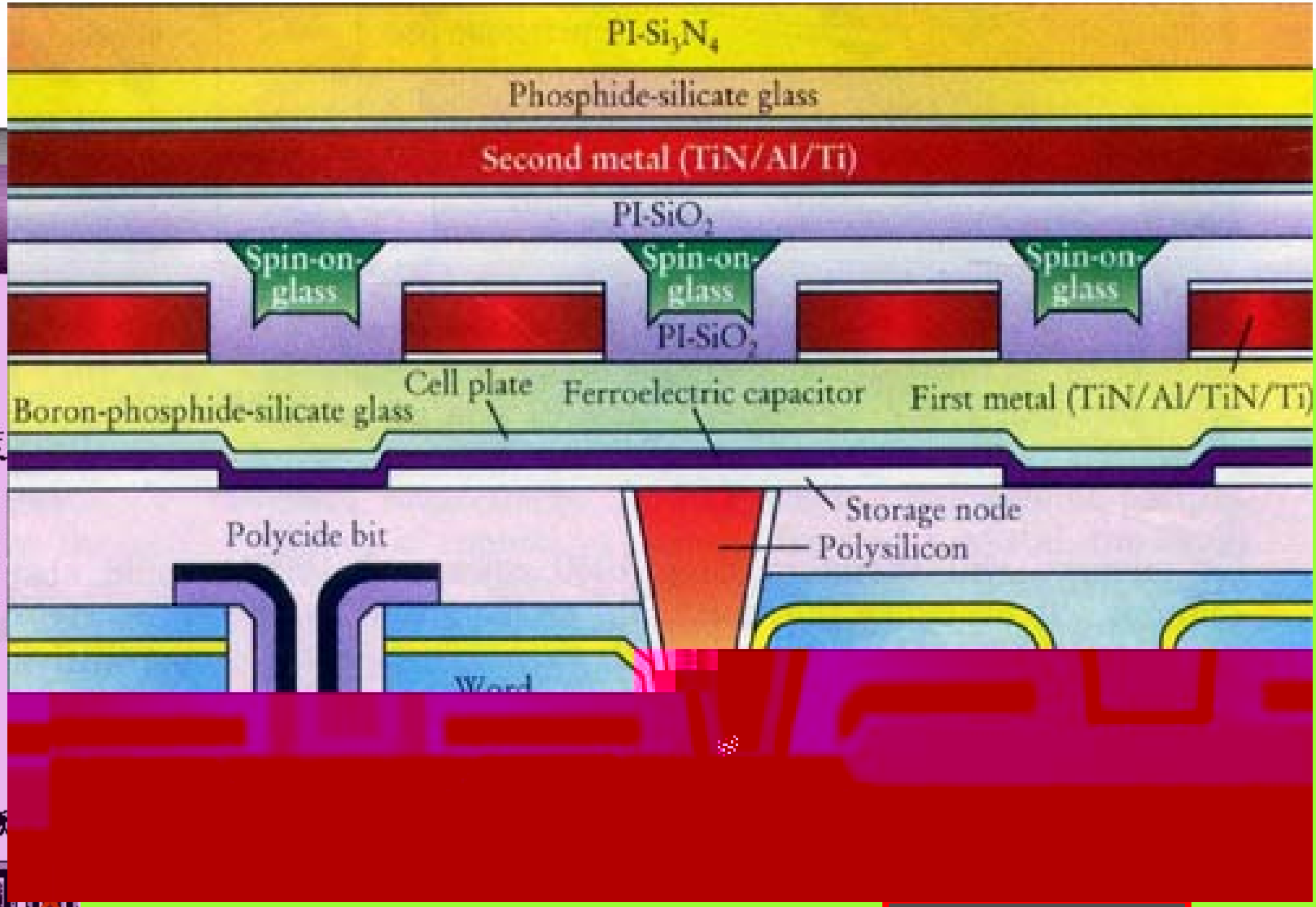
First Integrated
Circuit By
J. S. Kilby



4004 uP 1971

1948 1958

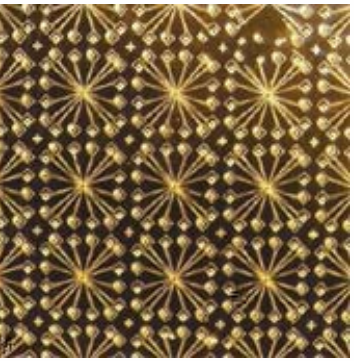
“ ”

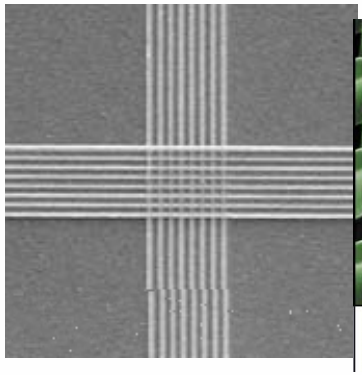

PI-Si3N4
Phosphide-silicate glass
Second metal (TiN/Al/Ti)
PI-SiO2
Spin-on-glass
Spin-on-glass
Spin-on-glass
PI-SiO2
Boron-phosphide-silicate glass
Cell plate
Ferroelectric capacitor
First metal (TiN/Al/TiN/Ti)
Storage node
Polysilicon
Polycide bit

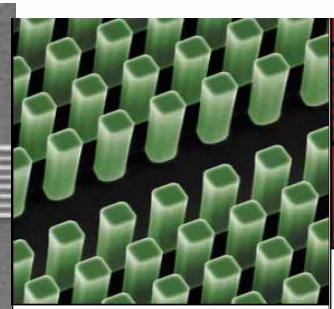
- (
)
-
-

-
  -
  -
-

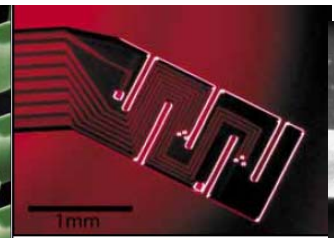
DZ



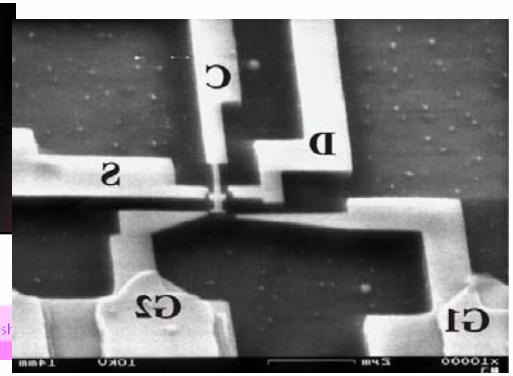




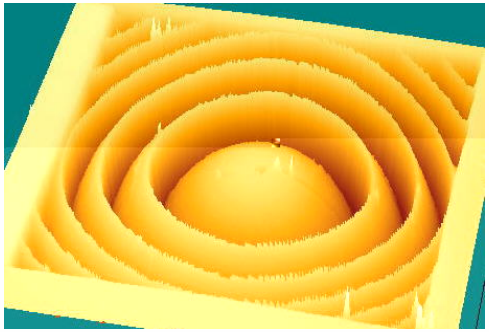
10 μm square silicon pillars coated with PECVD silicon dioxide are used to purify DNA from bacterial cells and to perform PCR amplification via a miniaturized thermo cycler.

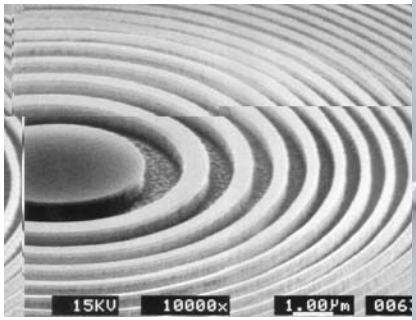


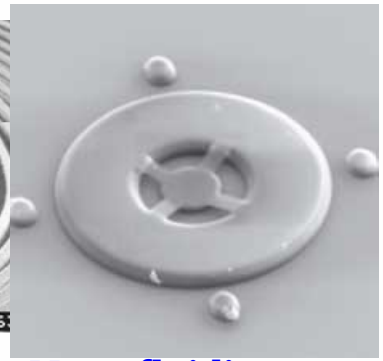
A multi-unit cuff microelectrode array was fabricated on polyimide. It was then used to investigate correlations between electrical activity of neurons at points proxi[illegible] and distal to a site of lesion in red swamp crayfish Procamb[illegible]s Clarkii.



SET





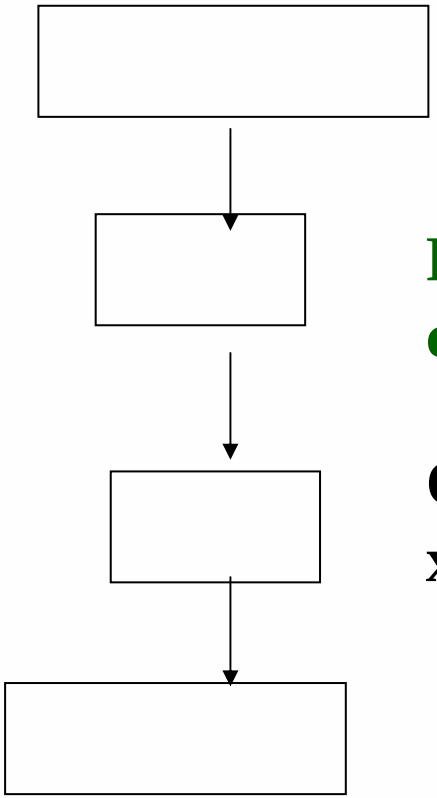


bragg-Fresnel lens for x-rays

Nano fluidic accelerometer

3D

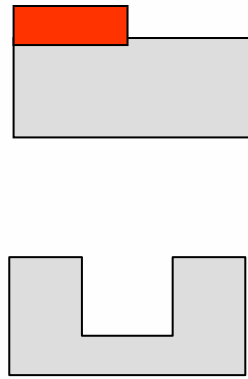
Top–down



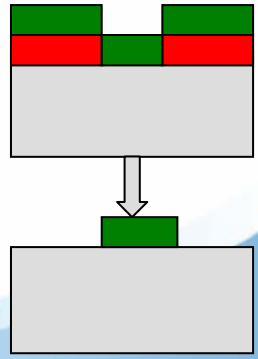
Si, GaAs, InP,
Quartz, glass, metal

Photon sensitive polymer
called “resist”

Optical, e-beam, ion beam
x-ray, proton, STM/AFM



Etching, lift-off, imprint



Top-down

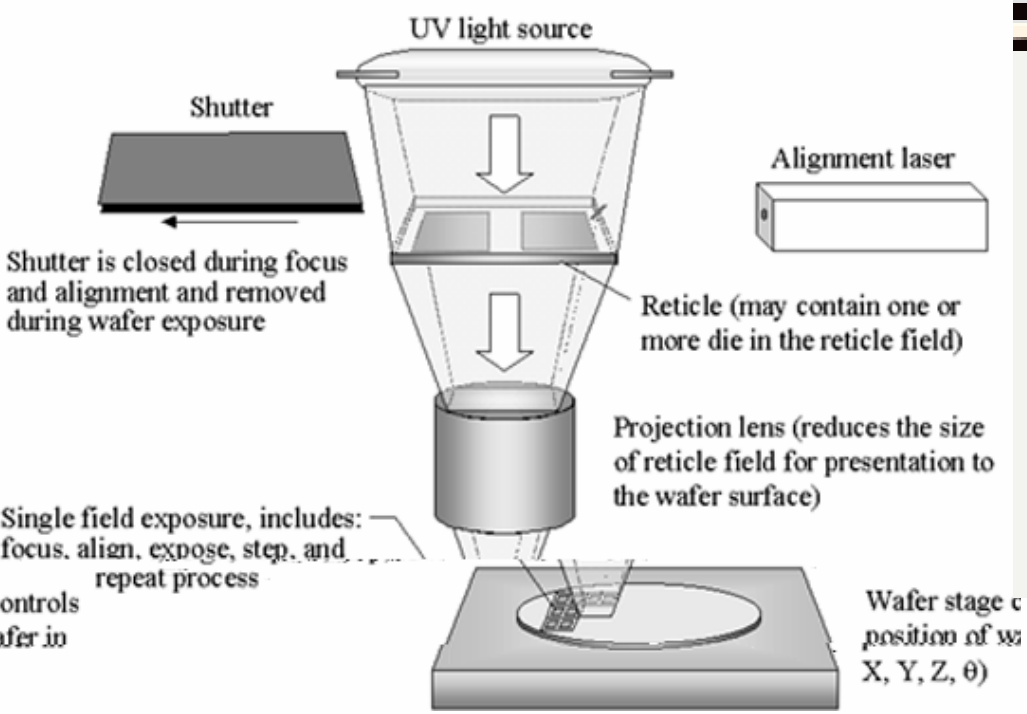
Top-down

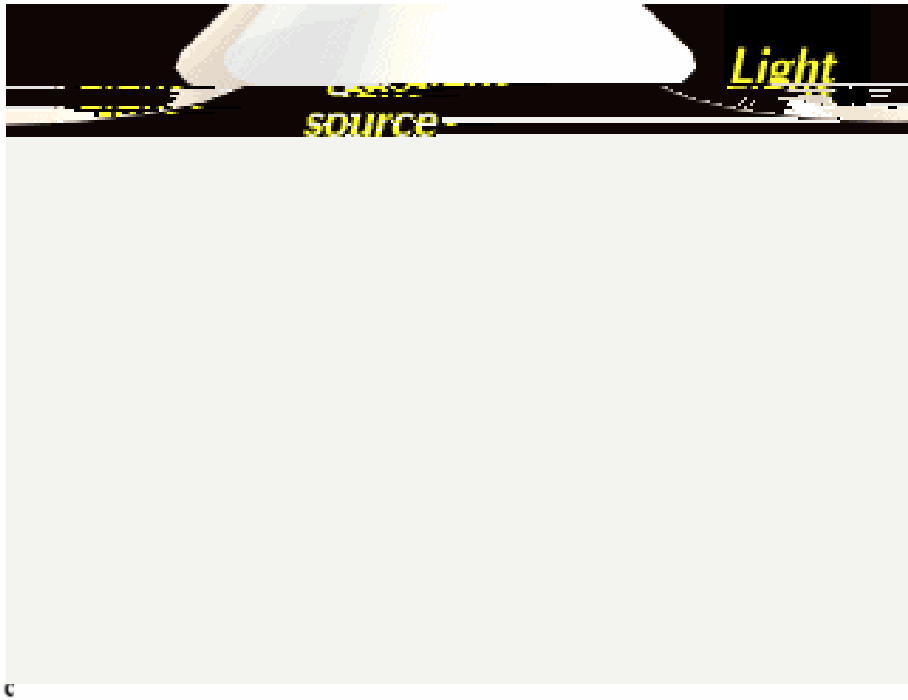
- **Optical lithography**
- **E-beam lithography**
- **EUV (extra-ultra violet) lithography**
- **Nano-imprint**

