Introduction to Display Technology
影像顯示技術與趨勢簡介

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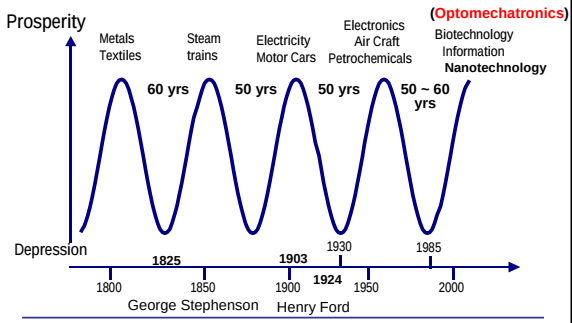
Contents

- **Introduction to Display technology**
  - ✓ Introduction to Display
  - ✓ CRT, PDP, LCD
  - ✓ Introduction to TFT-LCD
  - ✓ Digital TVs, Projector, LED, Micro display, Flexible display, OLED/PLED

Trend of the World



3C products

IA-products

影像顯示科技

- 視覺為五覺之首，是接受資訊與知識之大門

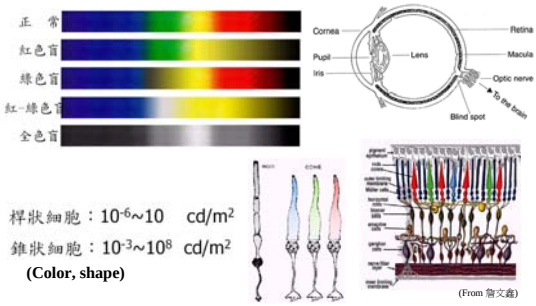
Why Display?

- Man-machine-interface
  (Display is a device used to exchange information between man and machine. 影像顯示 --- 永遠最愛的人機介面.)
- The contents of information could be numbers, text, and graphics.

Image

- "*Seeing is believing.*"
- Elements of a Image:
  - **Light source：**
    Sun-light, spot light, laser, CCFL, LED, EL …
  - **Objects**
    text, picture,
  - **Recording device**
    Eye, Camera,Video Cam., Cinematography, CCD, DV

Vision

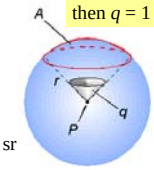


Unit of illumination

❑ **Units of illumination (one of System International units, SI) :**

	Unit	Symbol	Quantity measured
Dimensioned	1. Meter	m	Length
	2. Kilogram	kg	Mass
	3. Second	s	Time
	4. Ampere	A	Electric current
	5. Kelvin	K	Temperature
	6. Mole	mol	Amount of substance
	7. Candela	**cd**	**Luminous intensity**
Dimensionless	8. Radian	rad	Plane angle
	9. Steradian	**sr**	**Solid angle**

If $A = r^2$, then $q = 1$ sr



1 Candela (cd 燭光): a power level of 1/683 watt per steradian at λ=555nm (photopic peak, ν =5.4x10¹⁴Hz).
1 Lumen (lm 流明) = 1 cd emitted in angle of 1 sr
1 nit = cd/m²; 1 Lux = 1 lm/m²

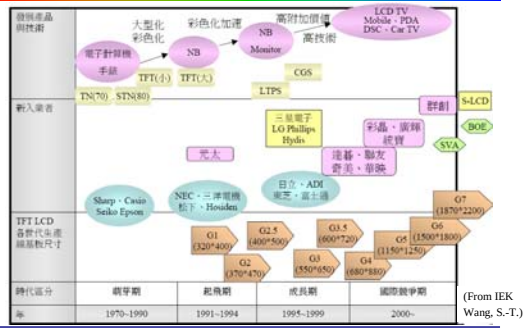
兩兆雙星

依據挑戰2008國家發展重點計畫，「兩兆雙星」產業的「兩兆」指的是，半導體產業及影像顯示產業，在2008年前年產值將各達一兆元以上；「雙星」則指的是數位內容及生物技術這兩項高度成長潛力的明星產業。

台灣LCD產業之發展

1. 扭轉向列 (Twisted Nematic, TN)型LCD
   1976年敬業電子與美商修斯飛機公司
2. 超扭轉向列 (Super Twisted Nematic,STN)型LCD
   1985年碧悠電子與美商歐利寶
3. 薄膜電晶體 (Thin Film Transistor,TFT) 型LCD
   1988年工研院電子所,1992年聯友光電,1993年元太科技
4. 大尺寸(10"以上)TFT-LCD
   1997年起華映(+三菱ADI)、友達(+松下,IBM) 、奇美(+富士通,IBM) 、瀚宇彩晶(+東芝) 、廣輝(+Sharp)

LCD產業之發展歷程



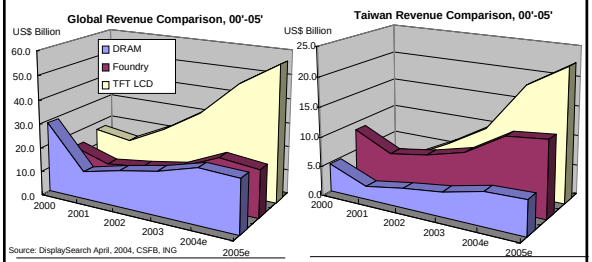
(From IEK Wang, S.-T.)

