黃光微影製程技術

Photolithography Process

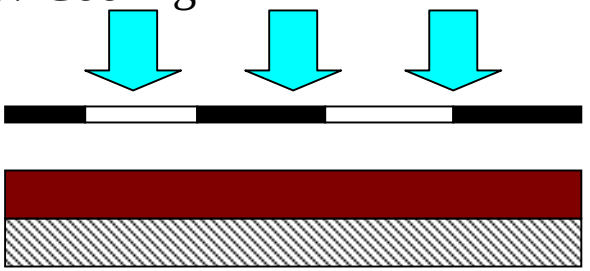
Photolithography Process

1. Photo-Resist (PR) Coating

- Pre-clean(150℃/2min OR 150°C/30min)
- 去水烘烤(Dehydration Bake) / Cooling
- Priming (HMDS) / Cooling
- PR Coating
- Pre-bake (Soft-bake) (90°C/1.5min OR 90°C/30min) / Cooling

2. Exposure

- exposed by aligner, stepper or scanner
- Post Exposure Bake (PEB)



3. Developing

- develop
- After Developing Inspection (ADI)
- hard bake (120°C/2min OR 120°C/30min)

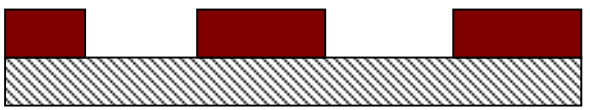
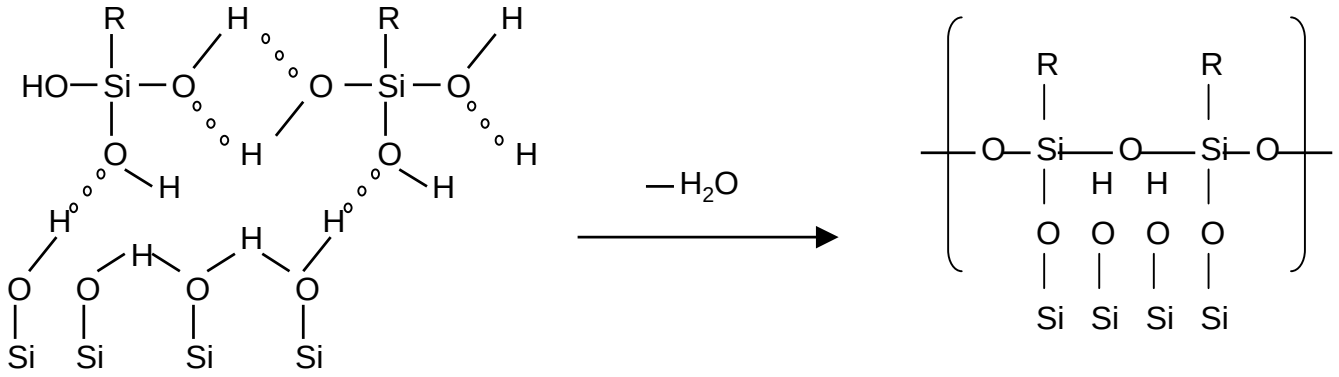


Photo-Resist (PR) Coating

Dehydration Bake

Purpose : Prevent poor PR adhesion to the substrate due to the hydrated surface



Method : Hot plate, Oven

Photo-Resist (PR) Coating

Priming (HMDS)

Purpose : To change the surface property from hydrophilic to hydrophobic (used for Si-based layer)

- Hexamethyldisilizane (HMDS)

$$(CH_3)_3\text{-Si-NH-Si-}(CH_3)_3 + 2H_2O \longrightarrow 2(CH_3)_3\text{-SiOH} + NH_3 \uparrow$$

Process Relativity : PR adhesion if insufficient,
Poor coating uniformity around the edge if too much

