Introduction to Micro/Nano Fabrication Techniques

Lecture 1
Dr. Yi-Chung Tung

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Fabrication of Nanomaterials

- Top-Down Approach
  - Begin with bulk materials that are reduced into nano-scale materials
  - Ex: Traditional Machining
- Bottom-Up Approach
  - Begin with atoms and molecules that can grown into zero, one, two, and three-dimensional nanostructures
  - Ex: Chemical Synthesis
- Hybrid
  - Top-Down + Bottom-Up

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Top-Down Approach

- Mechanical energy
  - Ball milling, polishing, grinding
- Thermal
  - Annealing, evaporation, pyrolysis
- High energy
  - Arch, laser, ion milling, reactive ion etching
- Chemical
  - Chemical etching, CMP, electropolishing, anodizing
- Lithographic
  - Photo, e-beam, EUV, X-ray, μ-cp, NIL, Nanosphere
- Nature
  - Erosion, decomposition, digestion

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Bottom-Up Approach

- Gas
  - Chemical vapor deposition, atomic layer deposition, MOCVD, MBE, ion implantation
- Liquid
  - Self-assembly, supermolecule, reduction, template synthesis
- Lithographic
  - Dip-pen, block co-polymer, STM writing
- Biological
  - Protein, nuclear acidcrystal formation

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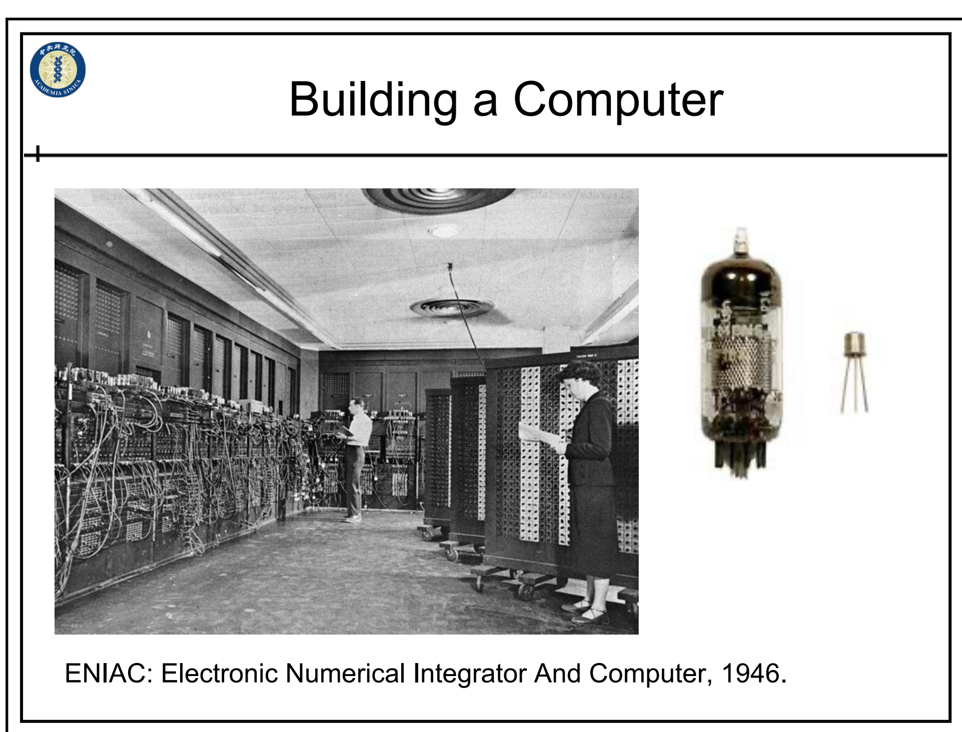

Building a Computer

ENIAC: Electronic Numerical Integrator And Computer, 1946.

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First Integrated Circuit

"What we didn't realize then was that the integrated circuit would reduce the cost of electronic functions by a factor of a million to one, nothing had ever done that for anything before" - Jack Kilby 2000 Nobel Prize

1958 Texas Instruments

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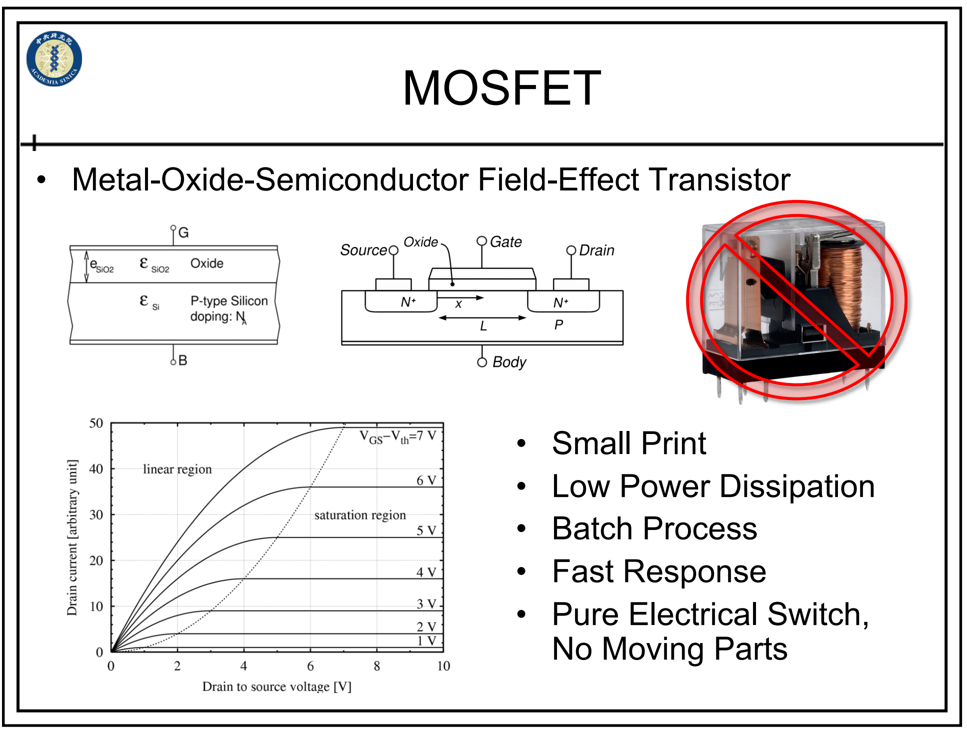

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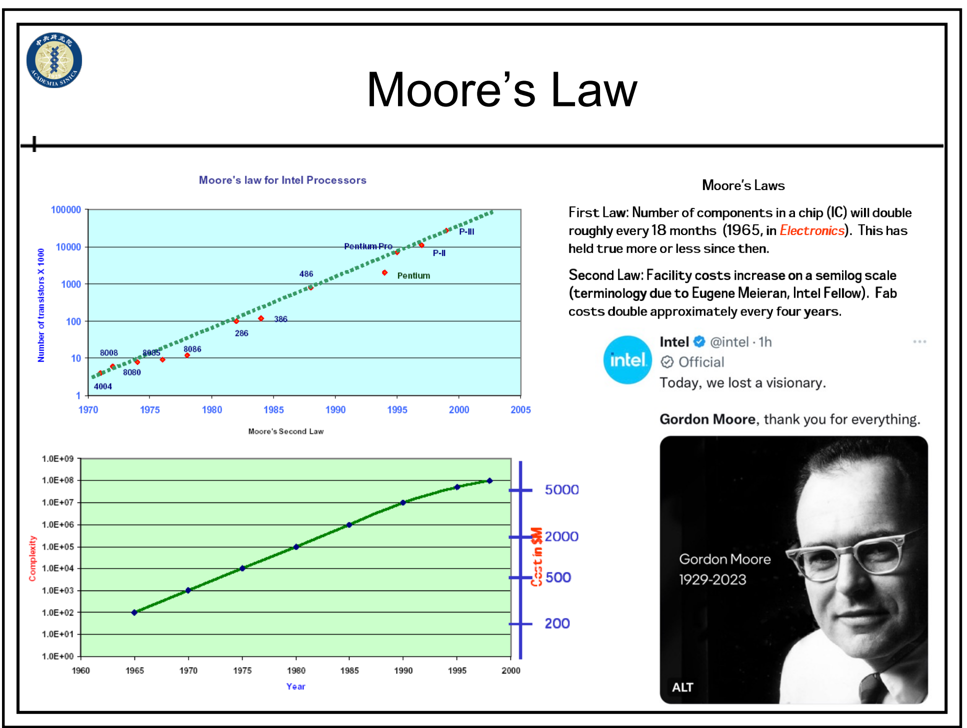

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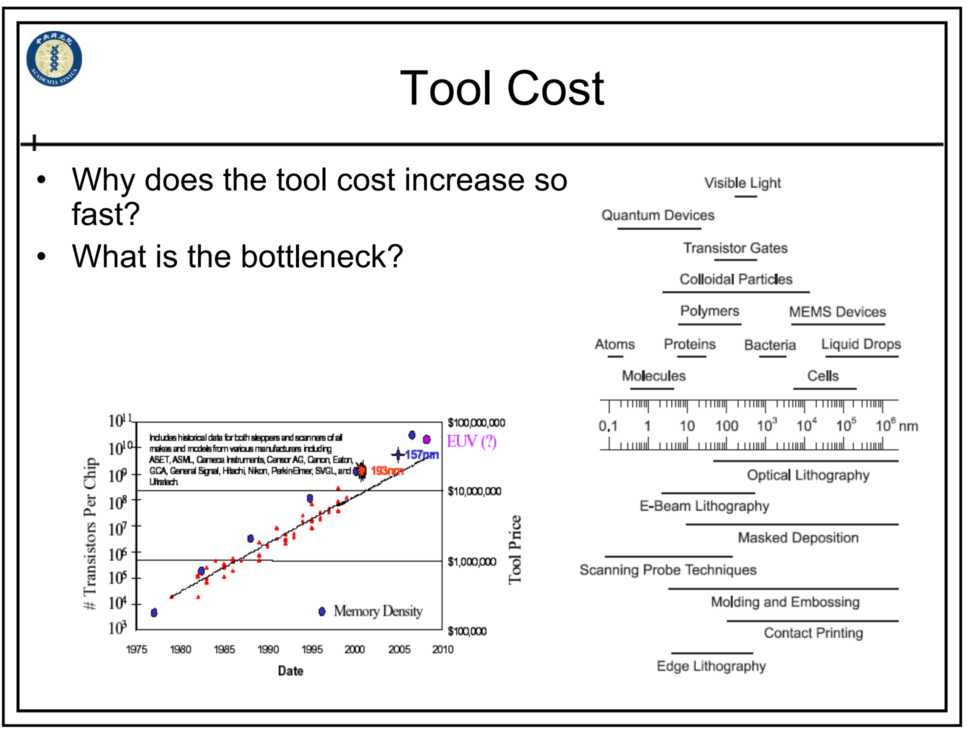