ITRS 2009

DRAM

“ ”





stage

wafer IC

40-50% total wafer process time, Determine the minimum feature size

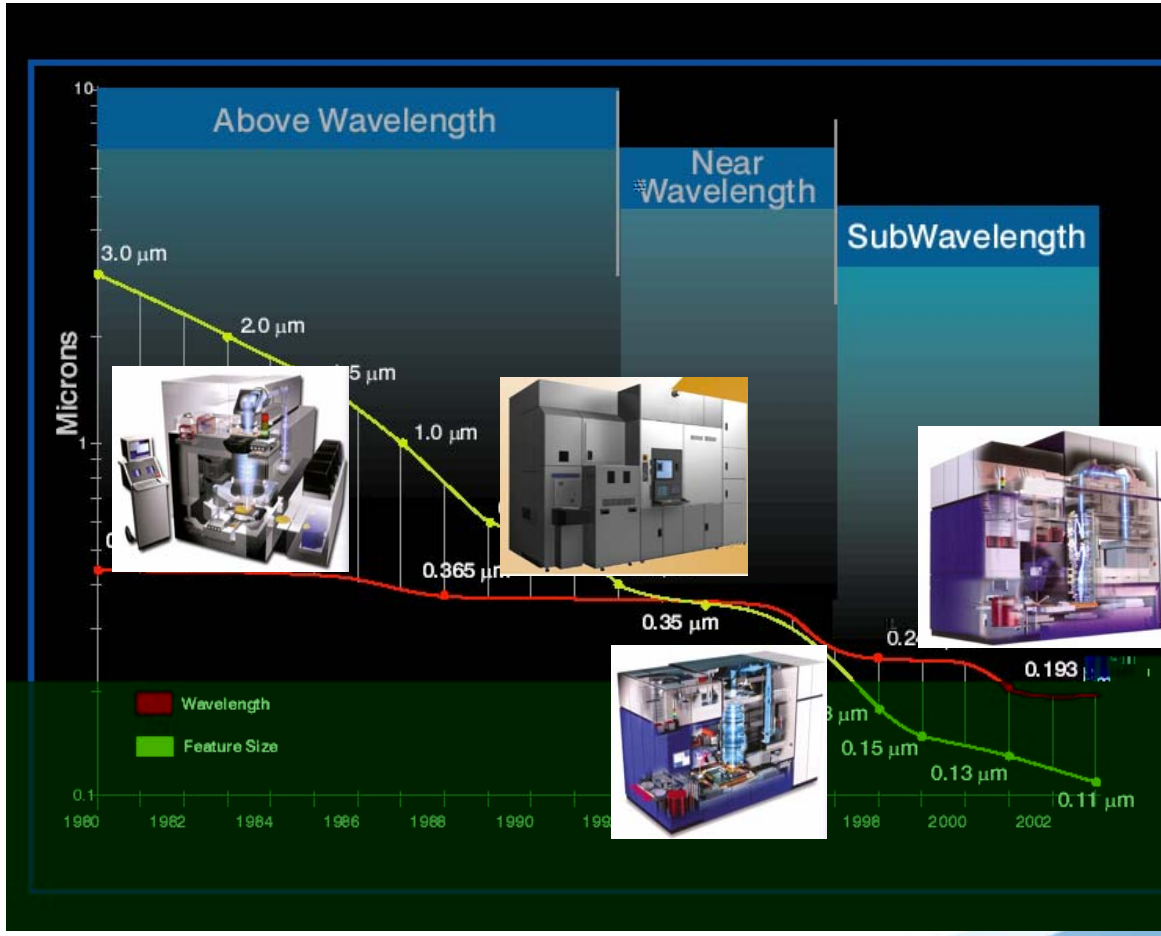
“ ”

g

1978 GCA

ASML

1.5



30 10 45nm

ASML Nikon Canon

“ ”

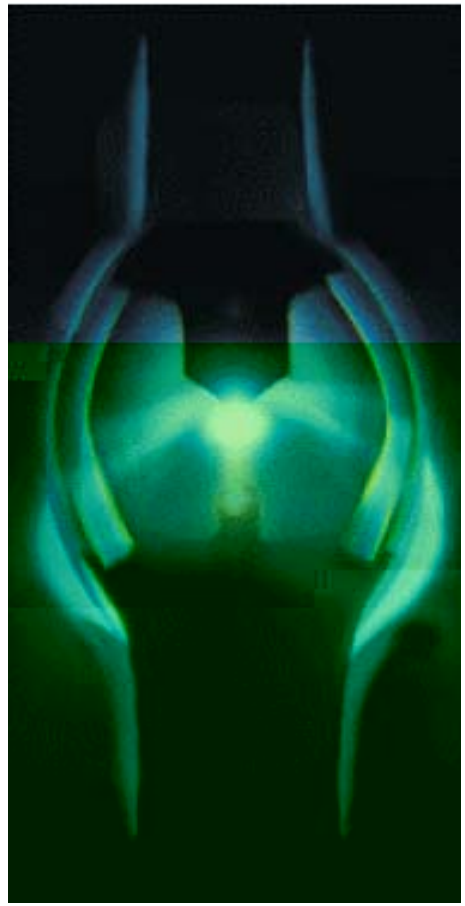
546 (e-line) ,436(g-line),365(i-line),
248(KrF), 193(ArF),157(F_2),EUV
(0.1-0.05Å), ,X

0.2——0.85 —1.44( )

“ ”

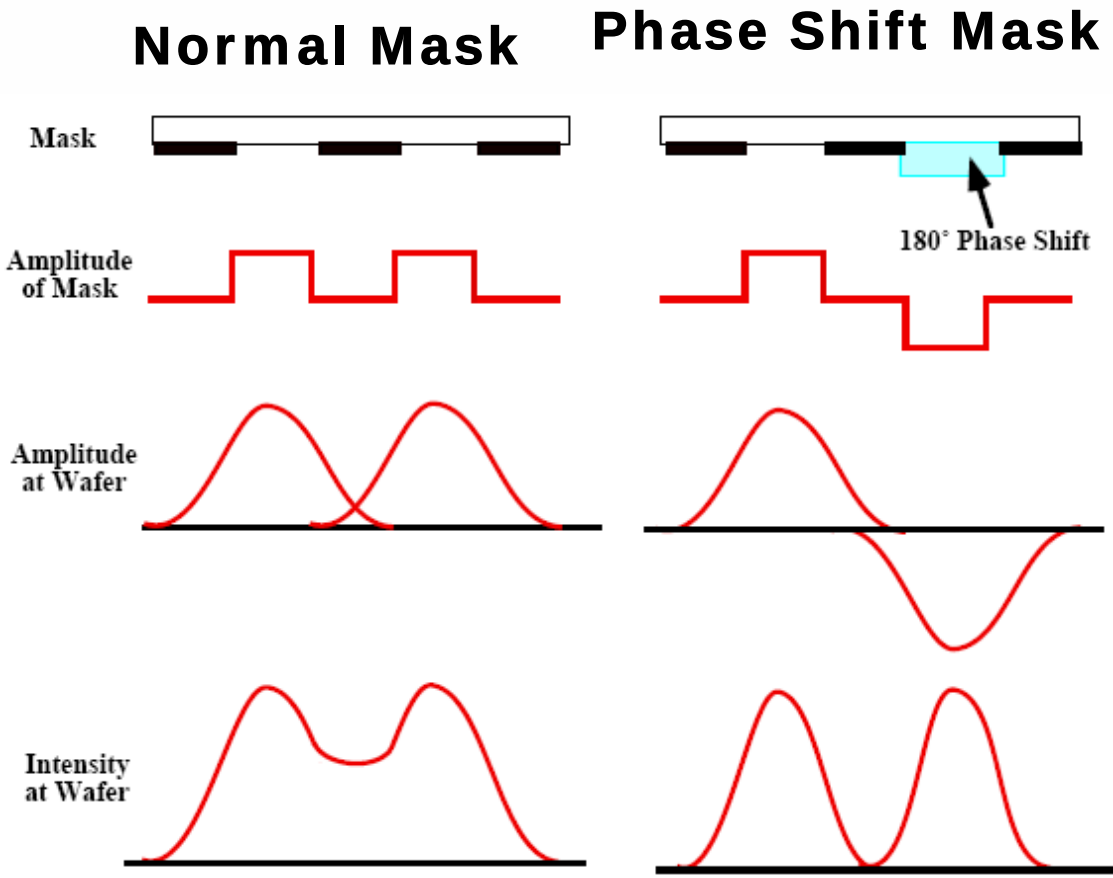
1 Using light source with shorter λ

	λ(nm)		
	436	g	>0.5μm
	365	i	0.5/0.35μm
KrF( )	248	DUV	0.25/0.13μm
ArF ( )	193	193DUV	90/65…32nm
Xe	13.5	EUV	Reflective mirrors



2 reduce k1

$$I = E \times E^*$$



Pattern dependent

k_1 can be reduced by up to 40 %

Optical Proximity Effect Correction

OPC

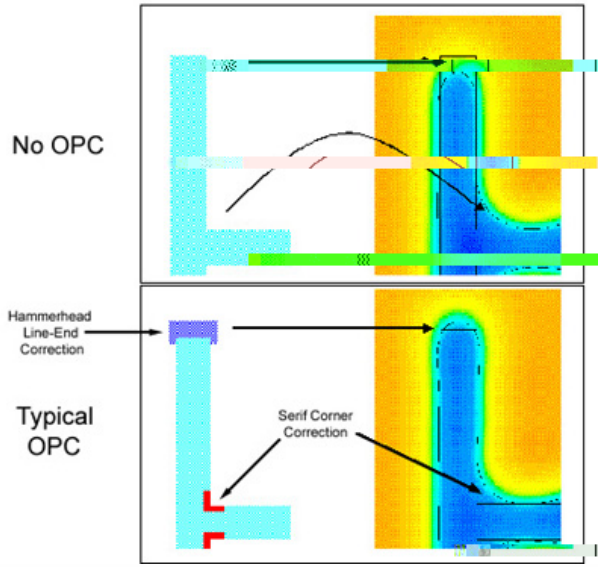
diffusion loading

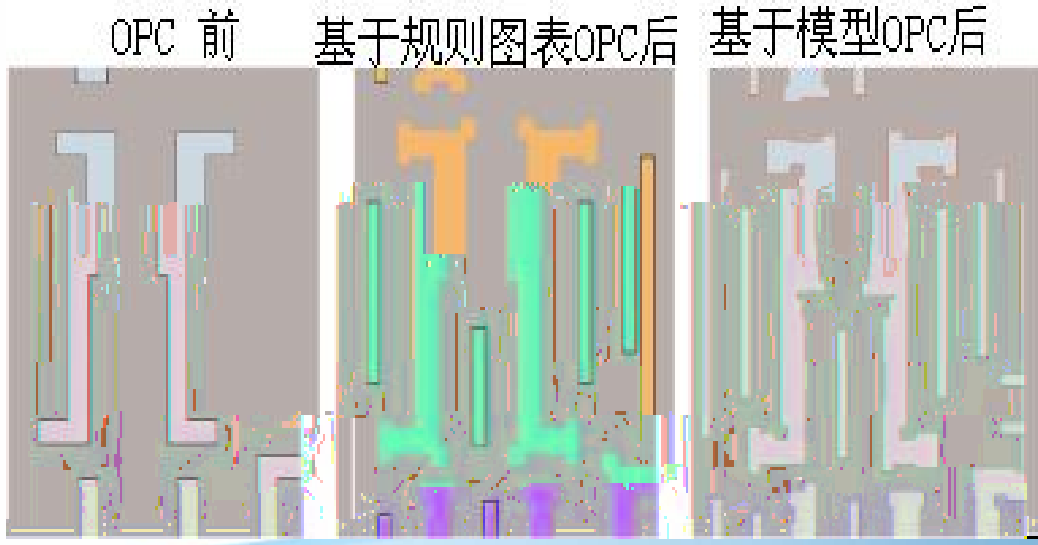
effect

OPC

OPC

OPC



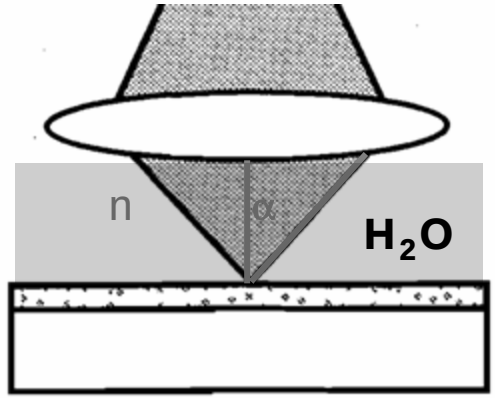


“ ”

3

Lens fabrication	
λ [nm]	*NA*
436	0.15-0.45
365	0.35-0.60
248	0.35-0.82
193	0.60-0.93

