

第四章 第一部份 晶圓製造

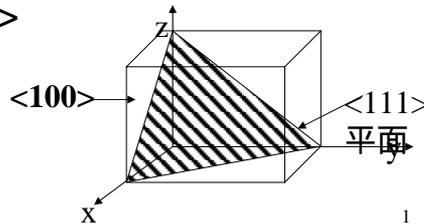
結晶性:

無晶型 (amorphous) - a :Si - solar cell

複晶型 (polycrystalline) - poly-Si – 電極

單晶 (single crystal) : 晶圓
薄膜 epi-Si

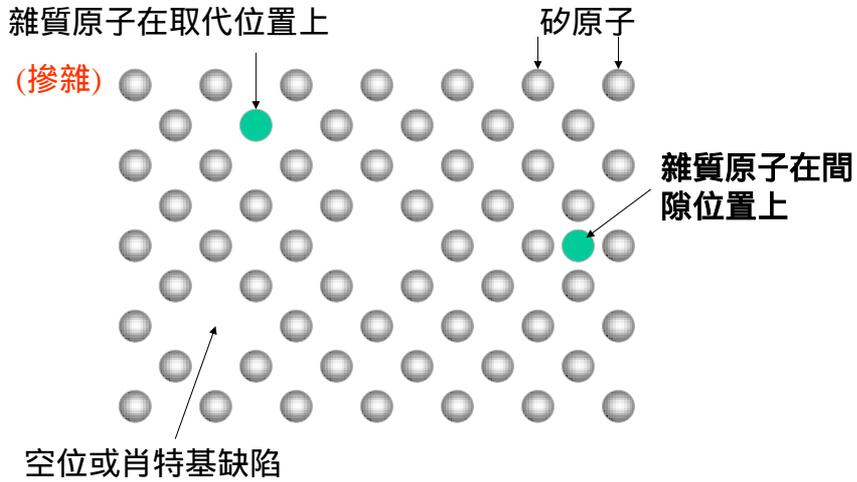
晶向 : $\langle 100 \rangle$ $\langle 111 \rangle$



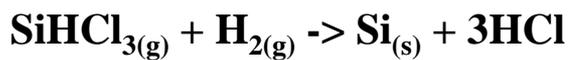
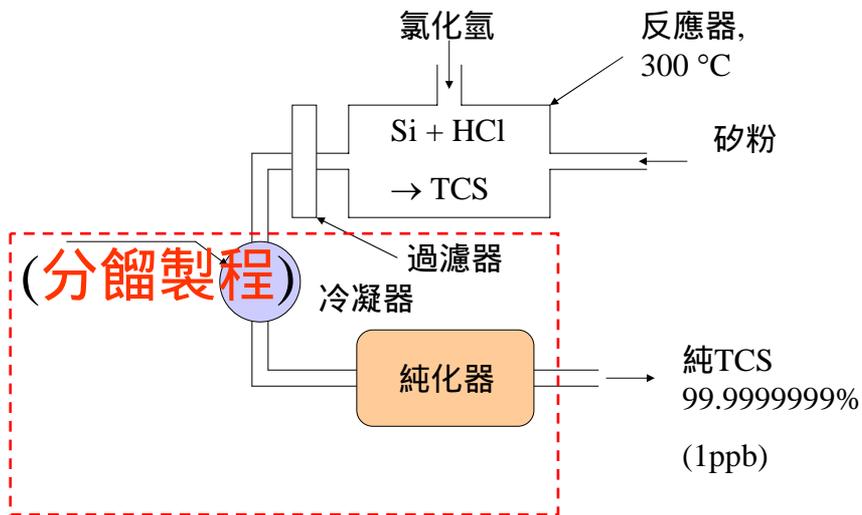
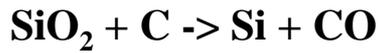
為何是矽?

