## Organic light-emitting diodes

# Introduction

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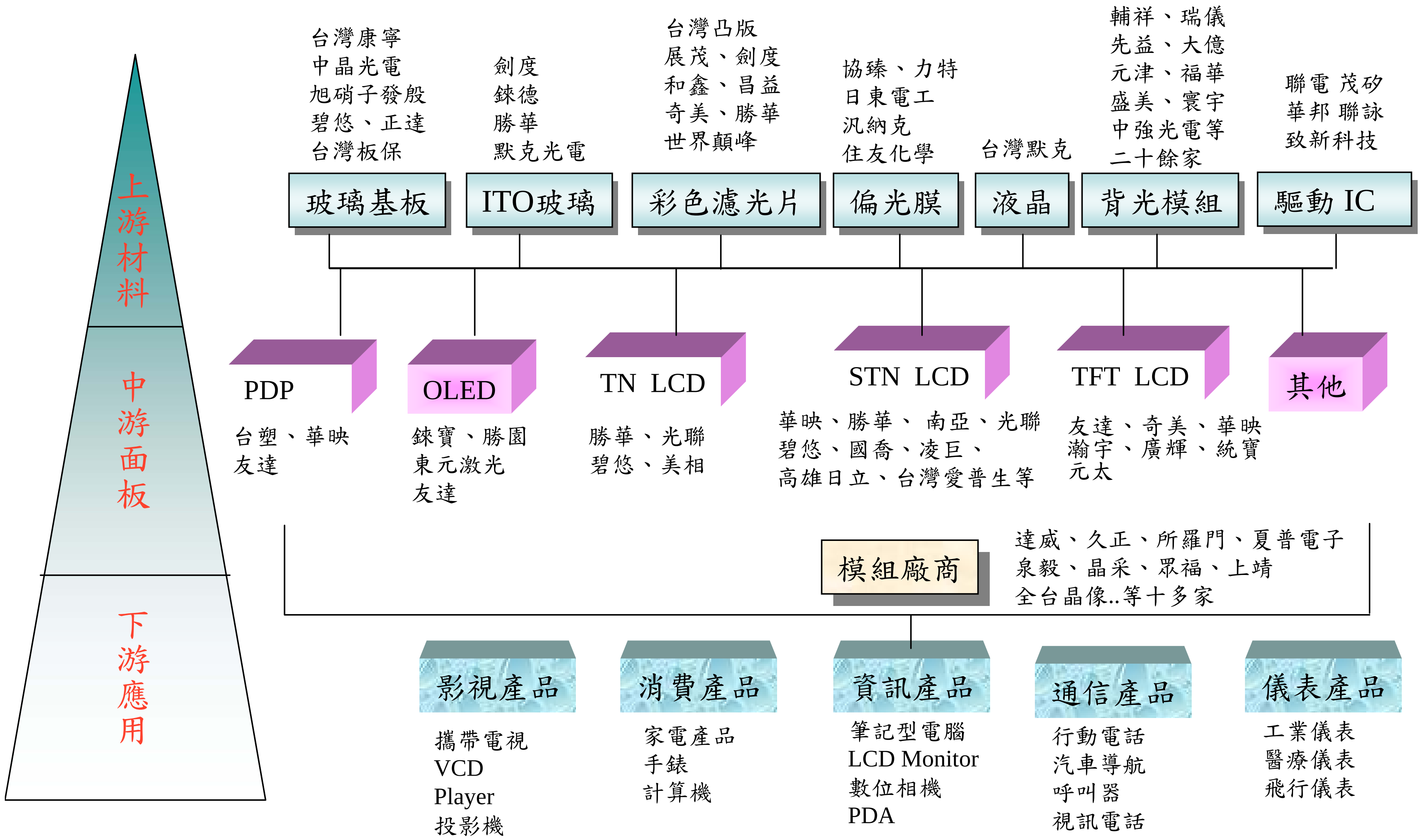
**From “兩兆雙星”……….. $$$$$$$$$$$$**