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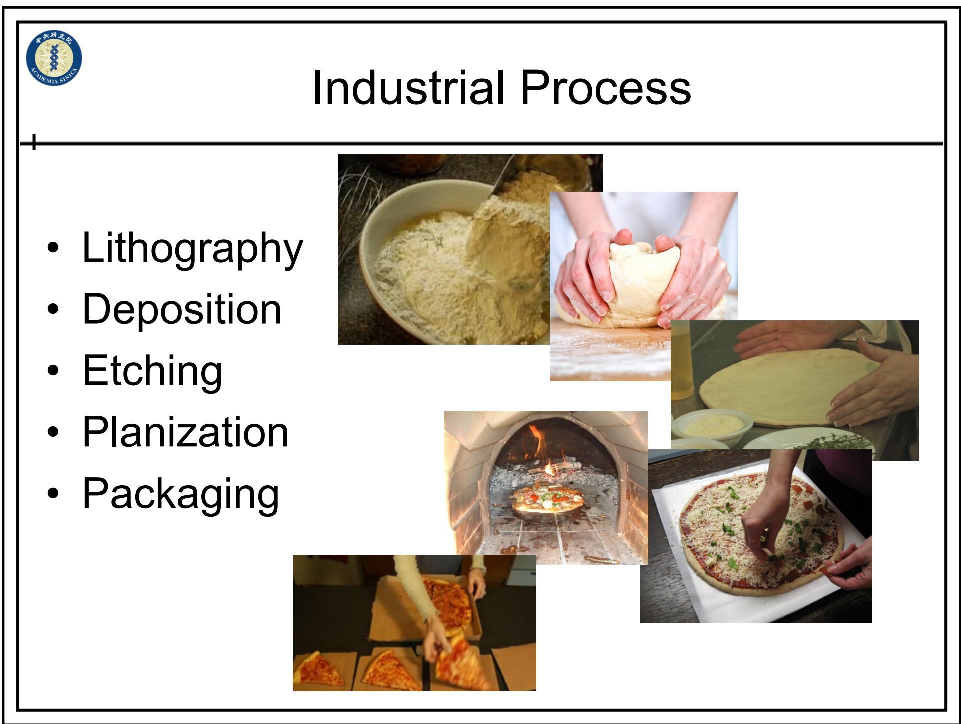

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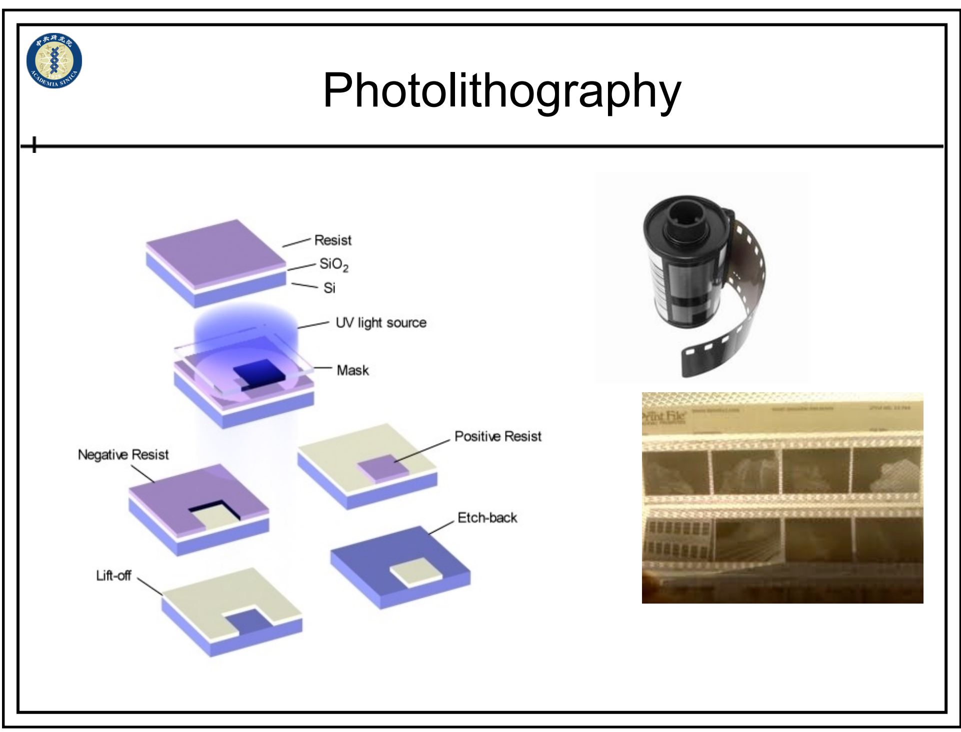

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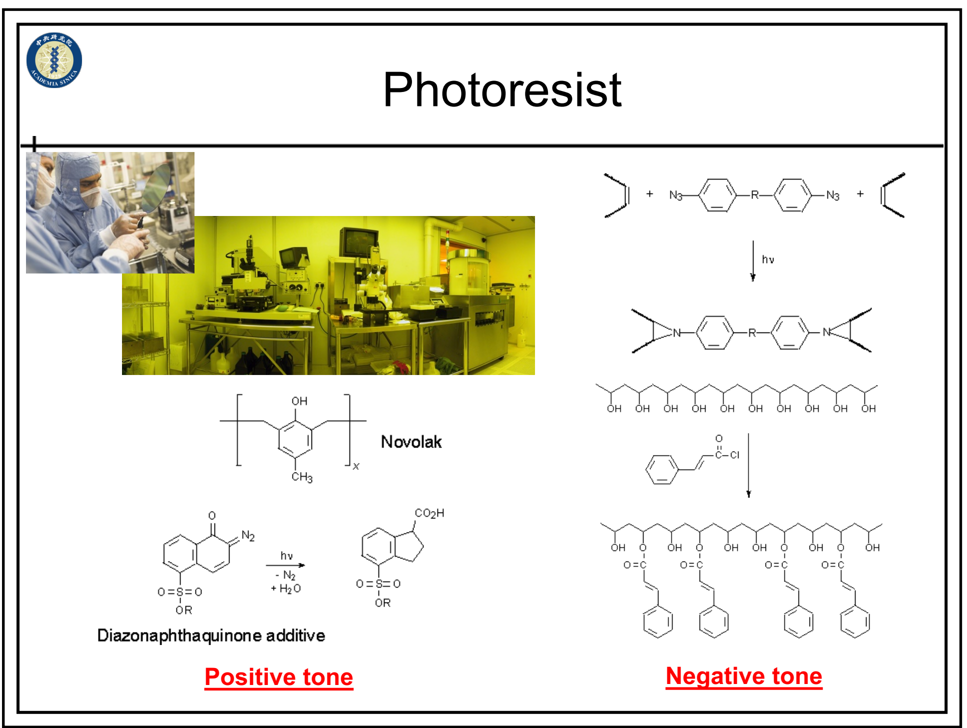

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STEP I: Cleaning

RCA Cleaning (By Radio Corporation of America in 1965)

Chemicals	Volume ratio	Procedure Time (min)	Operation Temperature	Function
Trichlorothane		5	Room T	Dissolve Organic
Acetone		5	Room T	Dissolve Organic
DI Water		5	Room T	Washing
H_2SO_4 (98%)-H_2O_2 (30%) (Piranha Solution)	3:1	10-20	～90℃	Oxide and Dissolve Organic and Metals
DI Water		5	Room T	Washing
HF(49 wt %)-H_2O	～2:100	10-20	Room T	Dissolve surface SiO_2
NH_4OH(29%)-H_2O_2(30%)-H_2O	1:1:5	10-20	～90℃	Oxide and Dissolve Metals
DI Water		5	Room T	Washing
HCl(37%)- H_2O_2(30%)-H_2O	1:1:5	10-20	～90℃	Oxide and Dissolve Metals
DI Water		5	Room T	Washing
Spin Dry (In lad – N_2 blow)				

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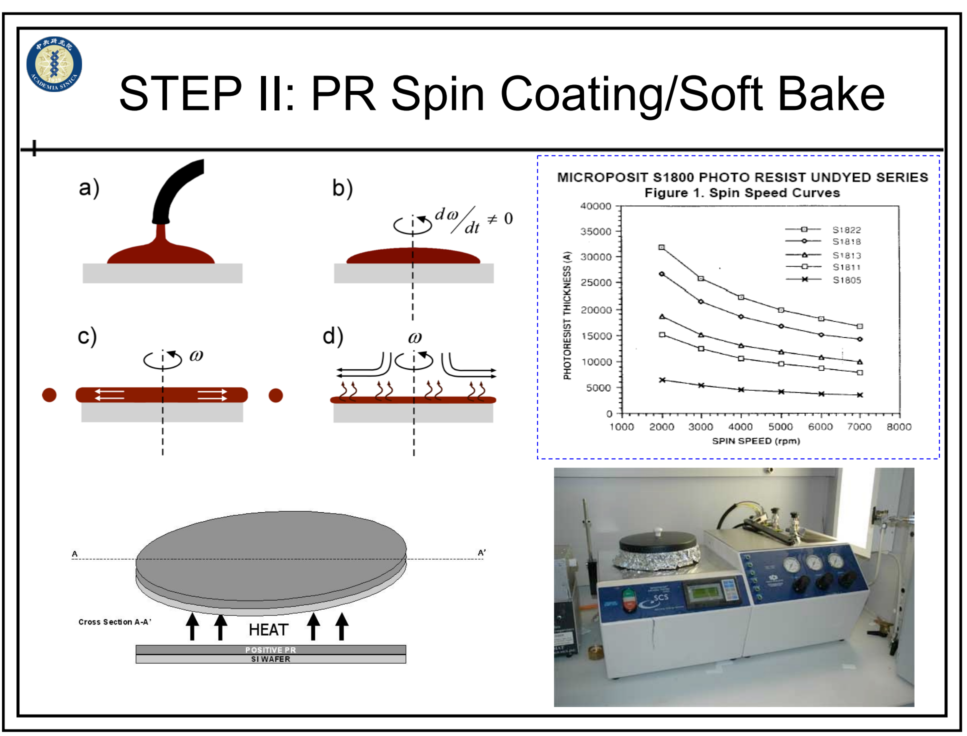

