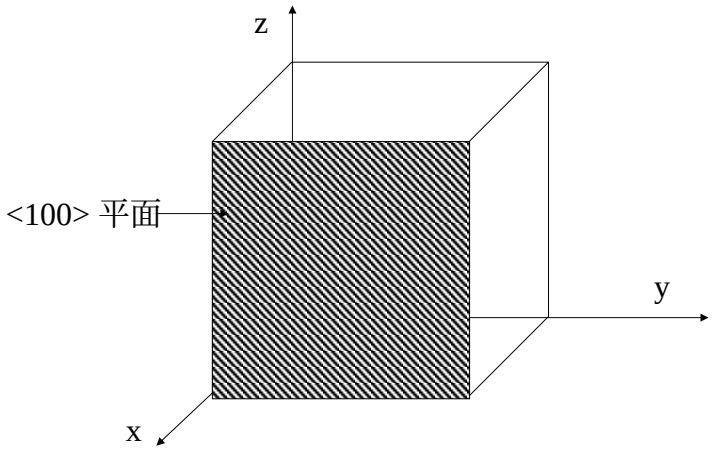
# 第二章　晶圓製造

## 為何是矽?

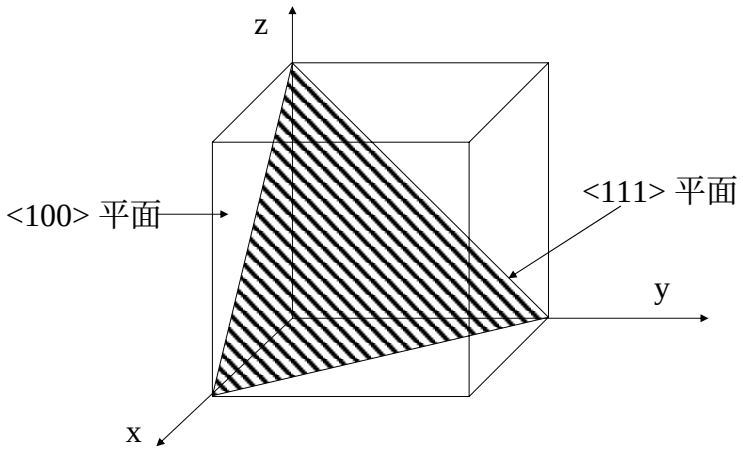
- 豐富，便宜
- 二氧化矽非常穩定，強介電常數，在熱製程中容易成長
- 大的能隙，寬廣的操作溫度範圍