Photo-Resist (PR) Coating

PR:包含樹脂(resin), 感光劑(photo active compound,PAC)
和溶劑(solvent)依遇光特性可分成正光阻和負光阻

-正光阻的特性: 照光之後可溶於顯影劑用於高解析度的製程

-負光阻的特性: 照光之後不溶於顯影劑適用於3μm以上的製程

Photo-Resist (PR) Coating

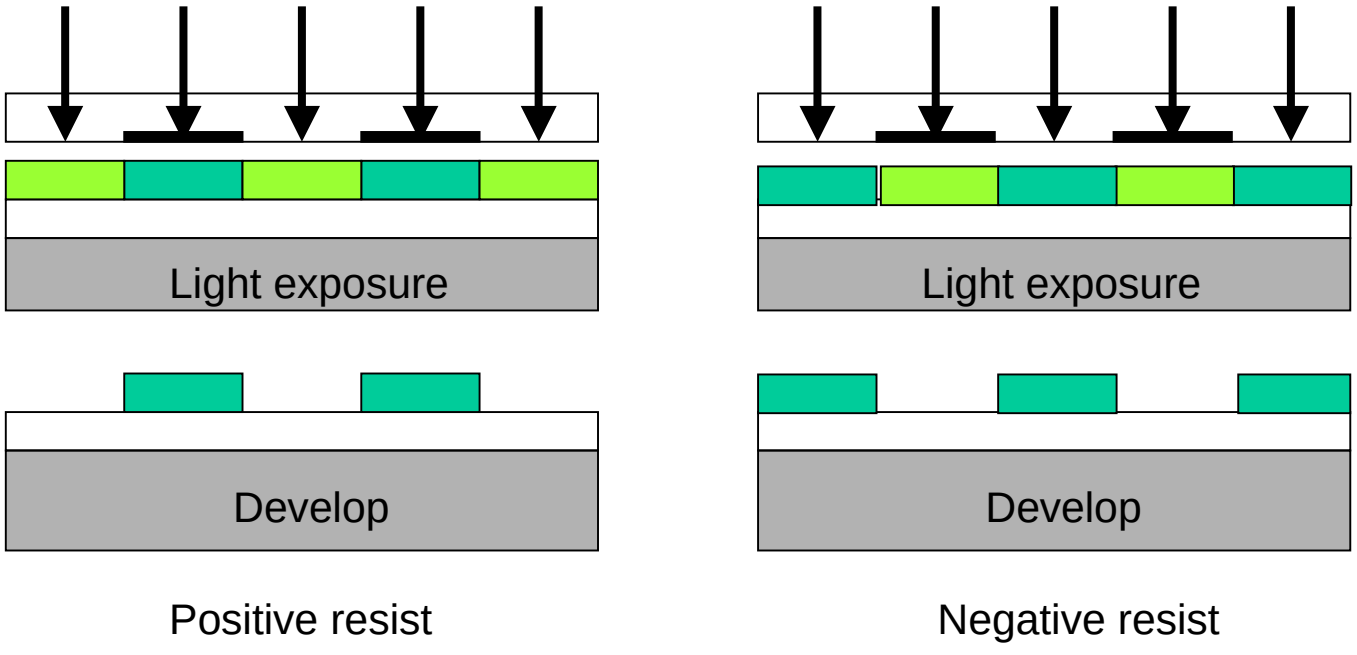
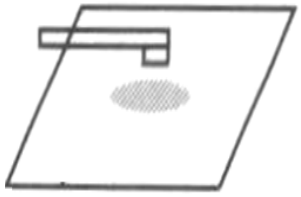
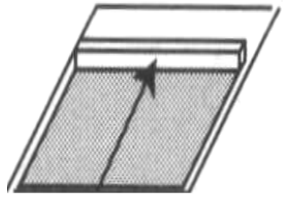


Photo-Resist (PR) Coating

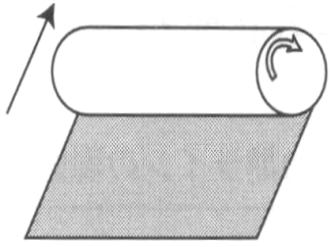
Ways of PR Coating : spin coating, extrusion(slit) coating …



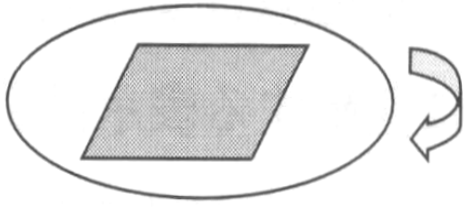
Spin Coating



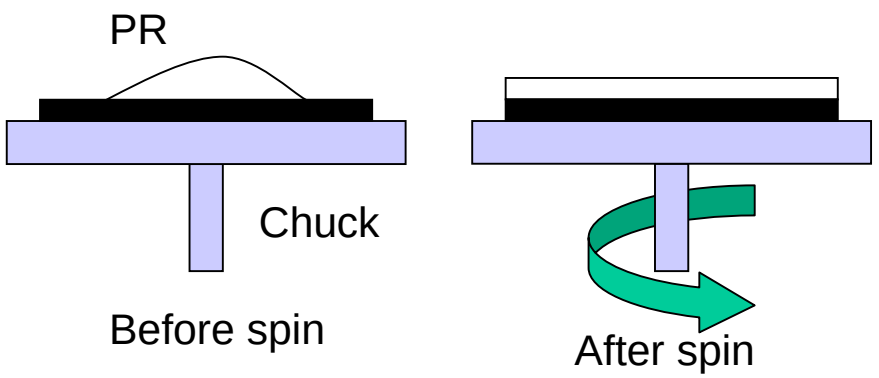
Slit (Extrusion) Coating

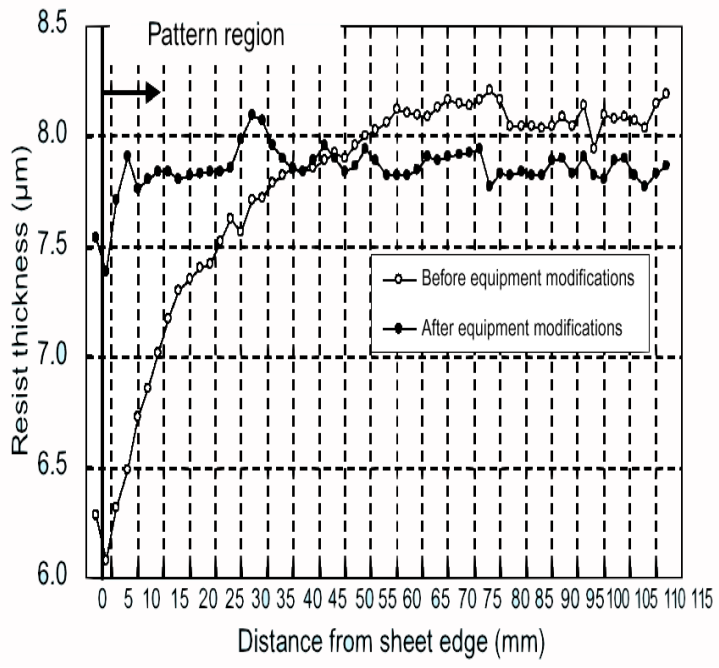


Roll Coating



Spin Coating Method (1)