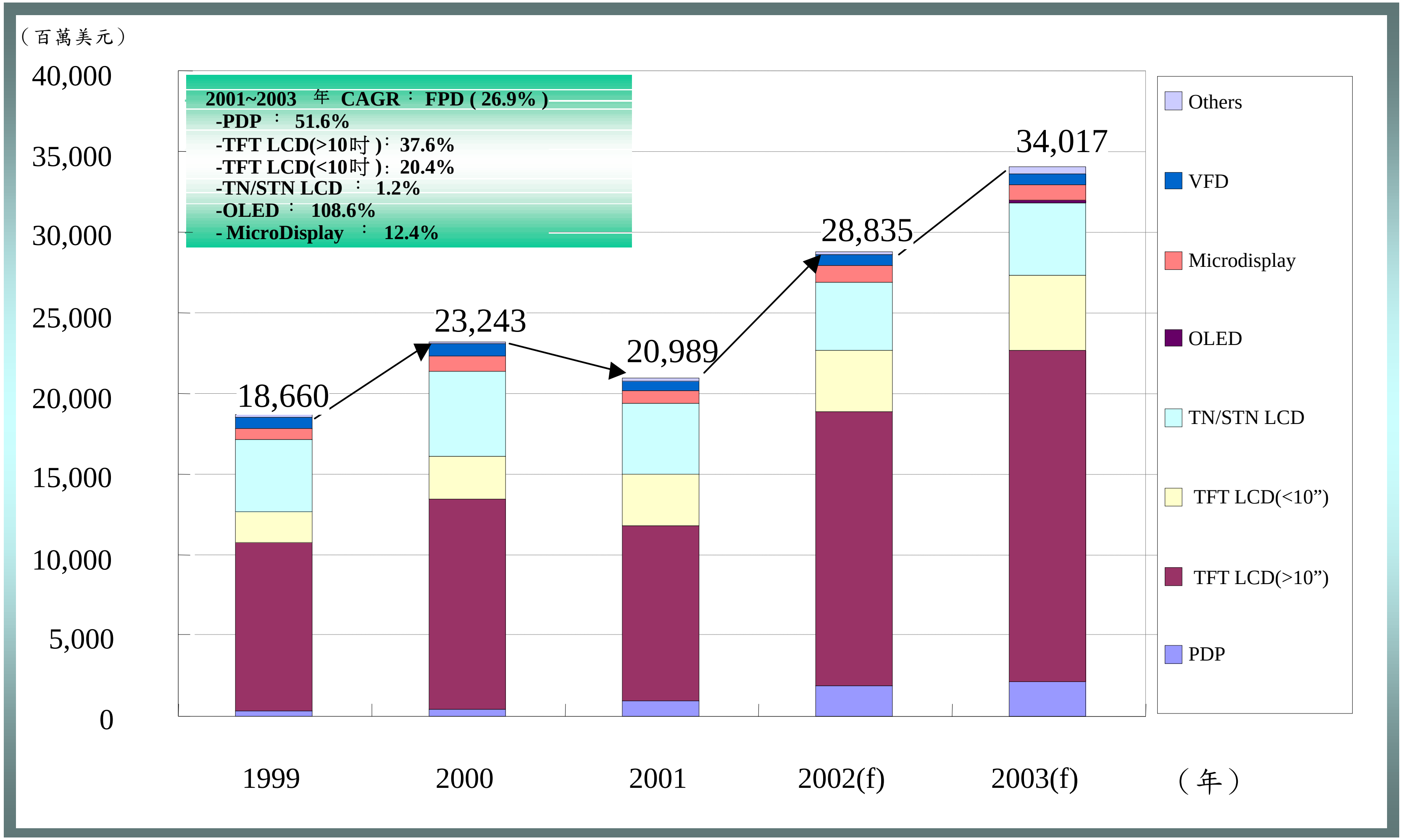
優勢產業（半導體、影像顯示）

明星產業（數位內容、生物科技）

# Taiwan Display Industry

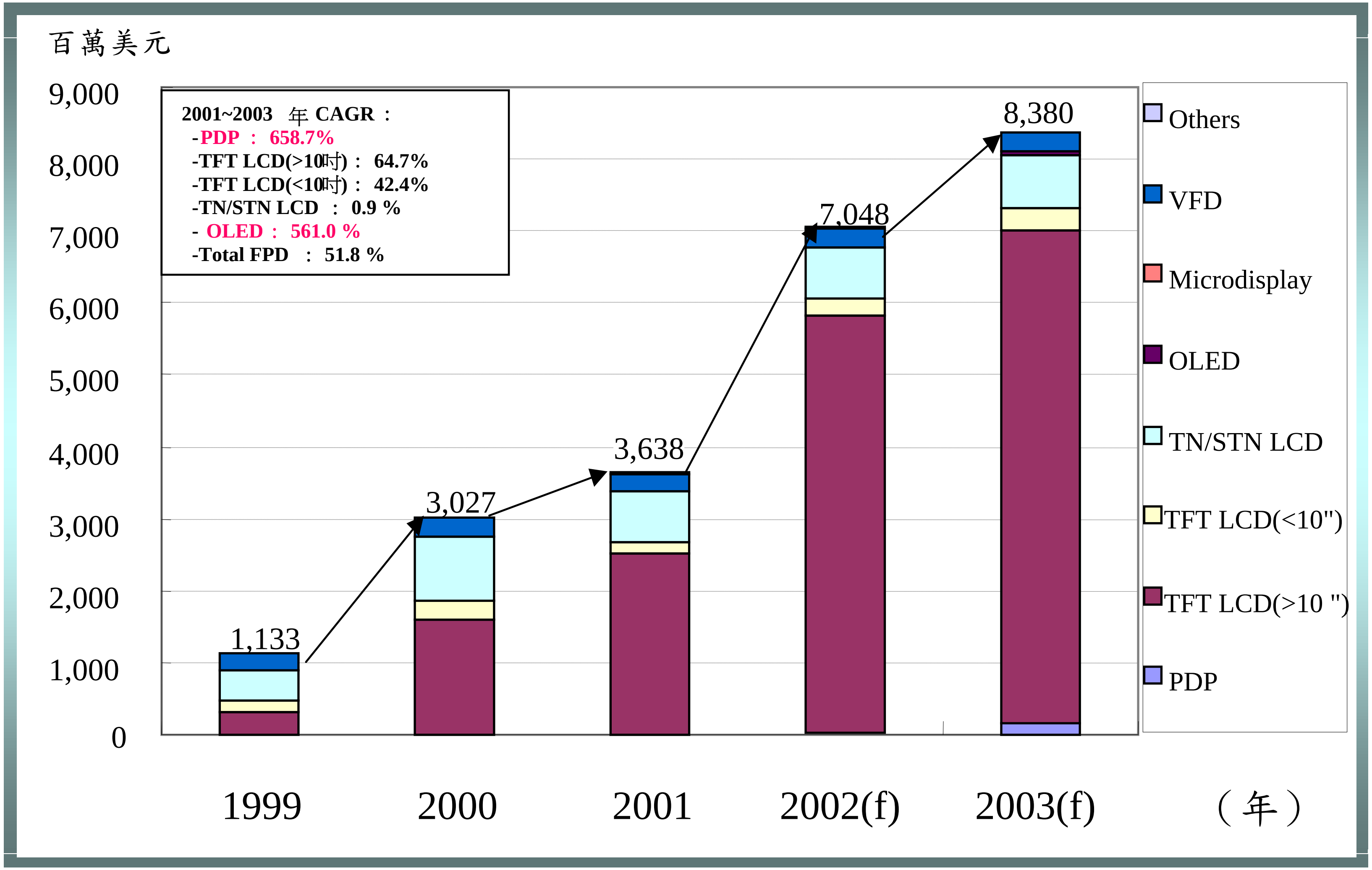


# 產業現況(Worldwide)




工研院經資中心(2002/03)

# 產業現況(Taiwan)




工研院經資中心(2002/03)