## 晶向平面: <100>

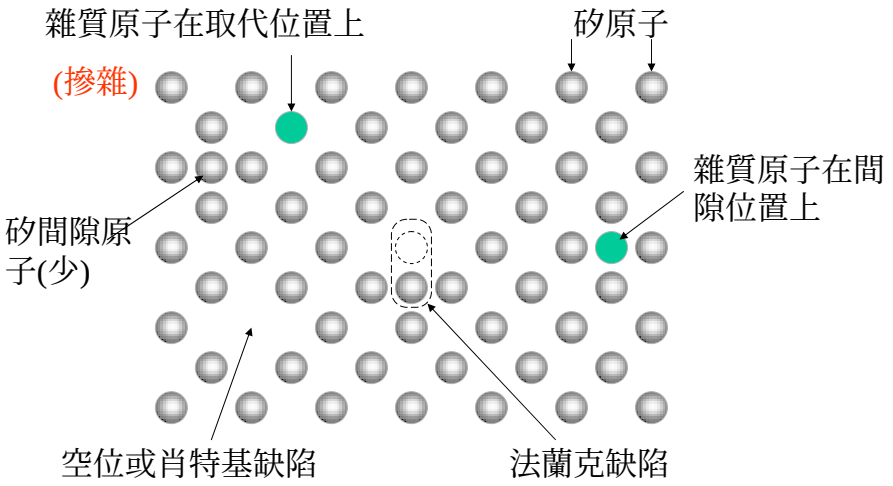


# 晶向平面: <111>

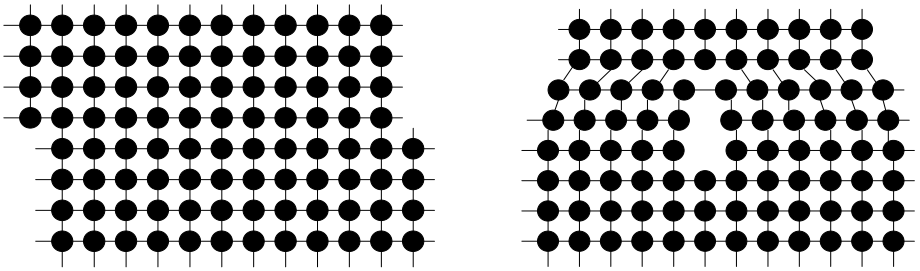





# 缺陷之表示



# 差排缺陷

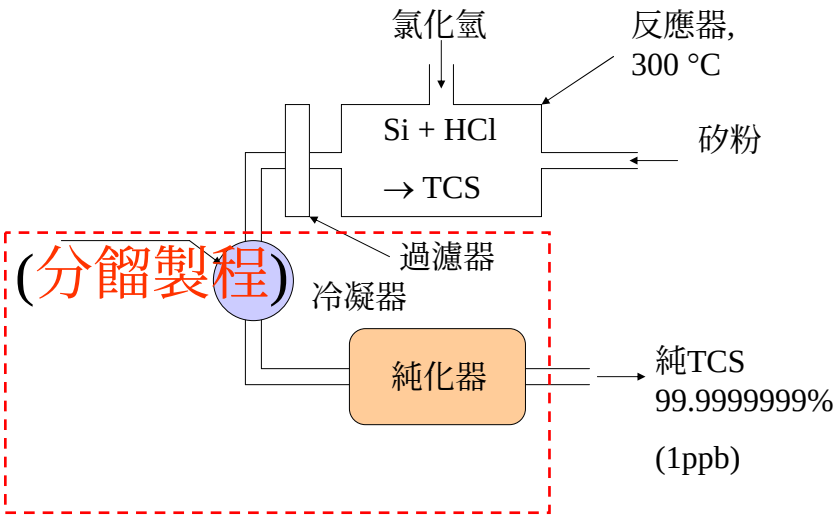




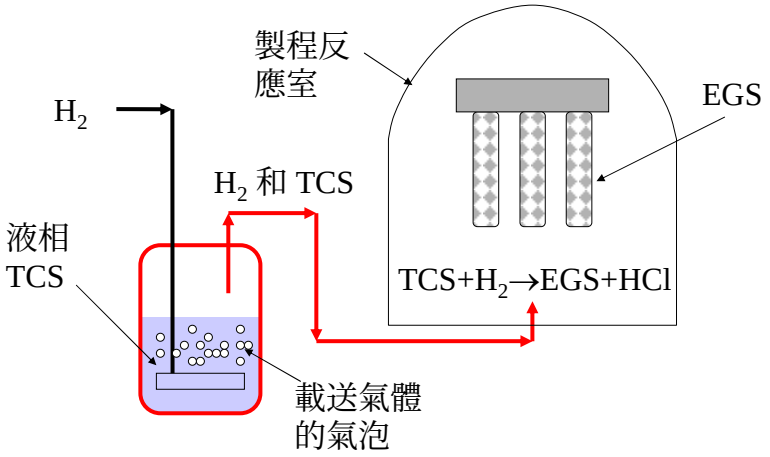
加熱 (2000° C)