ICs vs. Display Industry (I)

- ICs
  - Doubling the number of transistors on a wafer every 18 months through advancing process equipment to process smaller design rules.
  - Design rules & process could be standardized or simulated
  - Design house contribution
  - Going smaller and smaller
- TFT LCDs
  - Grow the substrate size every two years to double the number of panels per substrate by growing process equipment.
  - LCD process is still an "art"
  - Design house? It happened but not yet proven
  - Going larger and larger

(From C.E Wang)

ICs vs. Display Industry (II)



Source: DisplaySearch April, 2004, CSFB, ING

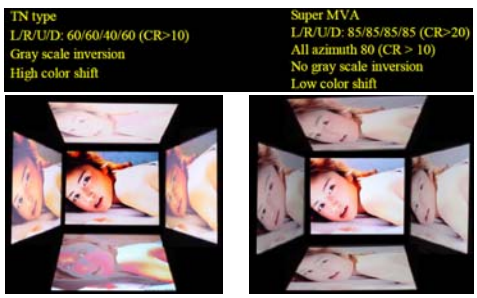
Rev. ($B)	2000	2001	2002	2003	04e	05e
DRAM	29.2	11.4	15.1	18.2	22.8	22.0
Foundry	14.0	9.2	11.3	14.2	21.3	19.6
TFT LCD	*16.8*	*14.6*	*22.3*	*32.1*	*47.7*	*54.9*

Rev. ($B)	2000	2001	2002	2003	04e	05e
TWN DRAM	4.8	2.2	3.3	4.2	5.7	5.9
TWN Foundry	8.7	5.6	6.6	8.3	12.2	12.9
TWN TFT	*2.4*	*3.1*	*6.4*	*10.3*	*18.7*	*22.7*

Basic Characteristics of Display

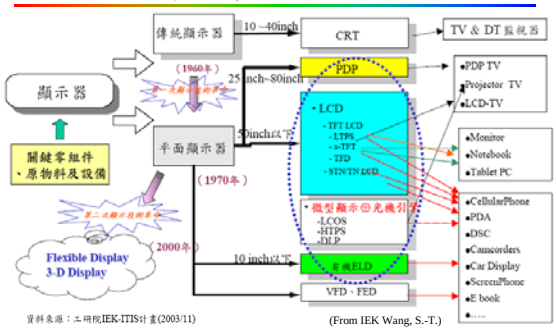
- ***Low cost***
- Light weight
- Thin thickness
- Wide viewing angle
- High contrast ratio and brightness
- Low power consumption and voltage
- Fast response time for wide temperature range
- Availability of full color
- Robust

Viewing Angle Problem of TFT-LCD



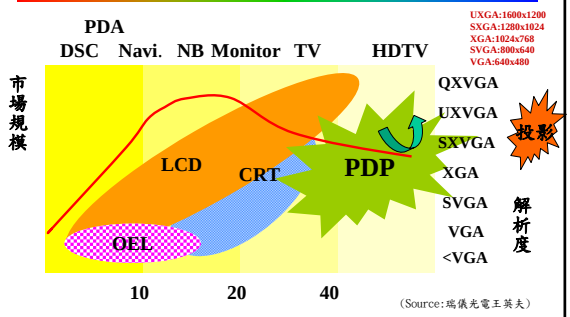
(**MVA**: multi-domain Vertically Aligned; **IPS**: in plane Switching) **(From CM 韋中光)**

各類平面顯示器



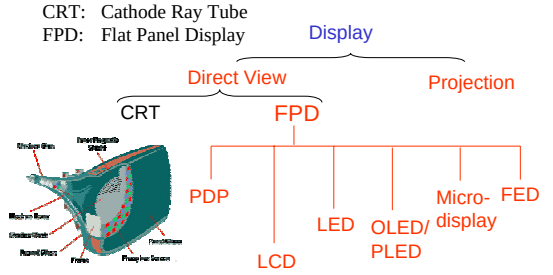
(From IEK Wang, S.-T.)

各類平面顯示器之定位



CRT & FPD

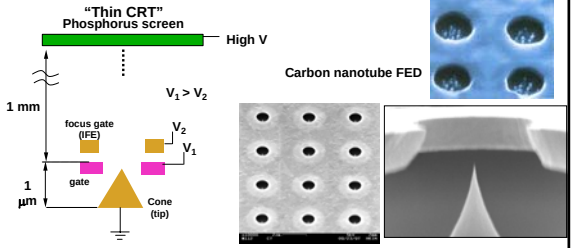
CRT: Cathode Ray Tube
FPD: Flat Panel Display

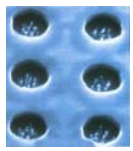


(From LS Huang)

FED (Field-Emission Device/Display)

- **Silicon emitters fabricated by oxidation sharpening and CMP techniques**



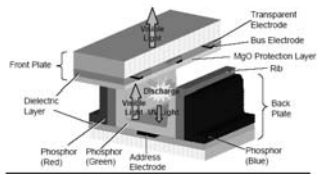


Problem: mass-production process & acceptable lifetime

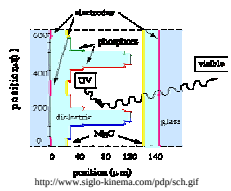
Source: Dr. H. Kim

PDP

- PDP: Plasma (電漿/等離子體) Display Panel
- PDP乃指"利用放電發光的顯示器". 在真空玻璃管中注入惰性氣體(Ne-Xe/He-Xe)，加電壓放電產生UV光,照射玻璃管內的螢光塗料發光．



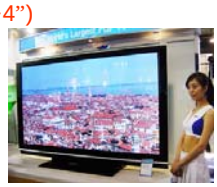
(From: 陳光郎)



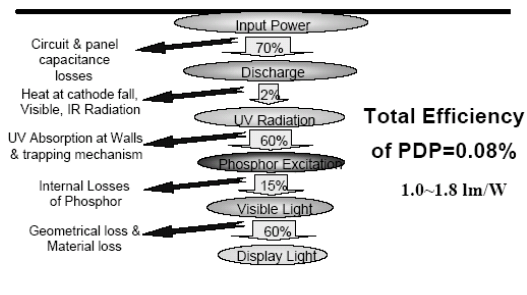
http://www.siglo-kinema.com/pdp/sch.gif

PDP

- 特色:
  平面、大畫面、相對薄(3~4")
  廣視角(上下左右~160°)、相對輕(~1/4 of CRT)、影像不受地磁影響
- 數位訊號
- 友達、華映、臺塑、聲寶
- 65" available, max. 102" Samsung @ 2005/5
- Disadvantages:
  Static burn-in problem, Power consumption, Cost, EM & IR radiation,