Immersion Lithography



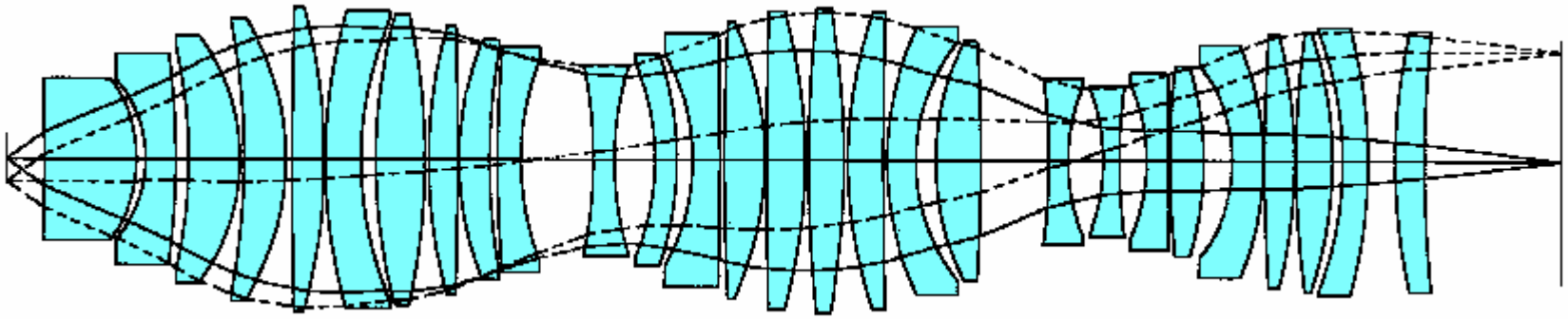
Numerical Aperture: $NA = n\sin\alpha$

$$R = k_1 \frac{\lambda}{NA}$$

$$n_{H_2O} = 1.44 \Rightarrow NA \approx 1.36$$

State of the Art: λ=193 nm, k_1=0.3, *NA*=0.93 $\Rightarrow$ *R*≈60 nm
=1.36 $\Rightarrow$ *R*≈40 nm

KrF--Stepper Projection Lens

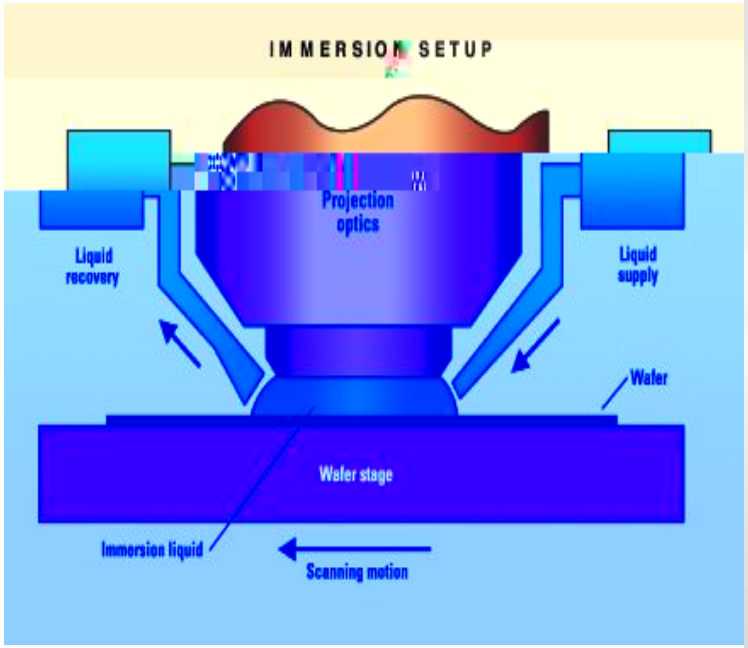


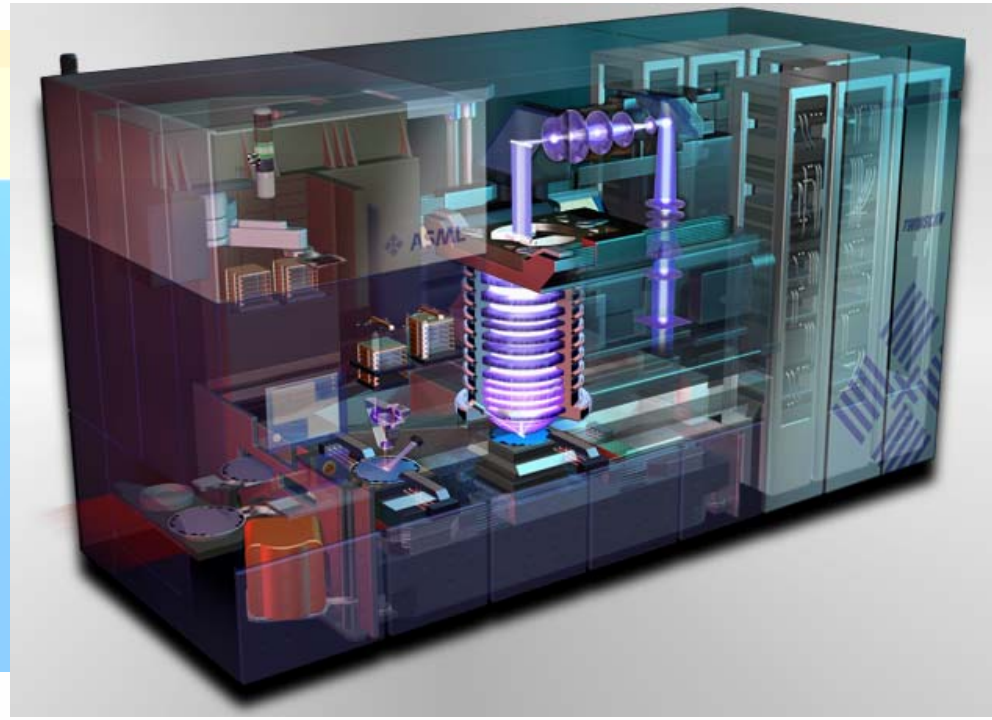
λ =248nm NA=0.55 Filed: 22mm, 28-lens optics

Japan Patent: Laid Open 8-166540

λ =193nm NA=0.75 Filed: 22mmx26m, 38-lens , a spherical optics

193nm





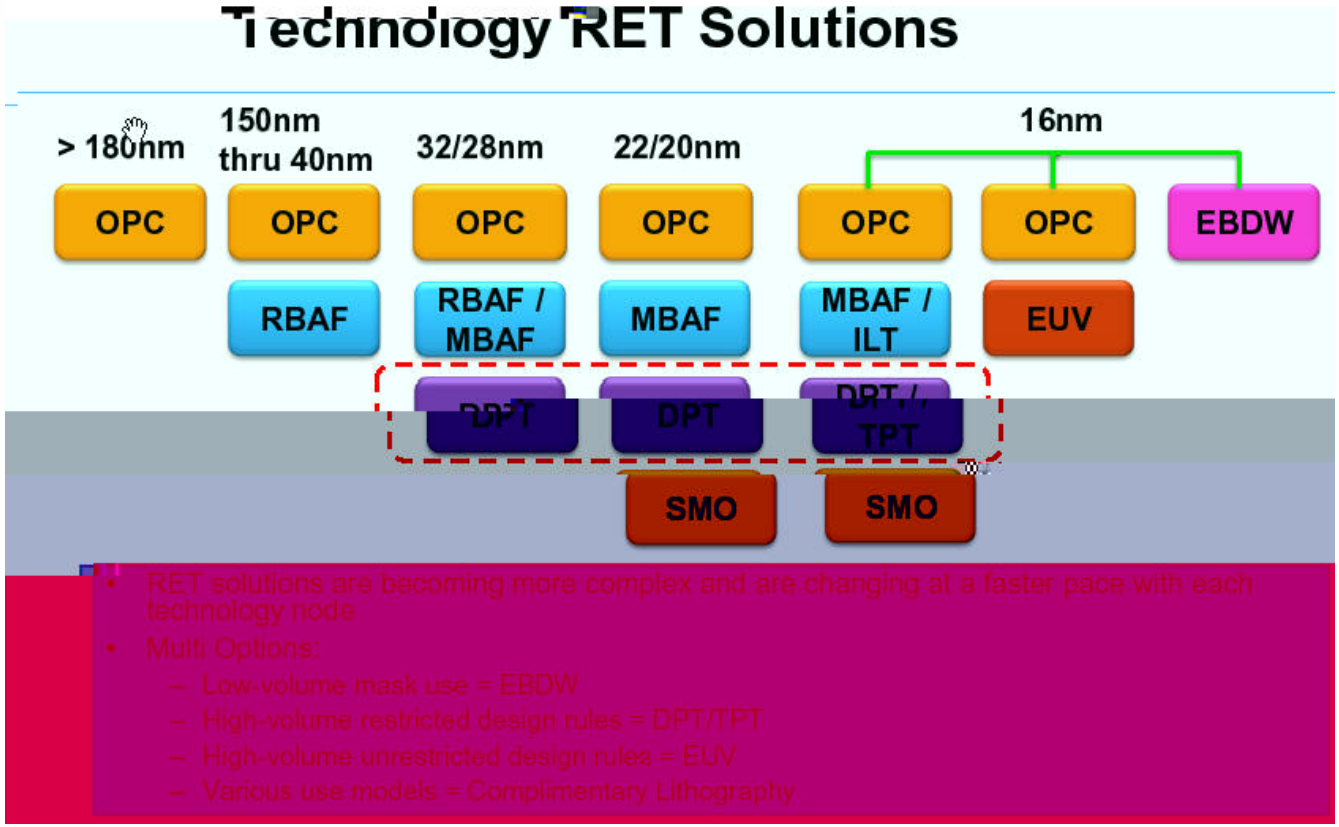
n

1.44

193nm 32nm

“ ”

- :
-
-
-
- OPC RET


Technology RET Solutions
> 180nm
150nm thru 40nm
32/28nm
22/20nm
16nm
OPC
OPC
OPC
OPC
OPC
OPC
EBDW
RBAF
RBAF / MBAF
MBAF
MBAF / ILT
EUV
DPT
DPT
DPT / TPT
SMO
SMO
• RET solutions are becoming more complex and are changing at a faster pace with each technology node
• Multi Options:
– Low-volume mask use = EBDW
– High-volume restricted design rules = DPT/TPT
– High-volume unrestricted design rules = EUV
– Various use models = Complimentary Lithography

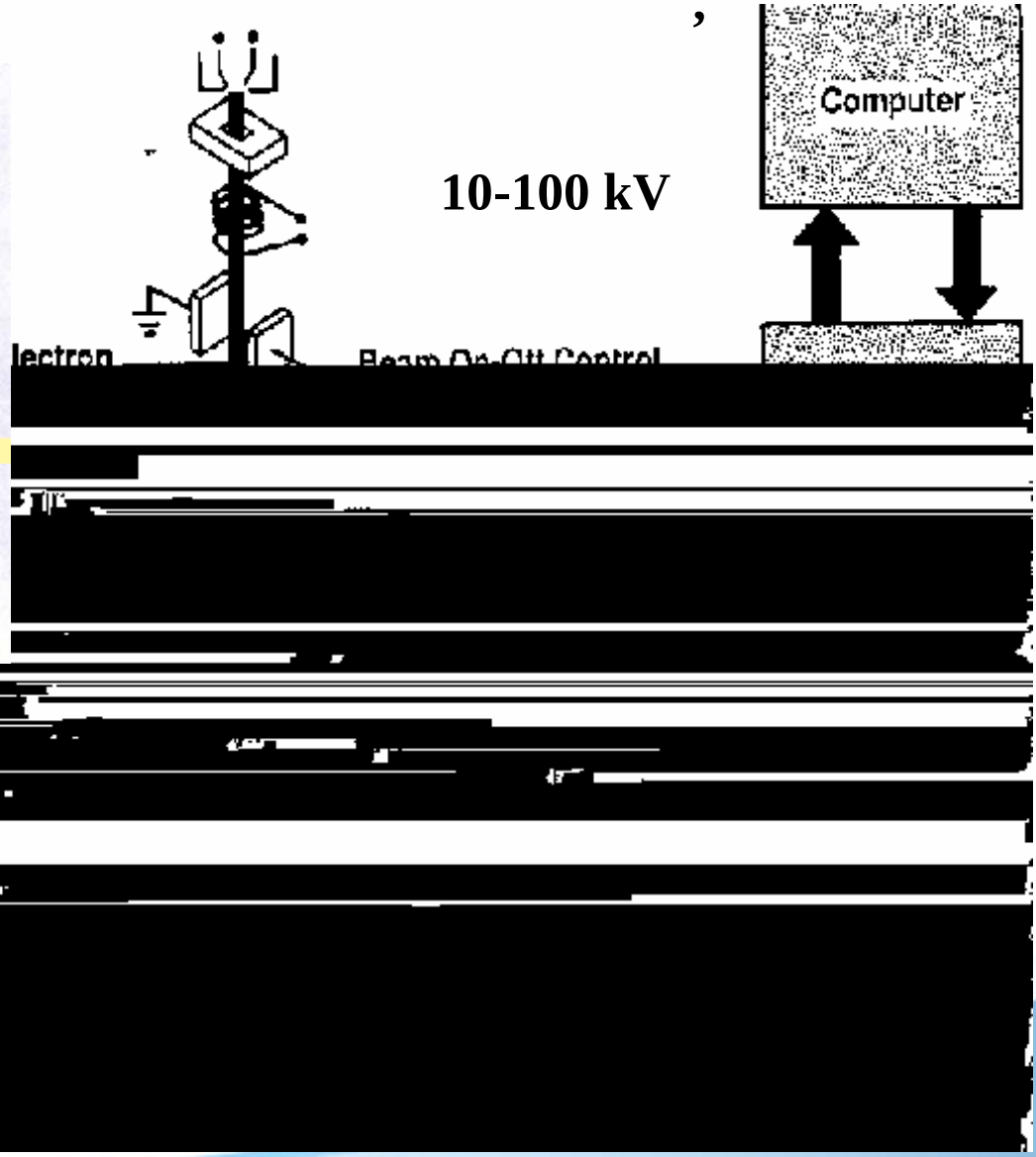
IC

RET

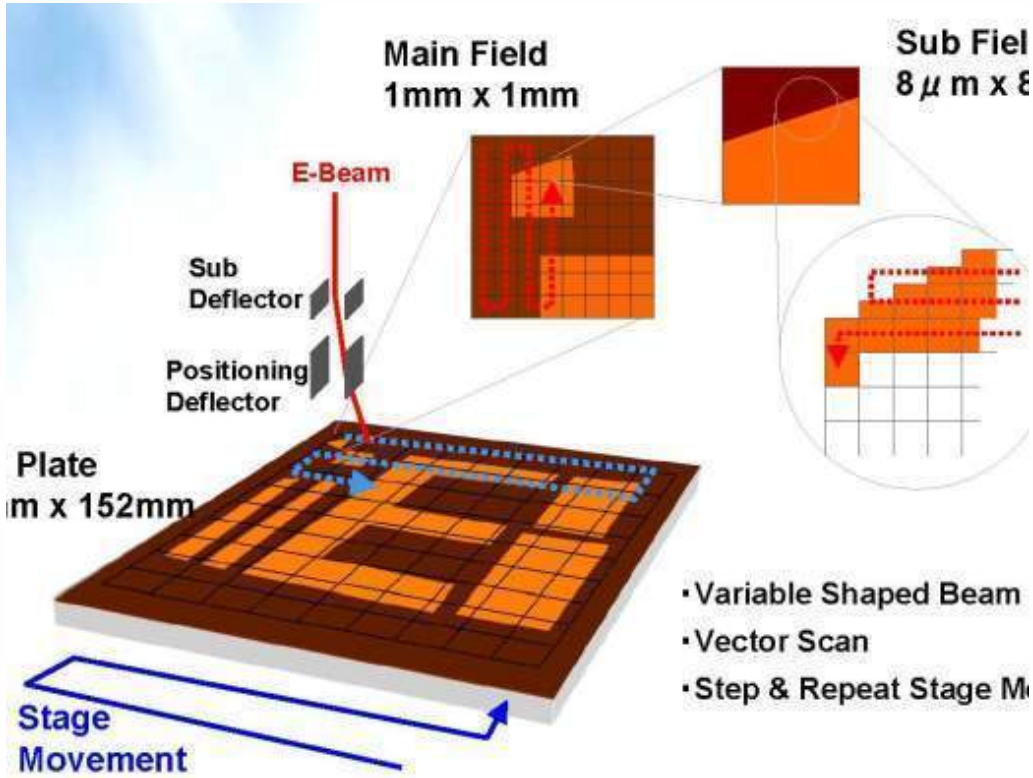
“ ”