$SiO_2$ + C → Si + $CO_2$

砂　碳　MGS　二氧化碳

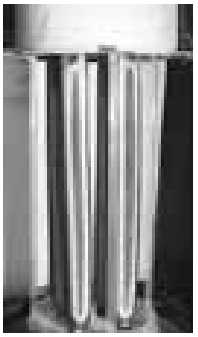


# 矽之純化 II





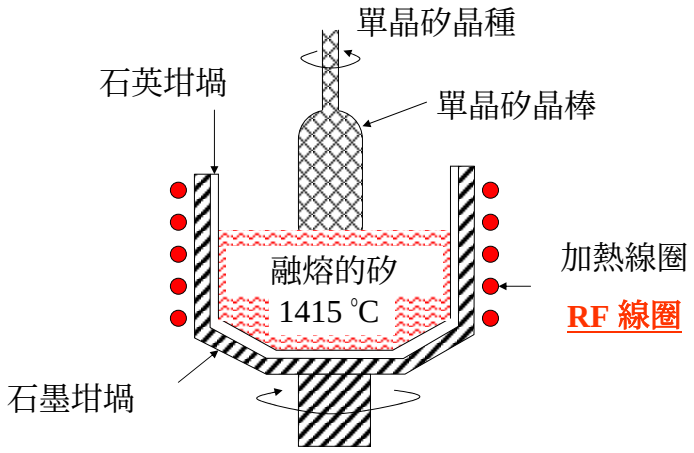

# 電子級矽



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

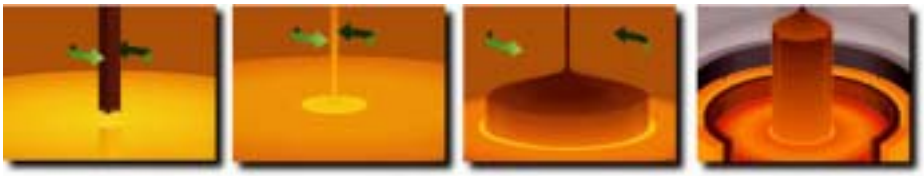
# 晶體提拉: CZ 方法

**查克洛斯基方法**



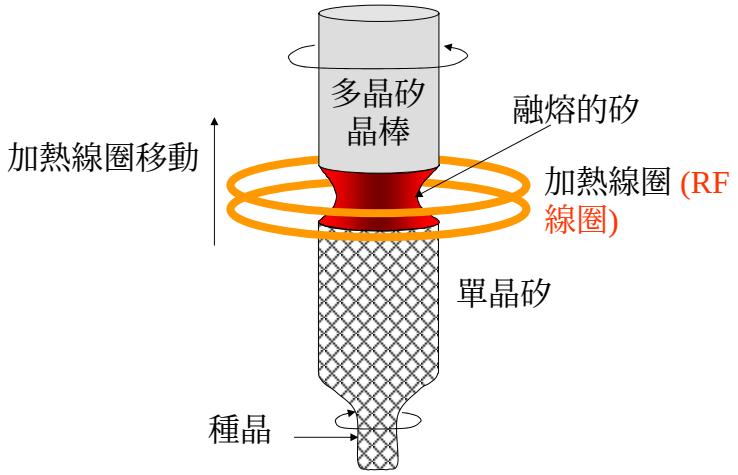



# CZ 晶體提拉



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

# 懸浮帶區法

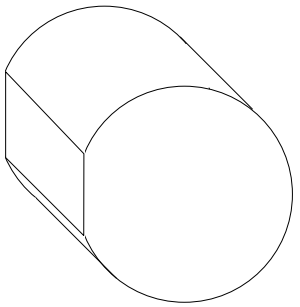




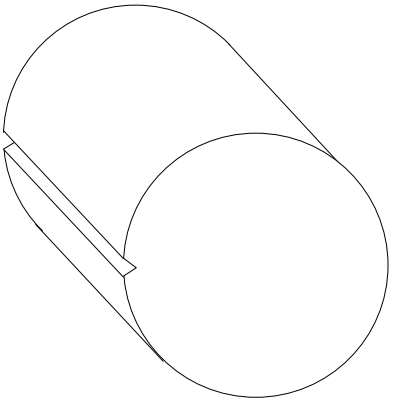

## 兩種方法之比較

- 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.