- better uniformity and defect free

- Spin Coating steps
  (1)dispense resist - flood wafer
  (2)accelerate the wafer - fast
  (3)spin at constant speed to get uniform thickness

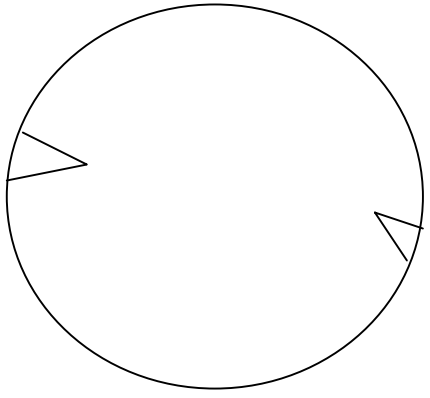
Photo-Resist (PR) Coating

Process Relativity

1.How to control PR target thickness and uniformity

2.Process related issues

(a) 箭影



(b) Striation(彩紋)

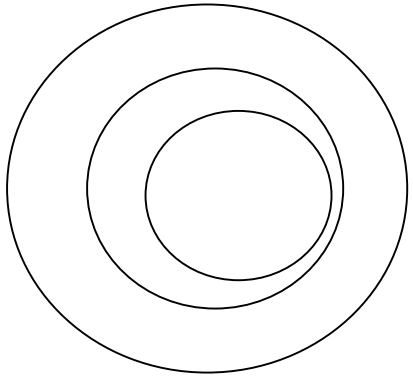
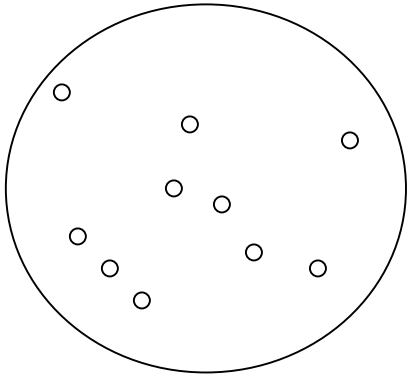


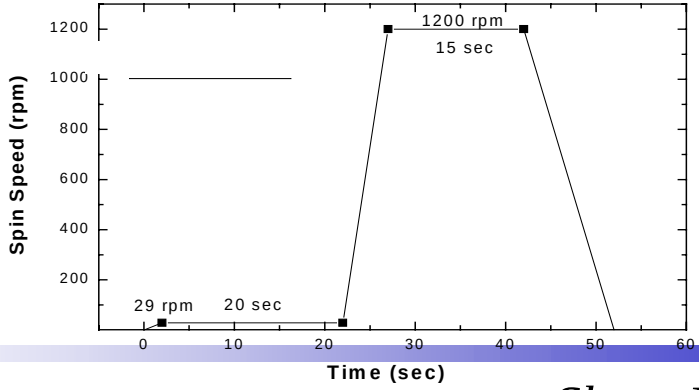
Photo-Resist (PR) Coating

(c) particle ….PR, Filter..



(d) Bad Adhesion …Humidity, Surface cleanness, HMDS

(e) Recipe Optimization



軟　烤
Soft-bake

目的：

1、是將光阻液中的溶劑含量由20至30% 至4至7%，光阻厚度因此也將減少約10至20%

2、軟烤有回火（annealing）的效果，使光阻平坦化

3、可增加光阻附著力。

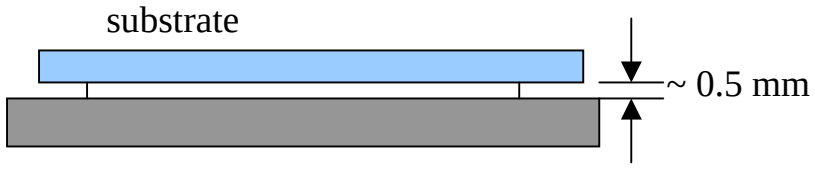
Photo-Resist (PR) Coating

Pre-bake (Soft-bake)