# Display industry Vision

●推動台灣成為全球第一大TFT 顯示器供應國

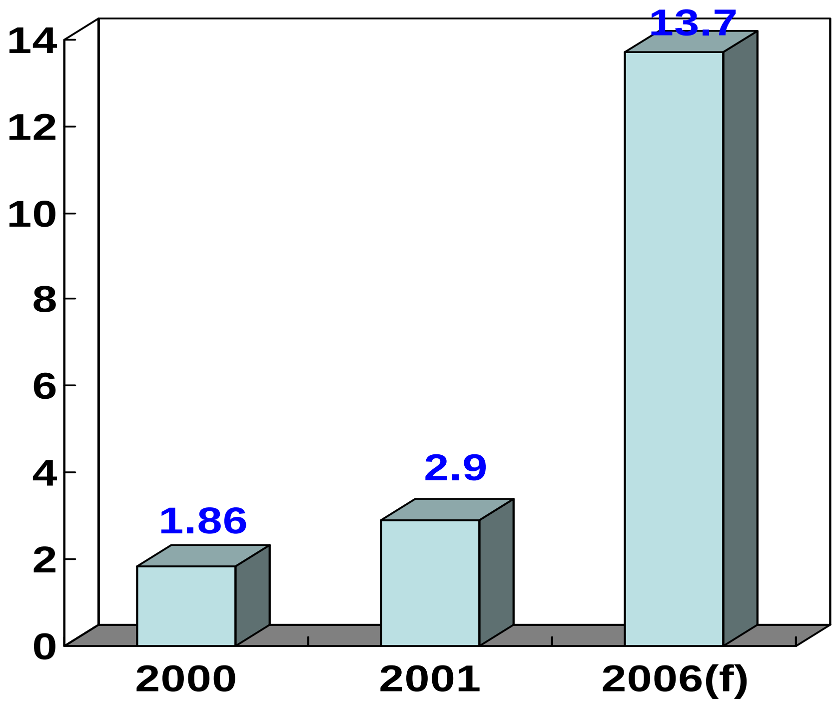
●建構台灣成為全世界最主要影像顯示產品研發及製造重鎮

●民國95年影像顯示產業產值達新台幣一兆三千七百億元以上

●未來五年民間投資金額達新台幣三千五百億元以上

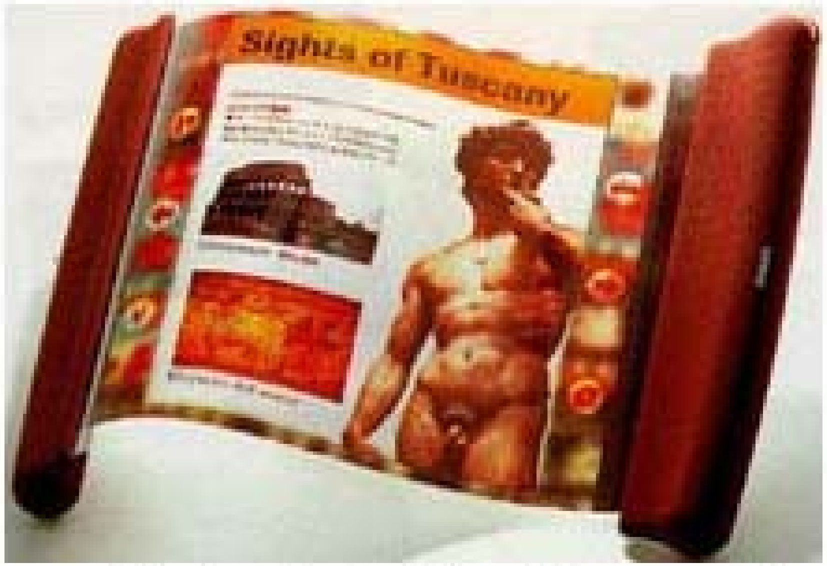
影像顯示產業產值

單位:NT$千億元



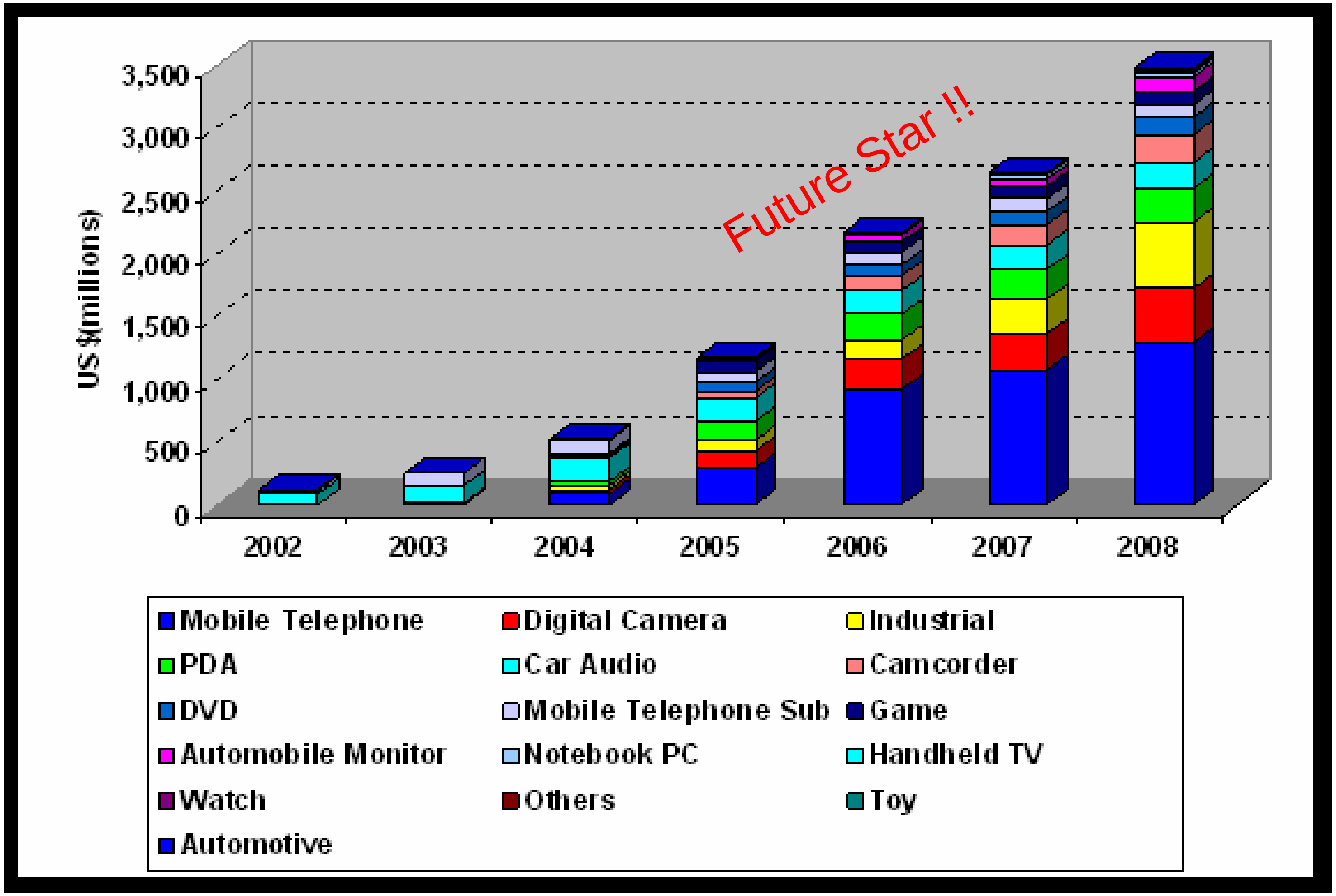
# Organic light-emitting diodes
# --The emerging technology