# 晶棒拋光、磨出平邊或缺口



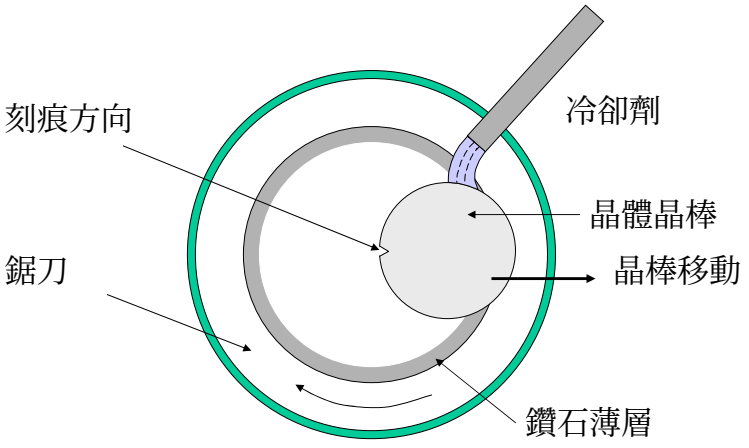
平邊, 150 mm 或更小者



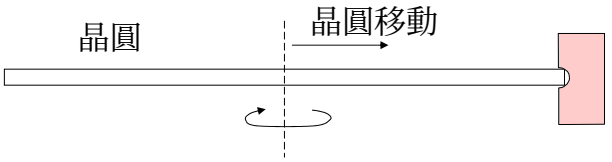
刻痕, 200 mm或更大者



# 2. 晶圓切片



# 3. 晶圓邊緣圓滑化




邊緣圓滑化前的晶圓

邊緣圓滑化後的晶圓

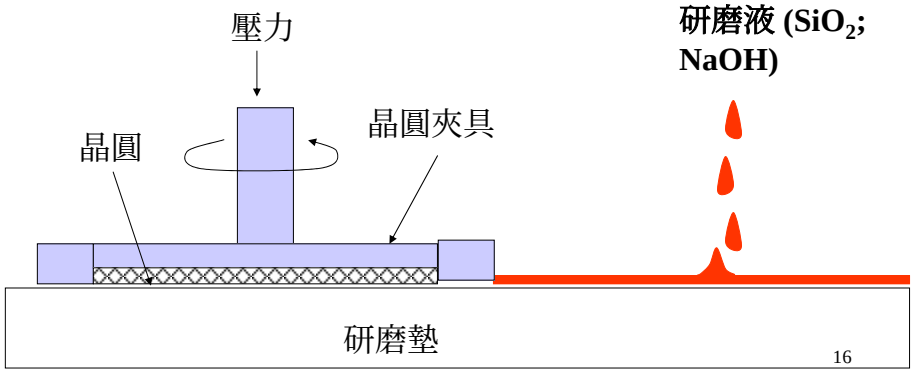


## 4. 晶圓粗磨

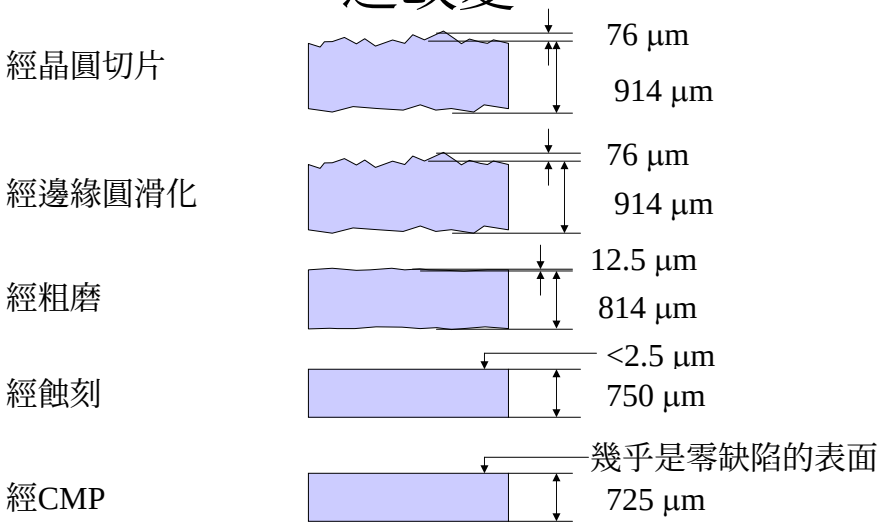
## 5. 濕式蝕刻:化學性地將晶圓表面之缺陷移除

$$3\ Si + 4\ HNO_3 + 6\ HF \rightarrow\ 3\ H_2SiF_6 + 4\ NO + 8\ H_2O$$

## 6. 化學機械研磨(CMP)



# 200 mm 晶圓厚度 及表面粗糙度之改變



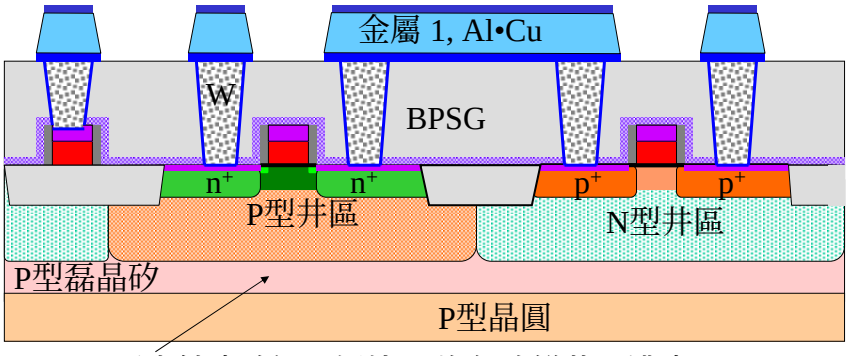



# 磊晶 (Epitaxy)

- 希臘字源 *epi*: 往上 *taxy*: 有次序排列的
- 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