- 豐富，便宜
- 二氧化矽非常穩定，強介電常數，在熱製程中容易成長
- 大的能隙，寬廣的操作溫度範圍

缺陷之表示



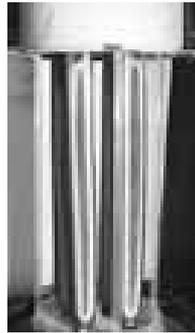
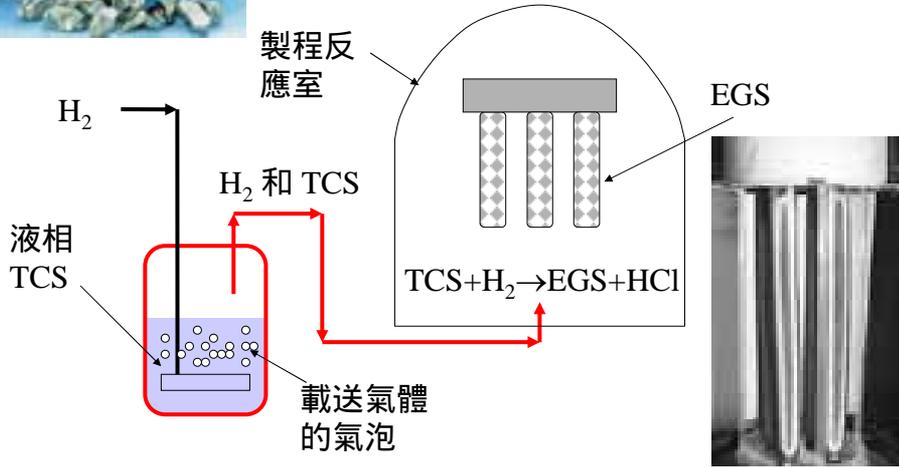
3