## OLED Displays

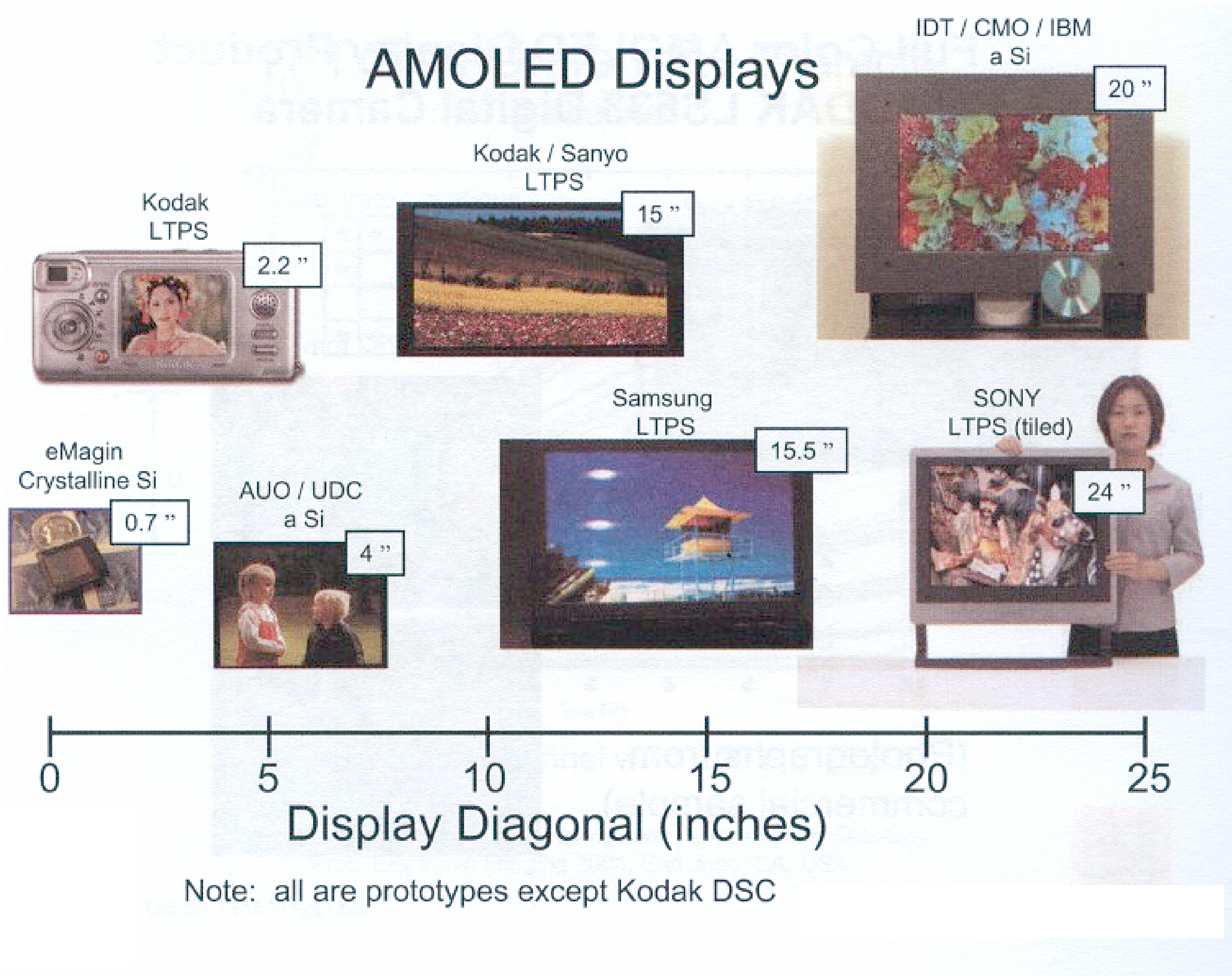



Pull out travel guide

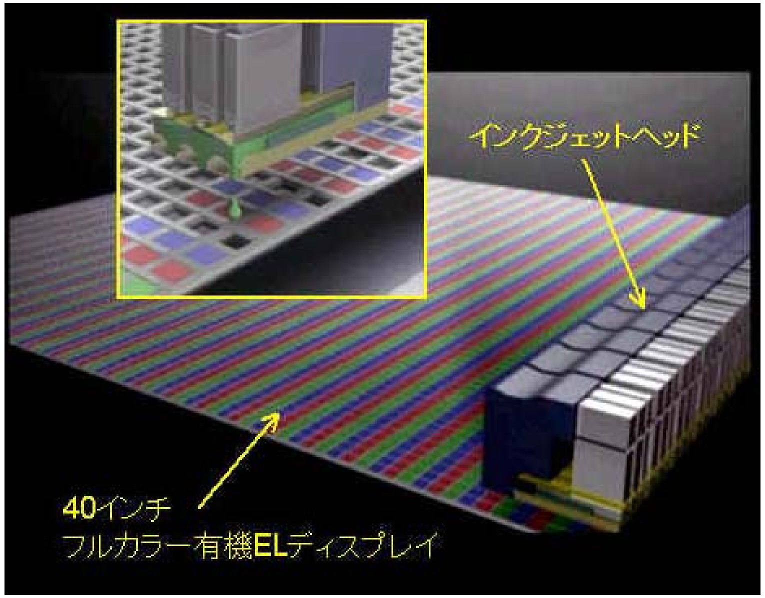
# OLED Revenue Forecast by Application




http://www.displaysearch.com/press/2003/122303.htm


AMOLED Displays
IDT / CMO / IBM
a Si
20 "
Kodak / Sanyo
LTPS
15 "
Kodak
LTPS
2.2 "
Samsung
LTPS
15.5 "
SONY
LTPS (tiled)
24 "
eMagin
Crystalline Si
0.7 "
AUO / UDC
a Si
4 "
0
5
10
15
20
25
Display Diagonal (inches)
Note: all are prototypes except Kodak DSC

# Seiko Epson: The largest OLED Display using IJP

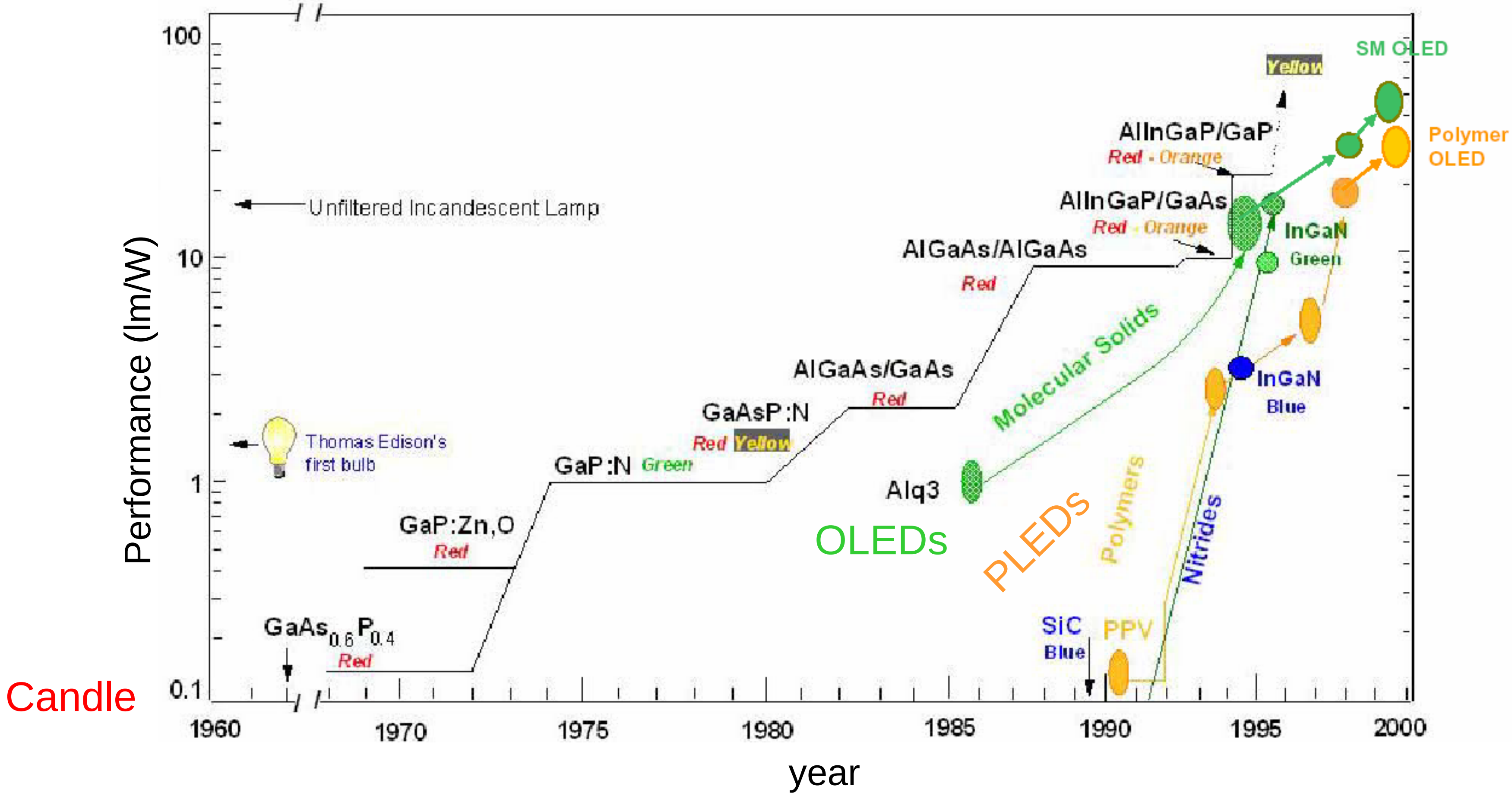

Screen size 40-inch diagonal
Number of pixels 1280 x RGB x 768dots (W-XGA)
Driving method Active matrix
Pixels per inch 38
No. of colors 260,000