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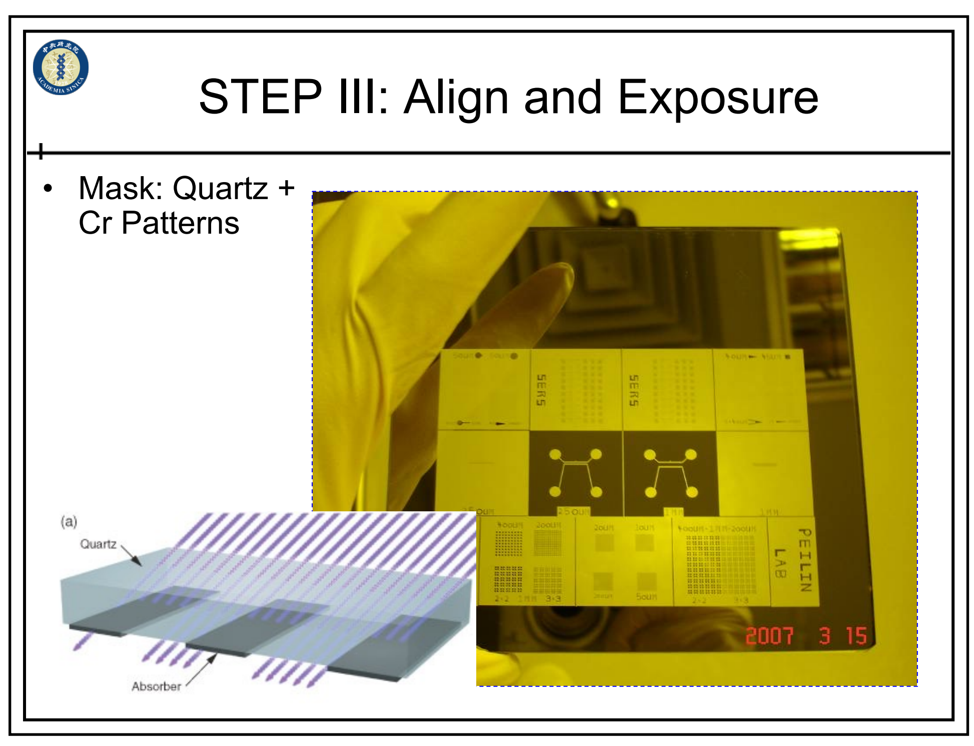

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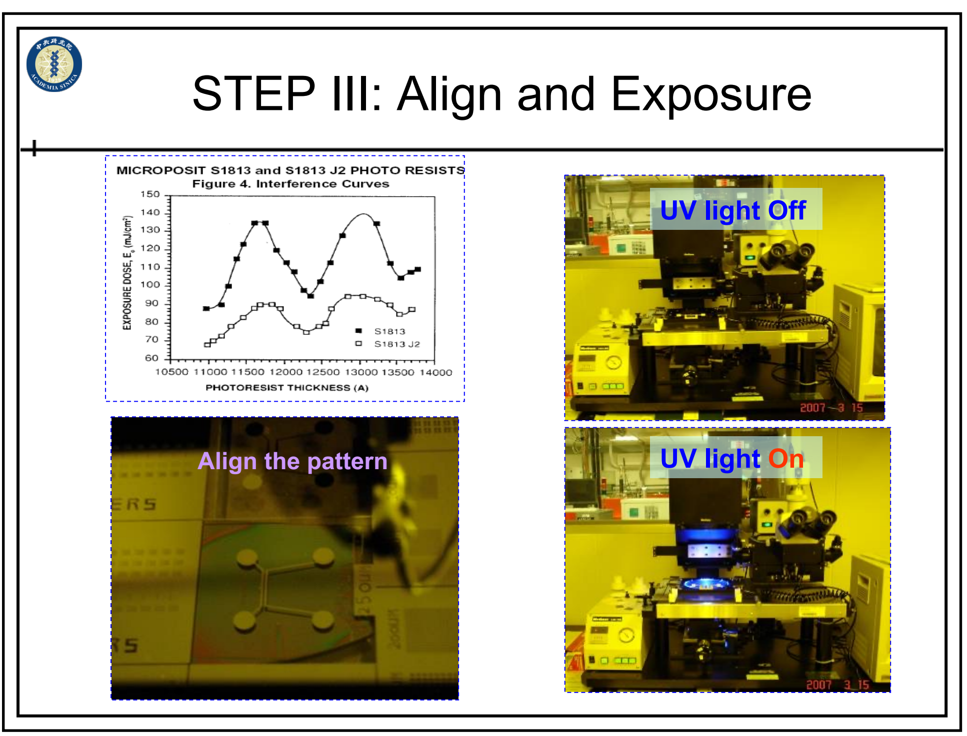

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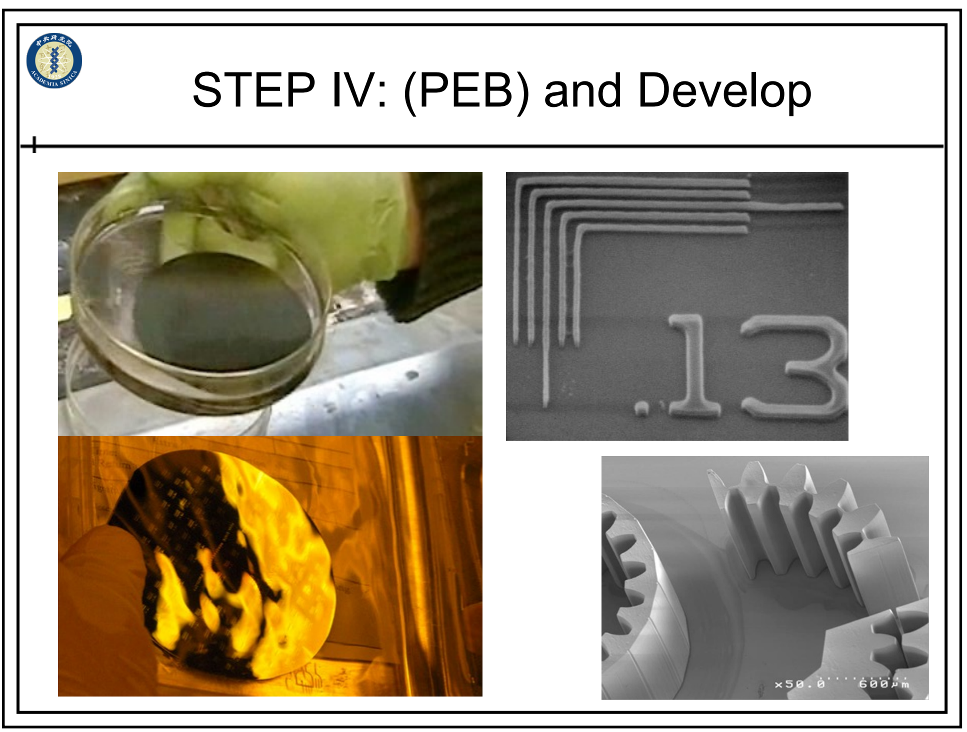

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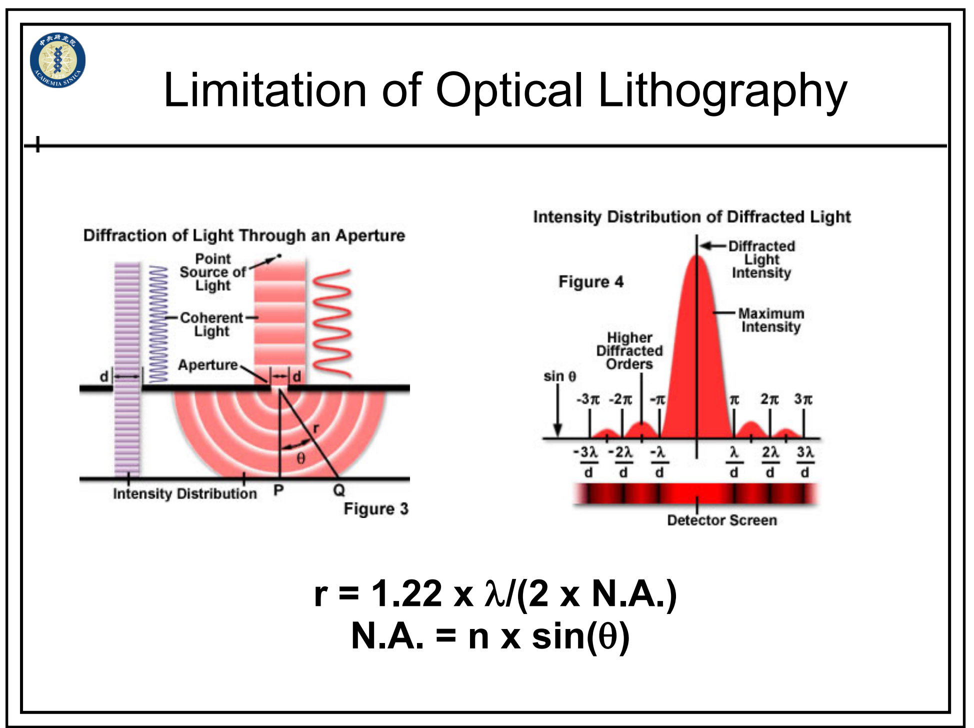

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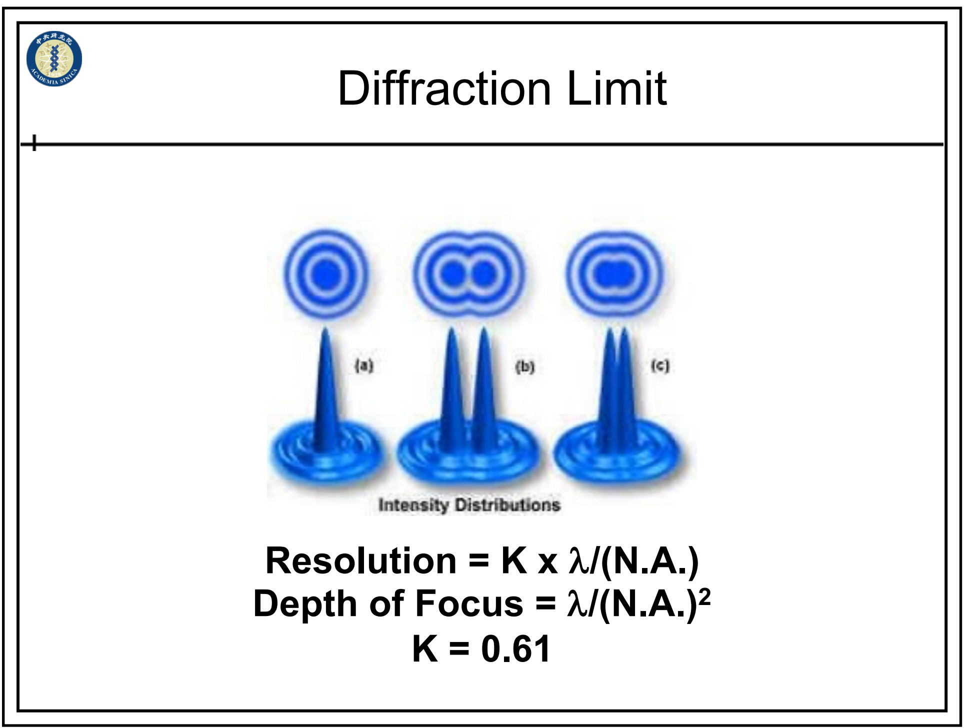