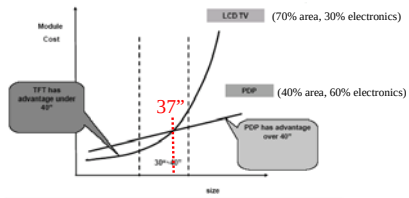


Total efficiency of PDP



(From: 陳光郎)

Cost comparison of PDP & LCD-TV

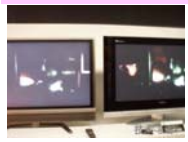


Generation	Substrate Size (mmxmm)	Capacity-Mother Glass (K pcs/M)	Capacity-42"panel (K panel/M)	Total Investment (Billion NT)	Investment per K panel/M (Billion NT)
LCD(G6)	1500 x 1850	90	270	66.3	0.25
PDP(G2)	968 x 1746	25	75	13.6	0.18
PDP(G3)	1936 x 1746	20	120	18.0	0.15
		42"視頻投資金額PDP：TFT＝		PDP(G2)	73.85%
				PDP(G3)	61.09%

(From: 陳光郎)

PDP vs. LCD-TV

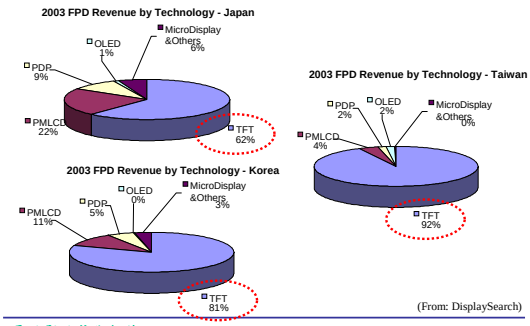
2005年5月日經BP社報道 松下電器



左爲液晶電視，右爲PDP電視光照度100lx時的畫質液晶電視畫質發白。照度爲2000lx時液晶電視的圖像顯然比PDP電視亮。

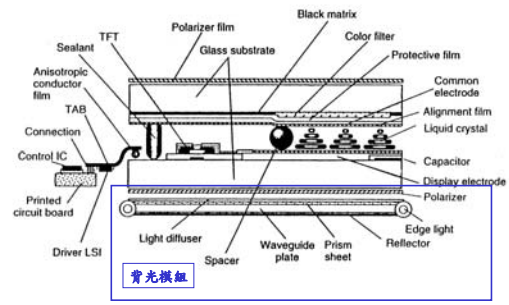
夏普進行比較的都是37英寸的電視。當時的電視節目播放的大多是演播室的情況和白天室外等比較明亮的場景，液晶電視的耗電量不到200W，PDP電視爲300W左右。

TFT-LCD vs. FPD

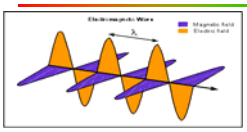


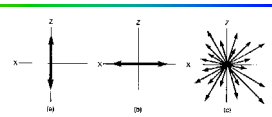
(From: DisplaySearch)

LCD structure

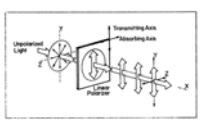


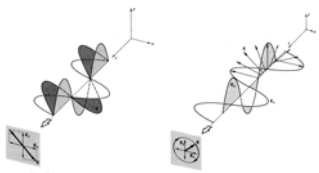
Polarization Light



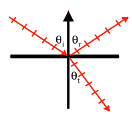


Source: Nick Strobel's Astronomy Notes. Go to www.astronomynotes.com for the updated and corrected version.

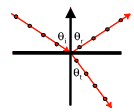




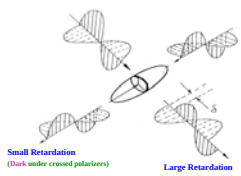
Polarization Light & Birefringence Effect

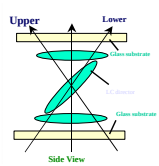


Parallel ("p") polarization



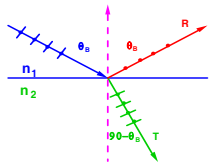
Perpendicular("s") polarization





(From CK LEE

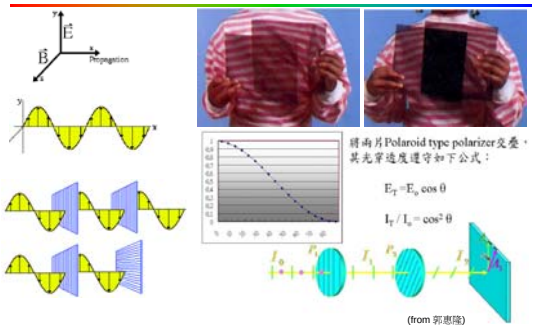
Snell's Law & Brewster Angle



- Snell's Law: $n_1\sin(\theta_B)=n_2\sin(90-\theta_B)$
  So, $\tan(\theta_B) = n_2/n_1$; If n_2=1.5; then θ_B ~53°
- The reflected light is linearly polarized;
- The transmitted light is partially polarized.

(Source: S.T. Wu)

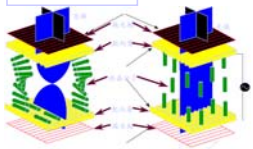
Malus's law



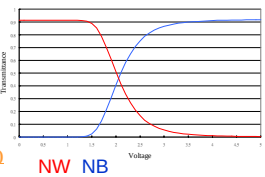
(from 郭惠隆)

LCD Display Principle

Ex. TN Mode



V-T Curve



LC為一光閥:控制通過光的強弱(本身不發光)

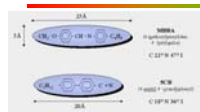
NW NB

外加電壓 ⇨ 改變液晶的排列方式 ⇨ 造成光極化態的改變

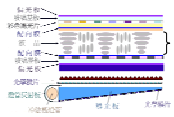
再搭配Polarizer或補償膜 ⇨ 完成亮暗顯示的效果

(from 翁逸君)

Liquid Crystal (I)



分子量: 300~800

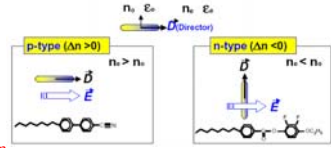


4~5μm

(0.3~0.4g for 12.1"LCD)

Birefringence: $\Delta n = n_e - n_o$

Dielectric Anisotropy: $\Delta\varepsilon = \varepsilon_e - \varepsilon_o$



Temperature ↗ Δn ↘, Δε ↘, viscosity ↘, Kii (elastic constant) ↘ etc.

