Plastic electronics: Outline of the course

· Introduction

· Electronic structure of organic (macro)molecules

· Optical properties of organic semiconductors

· Electronic transport

· Light emitting diodes

Part I: Device operation (Layer structure)
Part II: Device optimization, Color tuning
Part III: Device stability/Degradation

· Organic solid state lasers

Part I
Part II

Plastic electronics: Outline of the course

- Photodetecting devices
  - Photovoltaic cells
  - Xerography

· Organic field effect transistors

· Organic electroluminescent displays

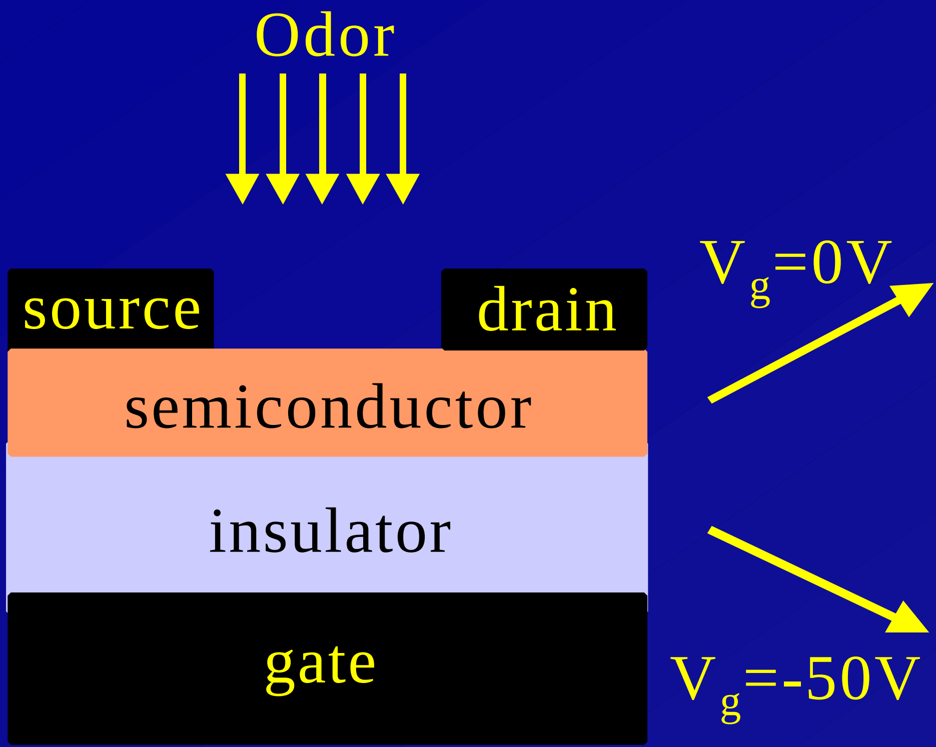
· Device fabrication

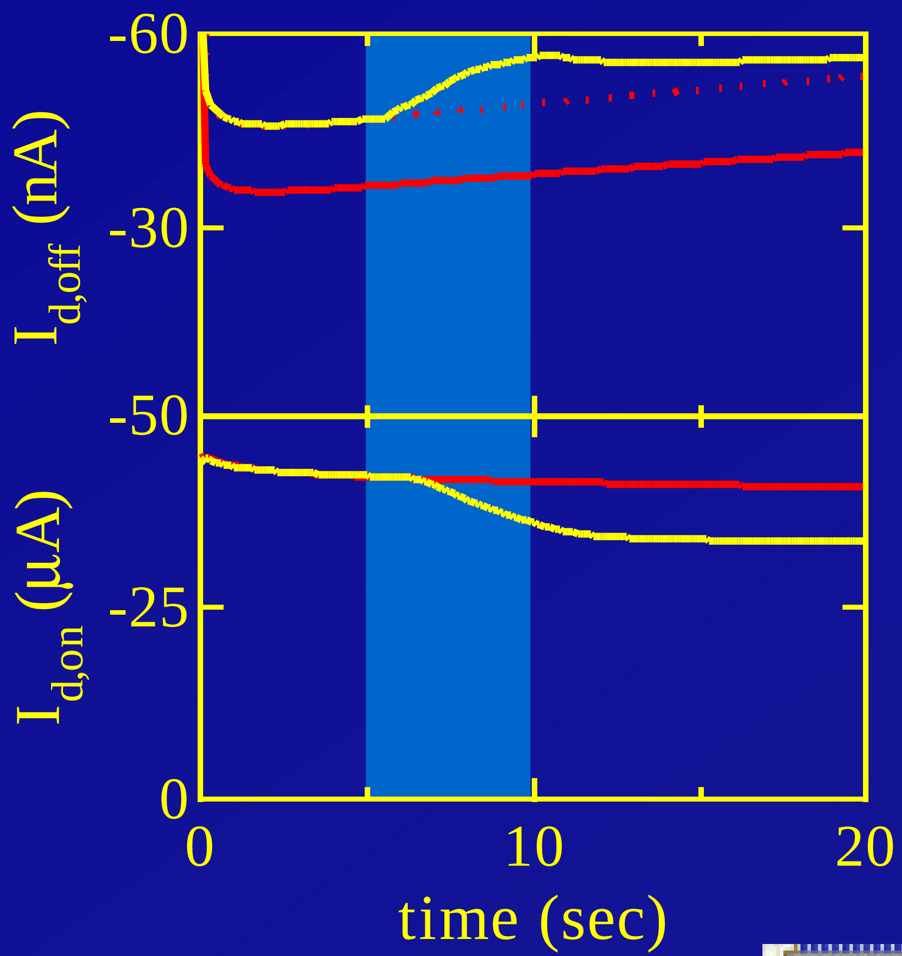
Organic FETs: Applications

- low cost RF-id-tags

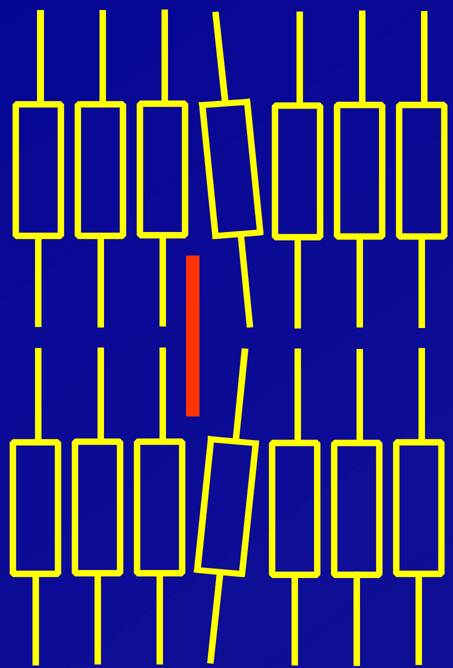
- chemical sensors

Transistor Chemical Sensors



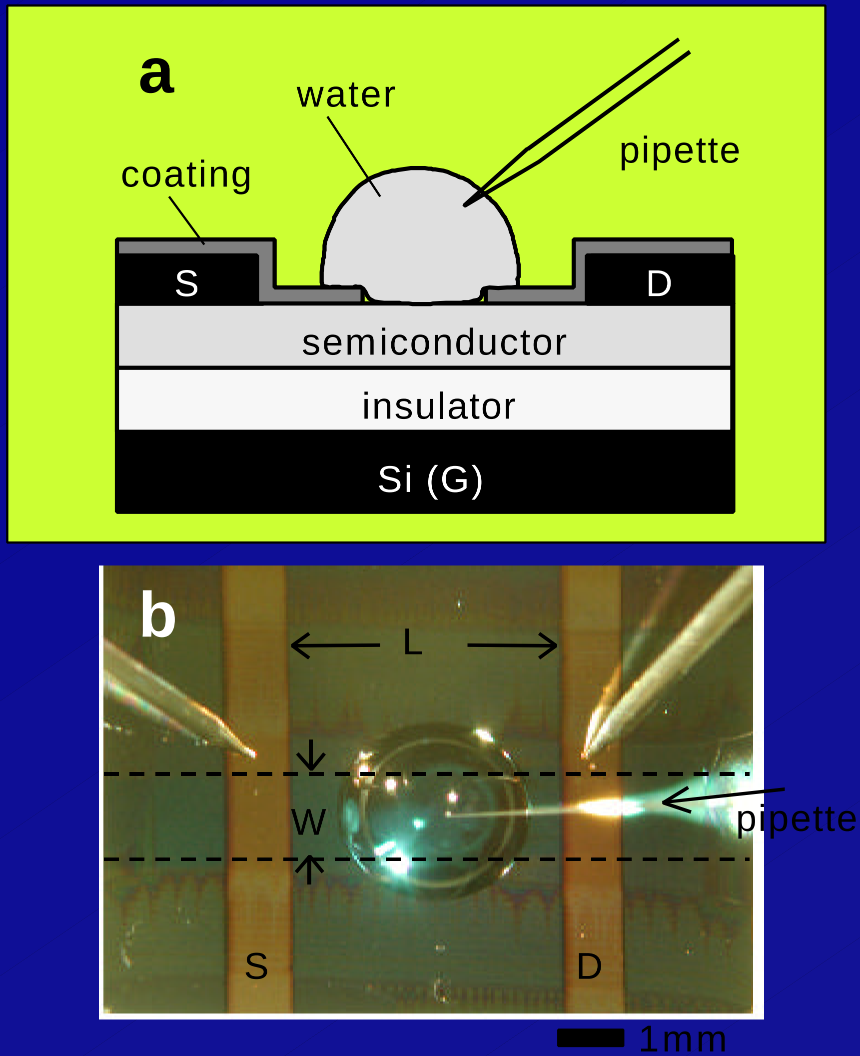