4

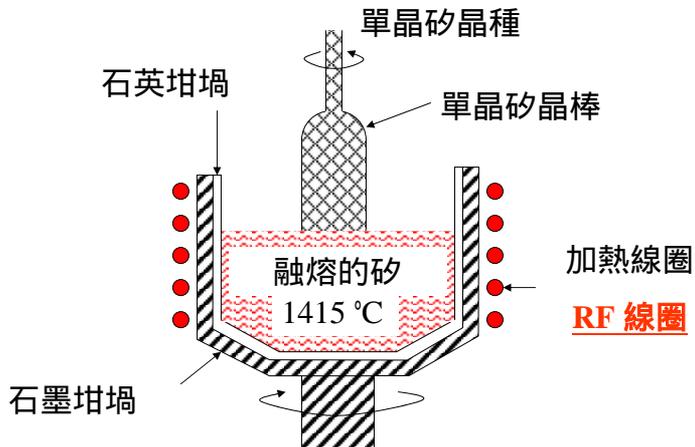


矽之純化 II

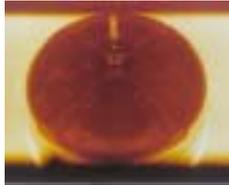


晶體提拉: CZ 方法

查克洛斯基方法



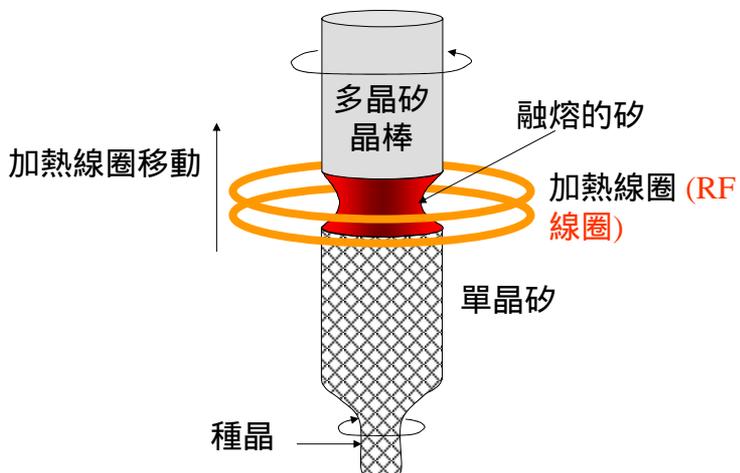
CZ 晶體提拉



Source: http://www.fullman.com/semiconductors/_crystalgrowing.html

7

懸浮帶區法



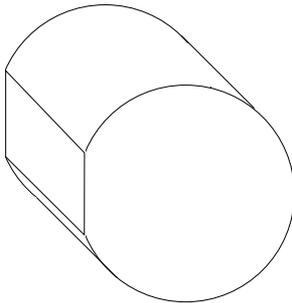
8

兩種方法之比較

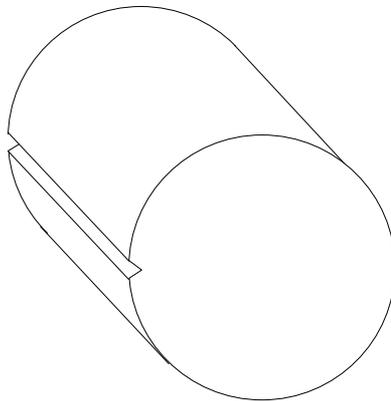
- CZ 方法較普遍
 - 較便宜
 - 大的晶圓尺寸 (300 mm)
 - 材料可再使用
- 懸浮帶區法
 - 純的矽晶體 (無坩堝; 較少之污染)
 - 較貴, 較小的晶圓尺寸 (150 mm)
 - 主要用作功率元件.