# 磊晶應用: CMOS




1. 更高純度(低O,C污染);2均勻改變載子濃度



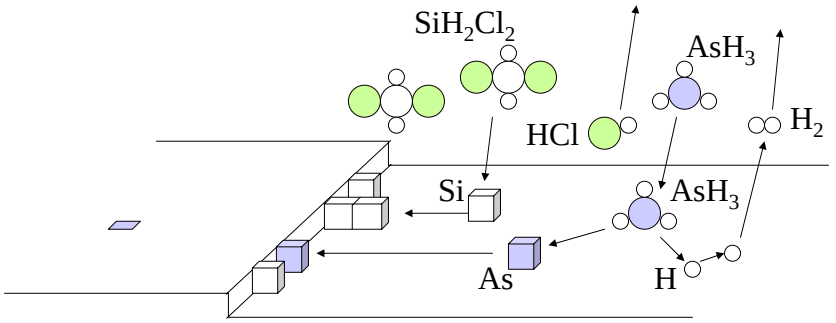
# 矽之來源氣體

| | | |
|---|---|---|
| **矽烷** | | **$SiH_4$** |
| **二氯矽烷** | **DCS** | **$SiH_2Cl_2$** |
| **三氯矽烷** | **TCS** | **$SiHCl_3$** |
| **四氯矽烷** | | **$SiCl_4$** |

## 摻雜之來源氣體

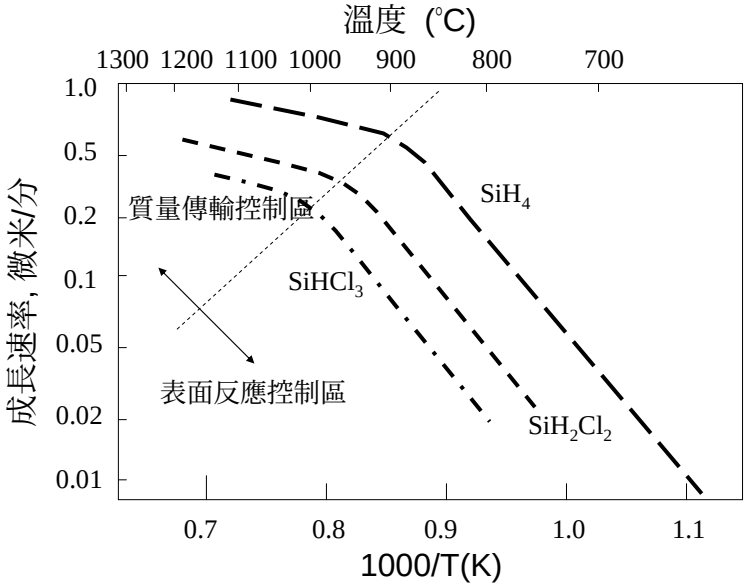
| | |
|---|---|
| **Diborane** | **B2H6** |
| **Phosphine** | **PH3** |
| **Arsine** | **AsH3** |