Semiconductor / Odor



- Odors in end-groups perturb core, change m.
- Immobile charges will shift V_T.
- Grain boundaries dominate transport.
- Odors in grain boundaries will change m.

Water-based sensing: Biosensing



Organic FETs: Applications

- low cost RF-id-tags

- chemical sensors

- display driver circuitry

Plastic electronics: Outline of the course

- Photodetecting devices
  - Photovoltaic cells
  - Xerography

· Organic field effect transistors

· Organic electroluminescent displays

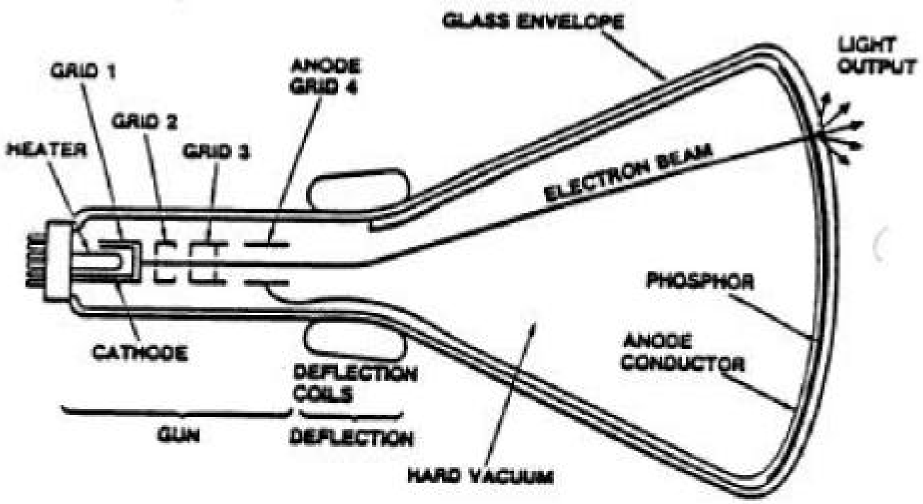
· Device fabrication

Standard Display Addressing Modes

- Sequential Addressing (pixel at a time)
  - CRT, Laser Projection Display
- Matrix Addressing (line at a time)
  - Row scanning, PM LCD, AMLCD, FED, PDPs, OLEDs
- Direct Addressing
  - 7-sement LCD
- Random Addressing
  - Stroke-mode CRT