9

晶棒拋光、磨出平邊或缺口



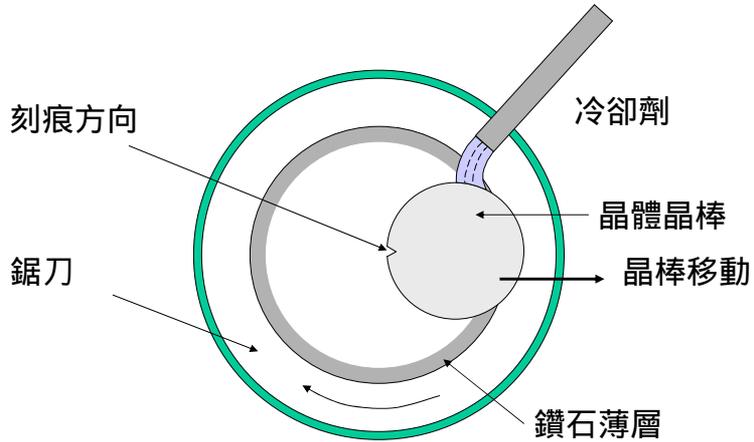
平邊, 150 mm 或更小者



刻痕, 200 mm 或更大者

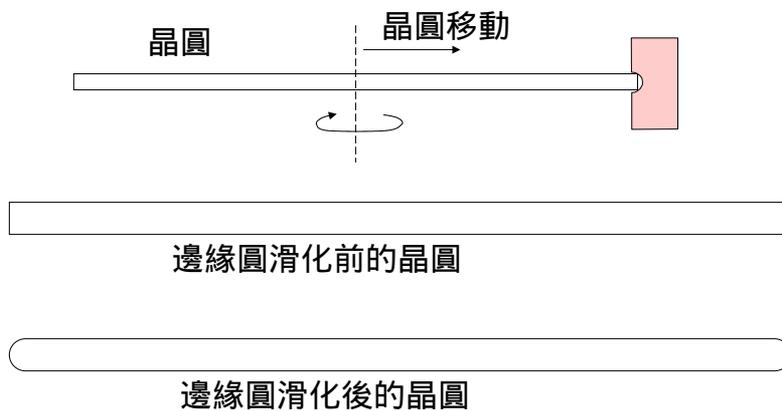
10

2. 晶圓切片



11

3. 晶圓邊緣圓滑化



12

4. 晶圓粗磨

- 粗略地研磨
- 一般常用的, 研磨粒子(Al_2O_3), 研磨漿-粗磨
- 移除大部分的表面傷害
- 製造一個平的表面

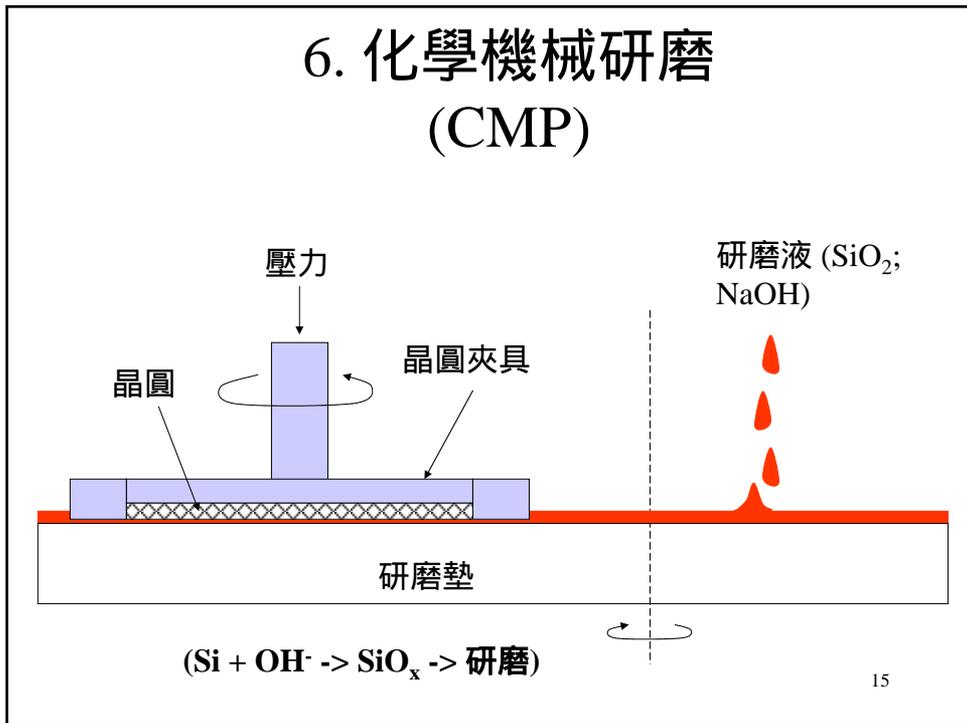
13

5. 濕式蝕刻

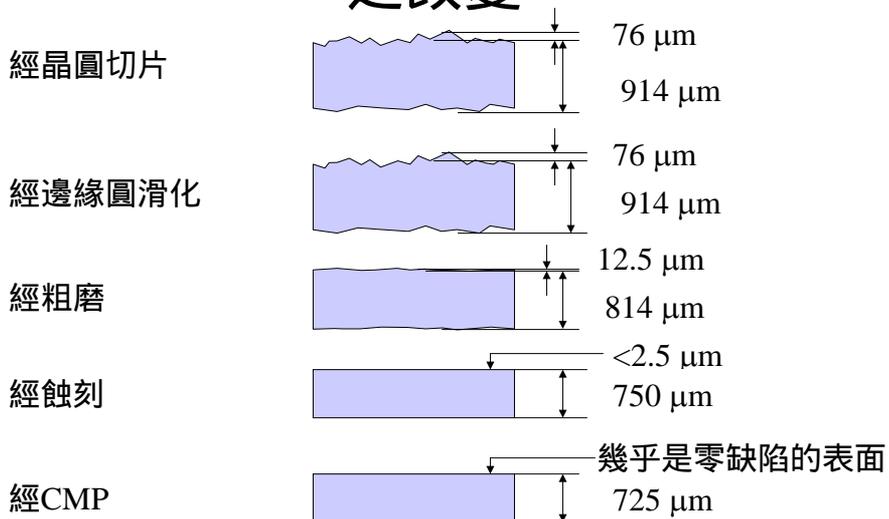
- 化學性地將晶圓表面之缺陷移除
- 4:1:3 混合 HNO_3 (79 wt% in H_2O), HF (49 wt% in H_2O), 和純 CH_3COOH .
- 化學反應:
- $3 \text{Si} + 4 \text{HNO}_3 + 6 \text{HF} \rightarrow 3 \text{H}_2\text{SiF}_6 + 4 \text{NO} + 8 \text{H}_2\text{O}$