Top-down

- Optical lithography
- E-beam lithography
- EUV(extra-ultra violet) lithography
- Nanoimprint



Stage

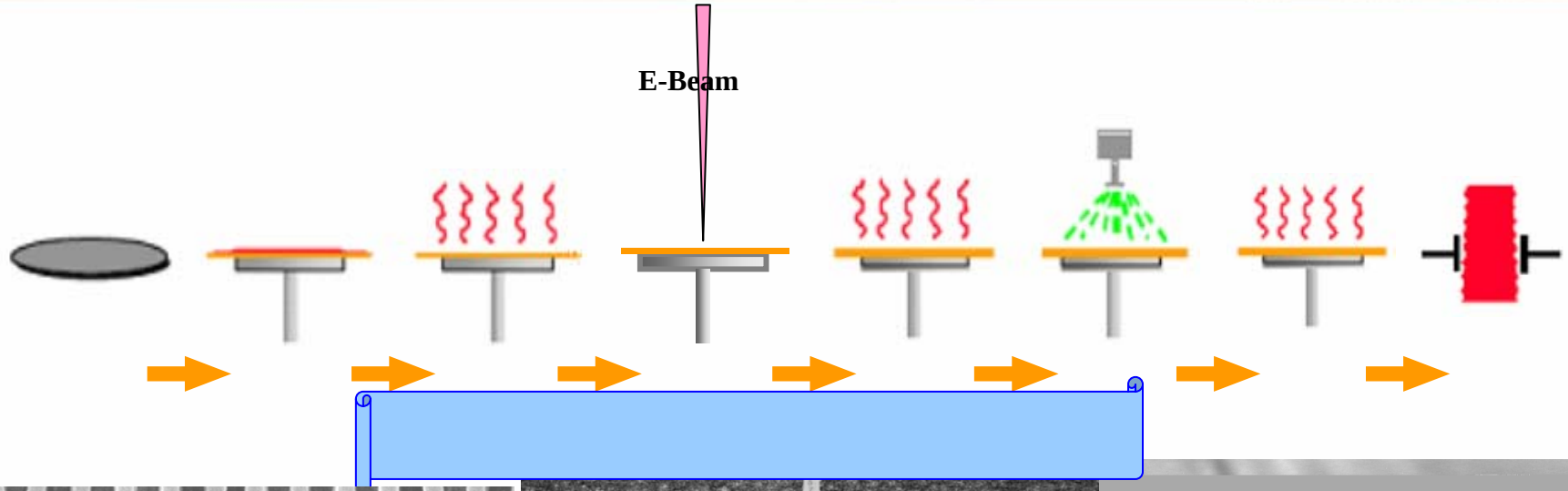


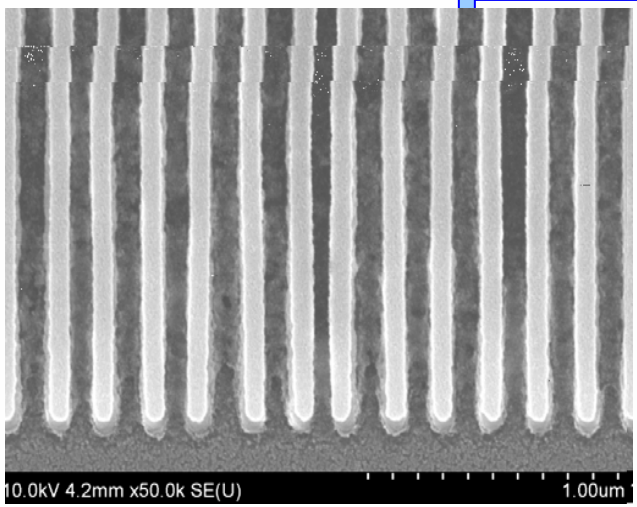
Similar principle as a scanning electron microscope

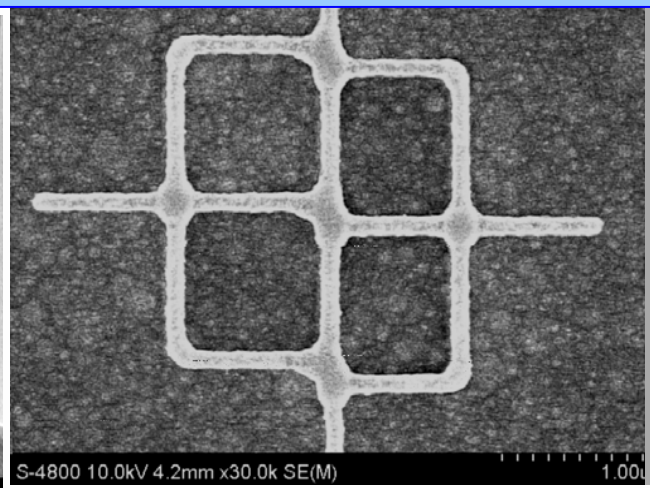
Electron-beam process Mix and Match Technology Resist technology Simulation Proximity effect correction

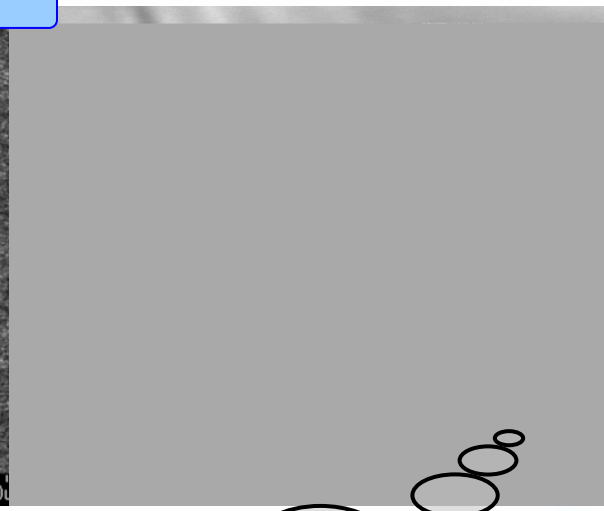
- (< 5nm)
- Large substrate size (12” wafer)
- Multi-level patterning (alignment error <20nm)
- High flexibility
- Fast prototyping

• spot size-electron lens aberration, space charge, mechanical stability
•proximity effect-electron forward and backscattering
•resist contrast


E-Beam


10.0kV 4.2mm x50.0k SE(U)
1.00um


S-4800 10.0kV 4.2mm x30.0k SE(M)



50

0.125-12.5nm

2-50nm

5-100nm

1-50nm

1-50nm

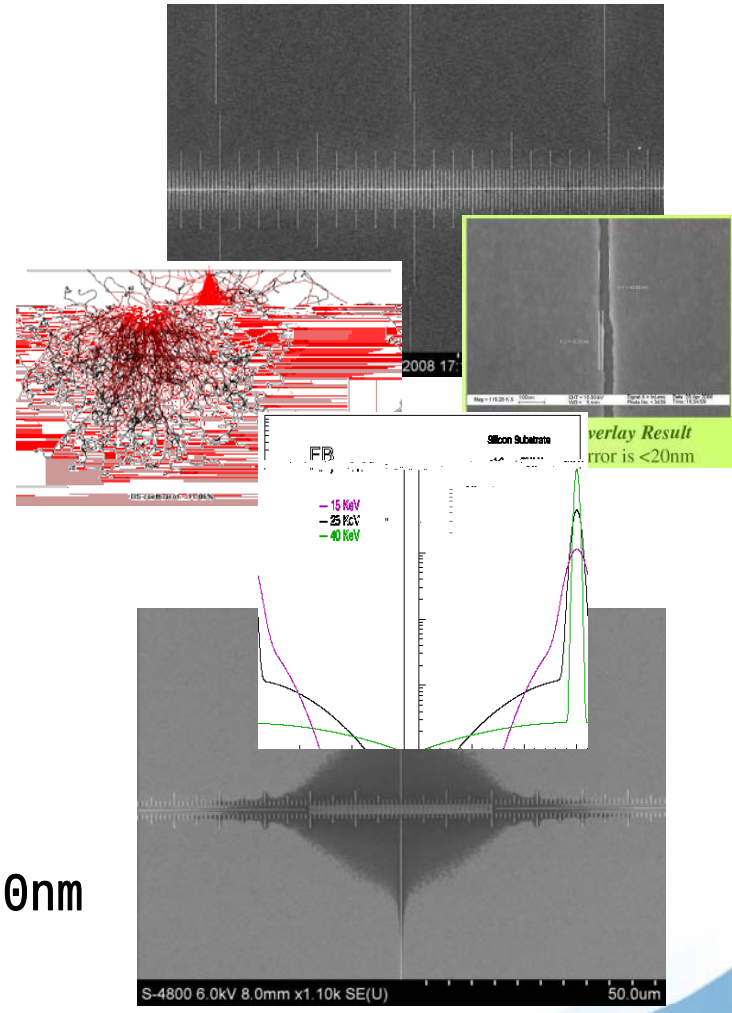
20-1000nm

20-500nm

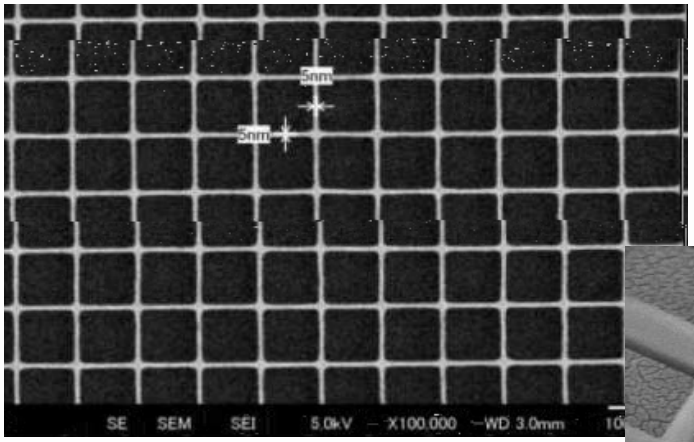
15-60nm

2-50

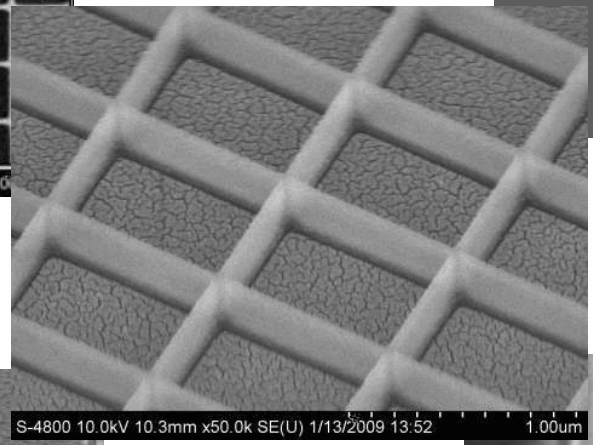
10-100nm



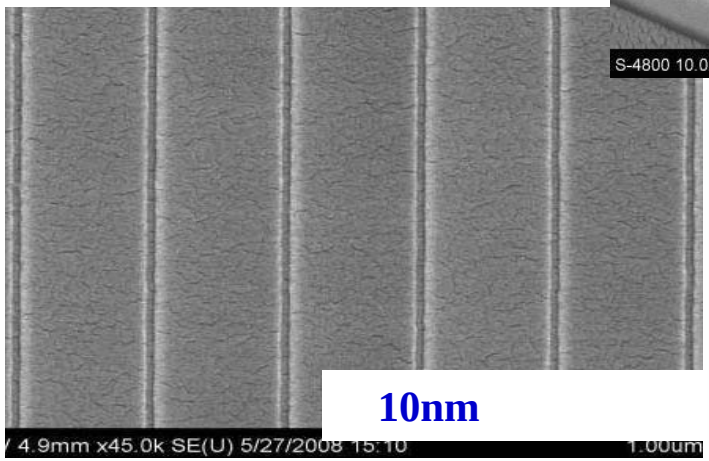
“ ”