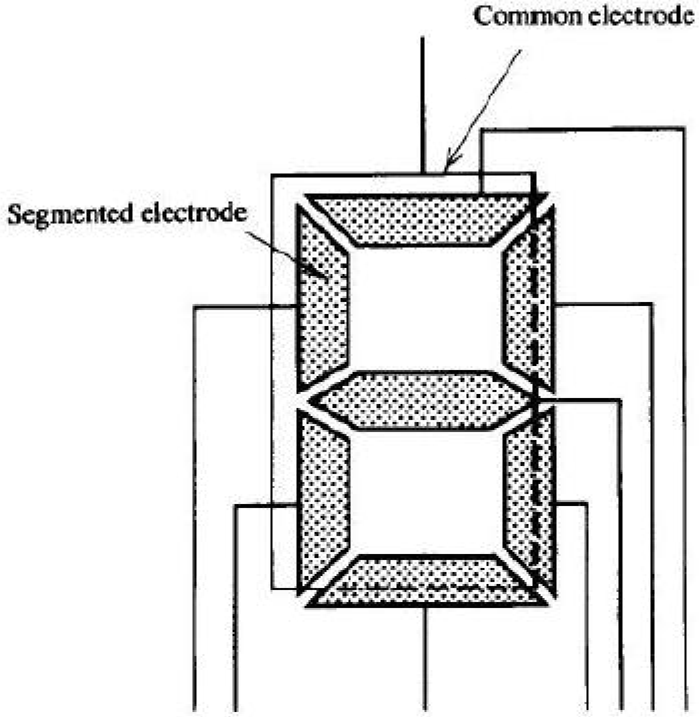
Sequential Addressing

- Time is multiplexed
  - Signal exists in a time cell
- A pixel is displayed at a time
  - Single data line
- Rigid time sequence and relative spatial location of signal
  - Raster scan
- Data rate scales with number of pixels
- Duty cycle scales with number of pixels



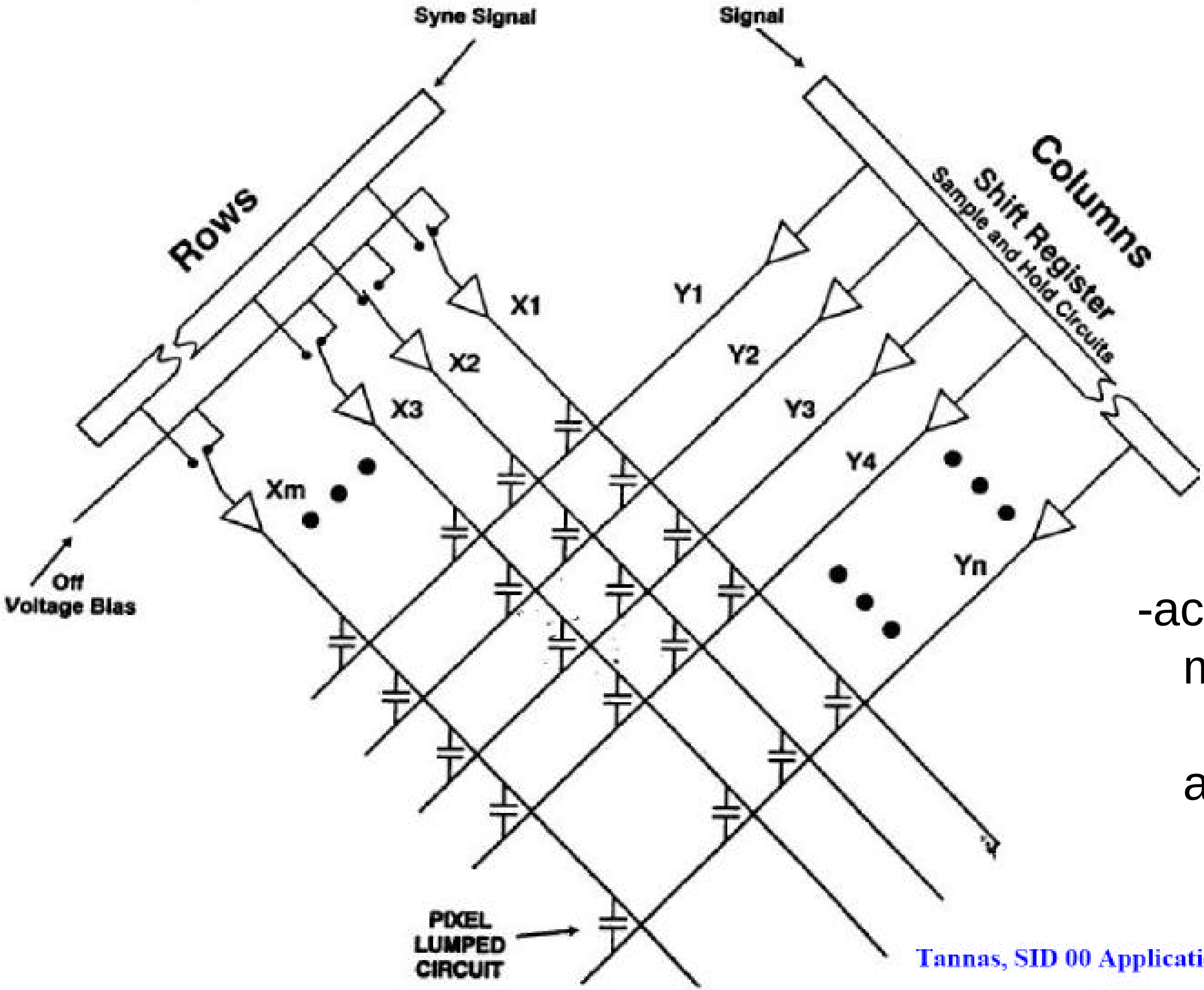
Direct Addressing

- Each segment require an independent circuit drive element
- Each segment requires continuous application of voltage or current to the display element
- For a N rows by Y columns display
  - M x N electrodes are required