14

6. 化學機械研磨 (CMP)

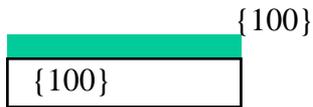


200 mm 晶圓厚度 及表面粗糙度 之改變



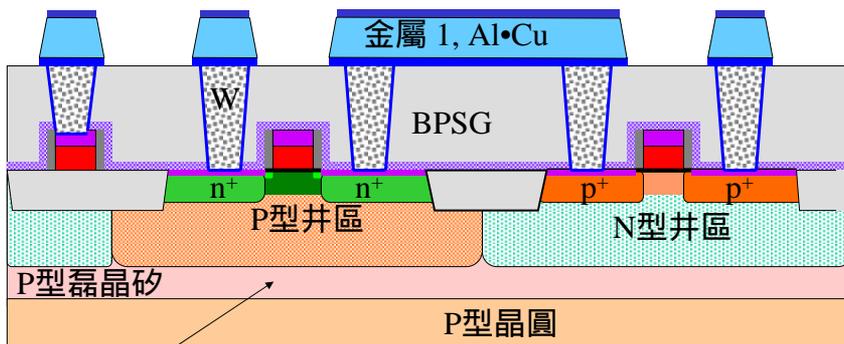
磊晶

- 希臘字源
- *epi*: 往上
- *taxy*: 有次序的, 排列的
- 磊晶層為一生長在單晶基片上單晶層
→ 基片和上層間存在一特定之晶體關係



17

磊晶應用: CMOS



1. 更高純度(低O,C污染); 2. 均勻改變載子濃度

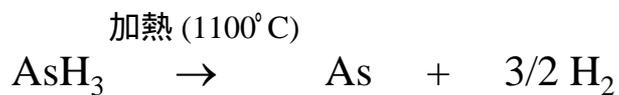
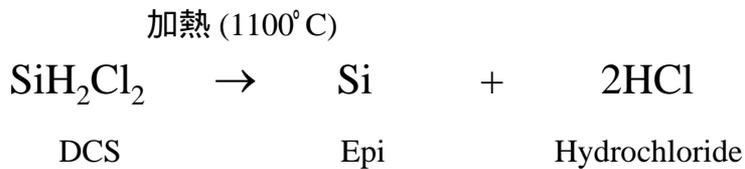
18

矽之來源氣體

矽烷		SiH_4
二氯矽烷	DCS	SiH_2Cl_2
三氯矽烷	TCS	SiHCl_3
四氯矽烷	摻雜之來源氣體	SiCl_4
Diborane	B_2H_6	
Phosphine	PH_3	
Arsine	AsH_3	