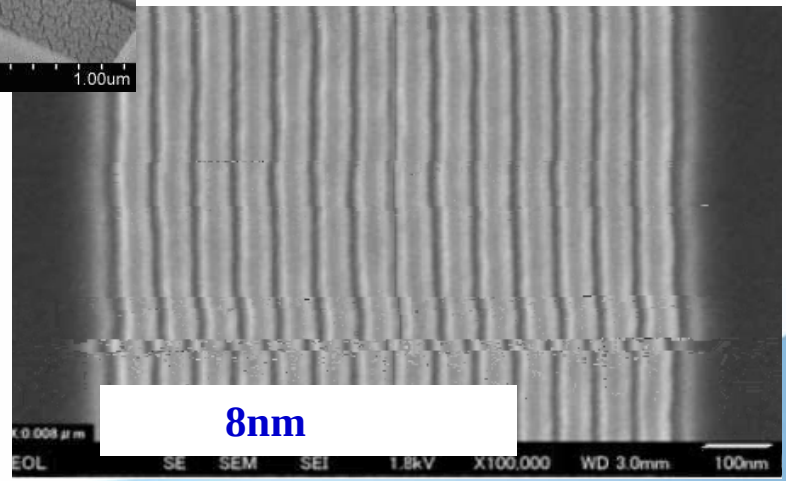
5nm



20nm

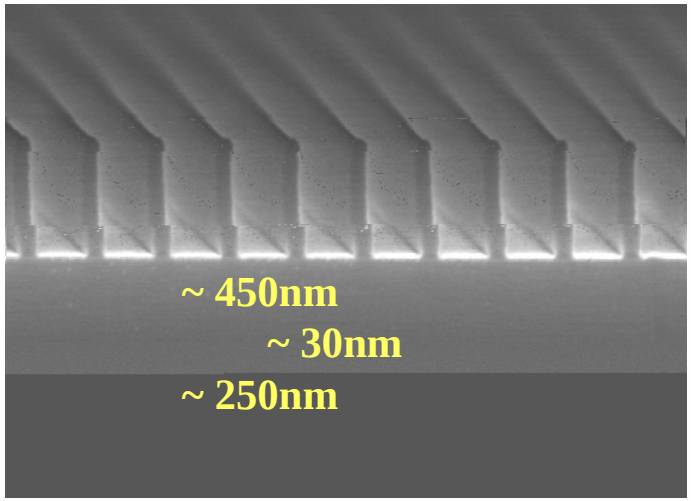


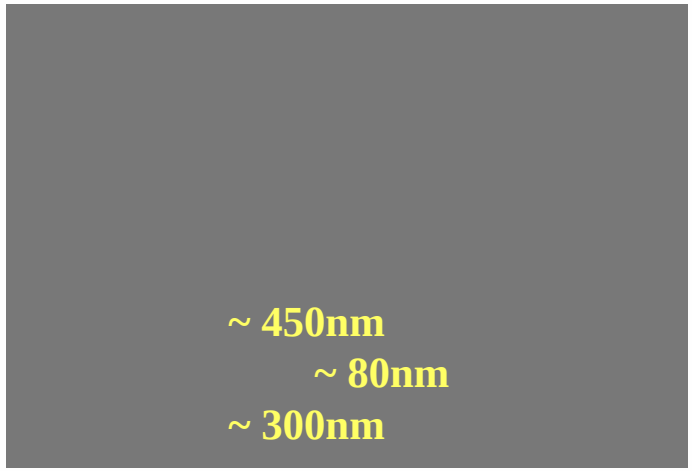
10nm

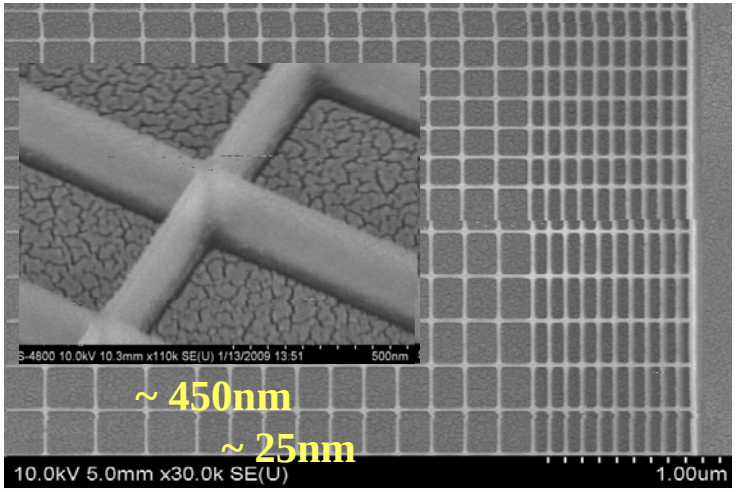


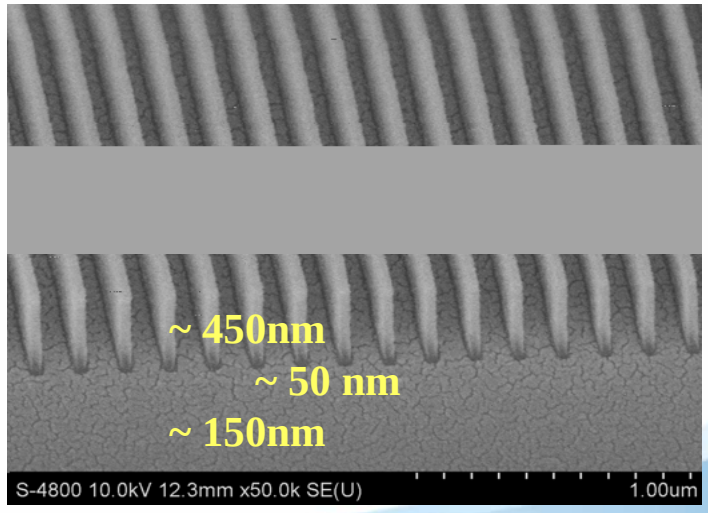
8nm

“ ”


~ 450nm
~ 30nm
~ 250nm


~ 450nm
~ 80nm
~ 300nm


S-4800 10.0kV 10.3mm x110k SE(U) 1/13/2009 13:51 500nm
~ 450nm
~ 25nm
10.0kV 5.0mm x30.0k SE(U) 1.00um


~ 450nm
~ 50 nm
~ 150nm
S-4800 10.0kV 12.3mm x50.0k SE(U) 1.00um

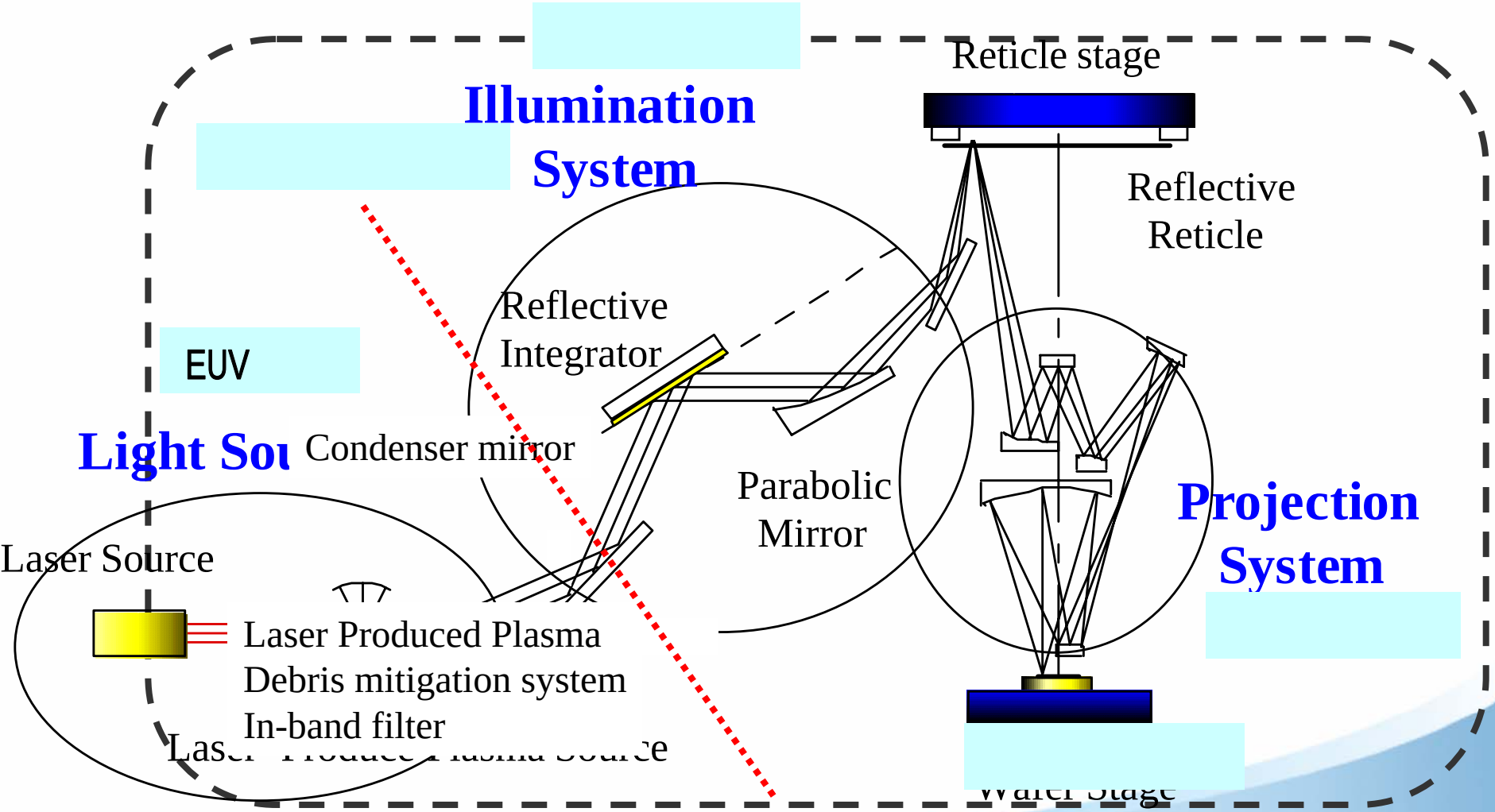
“ ”

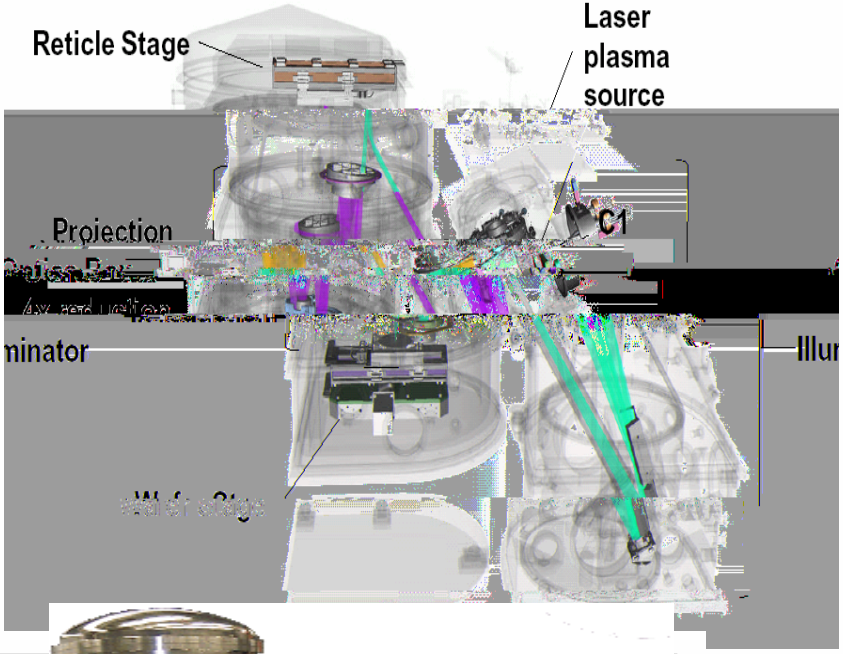
Nano-Scale Fabrication

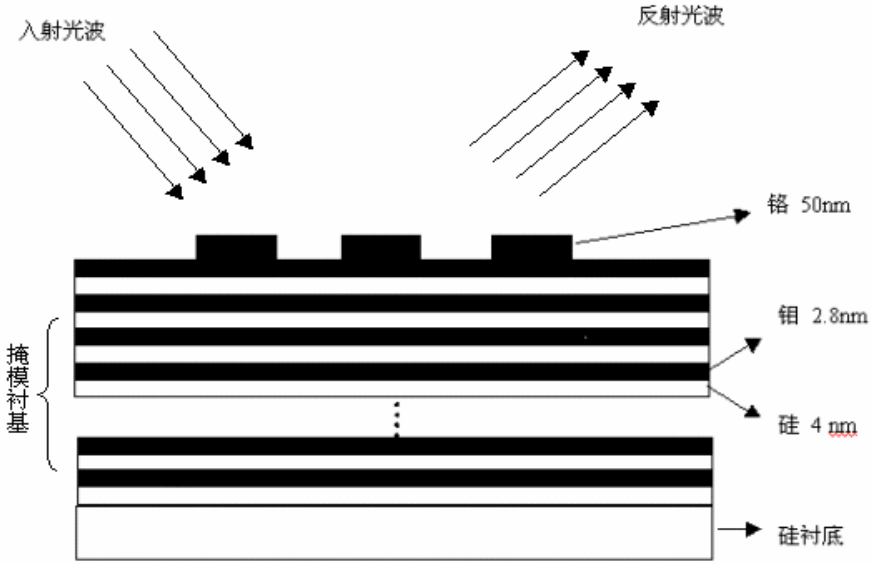
Top-down

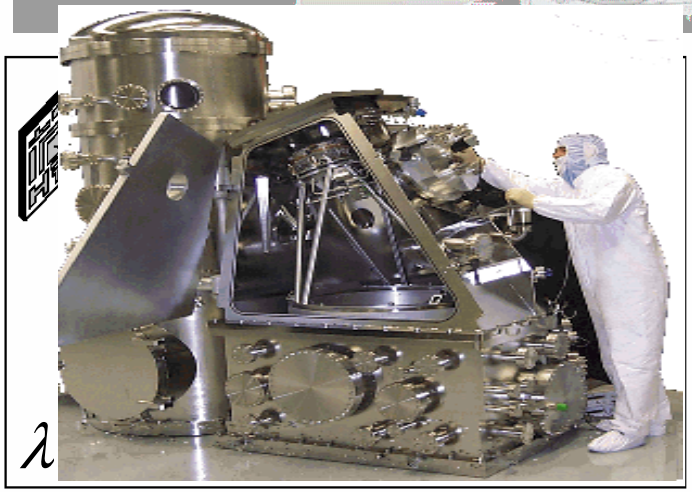
- Optical lithography
- E-beam lithography
- EUV(extra-ultra violet) lithography
- Nano-imprint