Viscosity influence the LC filling and response time

Liquid Crystal (II)

Response time

Rise time: $\tau_r \sim \gamma d^2/(\varepsilon_0\Delta\varepsilon(V^2-V_c^2))$

Delay time: $\tau_d \sim \gamma d^2/(\varepsilon_0\Delta\varepsilon V_c^2)$

d↘, γ ↘, Δε ↗, ⇨(τ_r ,τ_d ↘).

where

D: cell space

γ : viscosity

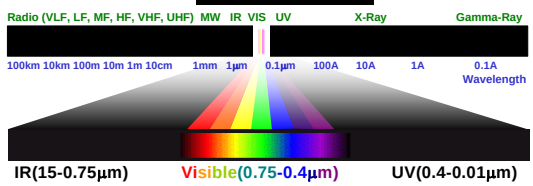
V_c: threshold voltage

Operating Voltage: $V = (K/\varepsilon_0\Delta\varepsilon)^{1/2}$; here $K=\pi^2K_{11}+\phi(K_{33}-2K_{22}) +4\pi\phi K_{22}\, d/p$

E_{ii}: elastic constant; p: pitch

Δε ↗ ⇨V↘.

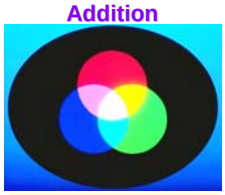
Light & Color



IR(15-0.75μm) Visible(0.75-0.4μm) UV(0.4-0.01μm)

Color Generation

Addition



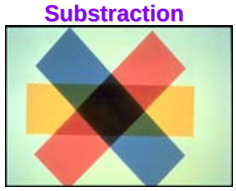
Primary Colors

Red (R) Green (G) Blue (B)

RGB

All together: WHITE

Substraction



Primary Colors:

Cyan (C) Magenta (M) Yellow (Y) and (optionally) Black (K)

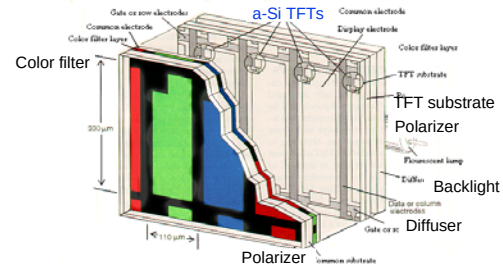
CMYK

All together: BLACK

Displays **Papers**

(Source: S.T. Wu)

TFT-LCD

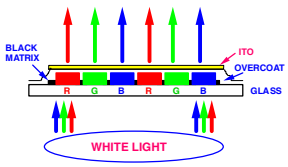


Each pixel is independently driven by a TFT

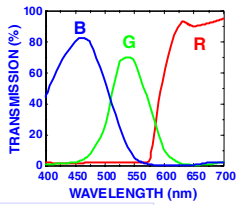
(Source：吳詩聰)

Color Filters

A. Structure



B. Transmission

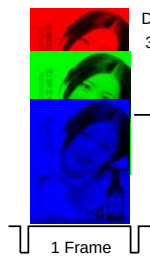


- **Light efficiency: 0.3x0.8~24%**
- **Resolution: 3 sub-pixels form a pixel**
- **Not preferred for projection displays**

(Source: S.T. Wu)

Color Generation

3-Channel Color

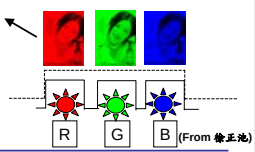


Drawback：
3 pixels needed

Color Sequential

Drawback：
Frame rate: 180Hz
→ f_{CLOCK} 變3倍

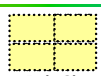
1 Frame (1/60 Sec)



(From 徐正池)

Types of Silicon

Amorphous Si



Poly-Si

Single Crystal Si

Parameters	a-Si	p-Si	c-Si
1. Electron Mobility:	1	10^{2}	10^{3}
2. TFT OFF-current:	10^{-12}	10^{-12}	10^{-13}
3. TFT ON-current (A):	10^{-4}	10^{-4}	10^{-3}
4. Dots pitch/inch:	300	1000	2000
5. Pixel Size (μm):	80	25	10
6. Infrastructures:	Good	Fair	Ex
7. Panel Size:	L+M	M+S	S

a-Si: Large panel; p-Si: Medium; c-Si: Micro-display

(From S.T.Wu)

HTPS vs. LTPS

HTPS: High Temperature Poly-Si

LTPS: Low Temperature Poly-Si

	Process Temperature	Poly-Si Formation	Gate Oxide Formation	Substrate	Cost
HTPS	> 900°C	Solid Phase Crystallization	Thermal Oxidation	Quartz	High
LTPS	< 600°C	Excimer Laser Annealing	Deposition	Glass	Low

(From 徐正池)

Types of Display

- Transmissive
  - High Temperature Poly-Si TFT LCD
  - Low Temperature Poly-Si TFT LCD
  - Liquid Crystal on Silicon
- Reflective
  - Liquid Crystal on Silicon
  - Digital Micromirror Device
- Emissive
  - Organic LED

Indoor

Reflective LCD Transmissive LCD

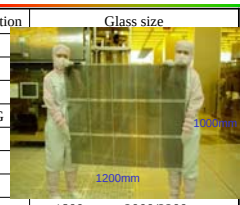
Outdoor

(From 徐正池)

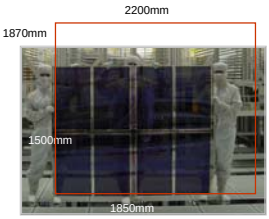
(from 翁逸君)