Purpose : Remove the solvent in the PR film

Method : Oven, Contact Hot-plate, Proximity Hot-plate

Contact Hot-plate



Proximity Hot-plate

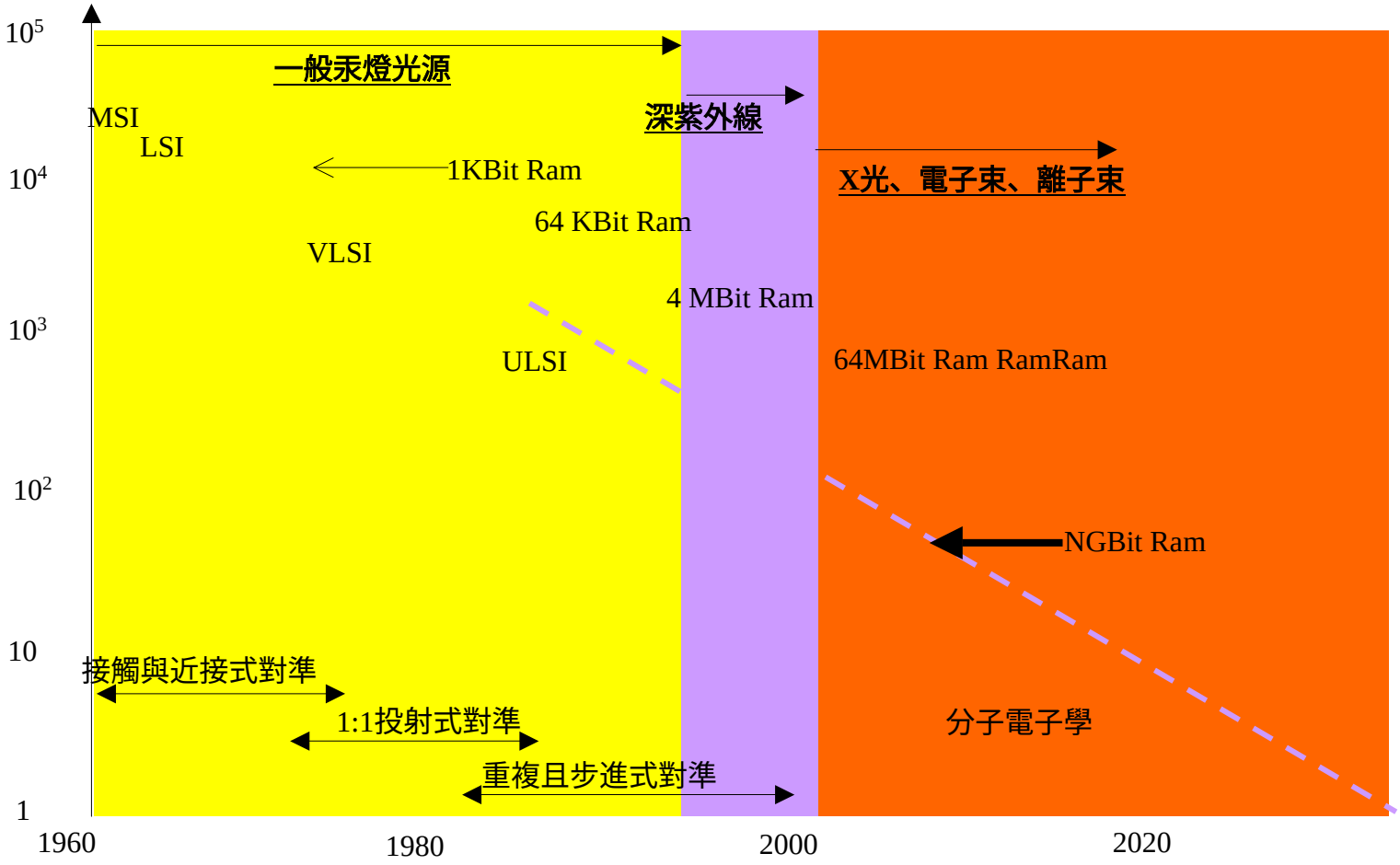
Process Relativity : Optimized condition for Temp. & Time,
Hot plate temp. uniformity & accuracy

Exposure

Exposure Light Source

Visible	450nm ~ 800 nm	
NUV	350nm ~ 450 nm	Hg-Arc G-line(436 nm) , I-line (365nm)
MUV	300nm ~ 450 nm	
DUV	100 nm ~ 300 nm	KrF(248nm); ArF(193nm); F2(157)
EUV	10nm ~ 100 nm	
Soft X-Ray	1nm ~ 25 nm	
Hard X-Ray	0.01 nm ~ 1 nm	

對準及曝光


10^5
10^4
10^3
10^2
10
1
一般汞燈光源
深紫外線
X光、電子束、離子束
MSI
LSI
VLSI
ULSI
1KBit Ram
64 KBit Ram
4 MBit Ram
64MBit Ram RamRam
NGBit Ram
接觸與近接式對準
1:1投射式對準
重複且步進式對準
分子電子學
1960
1980
2000
2020

Exposure

曝光的種類有:

接觸式(contact printing)

近接式(proximity printing)

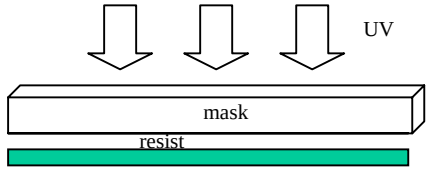
投影式(projection printing)