commercialization in 2007

**Main Specifications**
Screen size 40-inch diagonal
Number of pixels 1280 x RGB x 768dots (W-XGA)

http://www.epson.co.jp/e/newsroom/news_2004_05_18.htm

# Efficiencies of LEDs



# History of organic light-emitting devices (OLEDs)

**1963 --- First organic electroluminescent (EL) based on anthracene single crystal; (Pope *et al*.)**

Problem: low quantum efficiency and high operating voltage (>100V)

**1987 --- First organic electroluminescent (EL) based on amorphous organic molecules;**

**(Kodak; C. W. Tang *et al*.)**

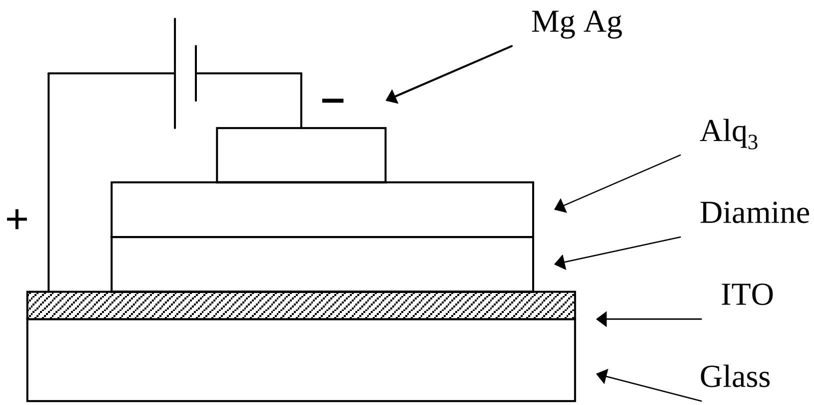
high quantum efficiency (~1%); low driving voltage

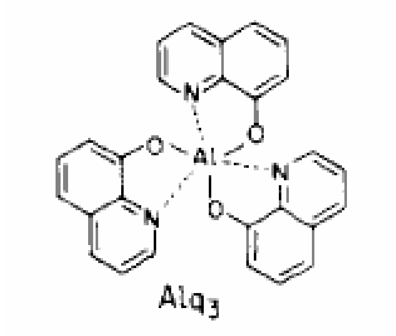
bi-layer structure; thin amorphous organic films

**1990 --- First organic electroluminescent (EL) based on polymer; (Cambridge University; Burroughes *et al*.**

polymer light-emitting diodes (PLEDs)