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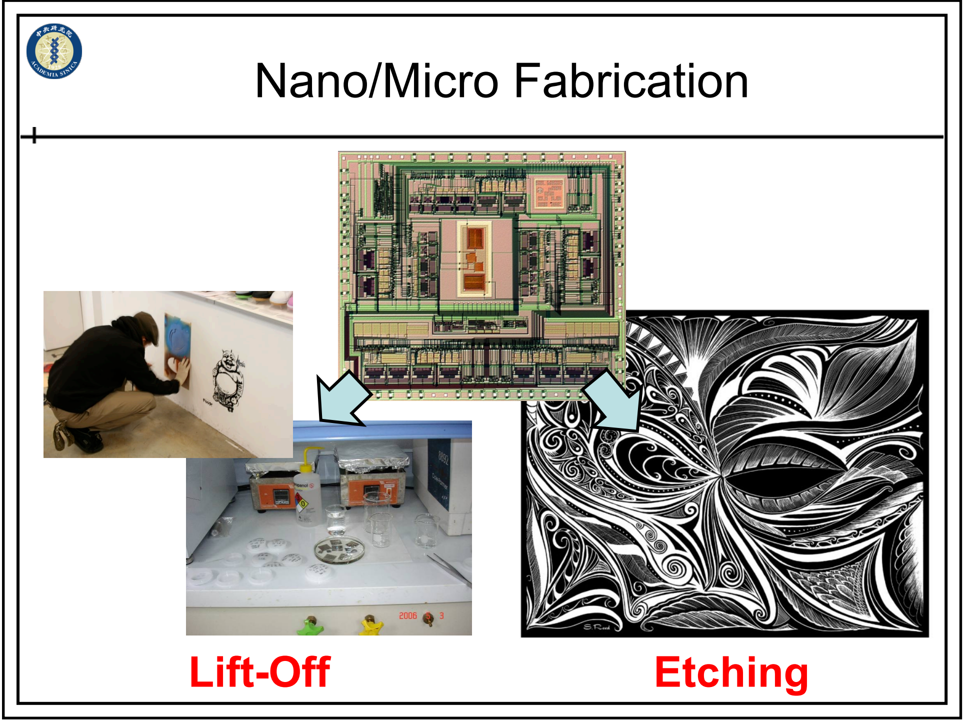

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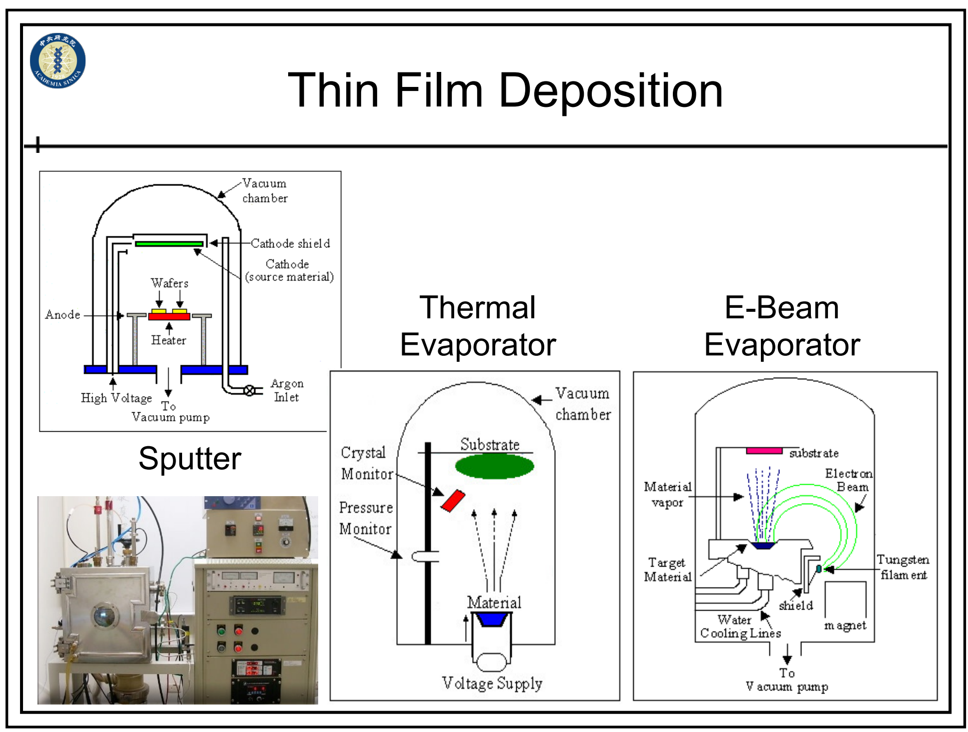

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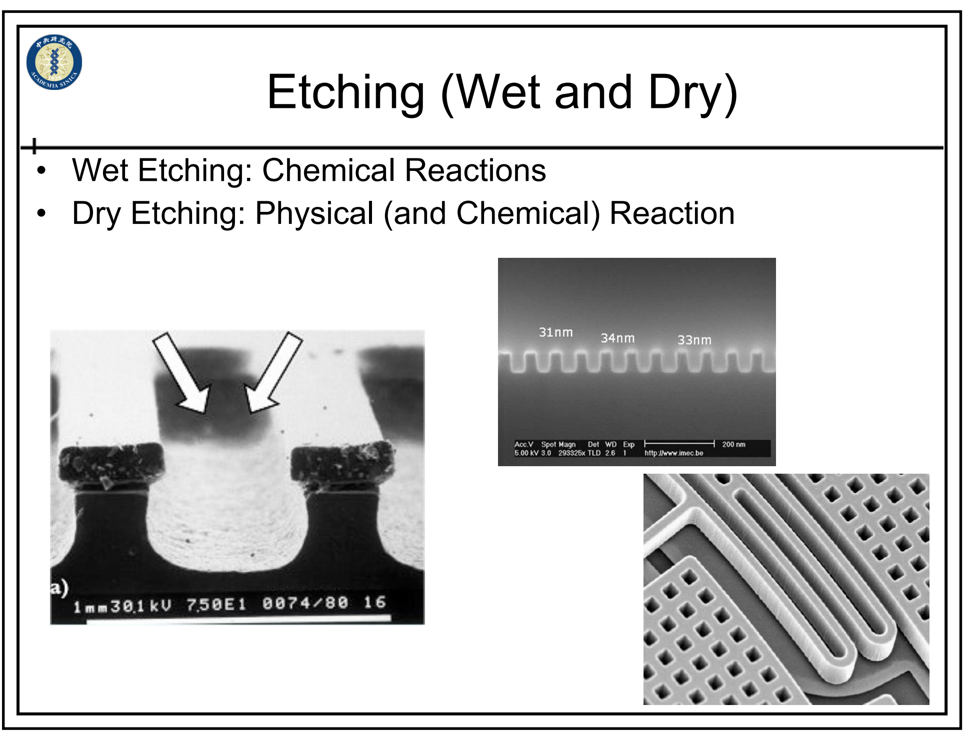

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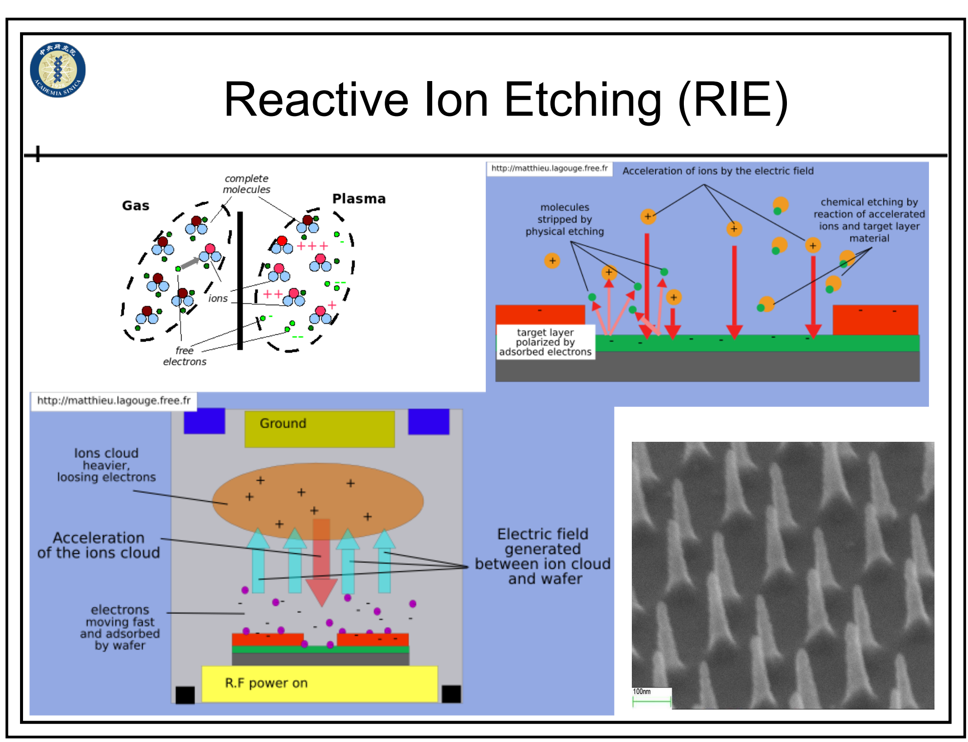
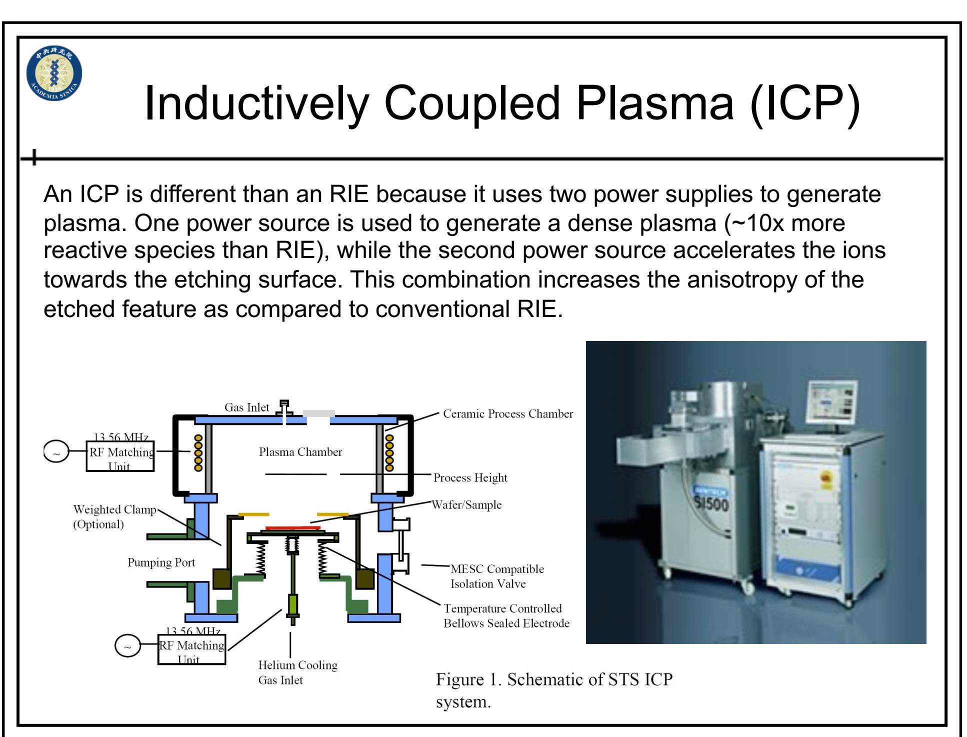
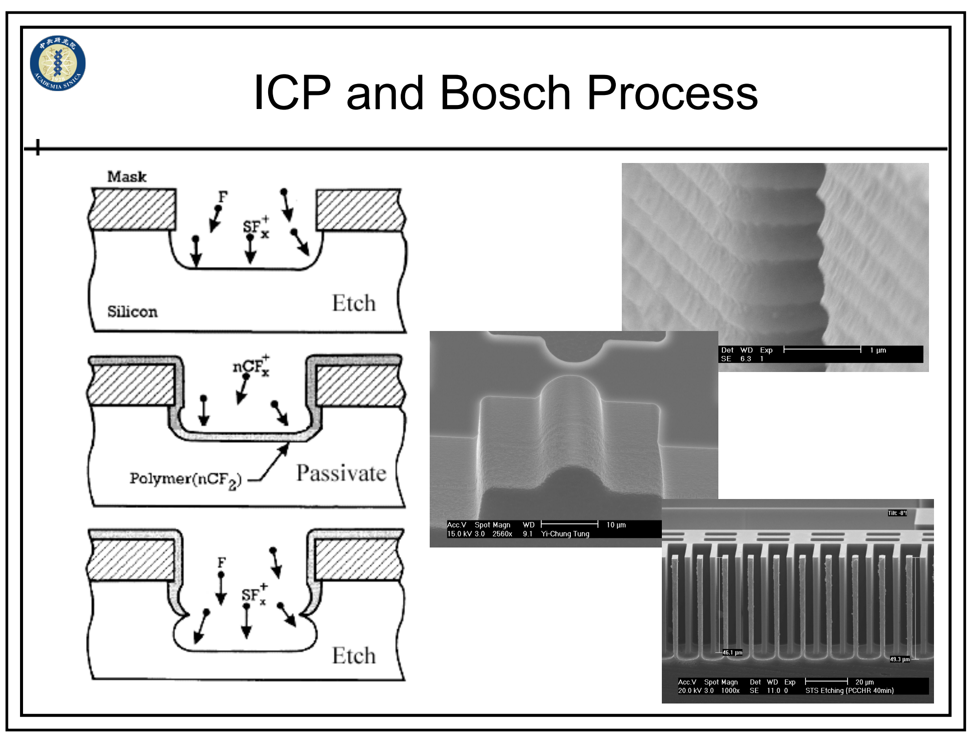