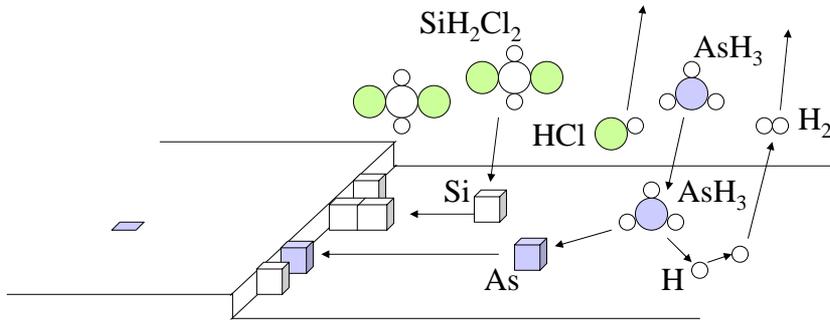
19

DCS 磊晶成長, Arsenic 摻雜



20

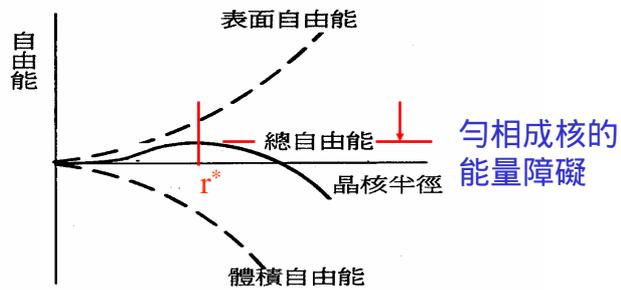
DCS 磊晶成長及As摻雜過程之示意圖



21

磊晶對多晶

成核:



$$G = 4 \pi \sigma_0 r^2 + \frac{4}{3} \pi g_v r^3$$

表面能
bulk energy

22

磊晶 對 多晶

成核: 根據古典 3-D 成核理論

$$r^* = 2 \gamma v / RT \ln (C/C_{eq})$$

γ : 表面張力; v : 莫耳體積

C/C_{eq} is a measure of super-saturation

$C/C_{eq} \uparrow$ $r^* \downarrow$ 傾向 多晶Si

成長: 需要高溫以得到足夠的表面遷移率

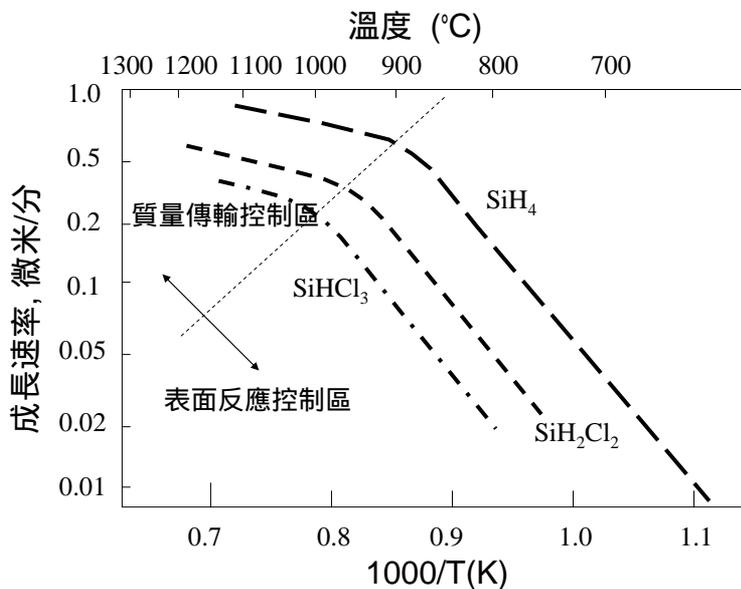
溫度太低 → 多晶 (550~650 °C)

或

非晶型 (< 550 °C)