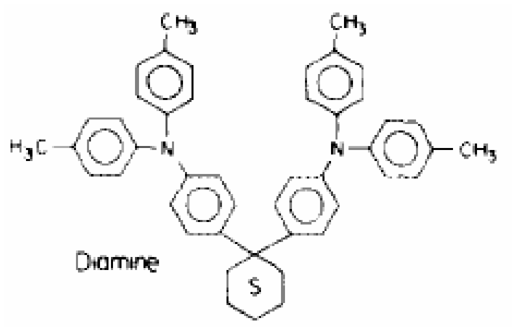
# Device structure of OLEDs



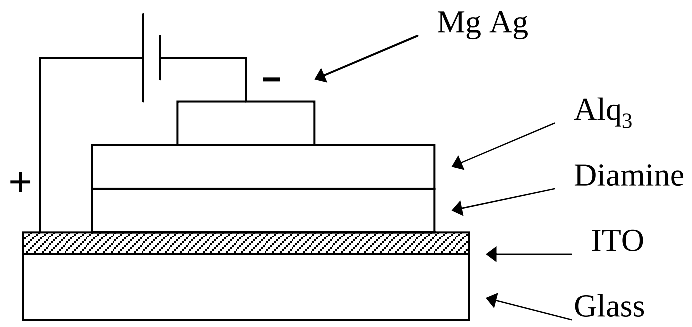



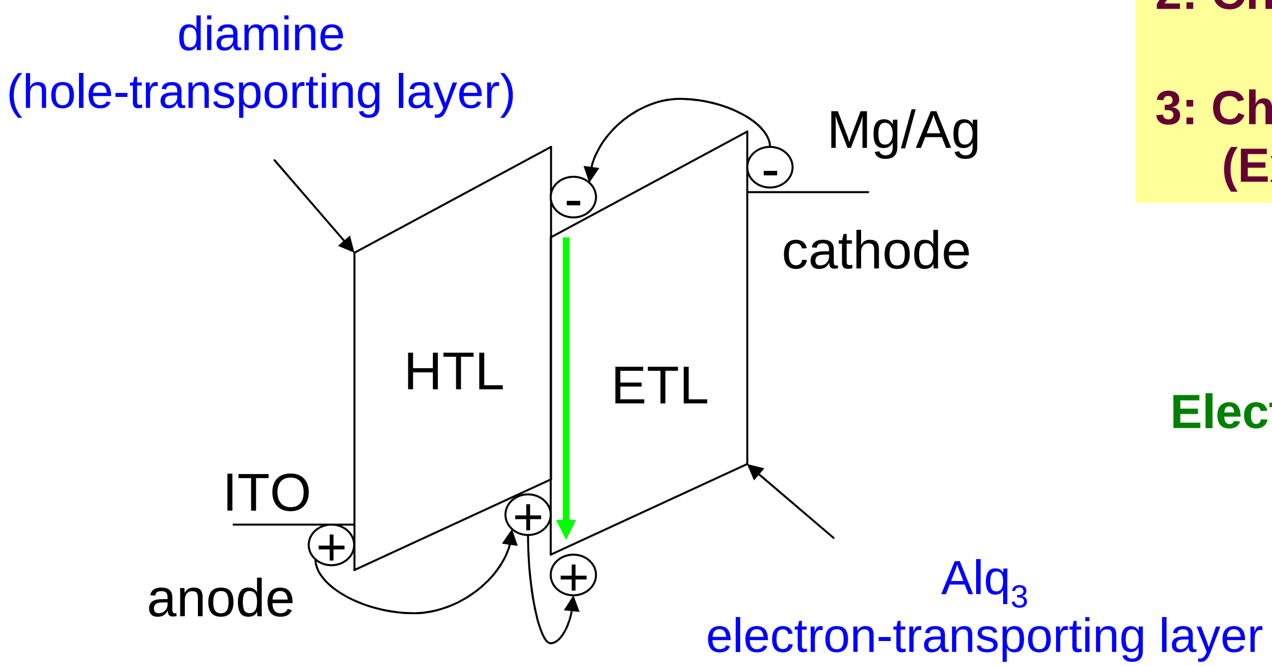

**Devices were fabricated by thermal evaporation**

**Drive voltage ~5V**
**QE: ~1%; 3 cd/A (green)**
**Fast response time (<1 μsec)**



# Operating mechanism of OLEDs




**Mechanism involves:**

**1: Charge injection**

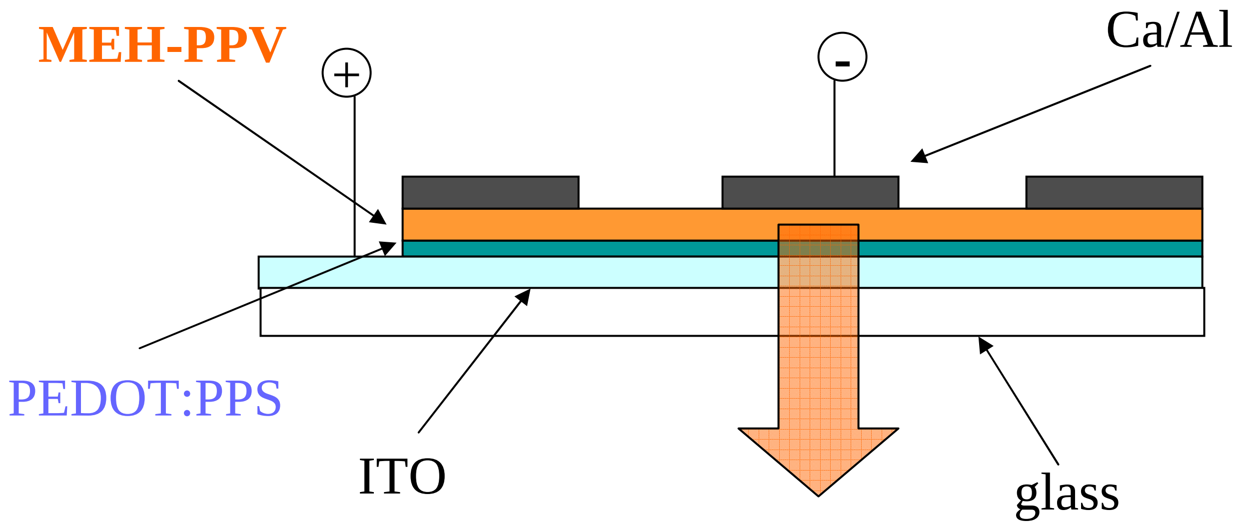
**2: Charge transport**

**3: Charge recombination (Exciton formation)**

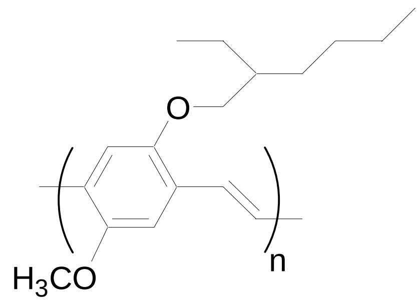
**Electrical field: >$10^5$ V/cm**

**100 nm; @~1V**

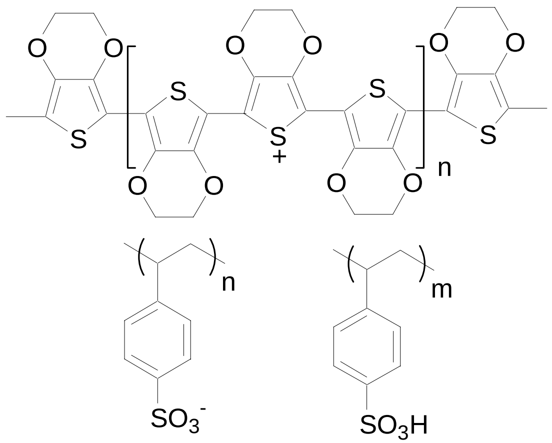
# Operating mechanism of PLEDs




MEH-PPV

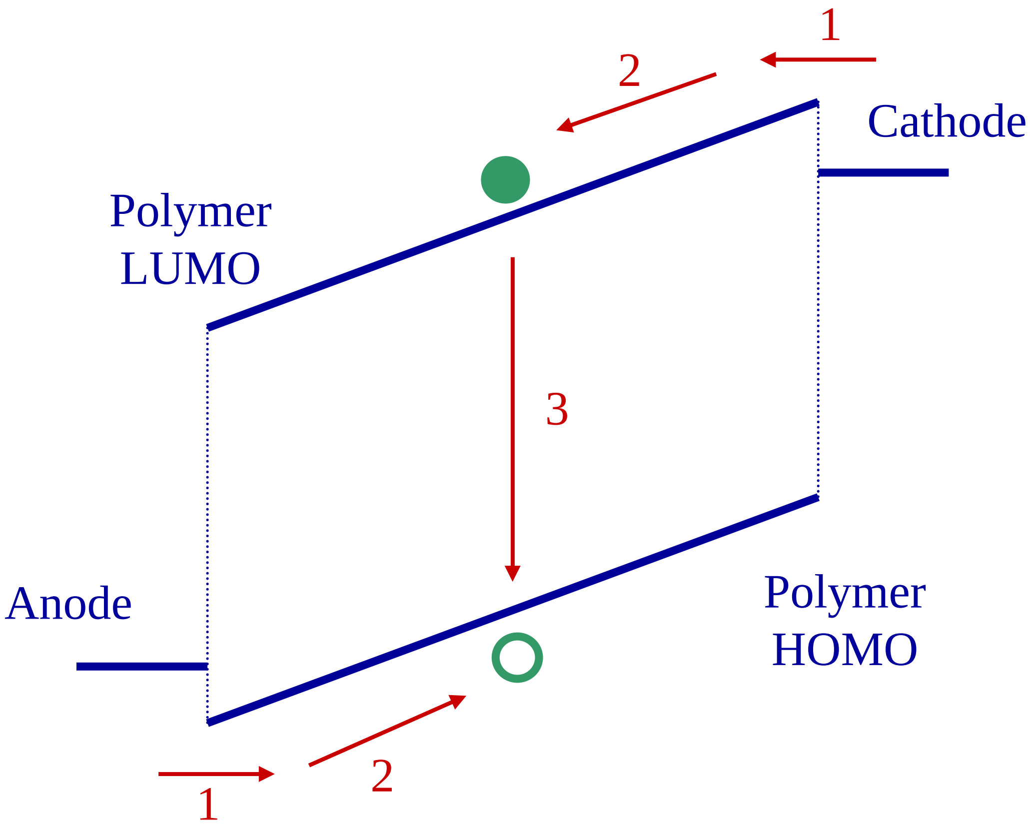


PEDOT:PPS



Devices were fabricated by spin-coating
Single emissive layer was used

# Device mechanism

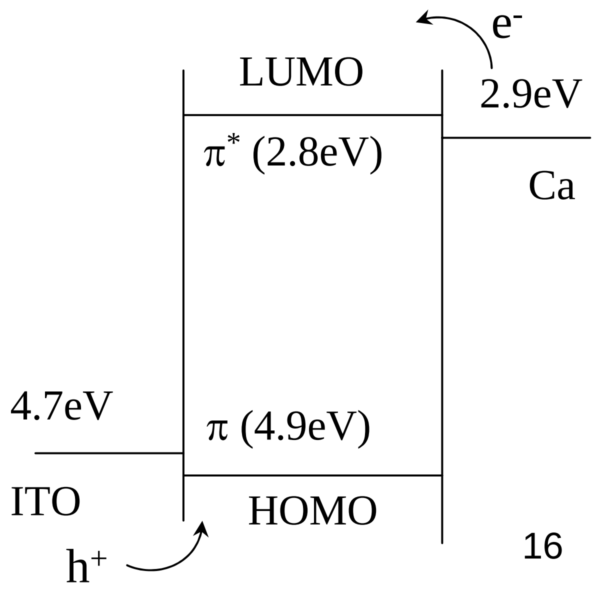



Mechanism involves:

1: Charge injection

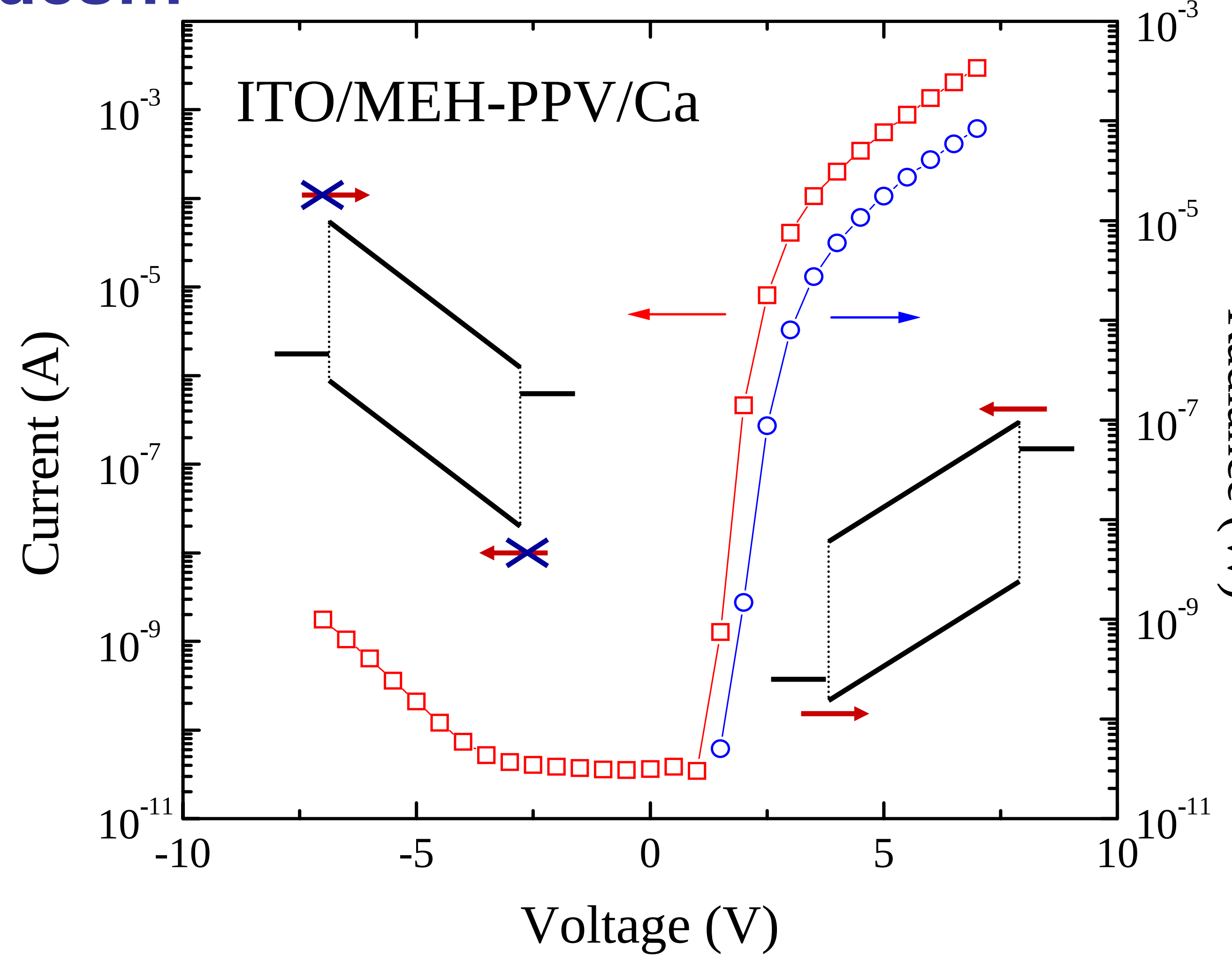
2: Charge transport

3: Charge recombination



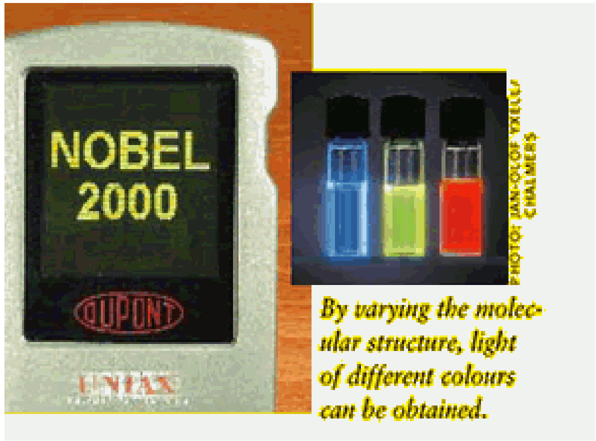
# I-V characteristics

## Diodes!!!



# Why PLEDs?

- Easy and low-cost fabrication
- Solution processability
- Light weight and flexible
- Easy color tuning
    - ✓Spin-coating for mono-color display
    - ✓Ink Jet printing for multi-colors display