Steemers, SID 94 Seminar Notes

Passive Matrix LCD

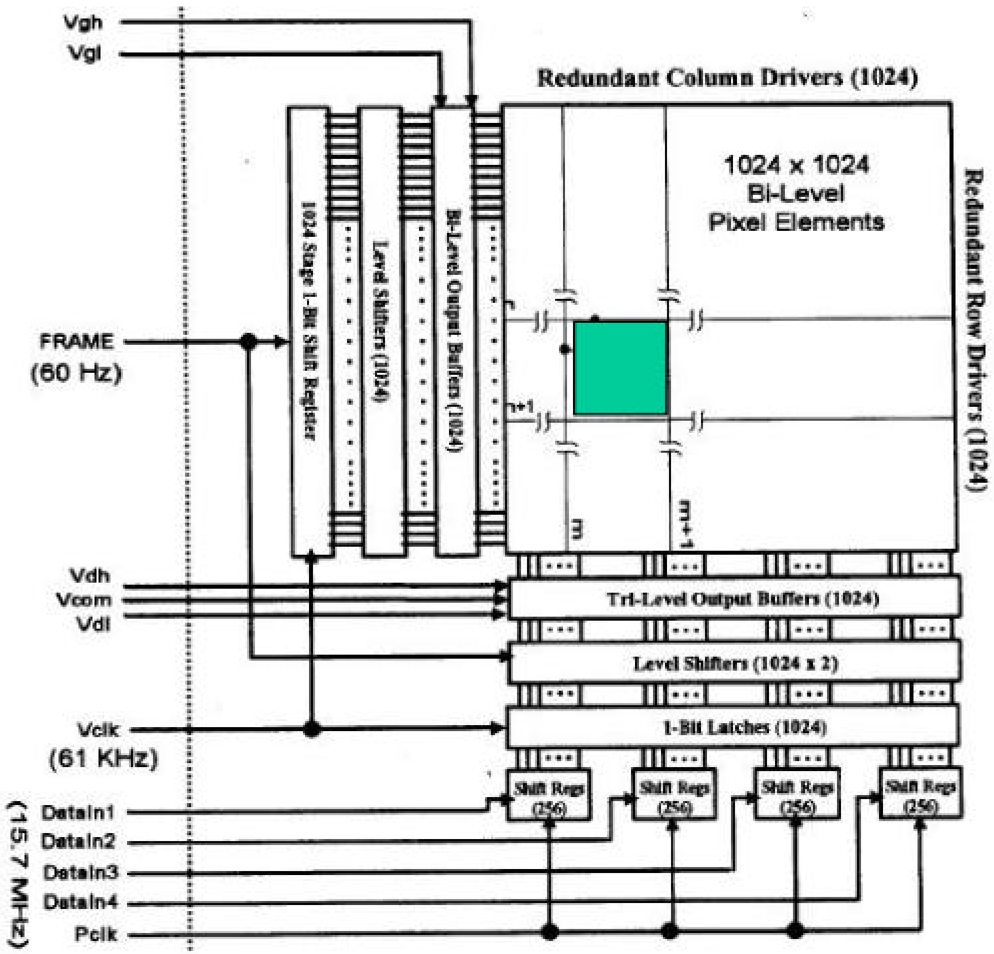


-actual driving schemes are much more complicated to realize grey scale and fast switching times

Tannas, SID 00 Applications Seminar

Driver Circuits

Row Driver Circuits

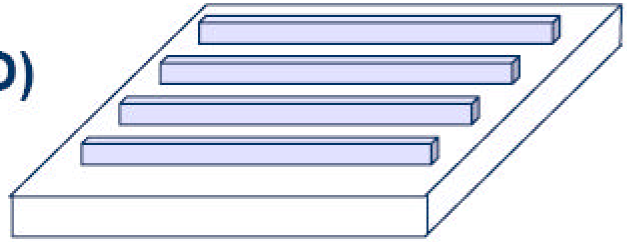


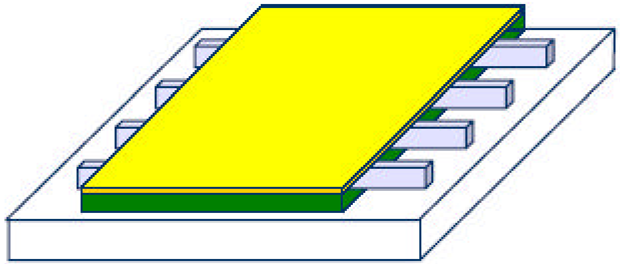
Display Pixel Array

Column Driver Circuits

Polymer OLED display fabrication steps

Deposit and pattern anode (ITO)

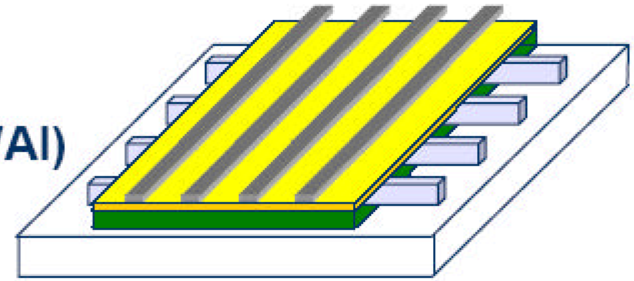




Pattern polymer layers
(first conducting then emissive)

Spin coating
Ink Jet printing
Screen printing
Web coating

Vacuum deposit and pattern cathode (Ba,Ca/Al)