TFT-LCD manufacturing

Generation	Glass size
1G	
2G	
3G	
3.5G	
4G	
5G	
6G	
7G	1800 mm x 2000/2200 mm



G5: 15" x 15 cuts



G6: 32" x 8 cuts

LCD manufacturing lines (I)

表一 台灣次世代顯示器生產線

廠商名稱	X(mm)	Y(mm)	Gen.	最大月產產能(k sheet)	量產時程(f)
AU Optronics (友達光電)	1100	1250	5	70	2003Q1
	1100	1300	5	70	2004Q2
	1500	1800	6	90	2005Q2
Chi Mei (奇美電子)	1100	1300	5	120	2003Q3
	1300	1500	5.5	100	2005Q1
CPT(中華映管)	1500	1800	6	30	2005Q2
Hannstar (瀚宇彩晶)	1200	1300	5	90	2004Q1
	1500	1850	6	30	2006Q1
	2120	2450	7	--	規劃中
Innolux Display(群創)	1100	1300	5	35	2004Q4
Quanta(廣達)	1100	1300	5	60	2003Q2
	1500	1800	6	90	2005Q3

資料來源：工研院IEK-ITIS計畫(2004/06)

http://www.st-pioneer.org.tw/第116期93年08月號

LCD manufacturing lines (II)

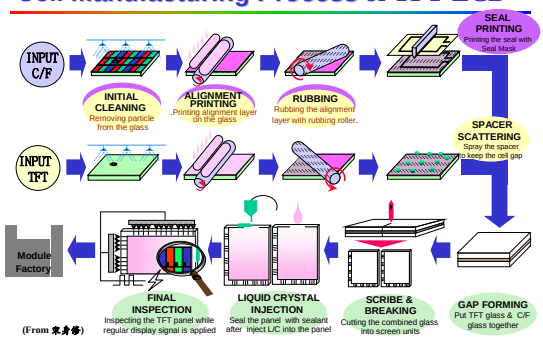
表二 主要競爭國家次世代顯示器生產線

區域	廠商名稱	X(mm)	Y(mm)	Gen.	最大月產產能(k sheet)	量產時程(f)
Japan	Sharp	1500	1800	6	45	2004Q1
		1500	1800	6	30	2005Q4
		2100	2400	7.5	30	2006
Korea	LG. Philips LCD	1000	1200	5	60	2002
		1100	1250	5	60	2003Q2
		1500	1850	6	90	2004Q4
		2120	2320	7.5	--	規劃中
	Samsung	1100	1250	5	100	2003Q2
		1100	1300	5	100	2003Q4
		1870	2200	7	100	2005Q2
	S-LCD	1870	2200	7	0	規劃中
China	BOE-Hydis	1100	1300	5	60	2005Q1
	SVA-NEC	1100	1300	5	45	2004Q4

資料來源：工研院IEK-ITIS計畫(2004/06)

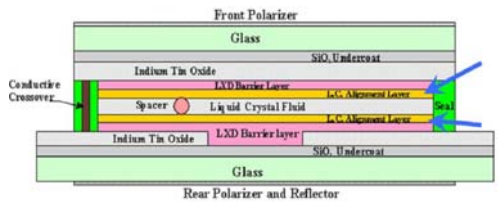
http://www.st-pioneer.org.tw/第116期93年08月號

Cell Manufacturing Process of TFT-LCD



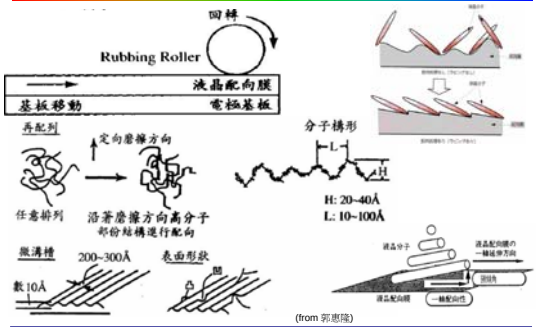
(From 宋身修)

Alignment layers



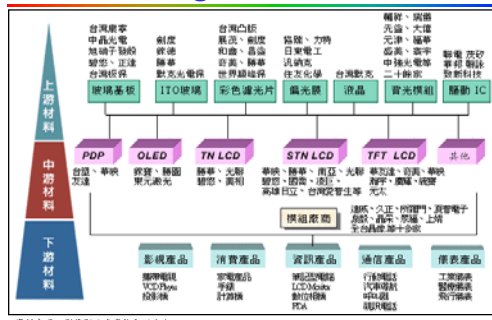
(from 郭惠隆)

Rubbing & Pretilt angle



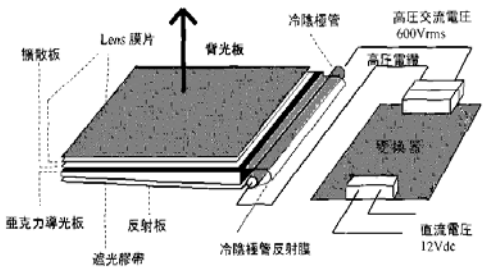
(from 郭惠隆)

Manufacturing structure of TFT-LCD



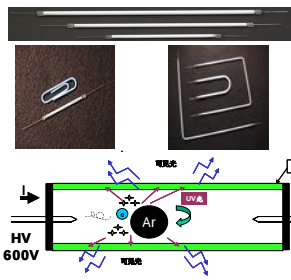
資料來源：影像顯示產業推動辦公室

背光模組



冷陰極螢光燈管 (CCFL)