EUVL

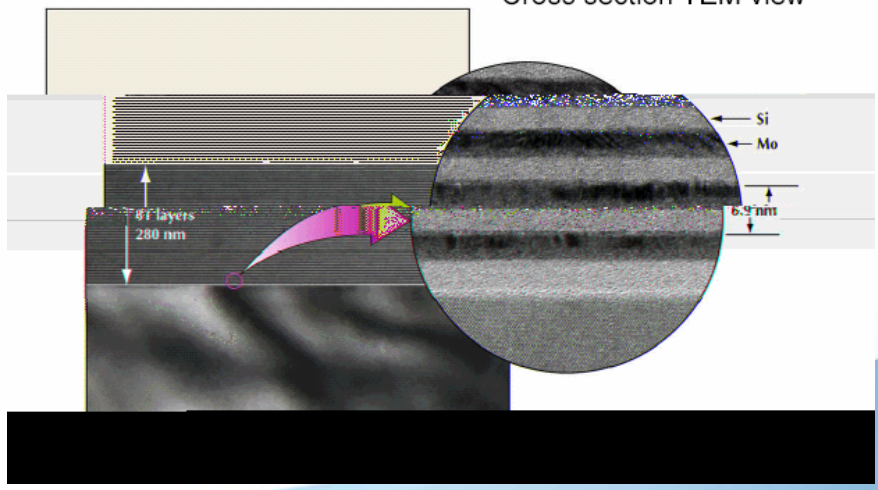

Illumination System
Reticle stage
Reflective Reticle
EUV
Reflective Integrator
Light Sou
Condenser mirror
Parabolic Mirror
Projection System
Laser Source
Laser Produced Plasma
Debris mitigation system
In-band filter





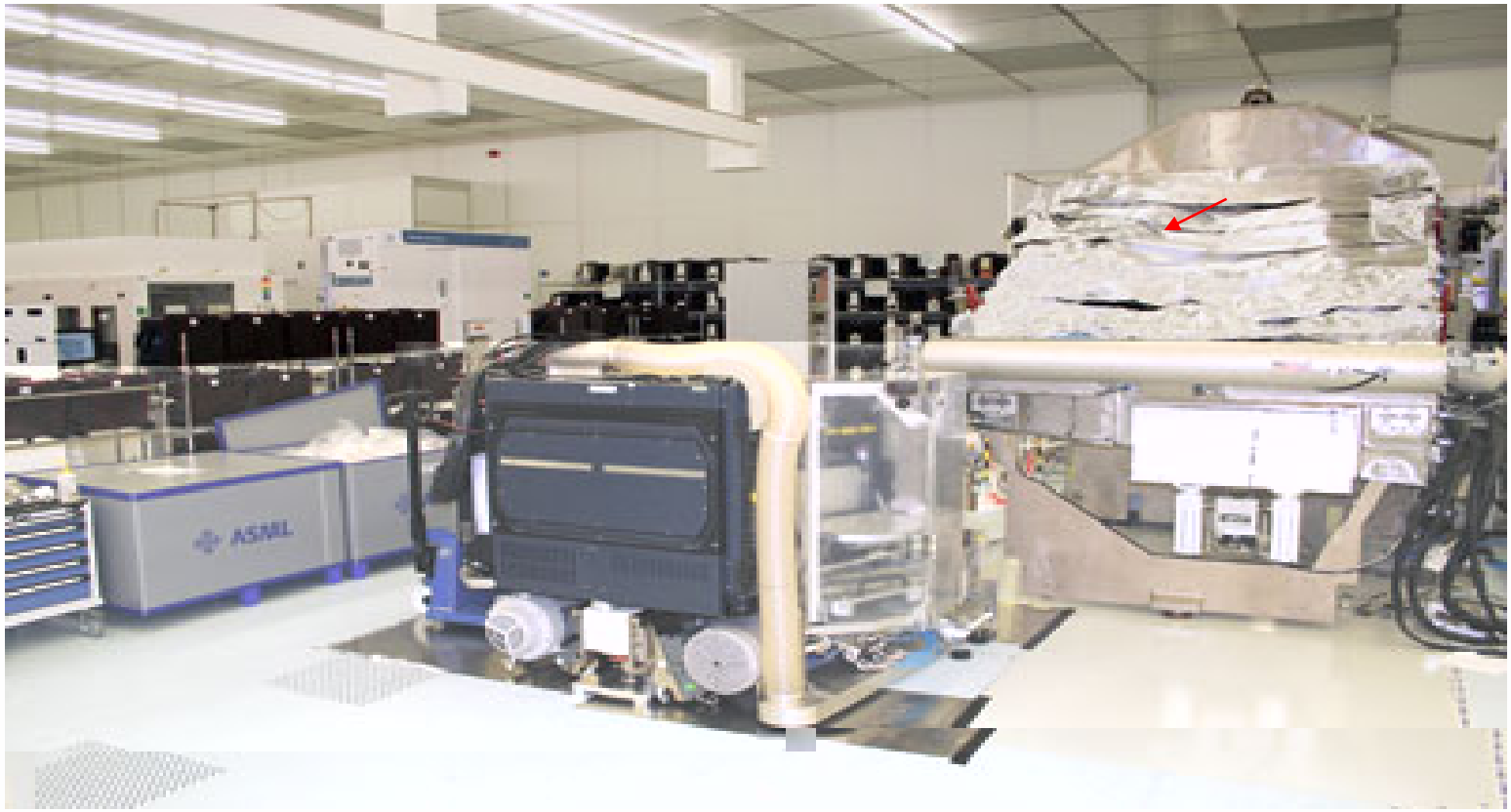


Cross section TEM view



“ ”

EUVL



2006 8 ,ASML IMEC CNSE(University at Albany) α EUVL SCANNER, More Moore EUV EUV
22nm 5000

“ ”

EUVL

(A): KrF resist high resolution
reasonable TP

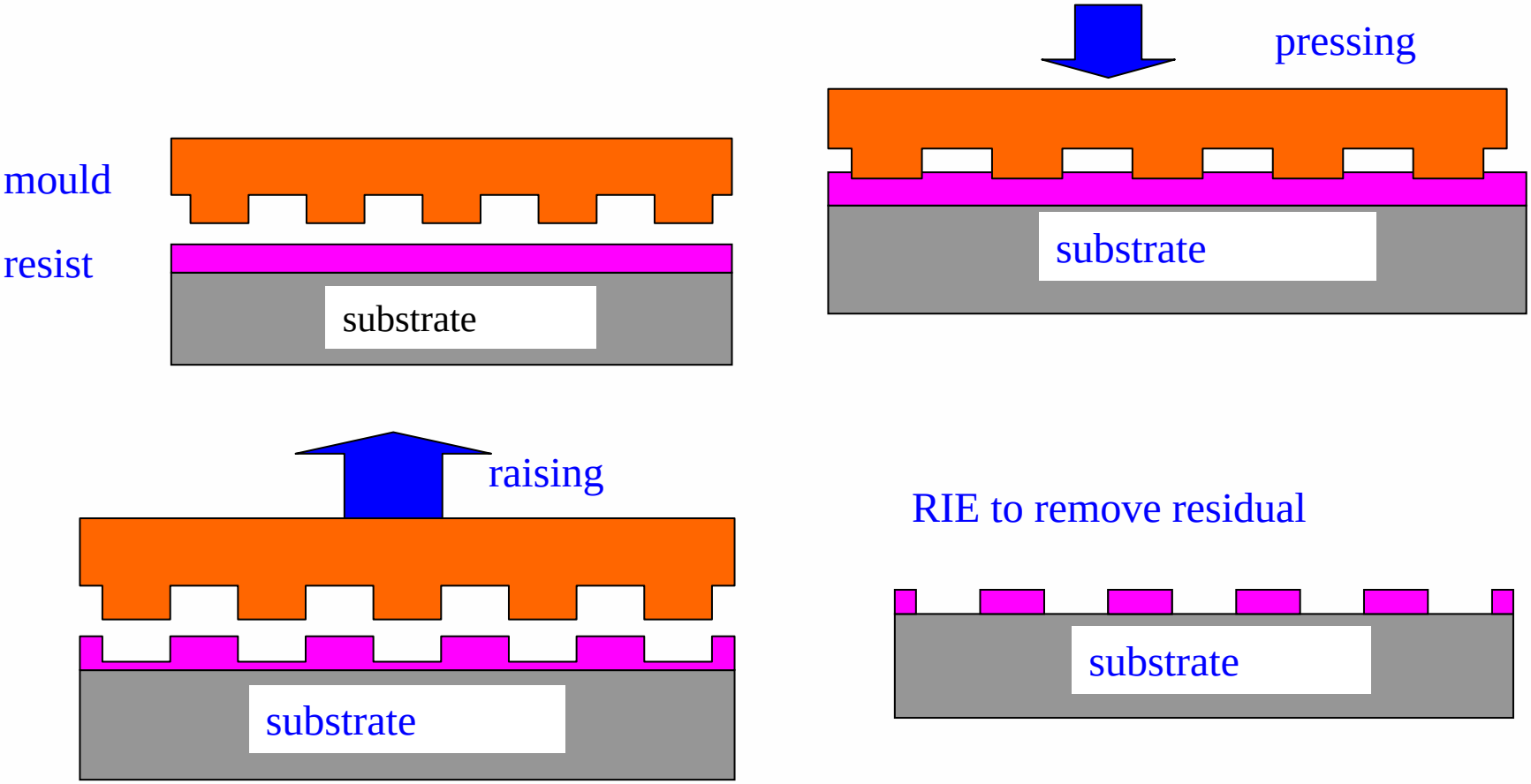
(B): (EUVL)

-
-
-
-
-

80wph 300mm 32nm

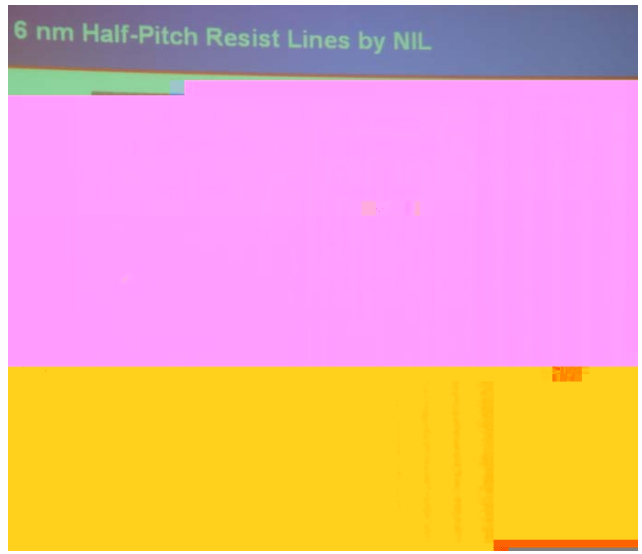
Top-down

- Optical lithography
- E-beam lithography
- EUV(extra-ultra violet) lithography
- Nano-imprint


mould
resist
substrate
pressing
substrate
raising
substrate
RIE to remove residual
substrate

(1) Comparison of EBL & NIL:

	EBL		NIL
1. Resolution:	+		+
2. Throughput:		−	+
3. Cost		−	+
4. Alignment	+		?
5. Damage		−	+



6nm NIL

IEEE NANO07

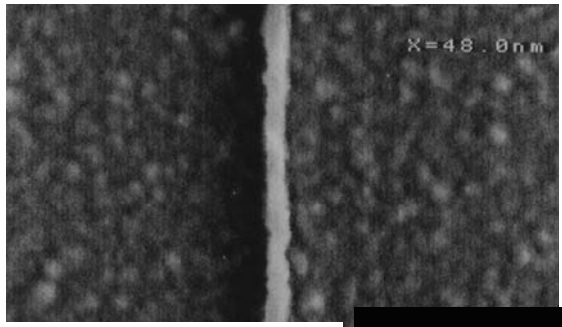
(2) Applications

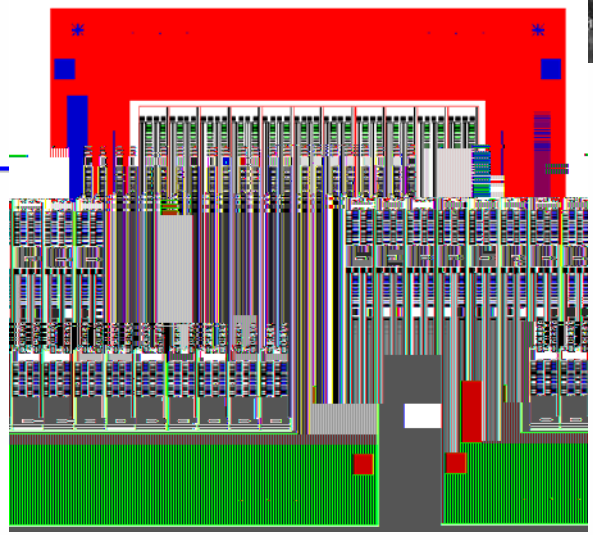
Nano CD,
opto-devices (e.g. gratings),
infrared detectors,
Semiconductor devices

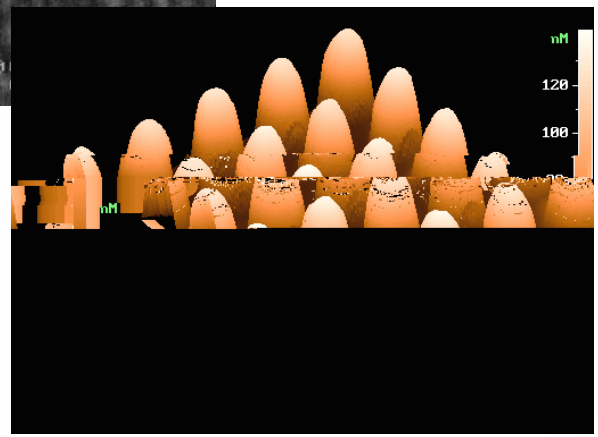
“ ”

Top-down

- Support more than 400 customers
- 12 national criterions on micro-lithography were issued from IMECAS