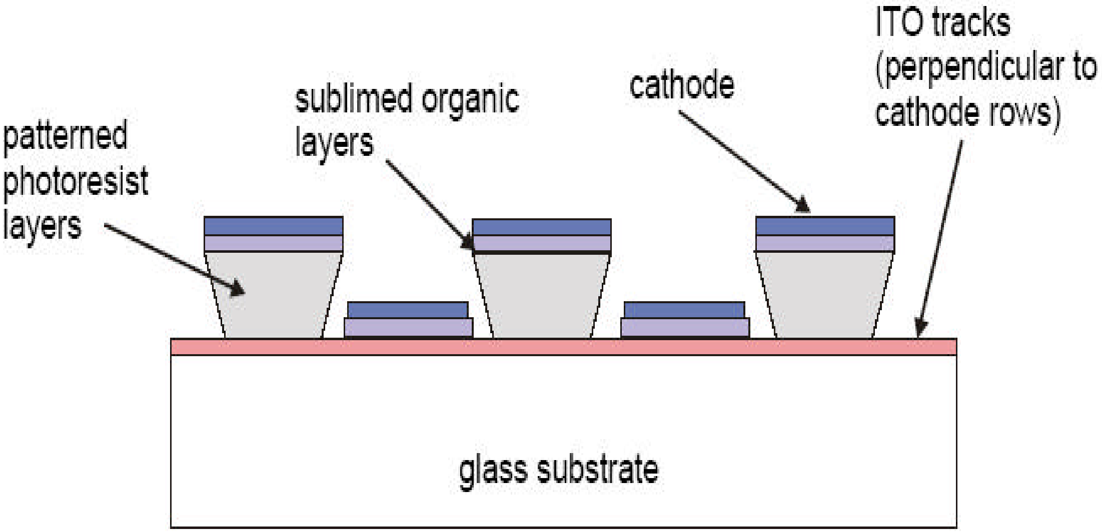


Patterning of the cathode rows: Kodak, Idemitsu etc.

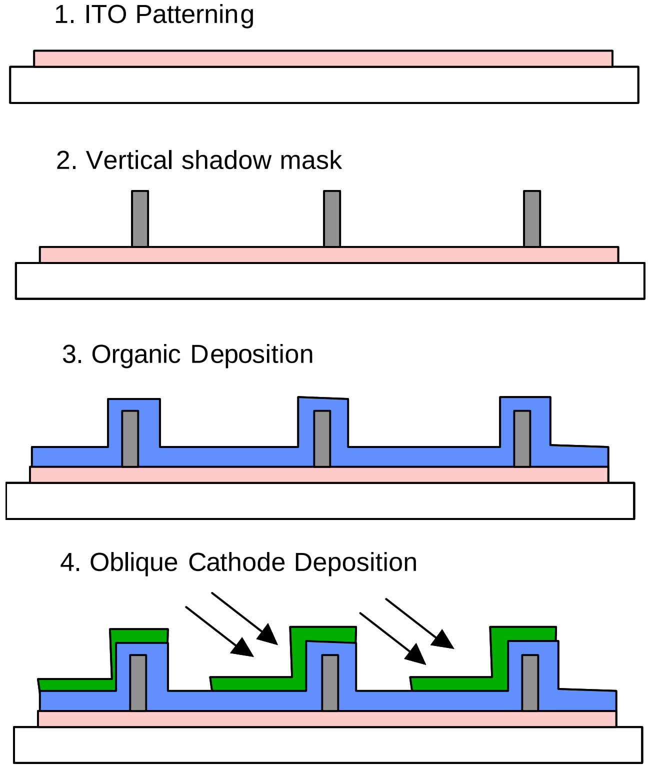
avoid wet chemistry to pattern cathode on top of organic layers:

(i) shadow mask for cathode

(ii) relief patterning of substrate enables automatic separation of cathode rows (ok for sublimed films, not for solution-processed polymers):



Angular Evaporation



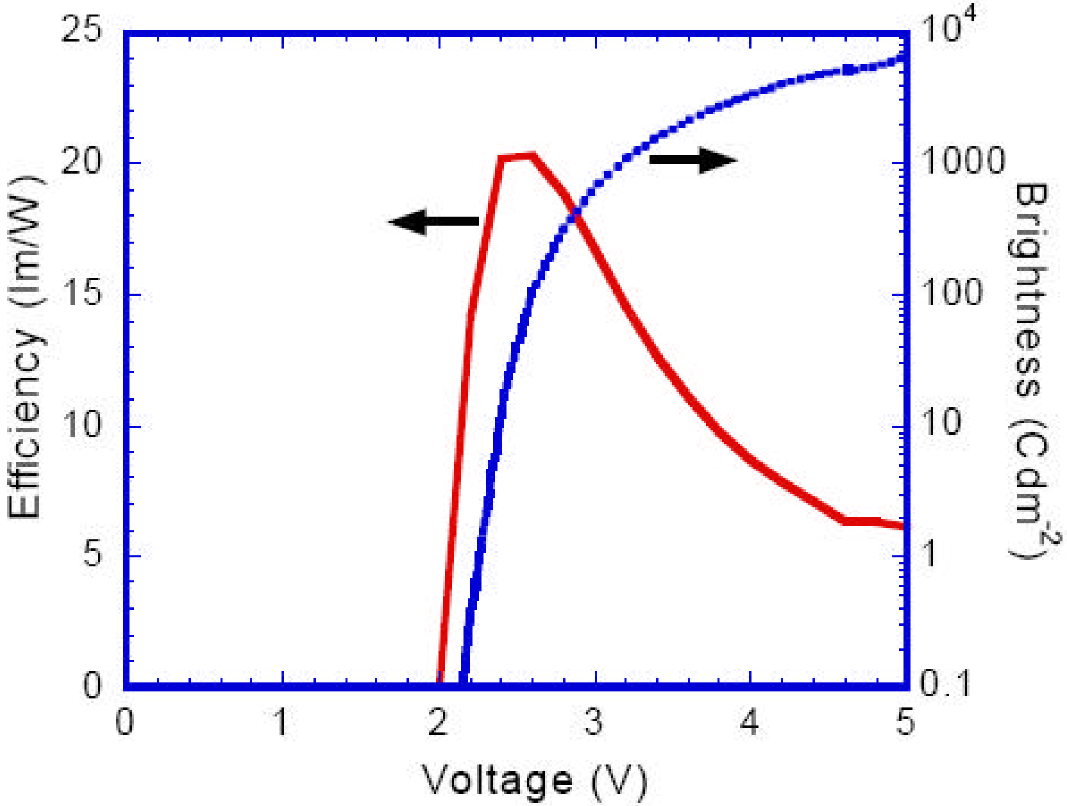
Effect on Luminance

(1000 x 1000 Display)

display resolution
VGA (640 x 480)
SVGA (800 x 600)
XGA (1024 x 768)
SXGA (1280 x1024)
UXGA (1600 x1200)