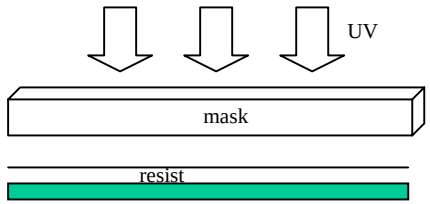
重覆步進式對準（step and repeat）

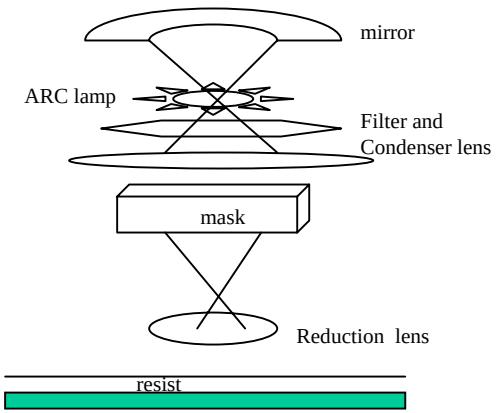
相位轉移光罩

電子雕像術（electron lithography）

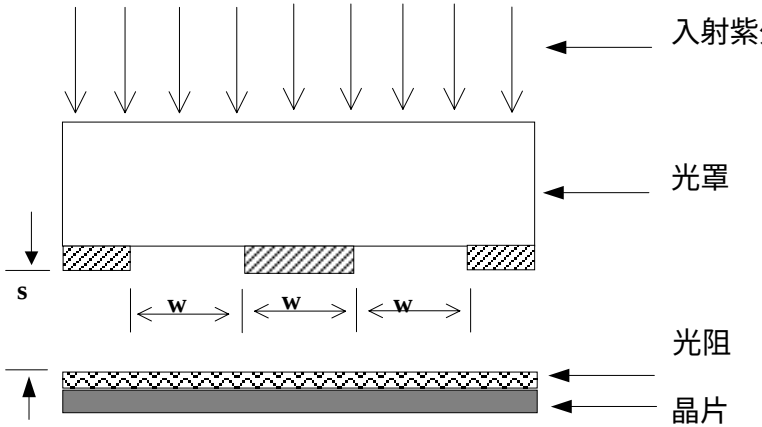
準分子雷射（excimer laser）

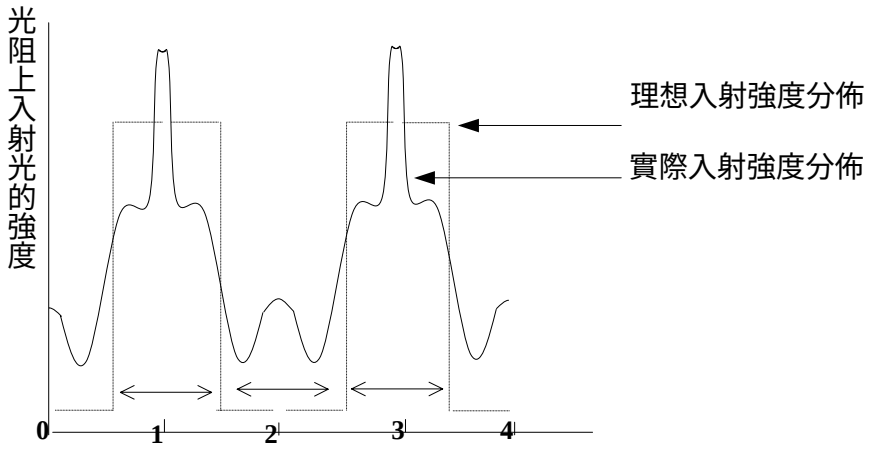






接觸式對準（contact align）





晶片上的位置（圖上單位僅為示意）

$$2w_{min} = 3\sqrt{\lambda\left(s + (1/2)z\right)}$$

其中s為光罩和光阻表面的距離，λ為入射光波長，z為光阻厚度

近接式對準
(proximity align)

$$2w_{\min} \approx 3\sqrt{\lambda s}$$

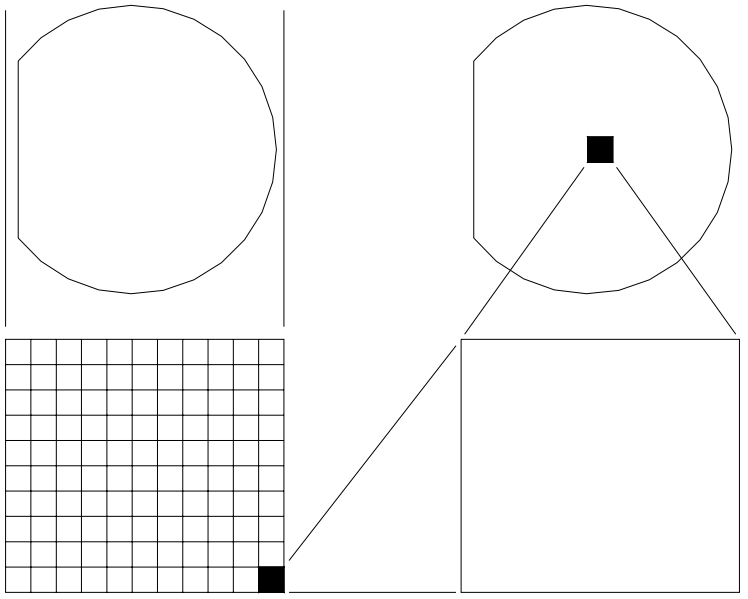
若光阻與光罩的間距10μm，入射光的波長400nm而言，最小線寬約為3μm，故解析度變差

投射式對準
(projection align)

類似投影機原理，將光罩上的圖形投影到光阻上。優點就是解析度可以很高，要配合步進設備。最初是以1：1的方式進行投射對準，進而將比例放大為10：1或5：1的比例進行投射式對準。