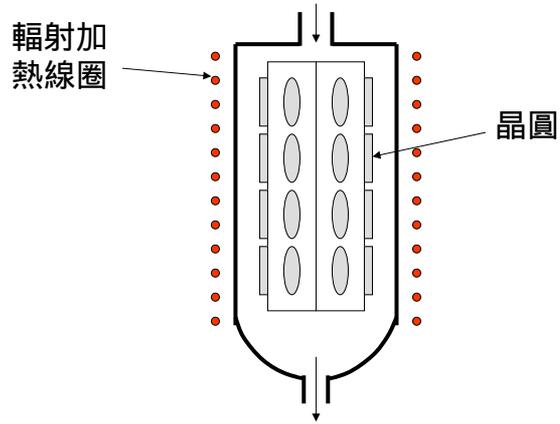
23

磊晶矽成長速率趨勢



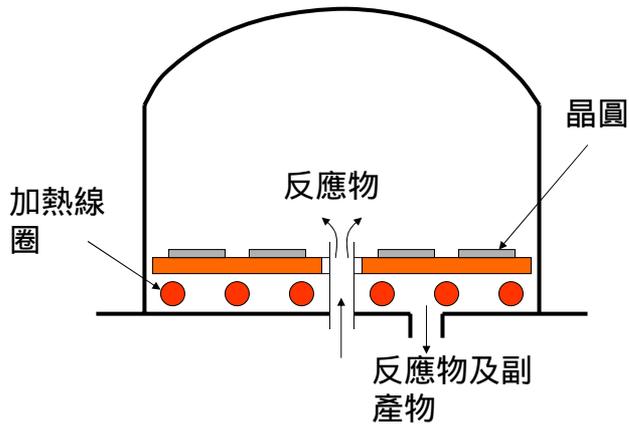
24

桶狀式反應器 (冷壁)



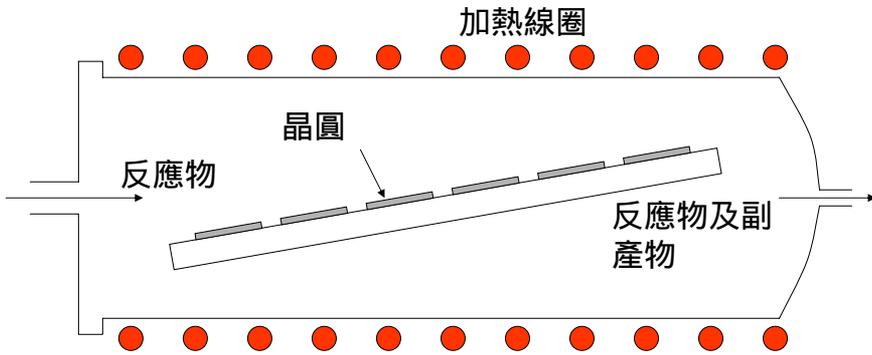
25

垂直式反應器 (冷壁)



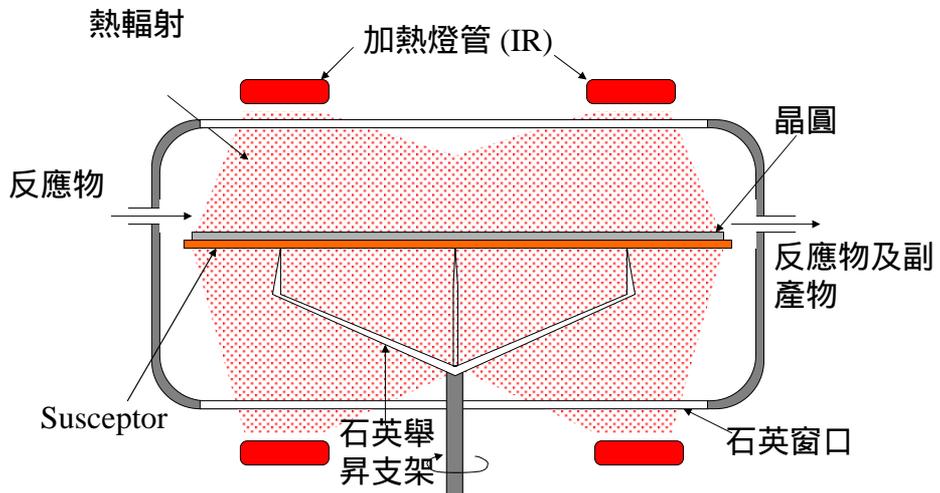
26

水平式反應器 (冷壁)