Reactive Ion Etching (RIE)
Gas
complete molecules
Plasma
ions
free electrons
http://matthieu.lagouge.free.fr
Acceleration of ions by the electric field
molecules stripped by physical etching
chemical etching by reaction of accelerated ions and target layer material
target layer polarized by adsorbed electrons
http://matthieu.lagouge.free.fr
Ground
Ions cloud heavier, loosing electrons
Acceleration of the ions cloud
Electric field generated between ion cloud and wafer
electrons moving fast and adsorbed by wafer
R.F power on


Inductively Coupled Plasma (ICP)
An ICP is different than an RIE because it uses two power supplies to generate plasma. One power source is used to generate a dense plasma (~10x more reactive species than RIE), while the second power source accelerates the ions towards the etching surface. This combination increases the anisotropy of the etched feature as compared to conventional RIE.
Gas Inlet
Ceramic Process Chamber
13.56 MHz
RF Matching Unit
Plasma Chamber
Process Height
Wafer/Sample
Weighted Clamp (Optional)
Pumping Port
MESC Compatible Isolation Valve
Temperature Controlled Bellows Sealed Electrode
13.56 MHz
RF Matching Unit
Helium Cooling Gas Inlet
Figure 1. Schematic of STS ICP system.



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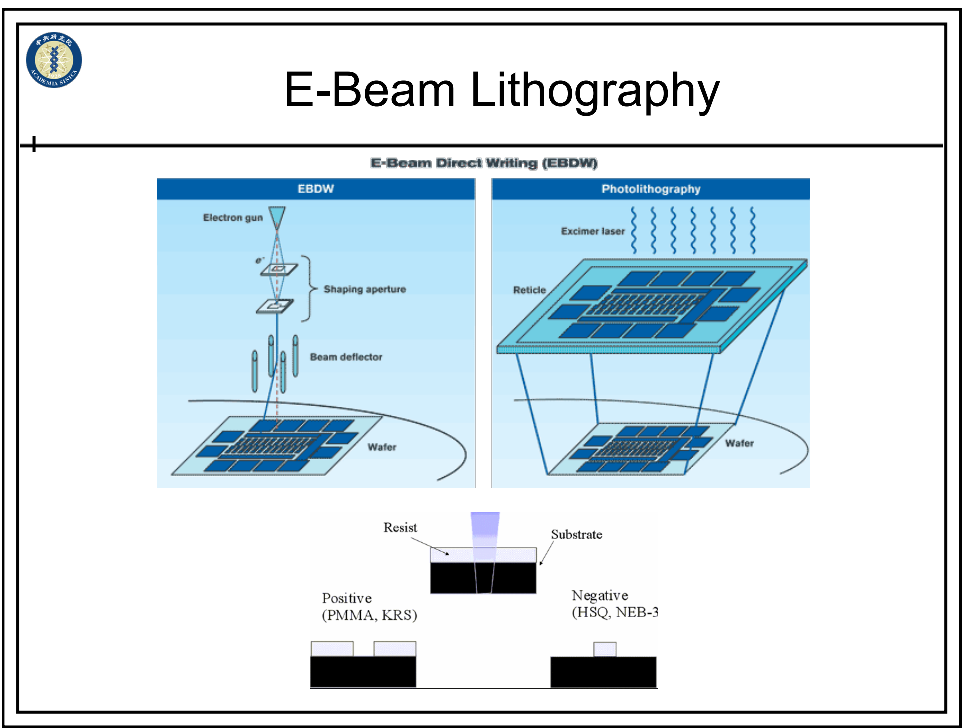

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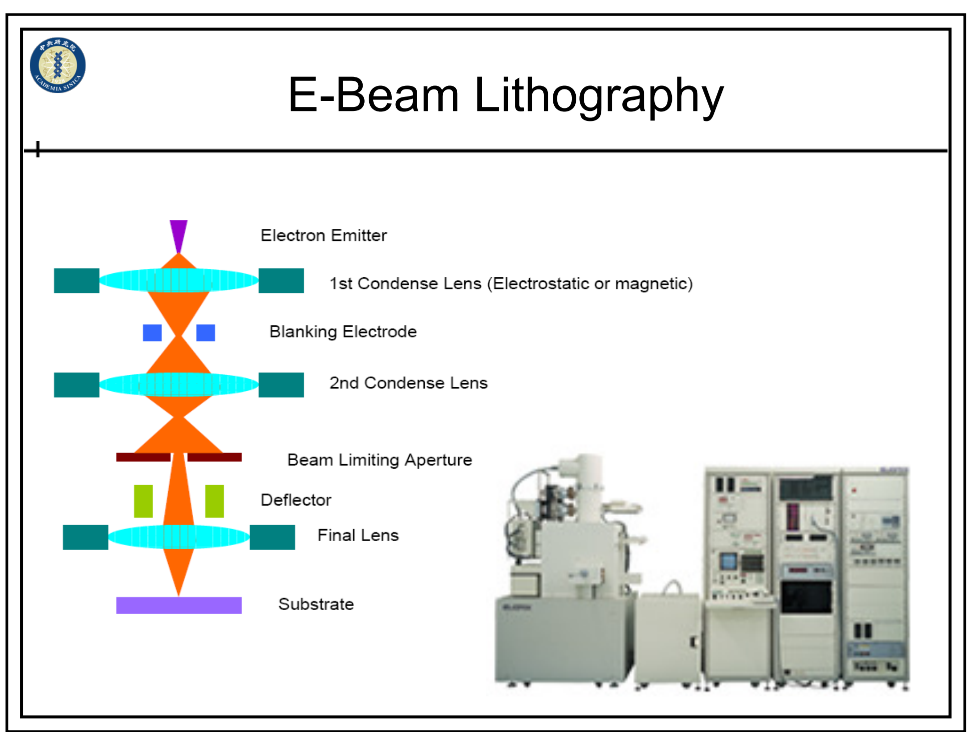

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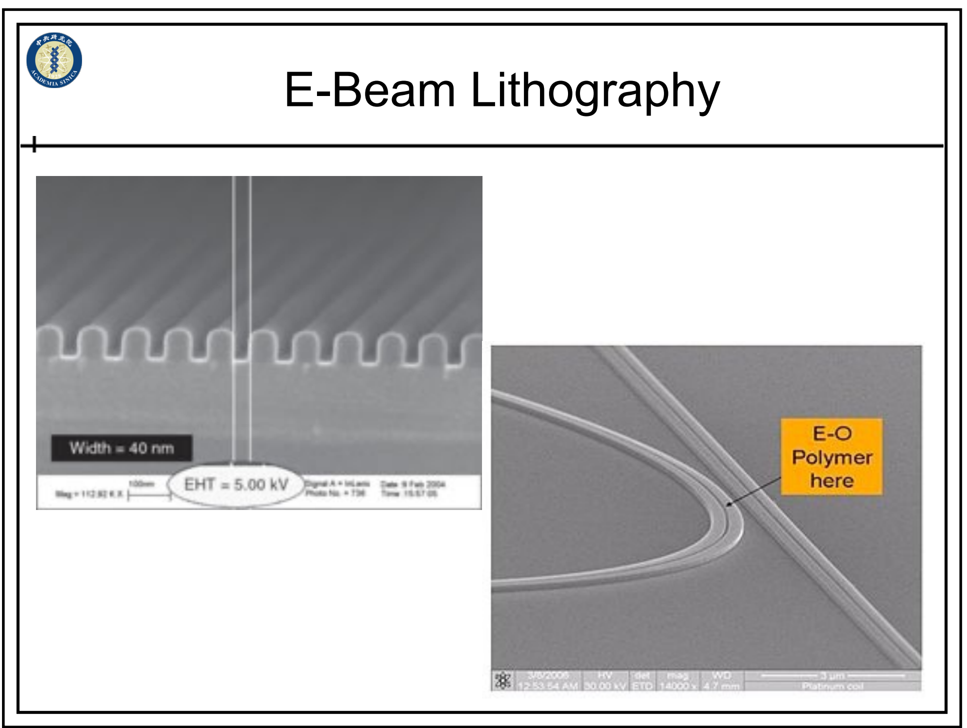