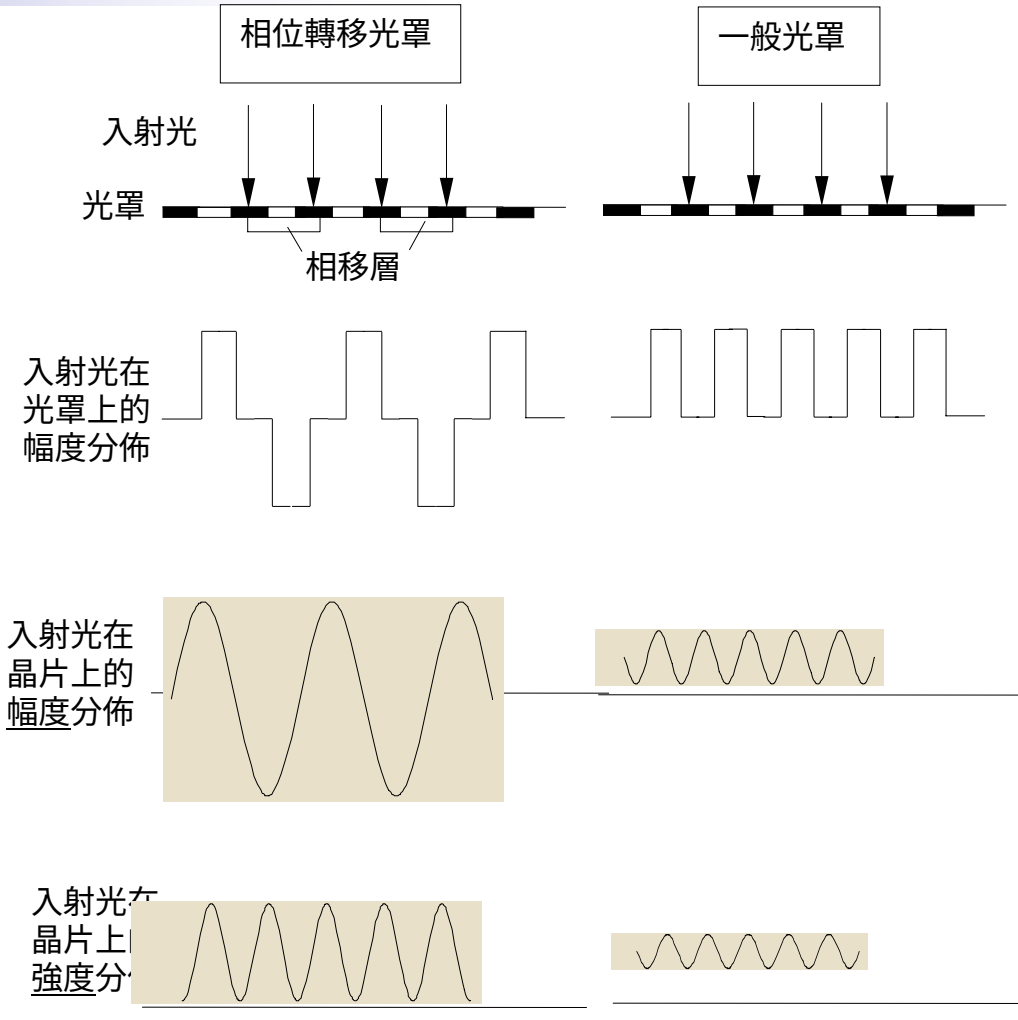
重覆步進式對準 (step and repeat)

光罩的圖形比所要的圖形放大五倍或十倍，光源透過光罩後，再經過適當的聚焦，將比例縮為所要的大小而投射在部分的晶片上，故整片晶片都要曝光的話，得進行重覆步進的工作。



相位轉移光罩

此技術主要將光視為電磁波，因光波有波長、振幅與相位。一般光罩控制入射光的幅度，而相位轉移式光罩還控制其相位。多透過一層相移層，將相位改變180度，之後在晶片上產生干涉，使得光強度在晶片上有明顯的強弱區分，因此可使解析度增加。



電子雕像術
（electron lithography）

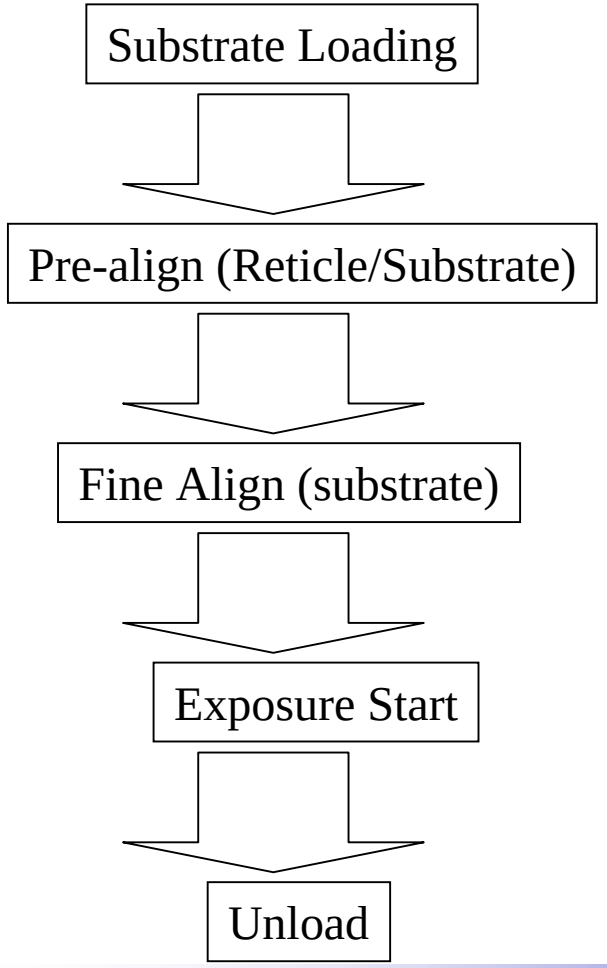
電子束曝光系統的優點就是可以直接生產所需的圖形，利用線圈的電場或磁場偏折控制電子