27

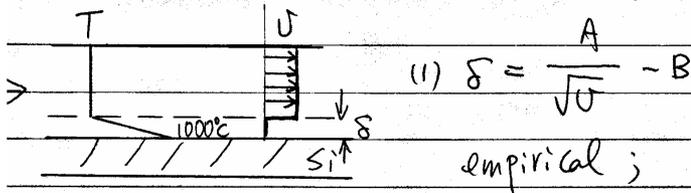
單一晶圓反應器



28

Modelling of CVD

Modelling of SiH_4 CVD in a cold-wall reactor
(J. Electrochem. Soc. Pg. 925, 1970)



$$(1) \delta = \frac{A}{\sqrt{U}} - B$$

empirical ;

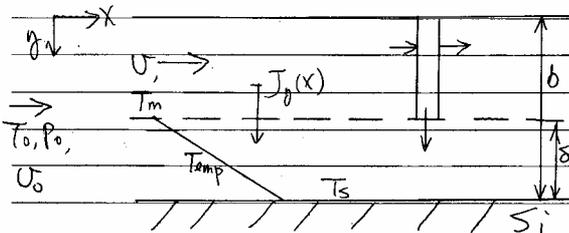
$$(2) Q = Q_0 (T/T_0)^m \quad 1.75 \leq m \leq 2.0$$

$$Q_0 \sim 0.2 \text{ cm}^2/\text{sec at } 25^\circ\text{C}$$

29

Modelling of CVD

at steady-state



(1) Inside the boundary layer (no bulk flow)

$$J_y(x) = -D \left(\frac{\partial C(x,y)}{\partial y} \right) = -D_0 \frac{T_0^2}{T^2} \left[\frac{\partial C(x,y)}{\partial y} \right]_0$$

$$\frac{T_s - T}{T_s - T_m} = \frac{b - y}{\delta} \quad (2)$$

30

Modelling of CVD

$$P = CRT \text{ (ideal-gas law) } \textcircled{3} \Rightarrow P(x, y)$$

partial P. of
SiH₄

from ① ~ ③

$$\Rightarrow J_0(x) T_0^2 R S / Q_0 (T_s - T_m) = - T^2 \left[\frac{d(P/T)}{dT} \right] \textcircled{4}$$

$$\Rightarrow \int_{T_s}^{T_m} - \left[J_0(x) T_0^2 R S / Q_0 (T_s - T_m) \right] \frac{dT}{T^2} = \int_{\frac{P(x, b-\delta)}{T_m}}^{\frac{P}{T_0}} d\left(\frac{P}{T}\right)$$

* $P_{SiH_4} = 0$ at surface
due to mass-transfer
limitation *

31

Modelling of CVD

$$\Rightarrow \text{at } y = b - \delta, P(x) = J_0(x) R T_0^2 \delta / Q_0 T_s \textcircled{5}$$

(2) In the turbulent region

shell-balance

$$-U(b-\delta) \frac{\partial C}{\partial x} = J_0(x) \textcircled{6}$$

$$U = U_0 \left(\frac{b}{b-\delta} \right) \left(\frac{T_m}{T_0} \right) \textcircled{7}$$

$$\Rightarrow J_0(x) = \frac{-U_0 b}{R T_0} \frac{dP}{dx} \textcircled{8}$$

$$\textcircled{5} + \textcircled{8} \Rightarrow \frac{\partial}{\partial x} [J_0(x)] + \frac{Q_0 T_s J_0(x)}{b U_0 T_0 \delta} = 0$$

$$\text{I.C. (from EQU ⑤): } x=0, P(0) = \frac{J_0(0) R T_0^2 \delta}{Q_0 T_s}$$

32