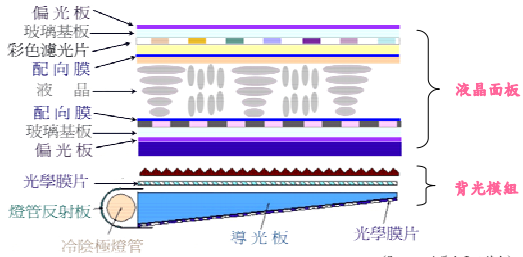
CCFL: Cold Cathode Fluorescent Lamp



1. 電氣及光學特性安定
2. 壽命長(標準電流下, 15,000Hrs~50,000Hrs以上)
3. 耐震, 耐衝擊性(100G以上)
4. 耐點滅特性(10萬次以上)
5. 可具調光性
6. 小型量輕(直徑Φ1.6~6.5 mm)
7. 低發熱量
8. 低消耗電力

背光模組功能說明

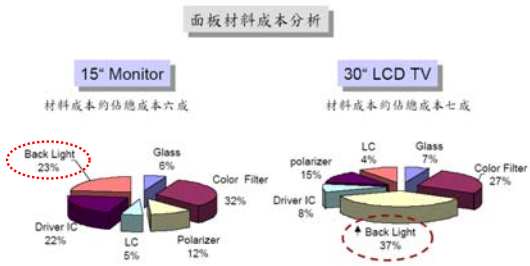
背光模組為LCD模組的一個重要零件，因液晶分子無法自主發光需要背光源方能看到LCD面板上所顯示之內容。



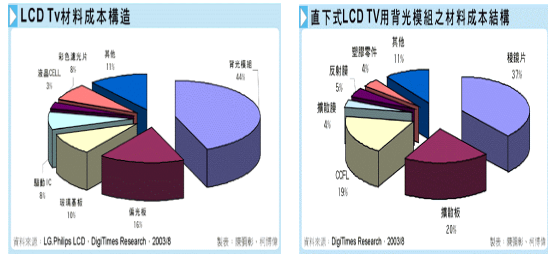
(Source:瑞儀光電王英夫)

背光模組

Cost of BLU



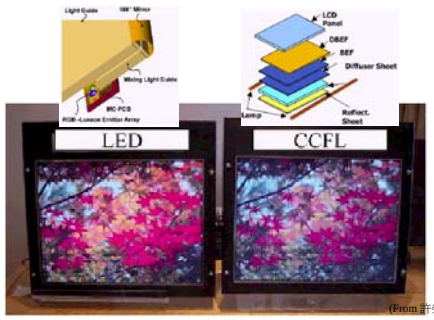
32"LCD TV背光模組成本分析



- LCD-TV 背光模組成本接近 50%，若要Cost down 應從背光模組著手
- 背光模組中，光學膜成本接近70%，若要Cost down 應從不需要光學膜之背光技術著手

(From:劉尚洲)

LED backlight



(From 許榮宗)

82" LED Backlight

CNT-BLU

Specification	CCFL	LED	CNT-BLU
Size (inch)	32	32	32
Luminance (nits)	12,000	9,500	15,000
Power Consumption (W)	110	185	85
Uniformity (%)	85	85	85
Life Time (hrs)	>50,000	>50,000	NA
Surface temperature (°C	<50	<50	NA
No. of Lamp/BLU	16	>1,000/1	1
Mass Production	Now	2006~2007	NA
Information source	FPD International 2003	CEATEC JAPAN 2004	

ITRI 20"

- White phosphor and planar structure
- The Largest CNT-BLU in the World (2004)

(From:劉尚洲)

顯示技術 & TV 尺寸

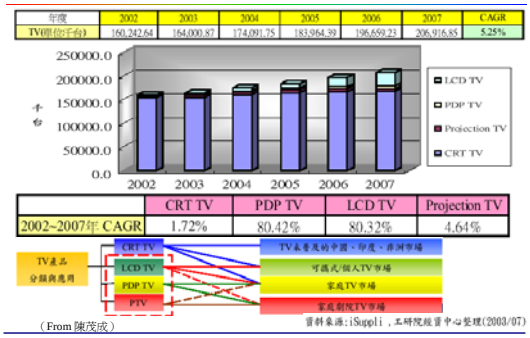
高畫質電視
- 平面電視
  - LC TV (20 ~ 60")
  - PDP (30 ~ 60")
  - CNT-FED
- 投影電視 (40 ~60")
  - DLP (DMD)
  - LCOS

(LED Display)

Digital TV

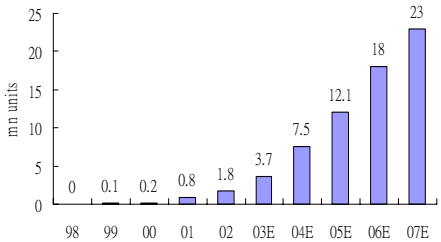
	採用標準	開播時間	類比訊號終止時間
美國	DSS/ASTC	1998	2006
歐洲	DVB-S/C/T	1998	2010
日本	DMB-T	1996	2010
中國大陸	ISDB-T	2001	2015
台灣	DVB-T	2002	2006

TV market



（From 陳茂成）

LCD TV Demand Grow for the Next 5 Years



Source: DisplaySearch,Merrill Lynch estimates

LCD HDTV

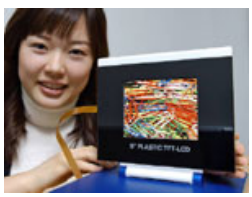
Samsung 82" S-**PVA mode**

1920*1080
1200:1 contrast, 92% NTSC
600 cd/m² brightness

AU Optronics 46”

1920*1080
800:1 contrast, 75% NTSC
600 cd/m2 brightness,
170˚, 1Q'04 MP

LCD on plastic



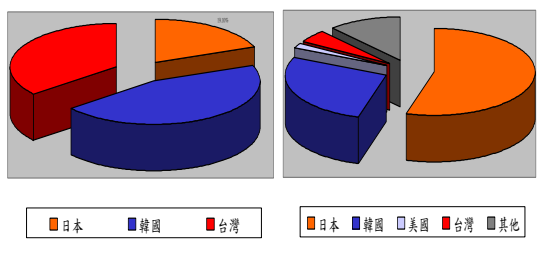
•全球最大的 5 英吋穿透式塑膠基板 (transmissive plastic) 薄膜電晶體液晶顯示器 (TFT-LCD)