# DCS 磊晶成長及摻雜(As)過程之示意圖

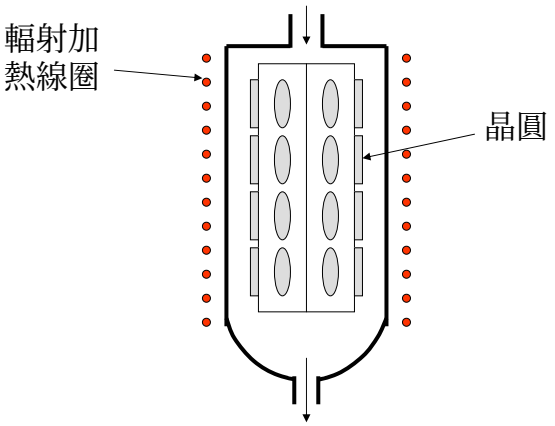





# 磊晶矽成長速率趨勢

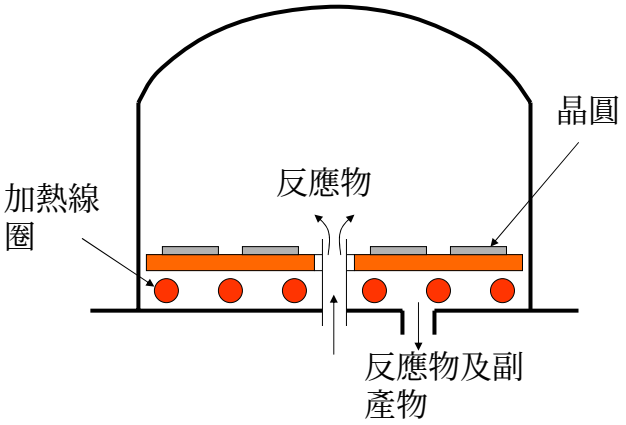


# 桶狀式反應器 (冷壁)

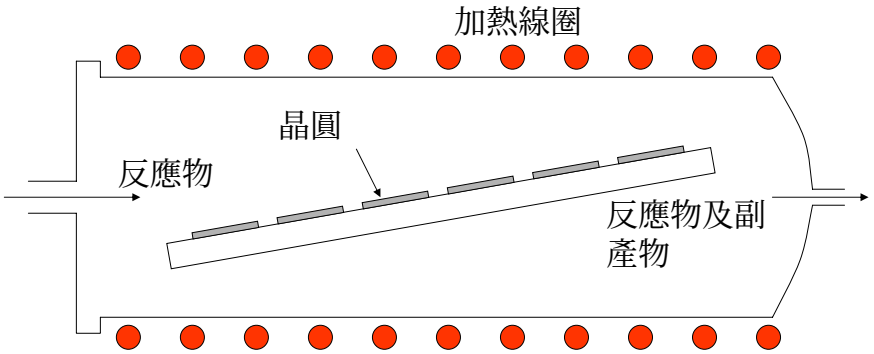





# 垂直式反應器 (冷壁)

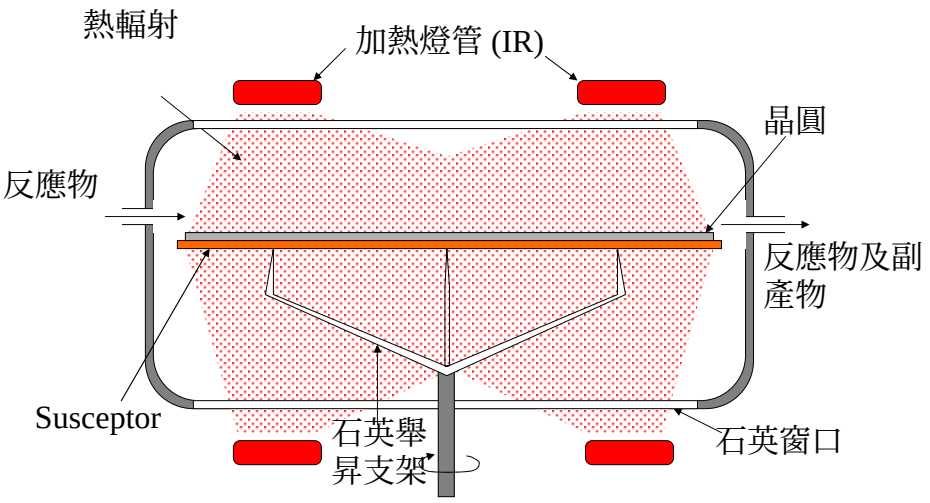


# 水平式反應器 (冷壁)



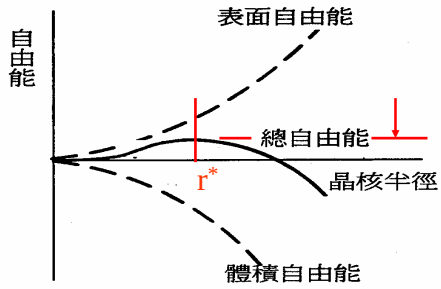



# 單一晶圓反應器



## 磊晶 對 多晶

成核:




勻相成核的能量障礙

$$G = 4\pi\sigma_o r^2 + 4/3\,\pi\, g_v\, r^3$$

表面能　　體積自由能



## 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

$C/C_{eq}$↑　$r^*$↓ 傾向 多晶Si

成長: 需要高溫以得到足夠的表面擴散率

溫度太低 → 複晶 (550~650 °C)
或
非晶型 (< 550 °C)