熱場發射電子槍（thermal field emisssion：TFE）：需要高真空度，高電流密度，解析度可達0.005至0.1。

一般光學雕像術解析度受限於光本身波長所產生的繞射，而電子雕像術的解析度則受限於電子在光阻上的散射。

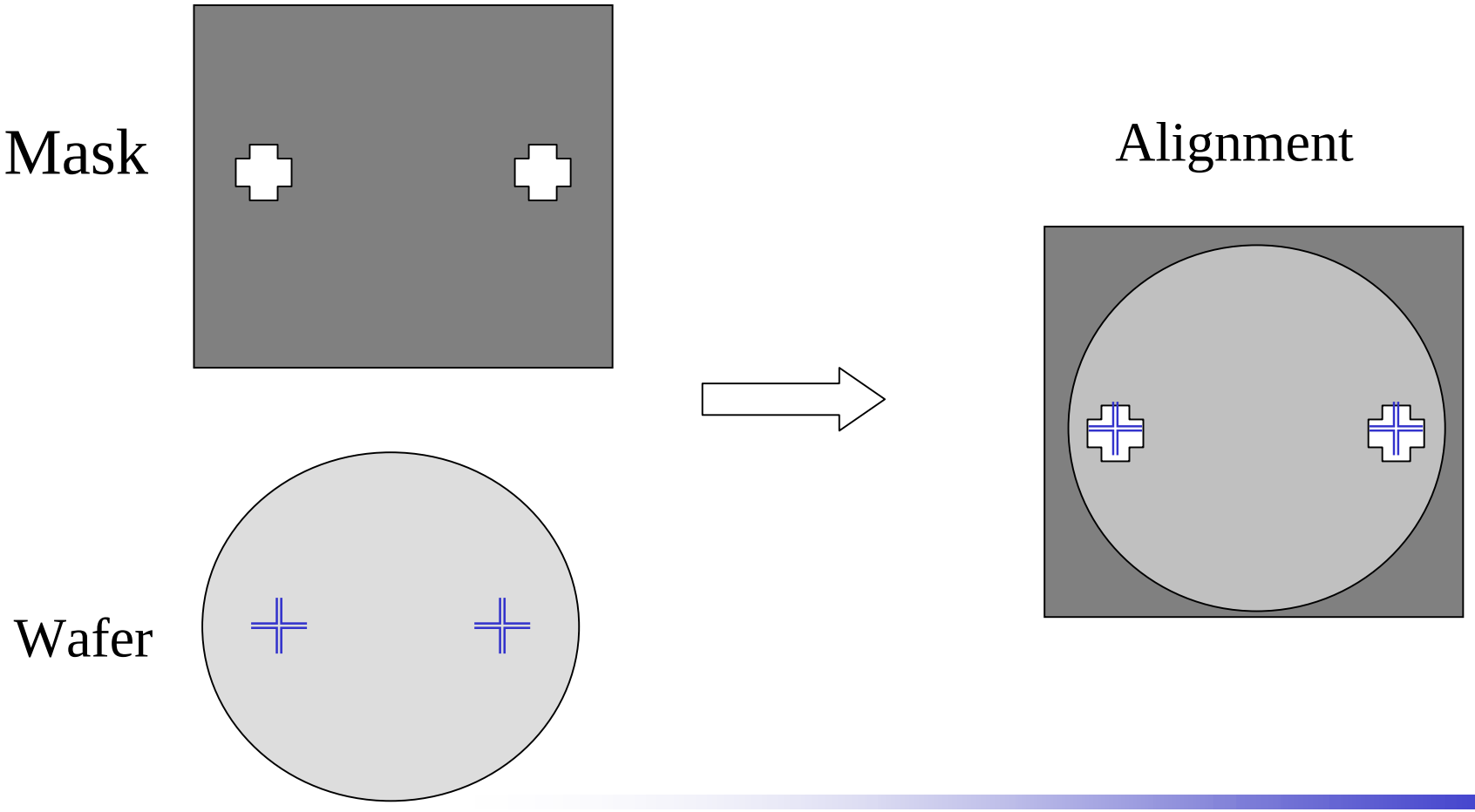
Exposure

Exposure Process



Alignment
對　準

利用對準標誌（align mark）將光罩與晶片進行校準



Developing

Purpose : To solute the exposed PR(positive) or unexposed PR using developing liquid

Developing liquid : Organic or Inorganic

Organic : TMAH: $(CH_3)_4NOH$ metal ion free for high resolution

Inorganic:NaOH or KOH..