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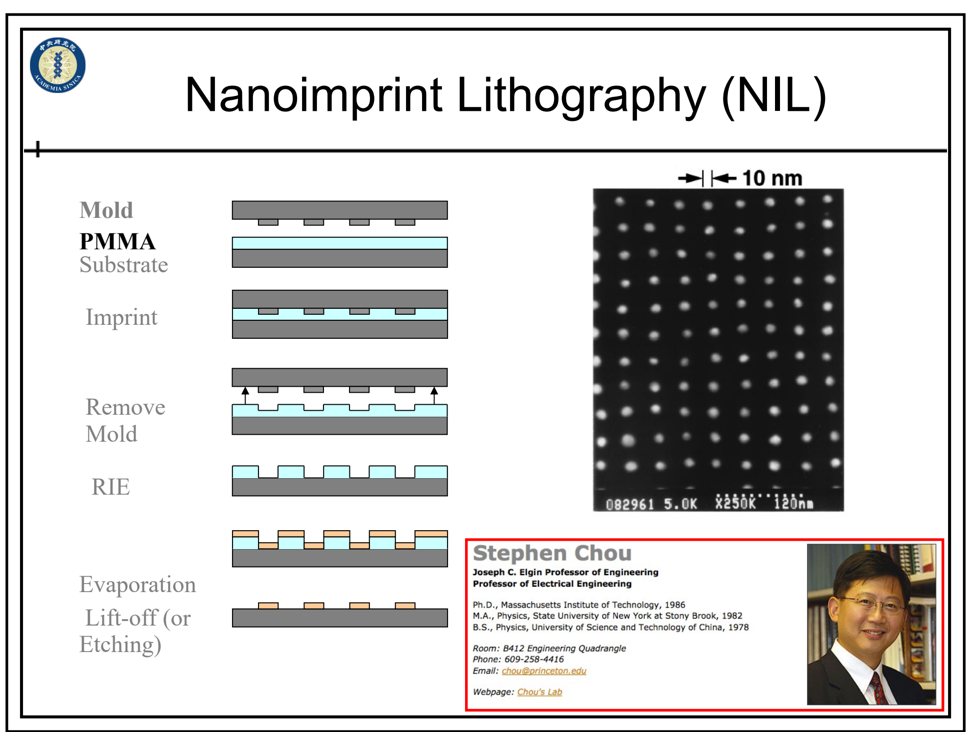

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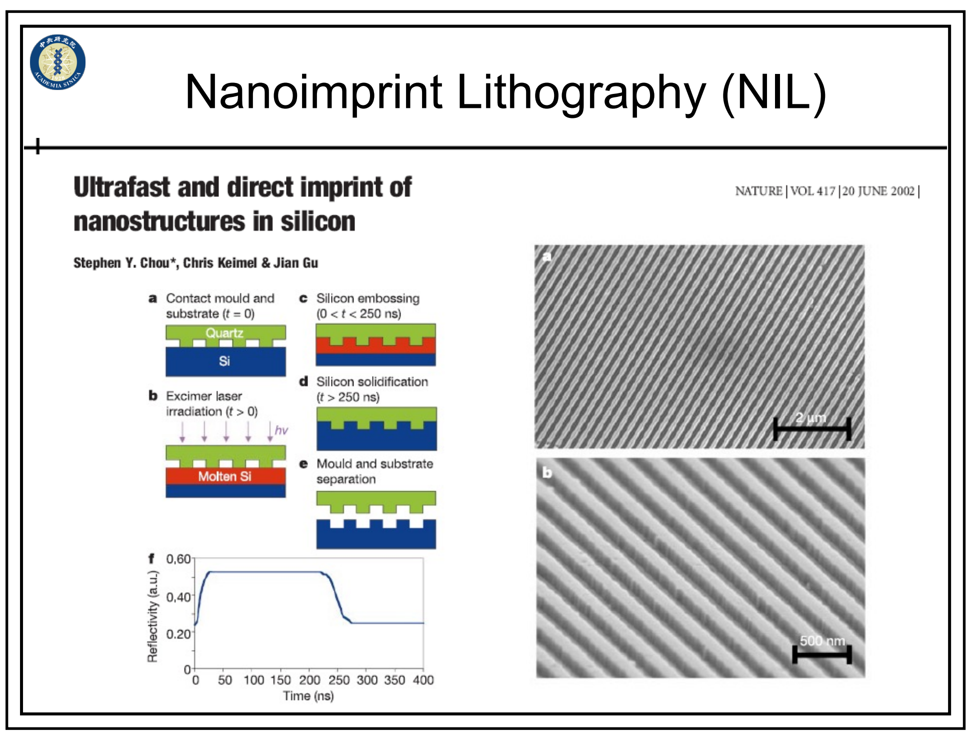

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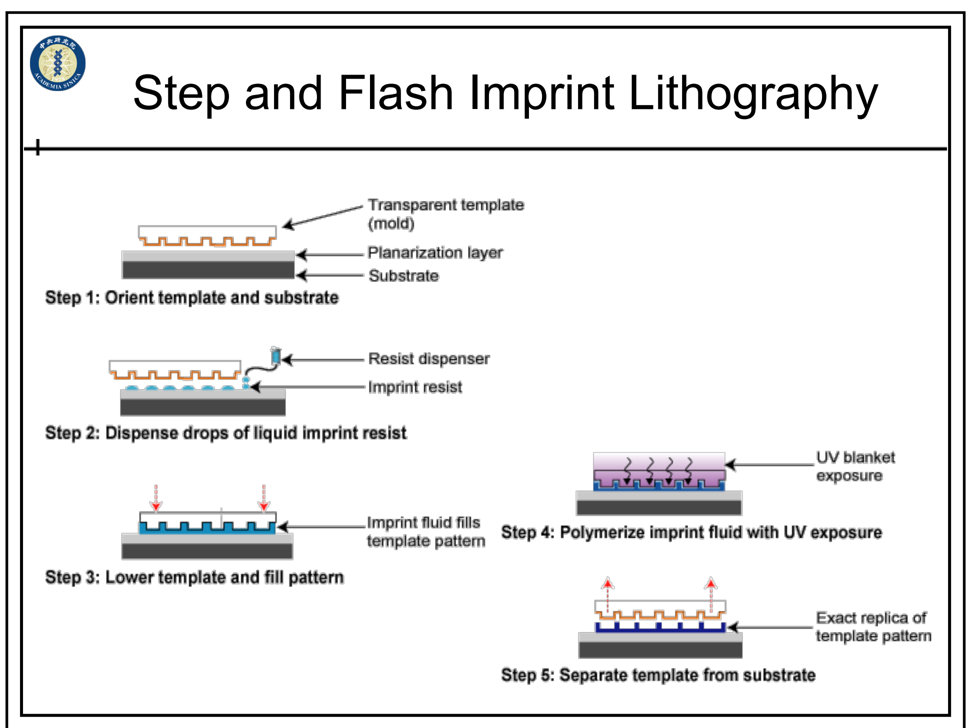

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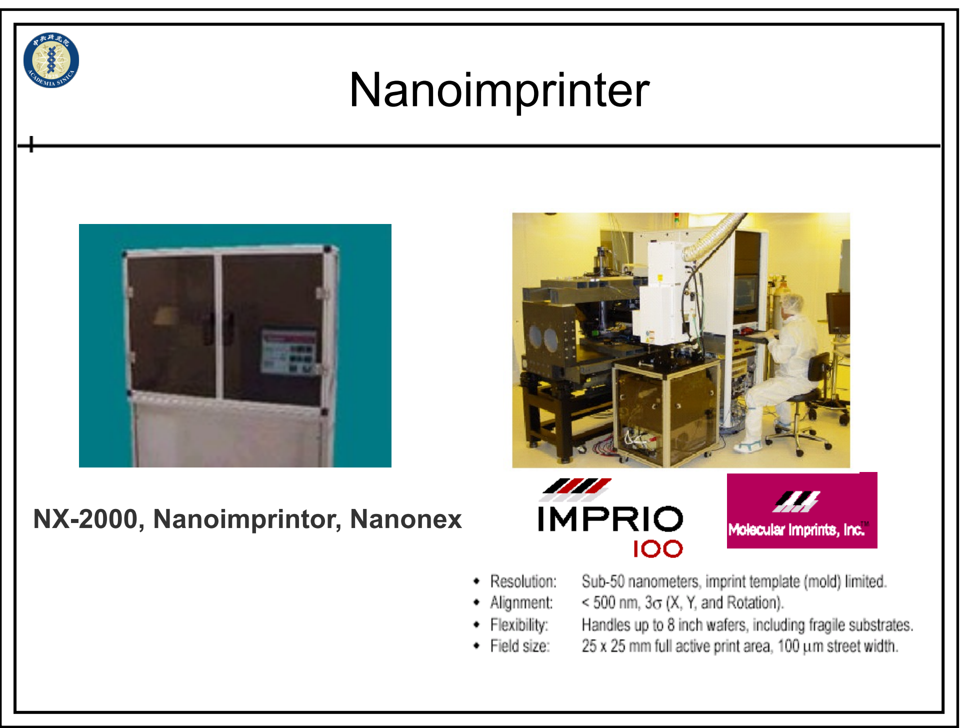