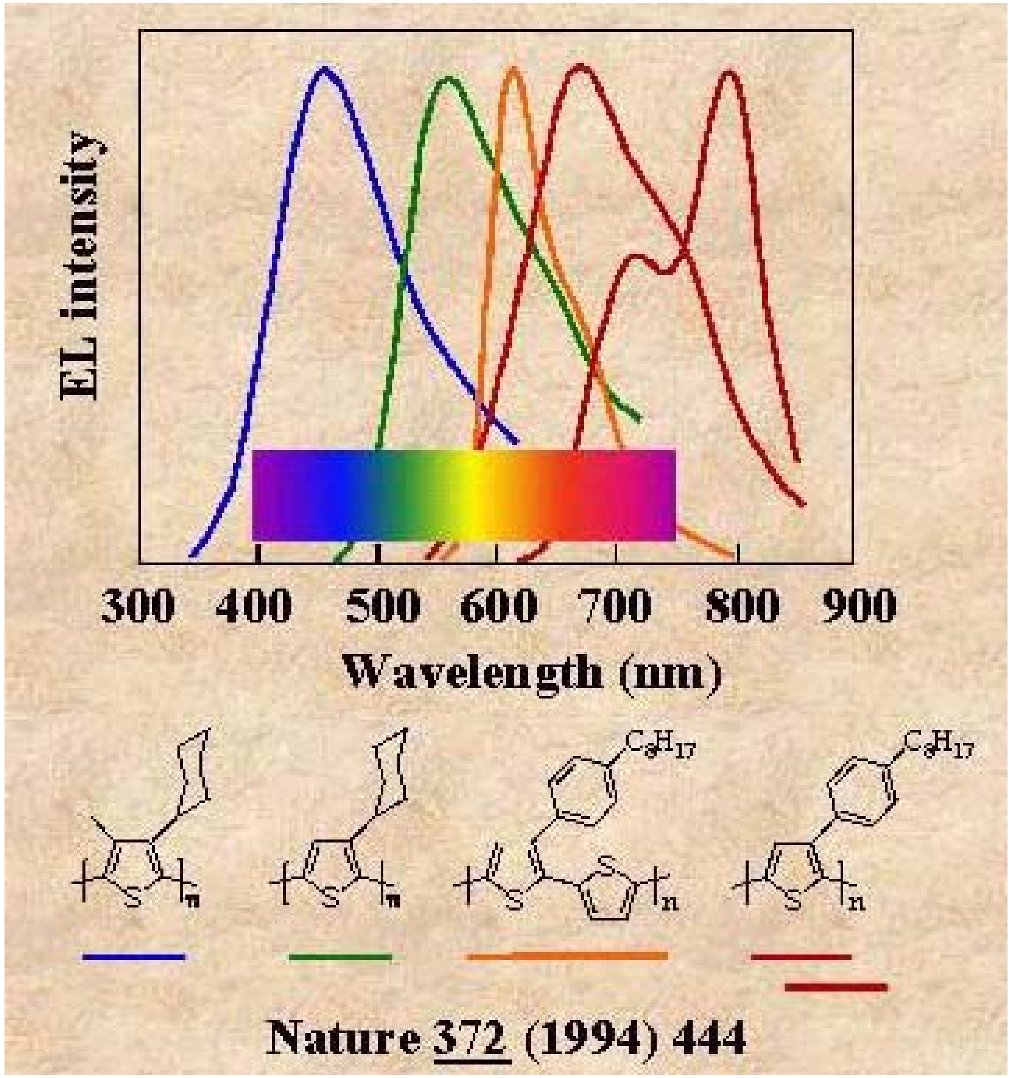




40-inch
commercialized in 2007

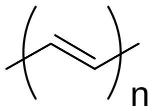
http://www.nobel.se/chemistry/laureates/2000/illpres/7.html
http://www.epson.co.jp/e/newsroom/news_2004_05_18.htm

# Family of light-emitting poly(thiophene)



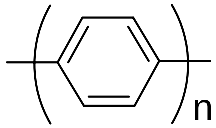
# Molecular engineering of light-emitting polymers

PA



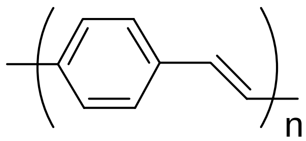

Eg = 1.4 eV

PPP



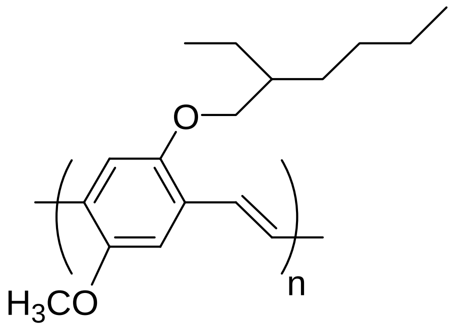

Eg = 3.0 eV

PPV




Eg = 2.4 eV

MEH-PPV




Eg = 2.1 eV

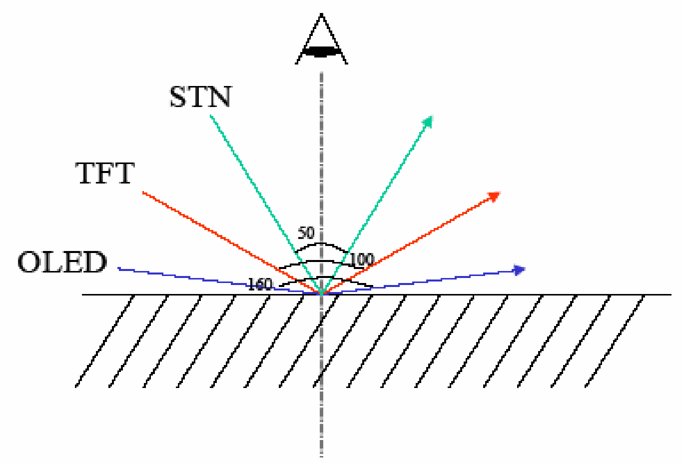
# The merits of OLEDs over other display technologies

- Flat and thin
- Wider viewing angle (> 160º)
- Saturated emissive color
- Wide operating temperature
- High contrast
- Flexible, Plastic can be used as substrates
- Light weight
- Fast response time (~$\mu$s)
- Low temperature processing
- Low cost

# Comparison of O/PLED with other display technology

| | STN | TFT | OLED |
|---|---|---|---|
| Viewing Angle | 50 | 100 | 160 |
| Response Time | Tenth to hundredth ms | Less than 1ms | Less than 1ms < 1μsec |
| Driving Method | Passive | Active | Passive /Active * |
| Contrast Ratio | ~8:1 | ~25:1 | ~100:1 |
| Power Consumption /w backlight (Units) | Several hundredth (mW) | Several (W) | Several tenth (mW) |

*PMOLED required passive driving
*AMOLED required active driving



# OLED Displays

# OLED Displays

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# OLED Displays

# OLED Displays

## AUO – world first 4” a-Si AMOLED (2003)

| Parameter | Features |
| --- | --- |
| Display Size | 4-inch |
| Resolution | $160 \times (RGB) \times 234$ |
| Sub-Pixel Pitch | $171um \times 264um$ |
| Driving Method | 2-TFT Voltage Programming |
| Color Number | 262K (6 bits) |
| Brightness | 300 $cd/m^2$ |
| Power Cons. | 670 mW |
| Substrate | a-Si TFT |
| Contrast ratio | >250 |
| Module thickness | 1.8 mm |
| Emission Type | Bottom Emission |

# Flexible OLEDs

**OLED built on flexible substrates**

**Flexibility**

**Ultra-lightweight and Thin**


http://www.universaldisplay.com/

# Flexible Electronics : Potential Applications

- Displays
  - PDAs
  - Camcorders
  - Mobile Phones
  - Video Phones
  - Pagers
  - Palmtop PCs
  - Satellite Navigation Systems
  - Children's Toys
- Smart Cards, RFID tags


## Reference of O/PLEDs


1. Tang, C.W., and VanSlyke, S.A. (1987). Organic electroluminescence diode, Appl. Phys. Lett. 51: 913-915.
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3. Friend, R.H., Gymer, R.W., Holmes, A.B., Burroughes, J.H., Marks, R.N., Taliani, C., Bradley, D.D.C., Dos Santos, D.A., Bŕedas, J.L., Lögdlund, M., and Salaneck, W.R. (1999). Electroluminescence in conjugated polymers, Nature 397: 121-128.
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