

CHE 4940 Fundamentals of Opto electronic Materials and Devices

(光電材料與元件基礎 2 學分)

課程說明:

教育化工系的同學，使認識光電材料與光電元件的基礎及其製程，俾便未來運用化學工程技術在這些相關的產業之中。

內容主要分為三大部分: 光電材料與元件基本原理, 無機光電材料與元件、有機光電材料與元件。

任課教師:

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教學進度：

I. 光電材料與元件基本原理：段興宇教授 M7M8

上課日期	授課內容
2/24	Semiconductor fundamentals
3/3	Principle of optoelectronic devices(I)
3/10	Principle of optoelectronic devices (II)
3/17	Principle of semiconductor-based solar cells
3/24	Integrated circuit (IC) manufacturing processes
3/31	Chemical vapor deposition (CVD)
4/7	Midterm

II有機光電材料與元件 Prof. 林昆翰 M7M8

成績評定

- Part I. 期中考, 50%.

教學方式

Lectures (power point presentations)

1. 投影片PDF檔下載：<http://mx.nthu.edu.tw/~hytuan/>

Overview of Integrated Circuits (IC) industry in Taiwan

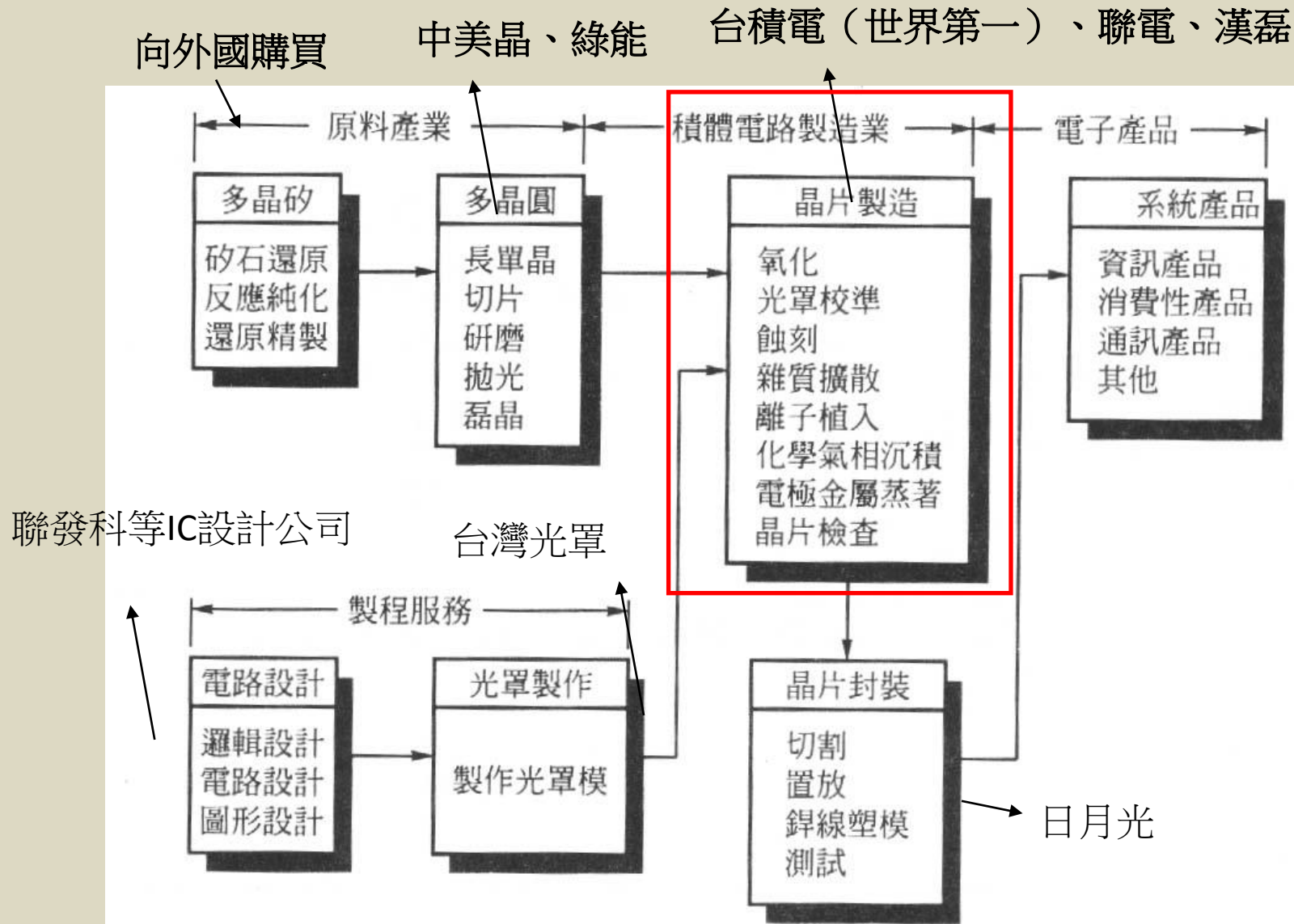
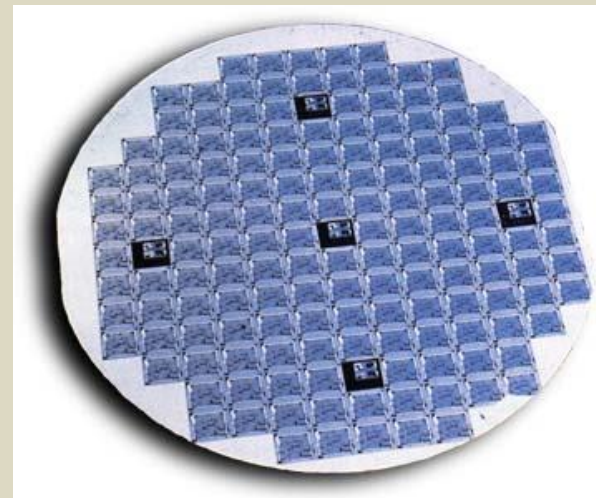
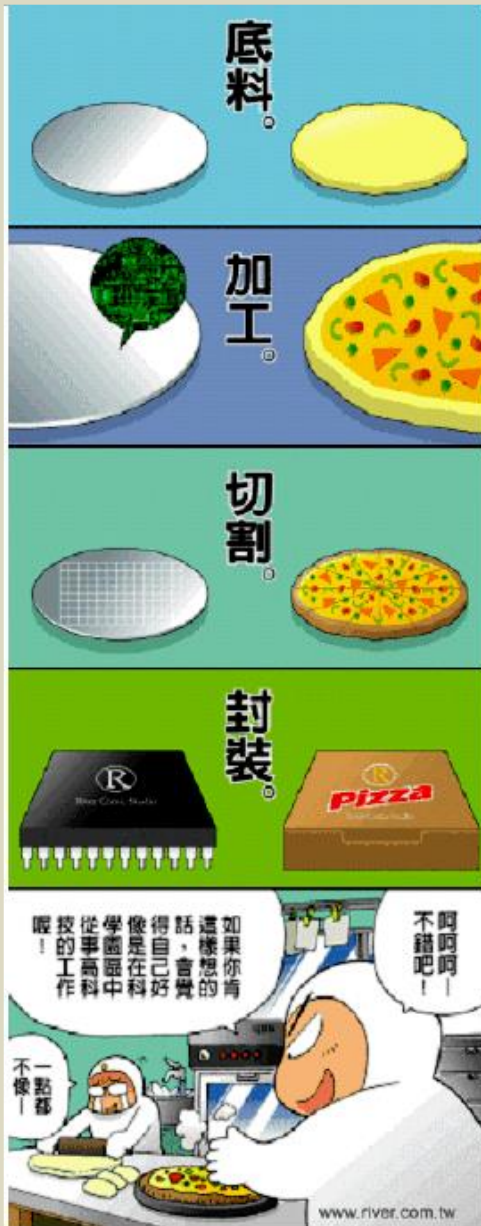
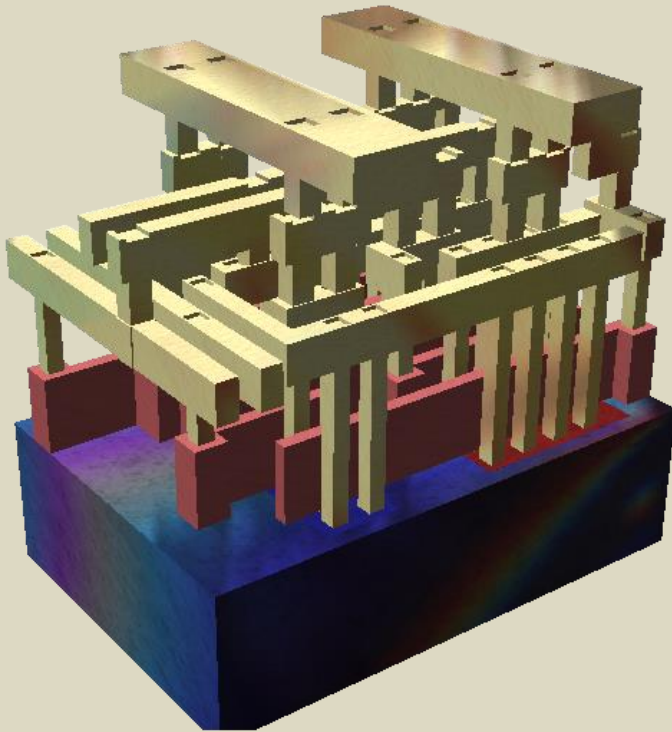