Drive Scheme	**Spot Brightness Required** **(x Average Screen Brightness)**
Sequential	10^6
Row Scanning	10^3
Row Scanning with memory	1
Direct Addressing	1

Passive matrix OLED-displays: Problems



- duty cycle is < 1/#rows

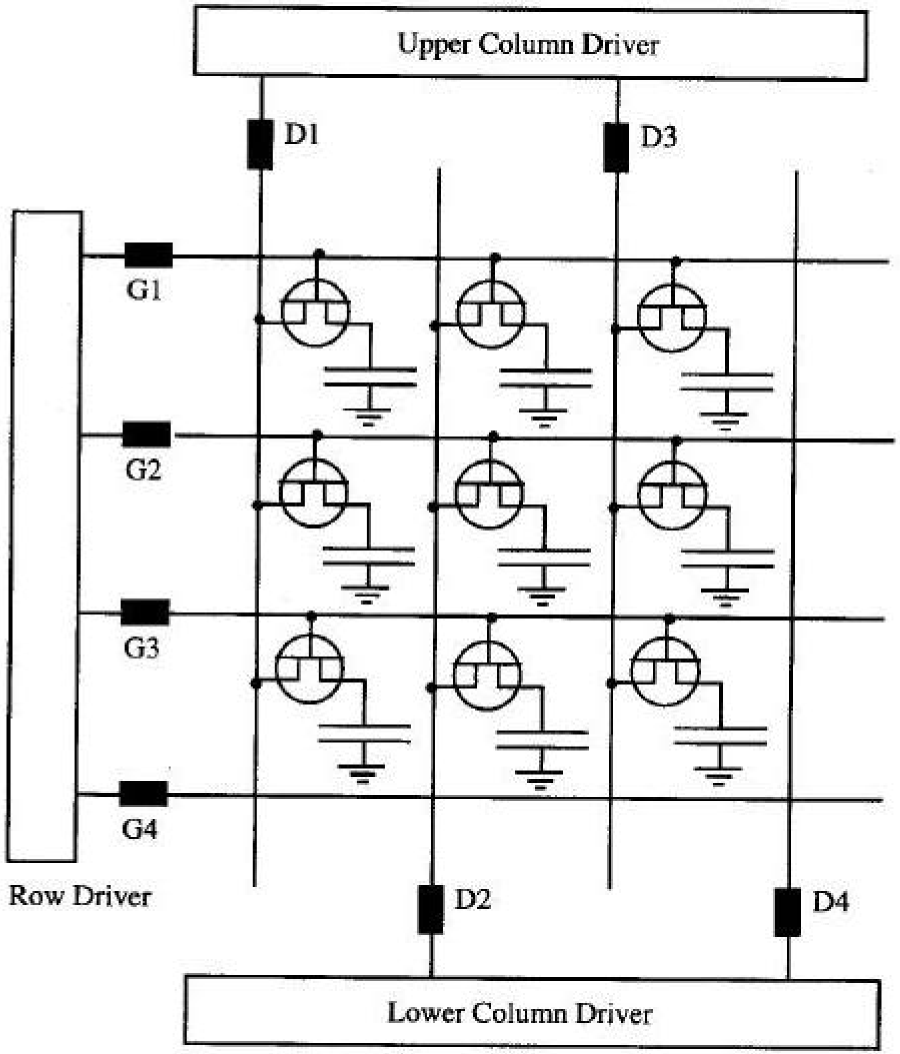
-need 200 cd/m^2
*768 (for XGA)
>10^5 cd/m^2

-required luminance might not be possible

- high voltages are required

- reduced efficiencies

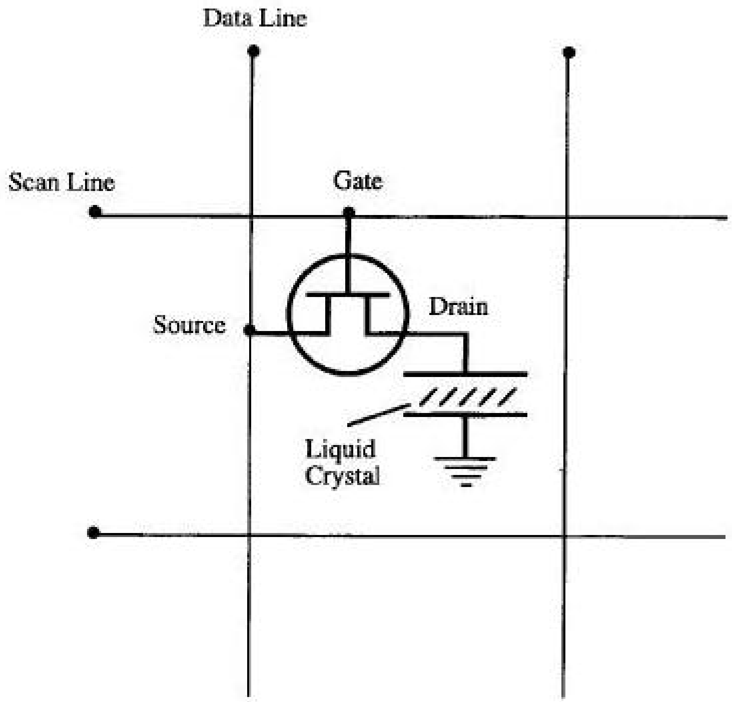
Active Matrix Addressing



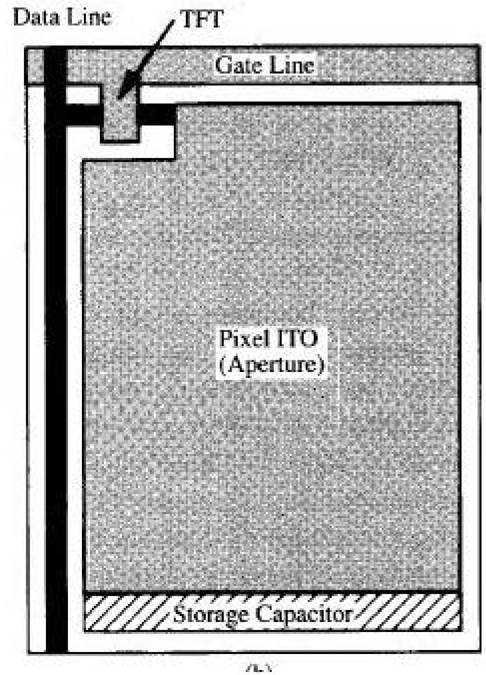
- •Introduce non linear device that improves the selection.
- •Storage of data values on capacitor so that pixel duty cycle is 100%
- •Improve brightness of display by a factor of N (# of rows) over passive matrix drive
- •Display element could be LC, EL, OLED, FED etc