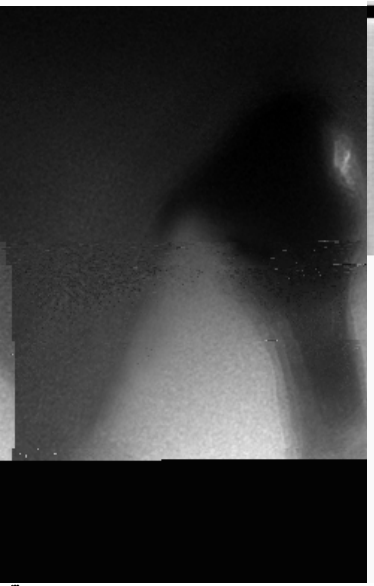


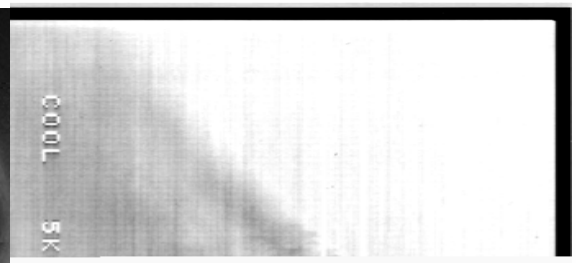


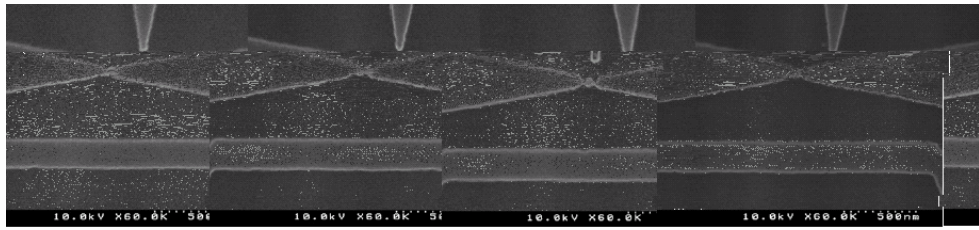


- Advanced optical mask and next generation mask-making;
- Nano-lithography: e-beam, x-ray, Nano-imprint;
- Resolution Enhance Technology : OPC, PSM, etc
- Join in national key project

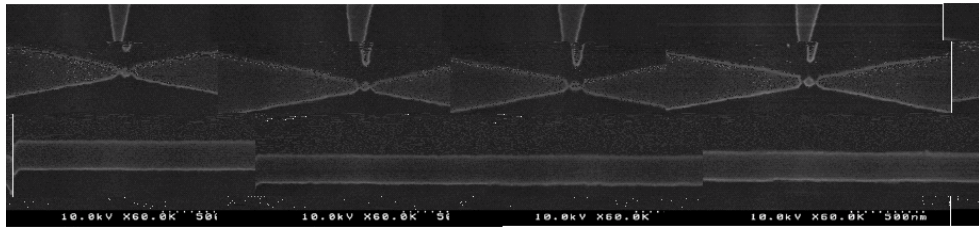
“ ”



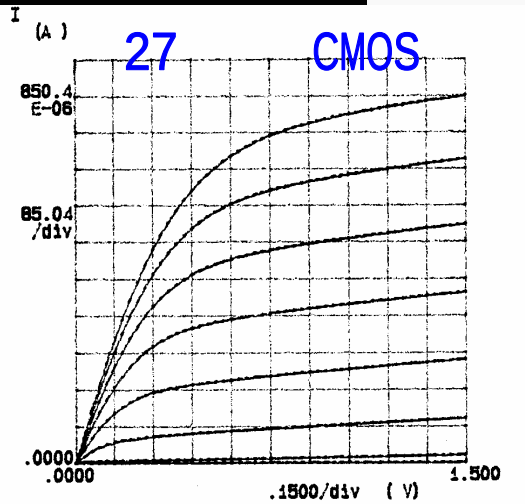


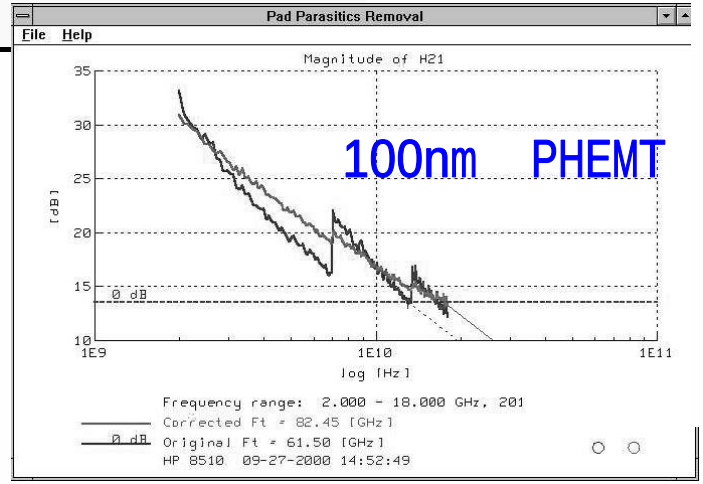


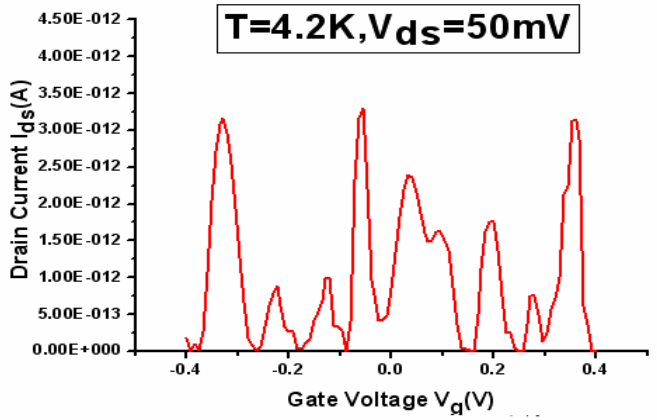
60 nm 50 nm 40-50 nm 30 nm



20-30 nm ~20 nm 10 nm Broken junctions

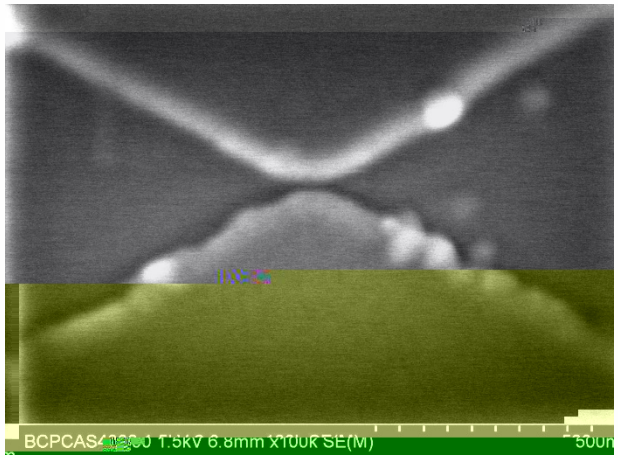


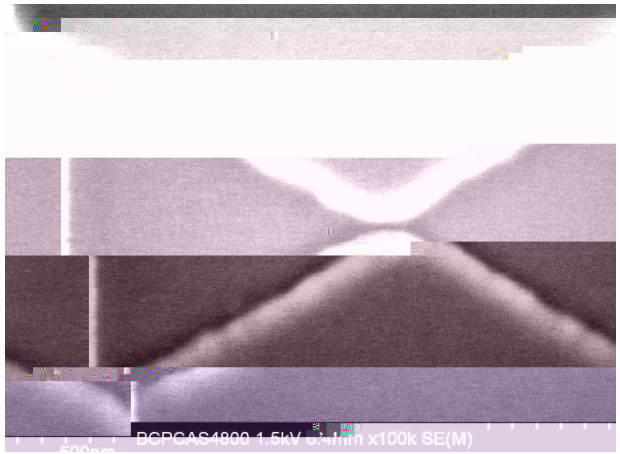




$C_g = 1.1aF$

“ ”


BCPCAS4800 1.5kV 6.8mm X100k SE(M)

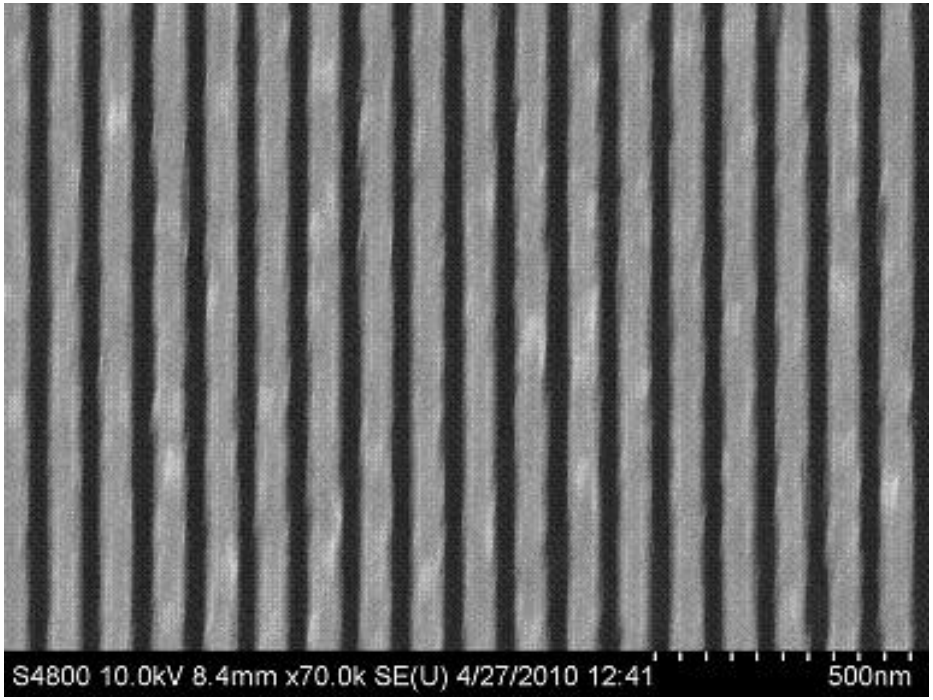

BCPCAS4800 1.5kV 6.4mm x100k SE(M)

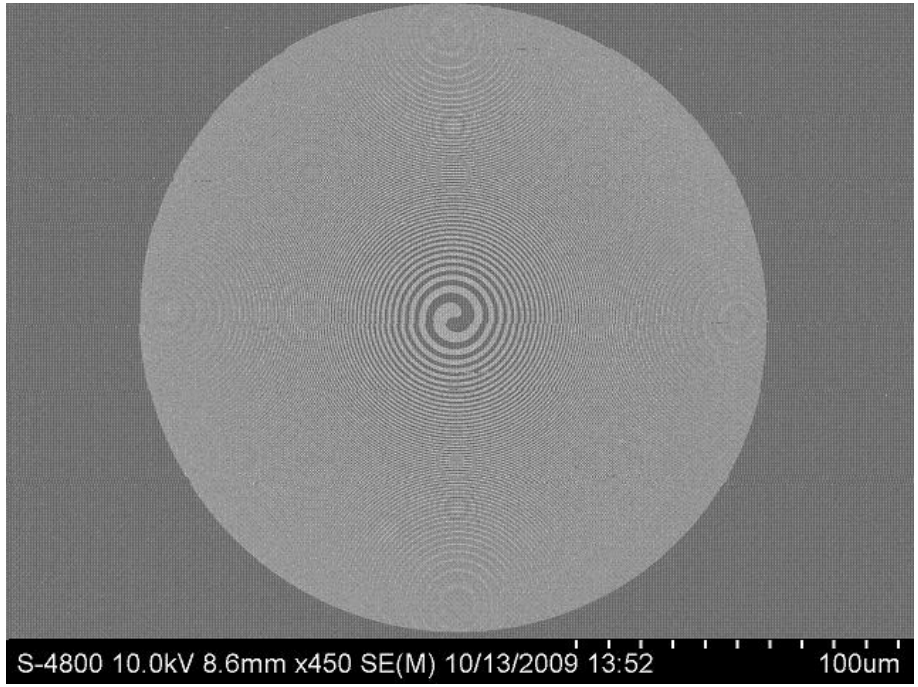

12.9nm
BCPCAS4800 1.5kV 6.8mm x100k SE(M)


14.9nm

13nm **100nm**

“ ”

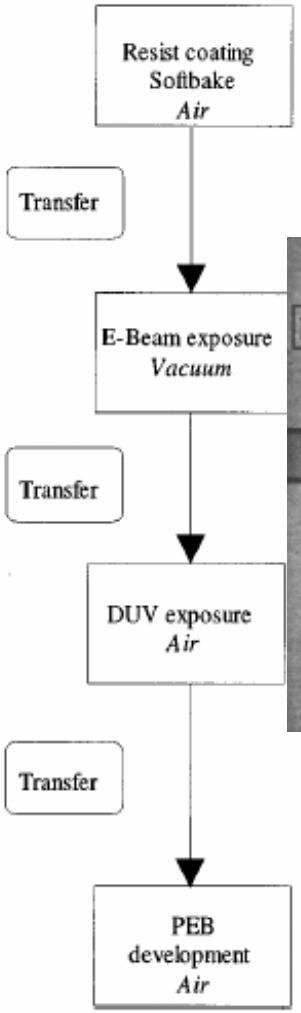




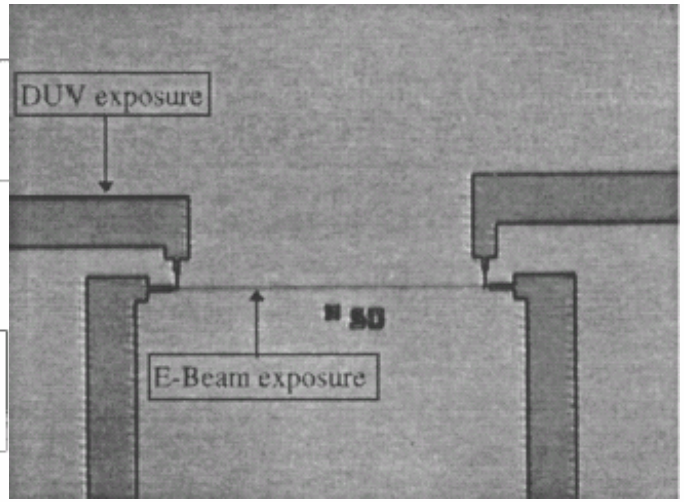
10000 /
2mmx2mm

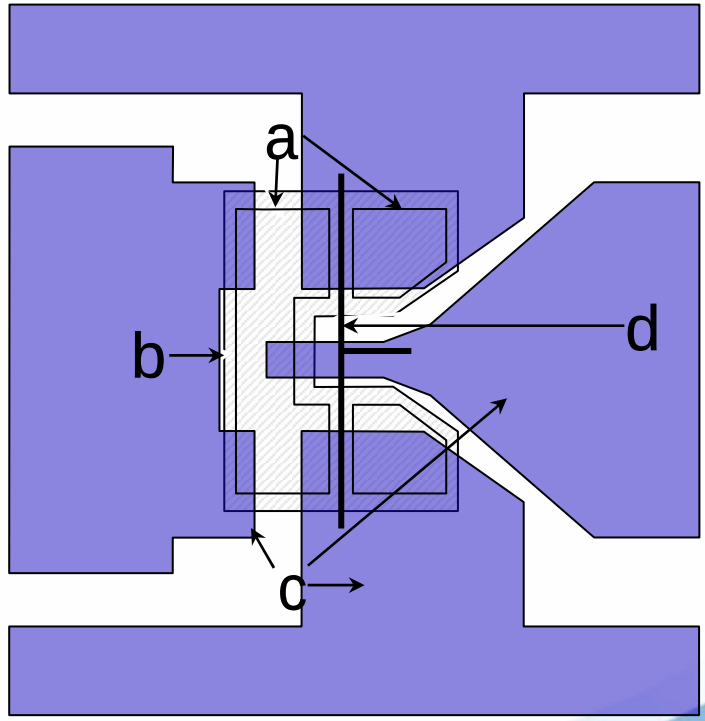
200

“ ”