圖 1.2 積體電路工業體系

Pizza vs microchip fabrication



Integrated circuits (ICs)



- Combination of transistors, diodes, capacitors in a chip
- Ultra large scale integration (ULSI) >1,000,000 components per chips
- Morre's law: the number of transistors on a chip were doubling every 18 months
- Intel four core Itanium CPU- Tukwila has over 2 billion transistors on a chip

Courtesy of wiki

Periodic Table of the Elements

1 1A H Hydrogen 1.00794	2 IIA He Helium 4.002602											13 IIIA B Boron 10.811	14 IVA C Carbon 12.0107	15 VA N Nitrogen 14.00674	16 VIA O Oxygen 15.9994	17 VIIA F Fluorine 18.9984032	18 VIIIA Ne Neon 20.1797
3 Li Lithium 6.941	4 Be Beryllium 9.012182											5 B Boron 10.811	6 C Carbon 12.0107	7 N Nitrogen 14.00674	8 O Oxygen 15.9994	9 F Fluorine 18.9984032	10 Ne Neon 20.1797
11 Na Sodium 22.989770	12 Mg Magnesium 24.3050	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIII	9 VIII	10 VIII	11 IB	12 IIB	13 Al Aluminum 26.981538	14 Si Silicon 28.0855	15 P Phosphorus 30.973761	16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948
19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.955910	22 Ti Titanium 47.867	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938049	26 Fe Iron 55.8457	27 Co Cobalt 58.933200	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.409	31 Ga Gallium 69.723	32 Ge Germanium 72.64	33 As Arsenic 74.92160	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.798
37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.90550	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.90447	54 Xe Xenon 131.293
55 Cs Cesium 132.90545	56 Ba Barium 137.327	57 to 71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.9479	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.078	79 Au Gold 196.96655	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98038	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
87 Fr Francium (223)	88 Ra Radium (226)	89 to 103	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (269)	109 Mt Meitnerium (268)	110 Ds Darmstadtium (271)	111 Rg Roentgenium (272)	112 Uub Ununbium (285)	113 Uut Ununtrium (284)	114 Uuq Ununquadium (289)	115 Uup Ununpentium (288)	116 Uuh Ununhexium (292)	117 Uus Ununseptium	118 Uuo Ununoctium

Atomic masses in parentheses are those of the most stable or common isotope.

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Note: The subgroup numbers 1-18 were adopted in 1984 by the International Union of Pure and Applied Chemistry. The names of elements 112-118 are the Latin equivalents of those numbers.

57 La Lanthanum 138.9055	58 Ce Cerium 140.116	59 Pr Praseodymium 140.90765	60 Nd Neodymium 144.24	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92534	66 Dy Dysprosium 162.500	67 Ho Holmium 164.93032	68 Er Erbium 167.259	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967
89 Ac Actinium (227)	90 Th Thorium 232.0381	91 Pa Protactinium 231.03588	92 U Uranium 238.02891	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)

Si, Si, Si, why Silicon???