Yeh & Gu

Pixel Element



Yeh & Gu

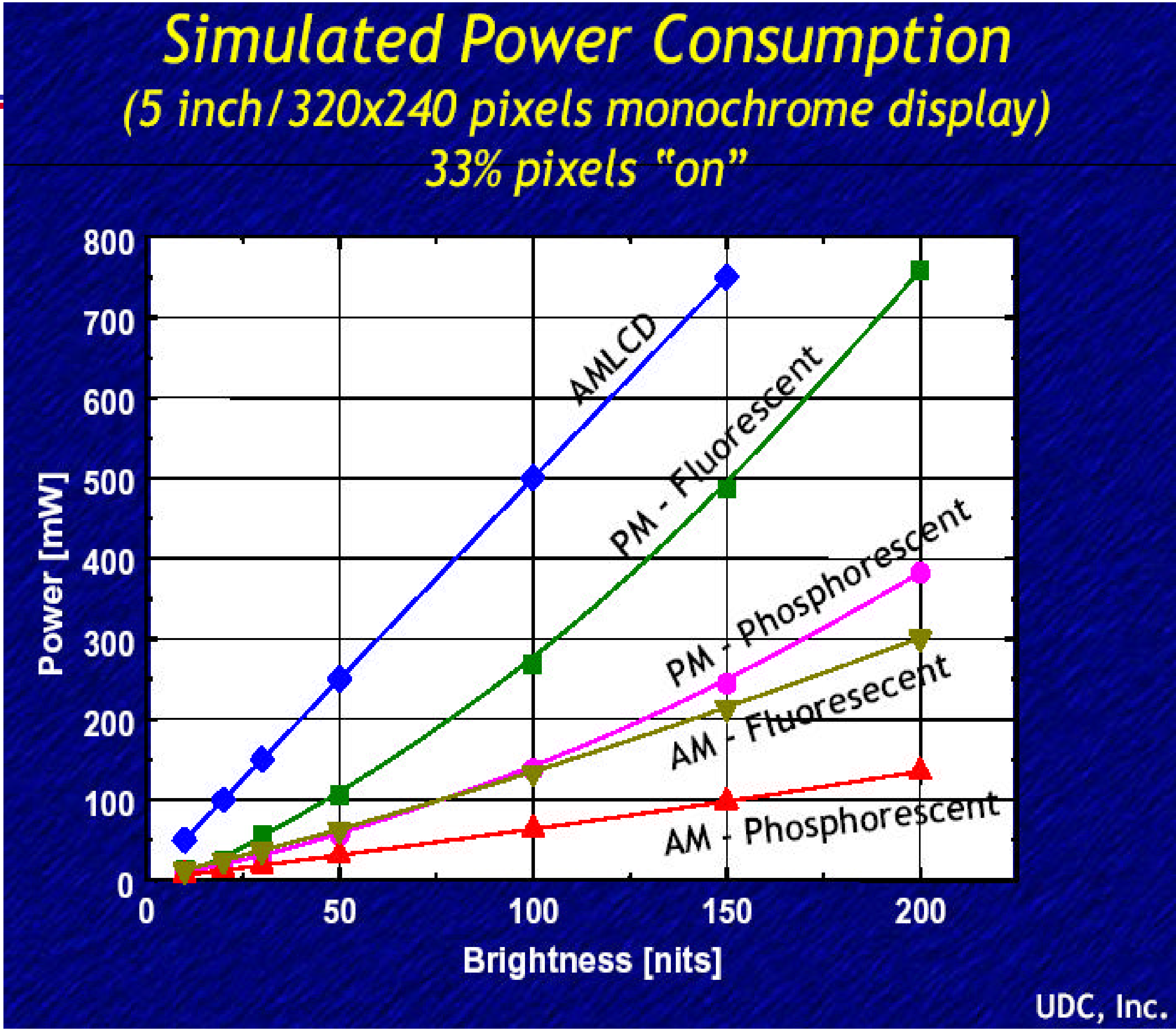


Need TFTs to improve flat panel display performance !

Amorphous Silicon

Poly Silicon

Organic TFT


Simulated Power Consumption
(5 inch/320x240 pixels monochrome display)
33% pixels "on"
Power [mW]
800
700
600
500
400
300
200
100
0
0
50
100
150
200
Brightness [nits]
AMLCD
PM - Fluorescent
PM - Phosphorescent
AM - Fluoresecent
AM - Phosphorescent
UDC, Inc.

Active-matrix TFT drive requires high performance TFTs:

polycrystalline silicon - developed for LCDs to provide on-plane row and column addressing - provides appropriate performance:

TDK - high temperature poly-Si

Seiko-Epson - low temperature poly-Si (laser annealed)