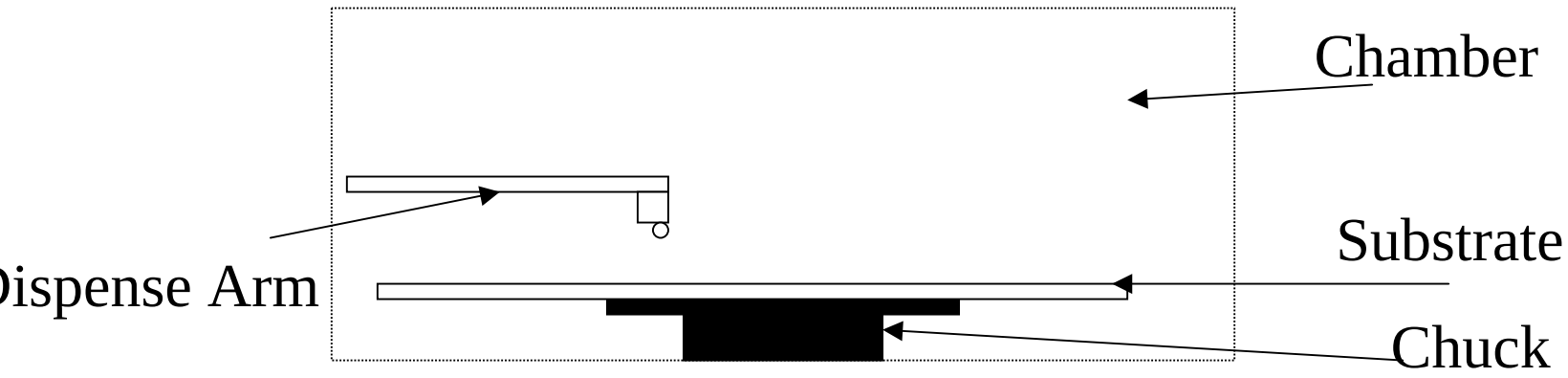
Developing

Hardware Related Issues

1. Chamber Design : Prevent water or PR re-deposition, Chuck level

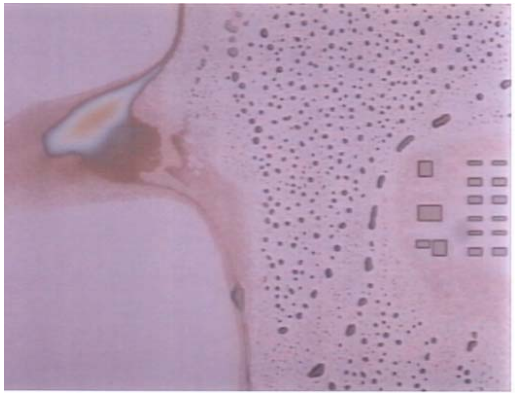
2. Exhaust Condition : Control humidity , Turbulence

3. Dispense Arm Design : Bubble issue, Spray uniformity

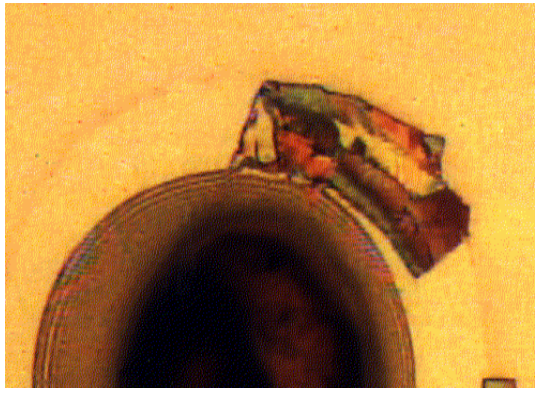


Developing

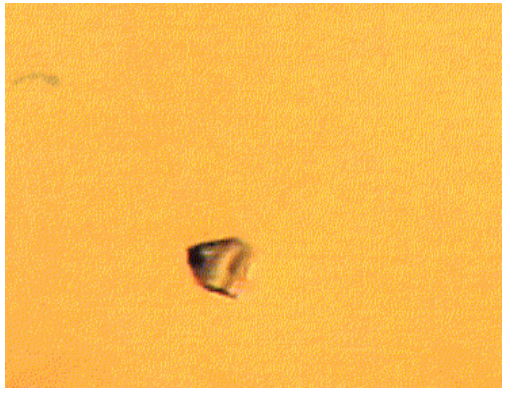
Process Relativity: CD Control, Uniformity, Defect Control



Water mark



PR Gel



Particle

硬 烤
hard bake

硬烤溫度較軟烤溫度來得高，此溫度高於光阻的玻璃轉變溫度（glass transition），故光阻將如溶融的玻璃，表面也將因表面張力而平坦化。

目的：

1、將光阻溶劑含量降到最低；
2、增加附著力，避免遇酸時剝落；
3、增加對酸的抵抗力；
4、使邊緣平滑，減少缺陷，如孔隙。

但過高的溫度將使光阻累積過多熱應力（thermal stress）而對附著性造成影響。一般而言，硬烤溫度約在120至200℃左右，時間在數分鐘至30分鐘不等（依需求而定）。