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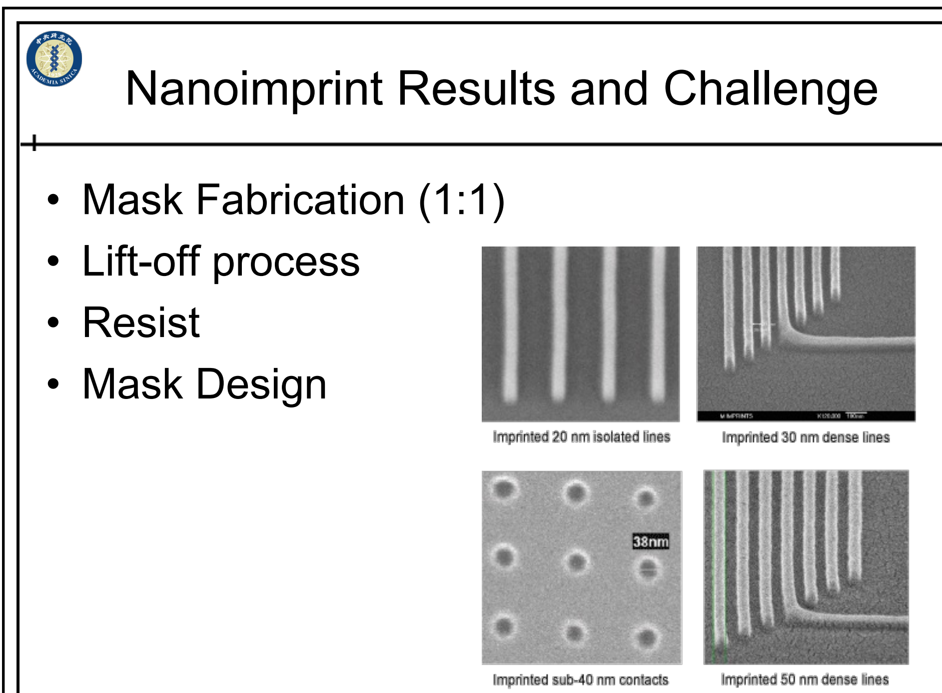

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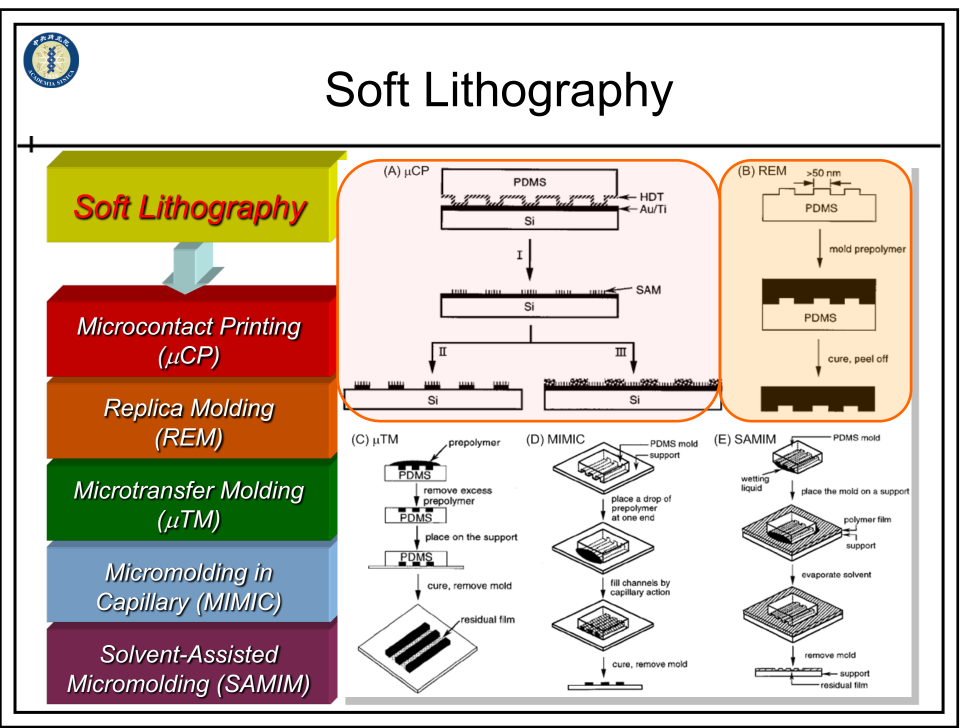

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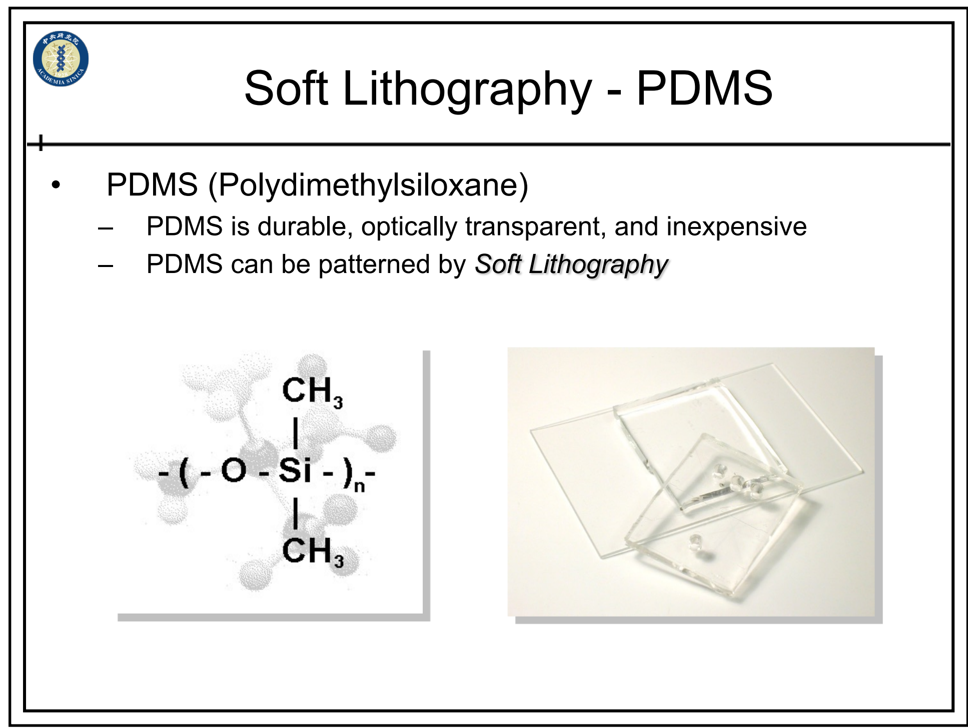

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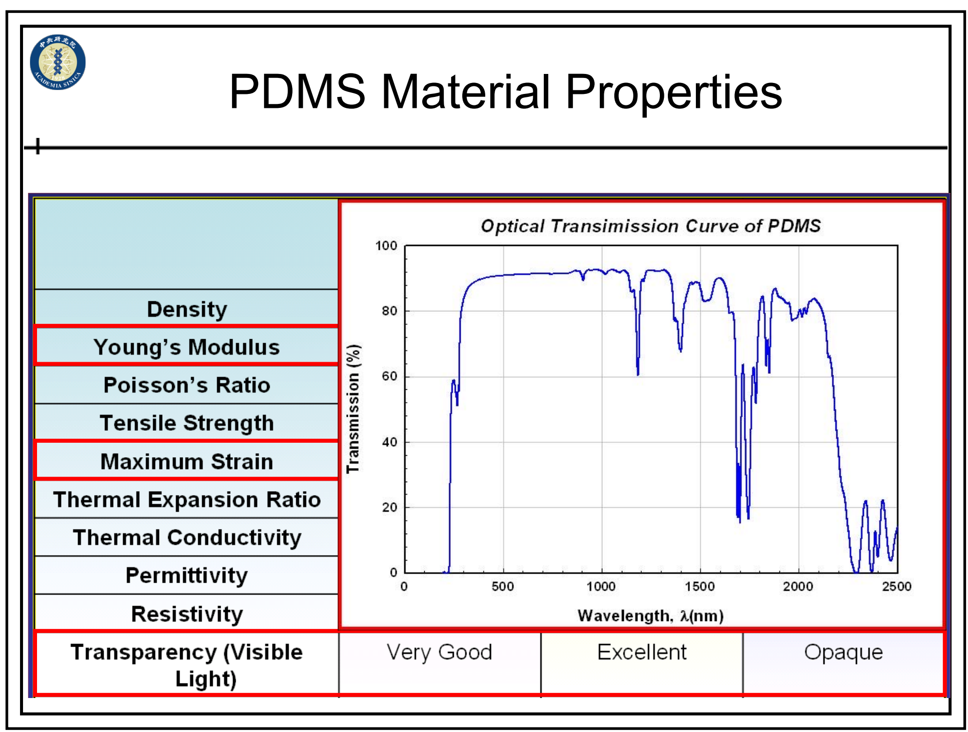

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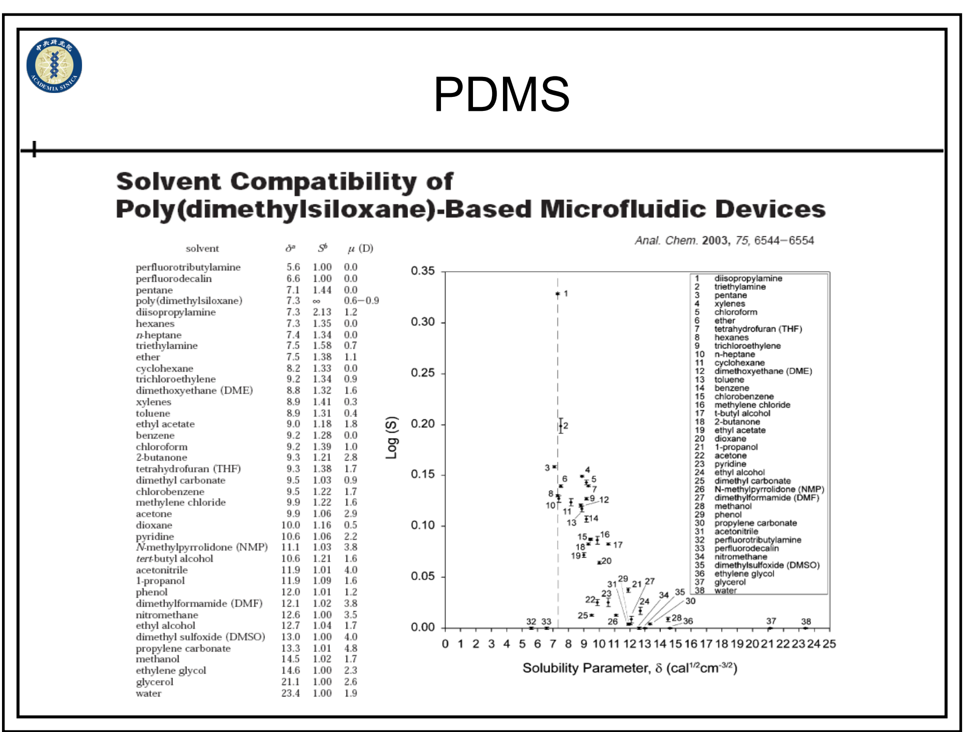

solvent	δ^a	S^b	μ (D)
perfluorotributylamine	5.6	1.00	0.0
perfluorodecalin	6.6	1.00	0.0
pentane	7.1	1.44	0.0
poly(dimethylsiloxane)	7.3	∞	0.6−0.9
diisopropylamine	7.3	2.13	1.2
hexanes	7.3	1.35	0.0
n-heptane	7.4	1.34	0.0
triethylamine	7.5	1.58	0.7
ether	7.5	1.38	1.1
cyclohexane	8.2	1.33	0.0
trichloroethylene	9.2	1.34	0.9
dimethoxyethane (DME)	8.8	1.32	1.6
xylenes	8.9	1.41	0.3
toluene	8.9	1.31	0.4
ethyl acetate	9.0	1.18	1.8
benzene	9.2	1.28	0.0
chloroform	9.2	1.39	1.0
2-butanone	9.3	1.21	2.8
tetrahydrofuran (THF)	9.3	1.38	1.7
dimethyl carbonate	9.5	1.03	0.9
chlorobenzene	9.5	1.22	1.7
methylene chloride	9.9	1.22	1.6
acetone	9.9	1.06	2.9
dioxane	10.0	1.16	0.5
pyridine	10.6	1.06	2.2
N-methylpyrrolidone (NMP)	11.1	1.03	3.8
tert-butyl alcohol	10.6	1.21	1.6
acetonitrile	11.9	1.01	4.0
1-propanol	11.9	1.09	1.6
phenol	12.0	1.01	1.2
dimethylformamide (DMF)	12.1	1.02	3.8
nitromethane	12.6	1.00	3.5
ethyl alcohol	12.7	1.04	1.7
dimethyl sulfoxide (DMSO)	13.0	1.00	4.0
propylene carbonate	13.3	1.01	4.8
methanol	14.5	1.02	1.7
ethylene glycol	14.6	1.00	2.3
glycerol	21.1	1.00	2.6
water	23.4	1.00	1.9