表 1.1 銻、矽、砷化鎵的基本性質之比較

性質	Ge	Si	GaAs
Atoms/cm ³	4.42×10^{22}	5.0×10^{22}	2.21×10^{23}
原子或分子重	72.6	28.08	144.63
密度(g/cm ³)	5.32	2.33	5.32
晶體結構	Diamond	Diamond	Zinc blende
熔點(°C)	937	1412	1238
介電常數	16	11.8	10.9
有效能階密度 導帶 N_c (cm ⁻³) 價帶 N_v (cm ⁻³)	1.04×10^{19} 6.1×10^{18}	2.8×10^{19} 1.04×10^{19}	4.7×10^{17} 7.0×10^{18}
電子親和力(V)	4.13	4.01	4.07
能隙(eV)	0.68	1.12	1.43
本質載子密度 n_i (cm ⁻³)	2.5×10^{13}	1.5×10^{10}	1.79×10^6
晶格常數(Å)	5.658	5.431	5.654
有效質量 電子 電洞	$m_e = 0.22m$, $m_h^* = 0.12m$ $m_h = 0.31m$, $m_h^* = 0.23m$	$m_e = 0.22m$, $m_h^* = 0.12m$ $m_h = 0.56m$, $m_h^* = 0.38m$	0.068m 0.56m
移動率(mobility) 電子(cm ² /V-s) 電洞(cm ² /V-s)	3900 1900	1350 480	8600 250
導熱係數(W/cm-0C)	0.6	1.5	0.8
比熱(J/g°C)	0.31	0.7	0.35
線性熱膨脹係數(°C ⁻¹)	5.8×10^{-6}	2.6×10^{-6}	6.86×10^{-6}
少數載子生命週期(sec)	10^{-3}	2.5×10^{-3}	$\sim 10^{-8}$

Silicon has smallest carrier mobility compared with Ge and GaAs.

Drawback of Ge

- Ge's device easily to leak at high temp.
- GeO₂ is water soluble
- melting point of Ge is only 937 C

Drawback of GaAs

- hard to get high quality and large size wafer
- need additional procedures to form dielectric materials

Advantage of Si

- Cheap raw materials, e.g., rock, sand, second most abundant element on earth, appear as SiO₂
- High melting point: 1415C
- stable silicon oxide (SiO₂) as dielectric materials

Optoelectronic devices using semiconductors: Si 、 III-V 、 I-III-VI,

many semiconductors are candidates

- LED (light emitting diodes)