•韓國三星電子於 2005 年 1 月 10 日在漢城展示全球最大的 5 英吋穿透式塑膠基板 (transmissive plastic) 薄膜電晶體液晶顯示器 (TFT-LCD)。該款顯示器能提供QSVGA (400x300) 的解析度，可應用於筆記型電腦及手機等可攜式裝置的螢幕

http://www.auxy.com/

全球LCD TV市佔率vs.面板生產規模

LCD 面板生產規模　　LCD TV產品市佔率



資料來源：DisplaySearch，拓墣產業研究所(2003/10)

(From:劉倉興)

Data projector

- The size-limit of the CRT-TV ~ 40", (> 100kg)
- Projection type is suitable for the large size display, e.g., 40"~60" (or more)
- Advantages of the data projector (in comparison with the RGB-CRT projector):
  - small size, light
  - high lumination (ANSI > 800Lumens)
  - high resolution (800x 600SVGA, 1024 x 768XGA)
  - lower price
  - user-friendly

VGA:640x480
SVGA:800x640
XGA:1024x768
SXGA:1280x1024
UXGA:1600x1200

Advantages of DLP

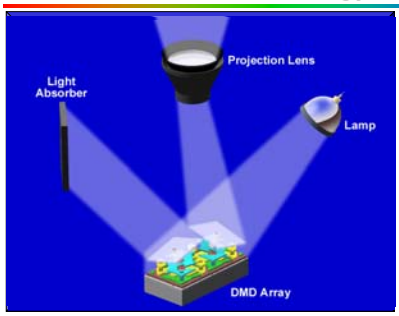
(DLP:Digital Light Processing)

- **High Resolution**
- **High Brightness**
- **High Contrast Ratio**
- **Fast Response Time**
- **Flicker-Free**

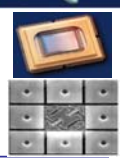
DLP™ Large Venue

Source: Texus Instrument Inc.

How DLP™ Technology Works



- DMD : Digital Micromirror Deivces



LCOS (Liquid Crystal On Silicon)

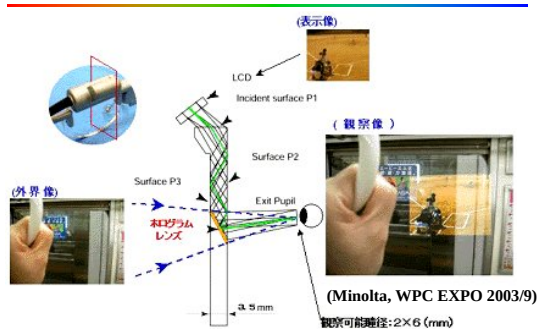
- Typical sizes of microdisplays are in the range 0.5-1.3 inch diagonal.

- High Electron Mobility
- High Aperture Ratio > 90%
- Very Fine Pixel Pitch
- Very High Resolution
- Low Power
- High Potential in Cost Down

Source: http://www.elis.rug.ac.be/ELISgroups/tfcg/microdis/index.html

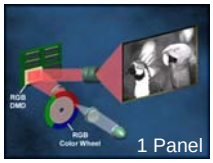
Micro Display

Holographic See-through Browser



(Minolta, WPC EXPO 2003/9)

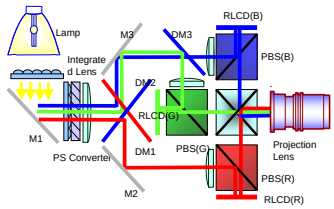
DLP Projector



Resolution: 1280 x1024

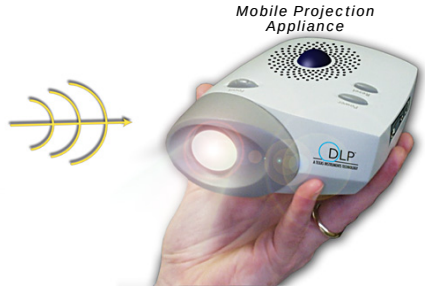
Pixels: 1280 x1024

LCoS panel x 3



Where is the Next? Lighter, Brighter, and Wireless

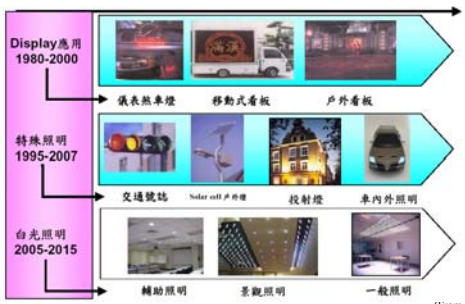
Mobile Information Appliance



Mobile Projection Appliance

Source: Texus Instrument Inc.

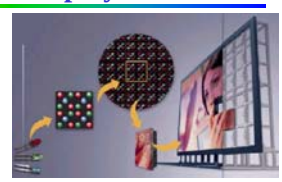
LED



(From 許榮宗)

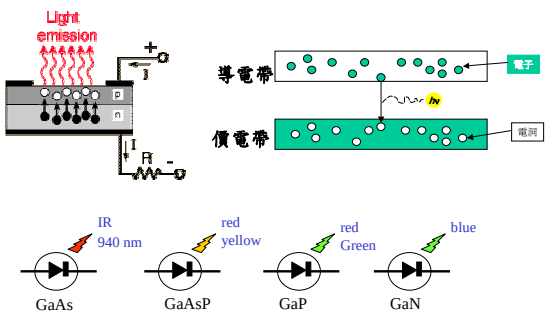
Large LED Display

- 室內用
  - pixel pitch 4-10 mm
  - brightness 1,000-2,000 nits
- 室外用
  - pixel pitch 7-30 mm
  - brightness 5,000-6,000 nits



(From 許榮宗)

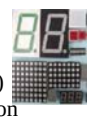
Light-Emitted Diodes (LED)

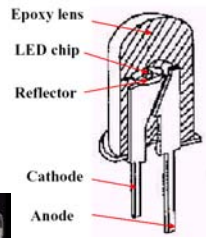


Light-Emitted Diodes (LED)