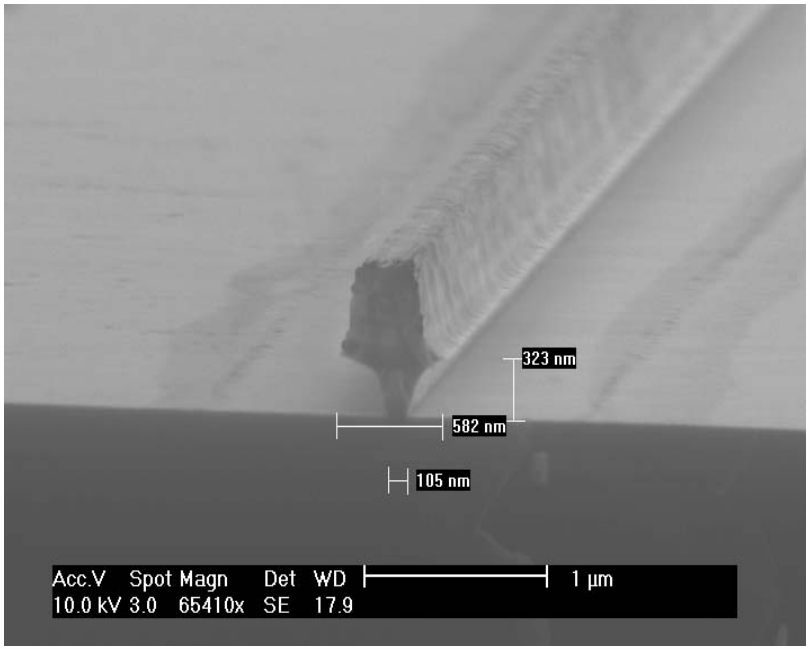


- Exposure tools: ASM-L 5000/55 stepper and JBX-5000LS e-beam system at 50keV

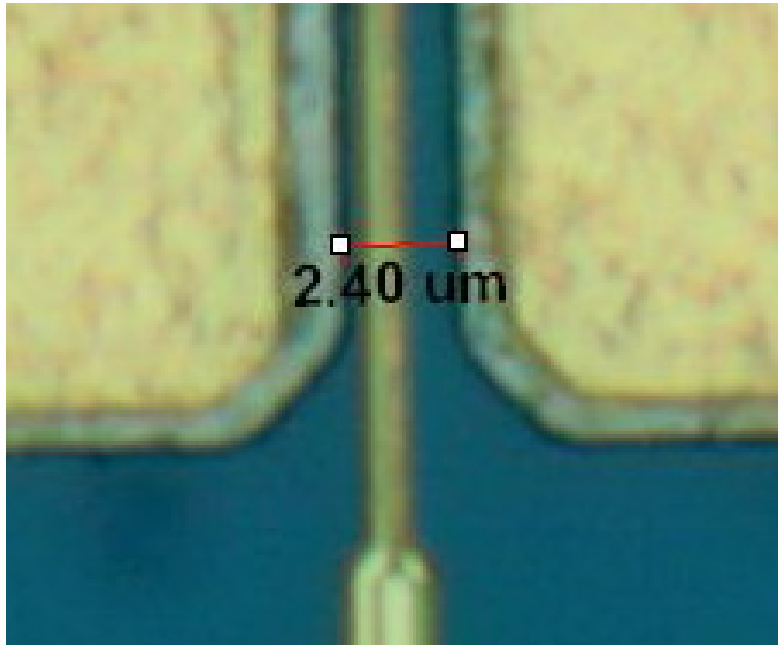




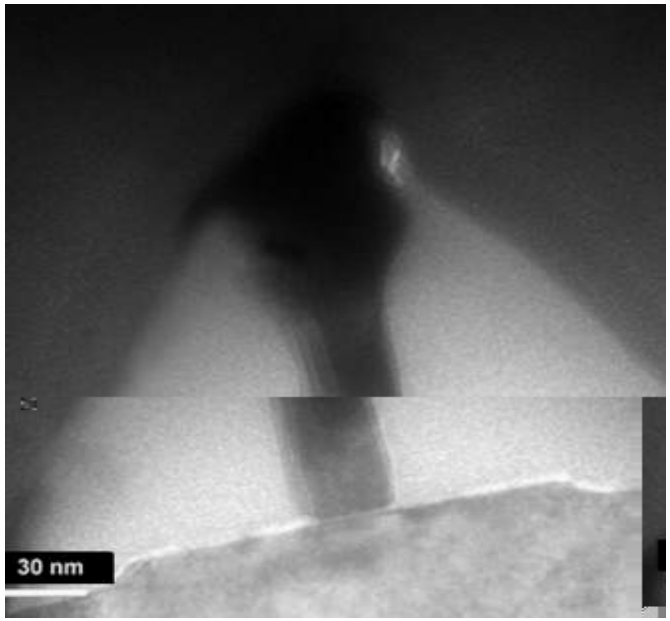
T

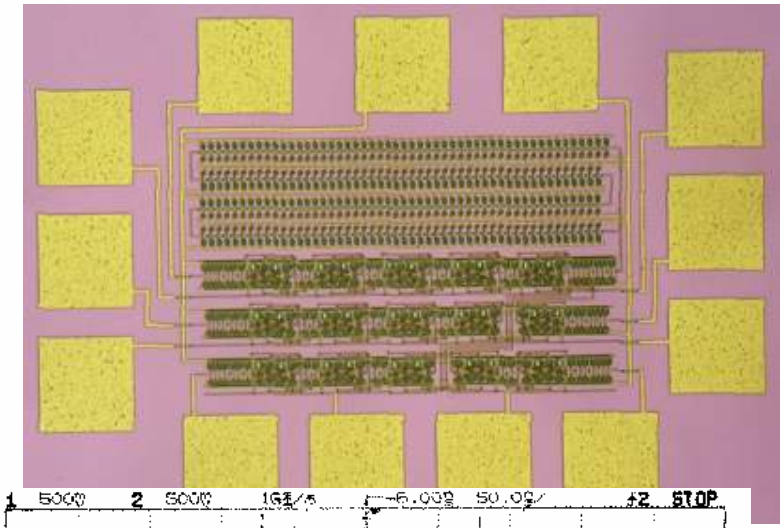

323 nm
582 nm
105 nm
Acc.V Spot Magn Det WD 1 µm
10.0 kV 3.0 65410x SE 17.9

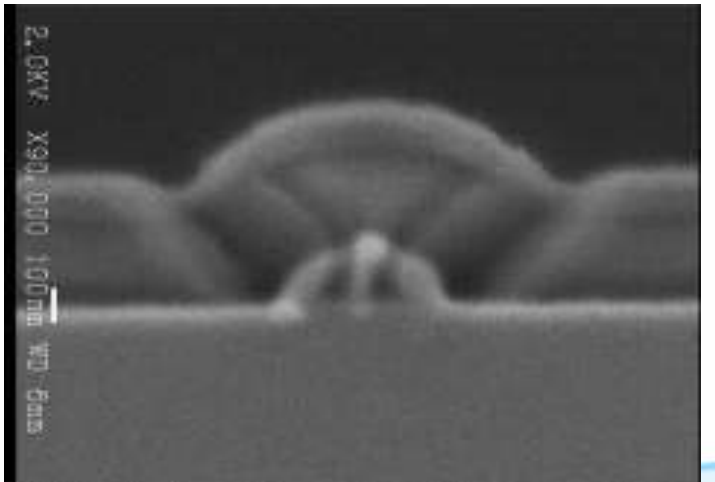
100nm T

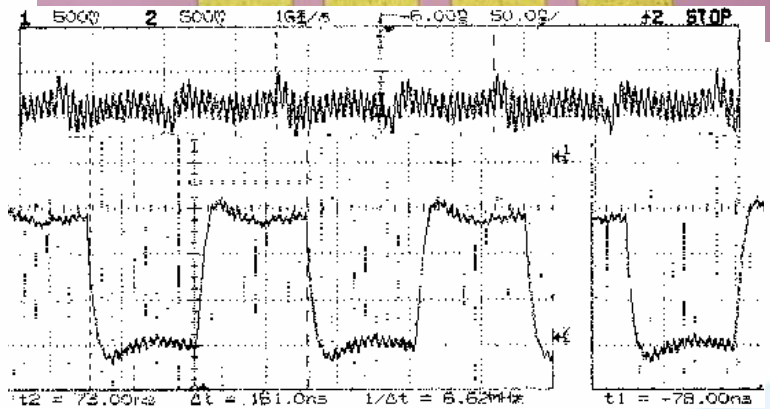

2.40 um

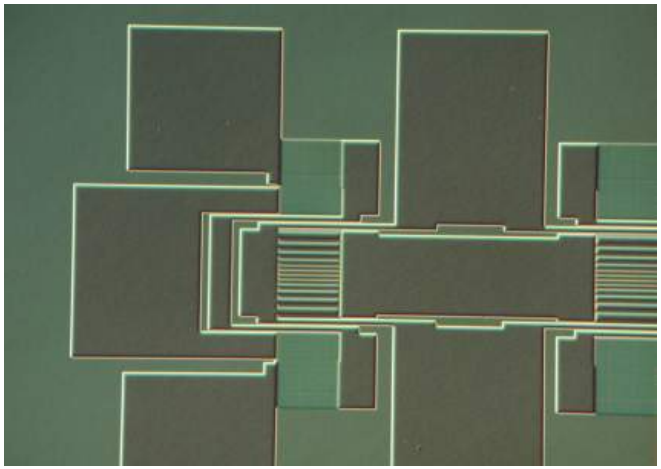
CMOS

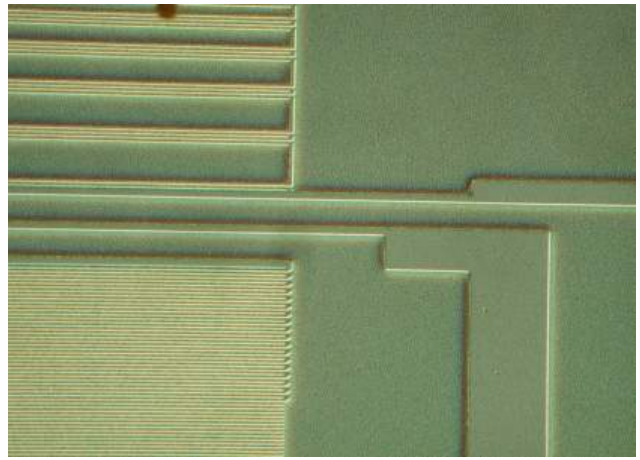

30 nm

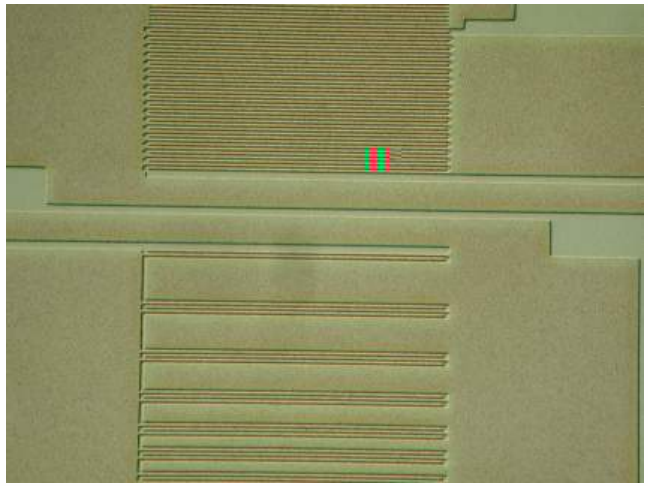


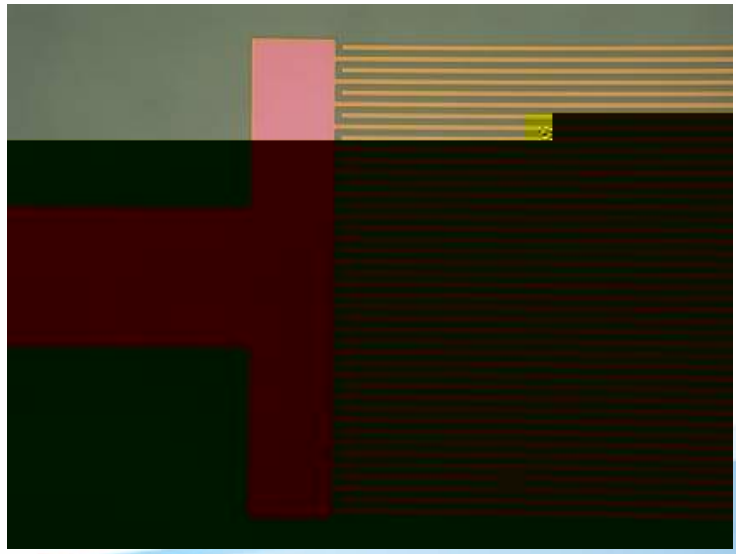



1 500Ω 2 500Ω 1GS/s -6.00s 50.0Ω/ +2 STOP
t2 = 72.00ns Δt = 161.0ns 1/Δt = 6.62MHz
t1 = -78.00ns









“ ”

Top-down

Q & A !