- Laser



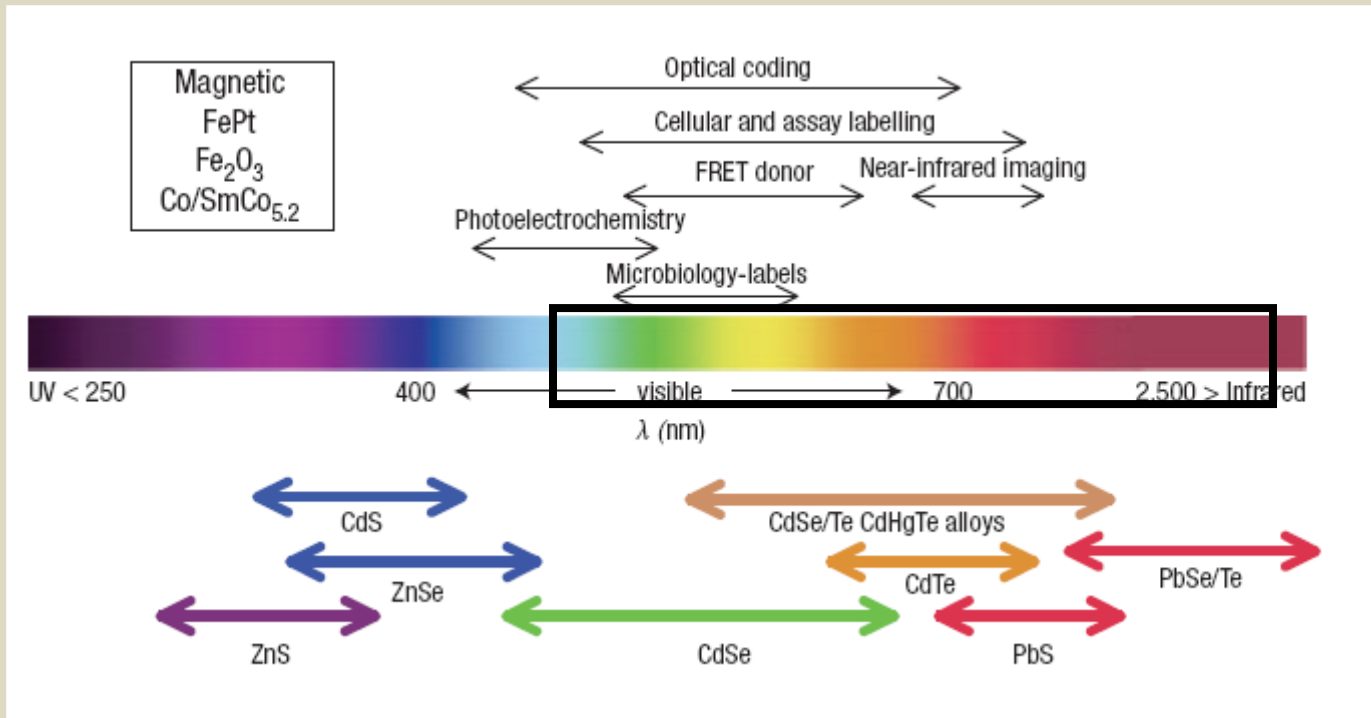
- Solar cell



- Photodetector



The band gap of **semiconductor** optoelectronic materials corresponding to a optical spectrum



$$E = hc/\lambda$$

$$E = 1.24/\lambda \text{ (eV)}$$

When E: electron volts

λ: μm

-direct band gap materials

-Compound (II-VI, III-V, IV-VI) semiconductors

LED – basic manufacturing processes

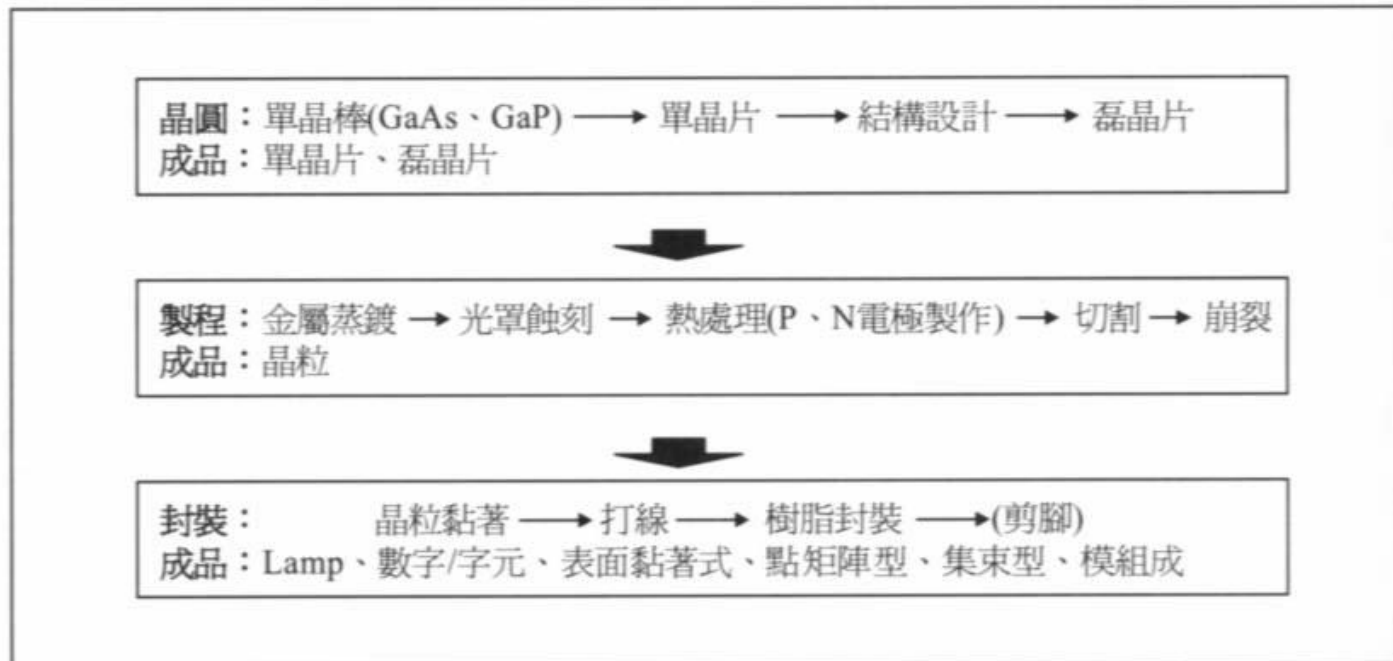


圖 3-3-1 發光二極體上、中、下游分工生產流程

Similar manufacturing process could be also applied to laser, solar cell industry