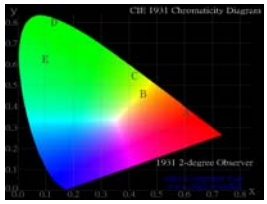
Advantages:

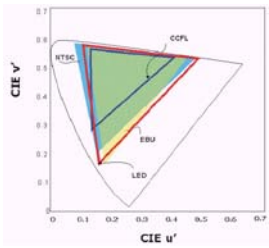
- Solid-state light source
- Small size
- No color filter needed
- Long-life (10^5~10^6 hrs)
- Low power consumption
- Fast response (~ 100 nano sec)
- High resistant to vibrations
- No mercury
- Robust





Color Gamut

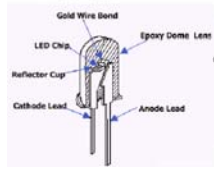


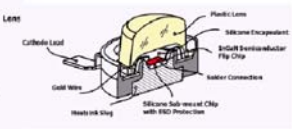


CIE 1931 chromaticity diagram of various MEH-PPV/DPO-PPV polyblends with following weight ratios: (A) 1:0 (B) 1:3 (C) 1:6(D)1:55 (E) 1:75

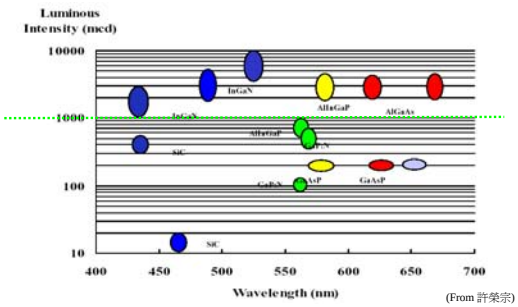
High Power LED

Tranditional LED	High Power LED
•5mm in diameter	•10-25 mm in diameter
•0.05-0.1 W	•1-5 W
•0.5-3 lm	•10-120 lm



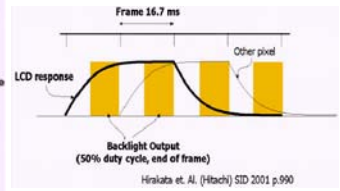


Performance of commercial LEDs



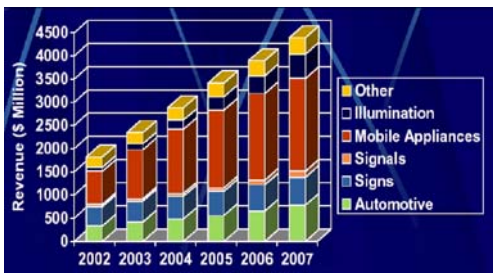
(From 許榮宗)

閃爍的背光源



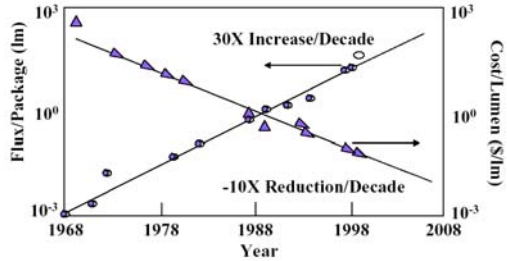
(From 許榮宗)

LED market prediction



(From 許榮宗)

Trend of LEDs (efficiency & cost)



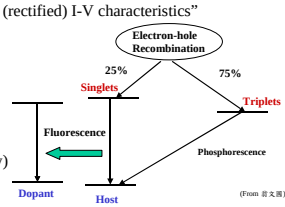
註: 以商業上之紅光LED產品爲計算基準, 數據由H.P. 公司之R Haitz提供.

(From 許榮宗)

82” LED Backlight

Organic EL vs. Organic LEDs

- Electrolumiescence (EL)
  - “The emission of light generated from the carriers electrically injected into a luminescent semiconductor”
- Organic Light Emitting Diode (OLED)
  - “Organic EL device with diode (rectified) I-V characteristics”
- Molecular
  - OEL, OLED
- Polymer
  - PLED (polymer LED)
  - LEP (light-emitting polymer)
  - PED (polymer emission display)



OLED & PLED

Samsung 2.2” OLED Panel(2002)

Resolution：170x220(QCIF)
pixel pitch：66x198(128ppi)
Brightness：＞200 cd/m2
＃ of color：262144
aperture ratio：32%

Toshiba 17” PLED

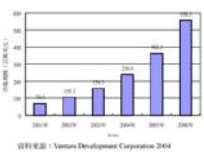
(From 陳良吉)

Advantages of OLED

- **Self Light-Emitting (Backlight and Color Filter are not needed)**
- **High Brightness**
- **High Contrast**
- **Simple Structure → Low Cost**
- **Low Driving Voltage (3 ~ 9 V) → Power Saving**
- **Light Weight, Thin Thickness (1 ~ 2 mm)**
- **Wide Viewing Angle (>160 degree)**
- **Fast Response Time (10 μs)**
- **Full Color Available**

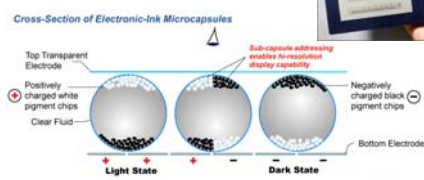
可撓曲的顯示器(Flexible Display)

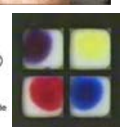
200PPI, 2”, 320x240 @2005 SID



Paper-like display

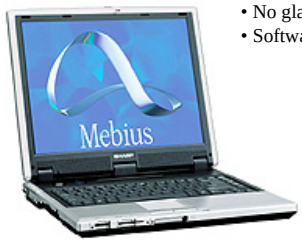
Combination of the convenience, robustness and readability of printed material with the vast and flexible information content of laptop computers





(Hayes & Feenstra)

Sharp全球第一款3D LCD-Notebook



- Sharp, Mebius PC-RD3D
- (350000￥ @2003/10)
- No glasses
- Software development

The world is always moving forward

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