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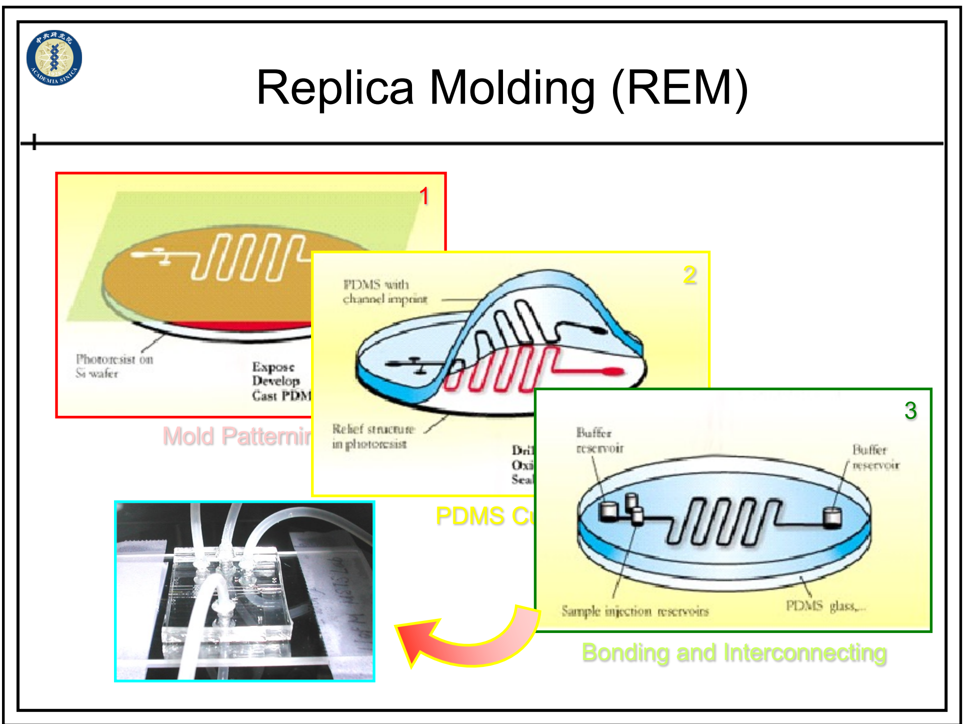

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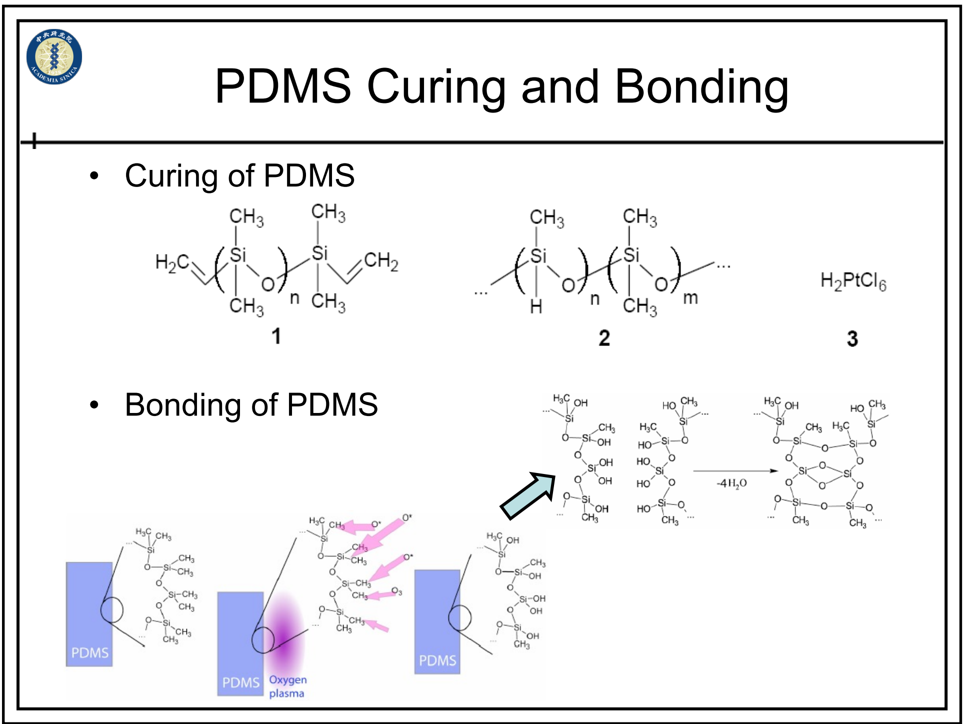

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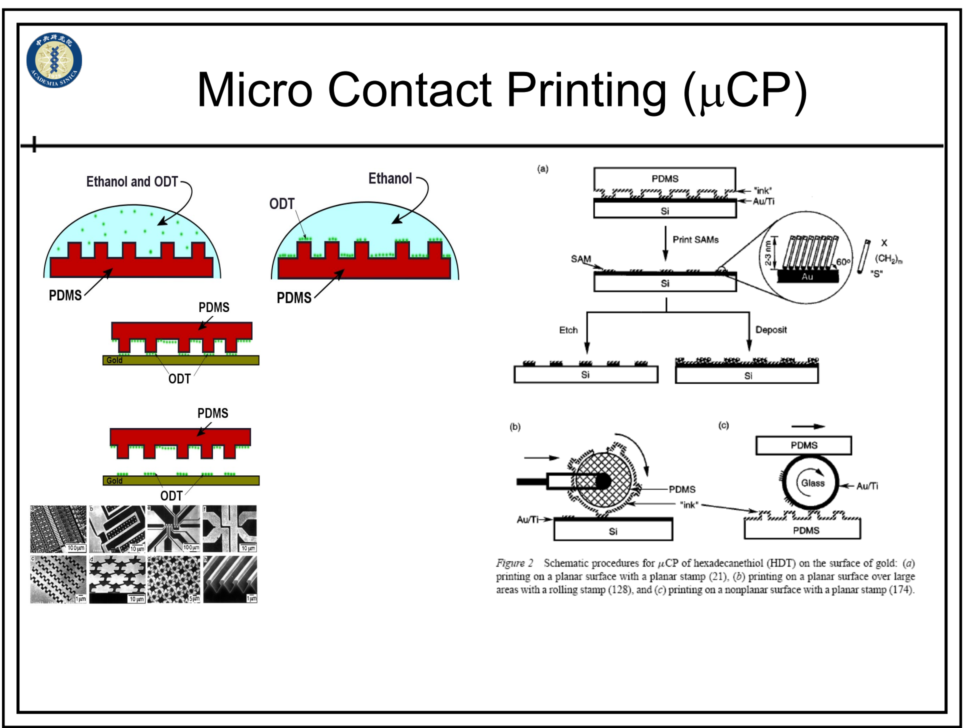

Figure 2 Schematic procedures for μCP of hexadecanethiol (HDT) on the surface of gold: (*a*) printing on a planar surface with a planar stamp (21), (*b*) printing on a planar surface over large areas with a rolling stamp (128), and (*c*) printing on a nonplanar surface with a planar stamp (174).

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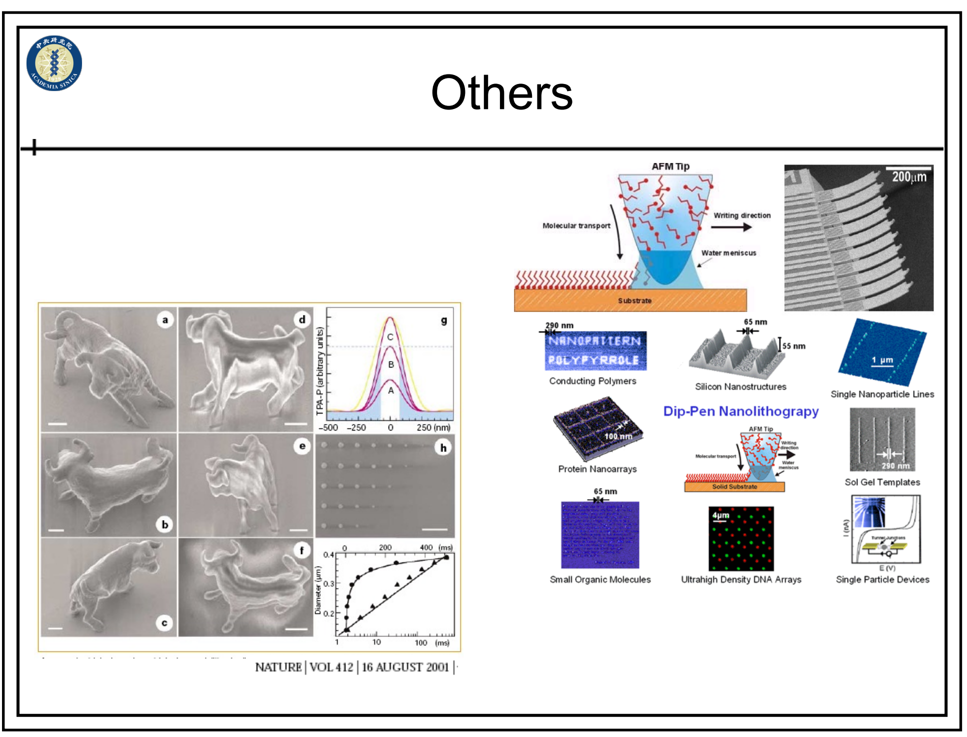

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