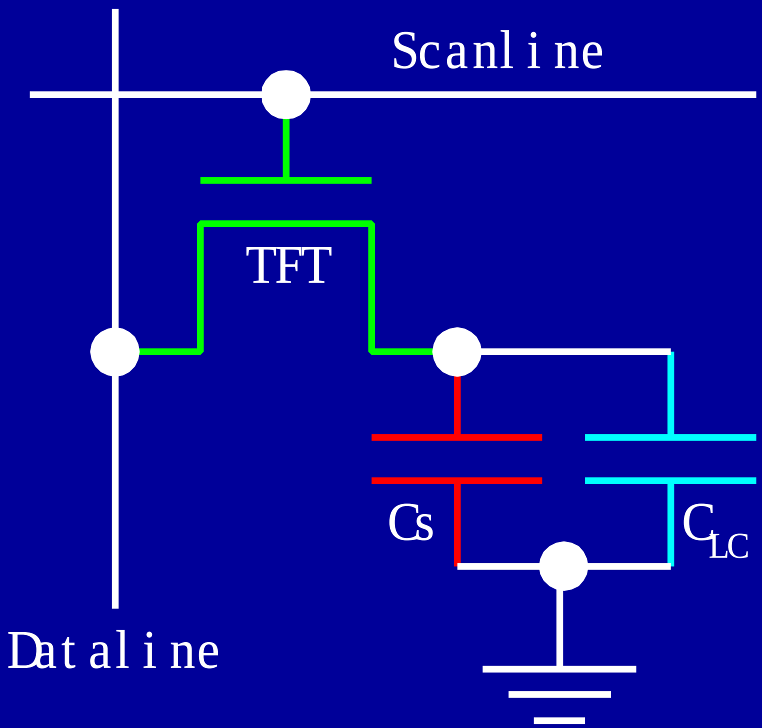
Advantages:

Allows LEDs to run CW, close to optimum luminous efficiency

Removes constraint on # rows

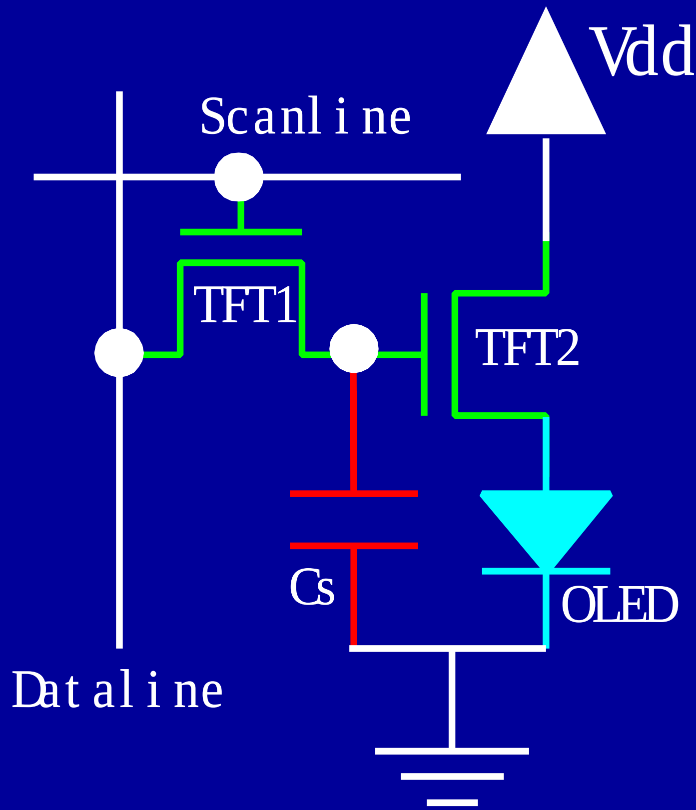
Removes requirement for cathode patterning

Basic Pixel for LCD and OLED Display



(A)

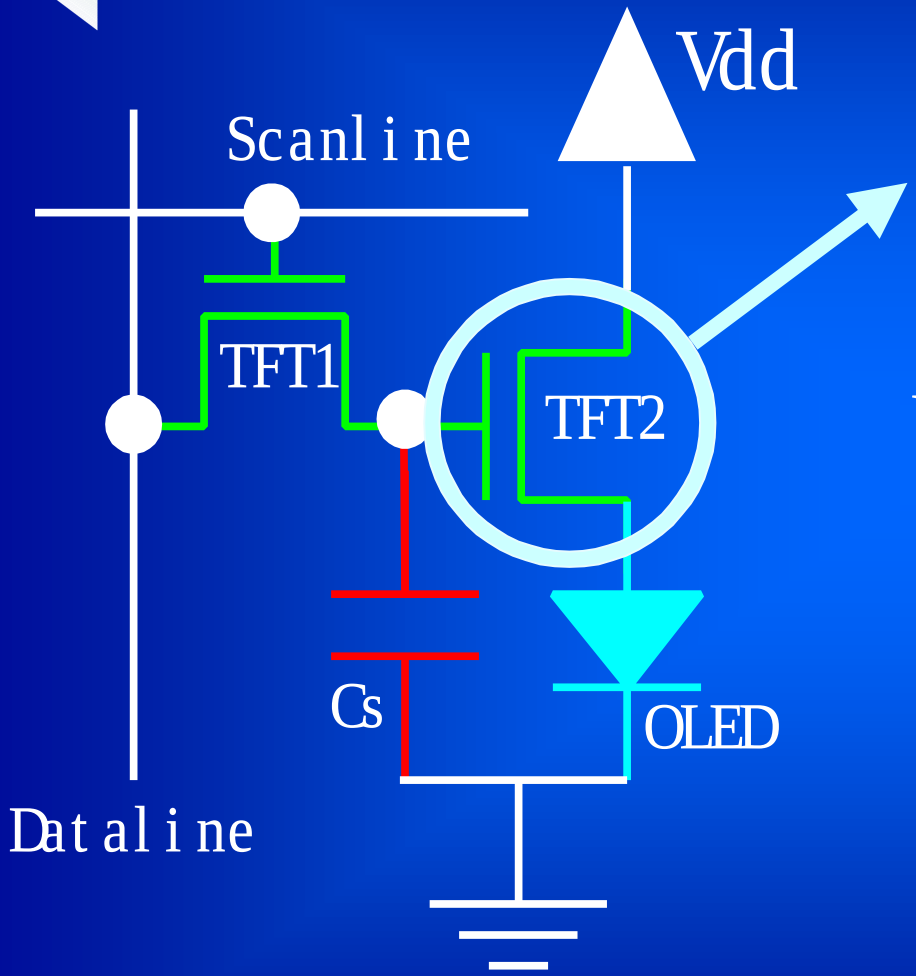
Pixel for LCD



(B)

Pixel for OLED

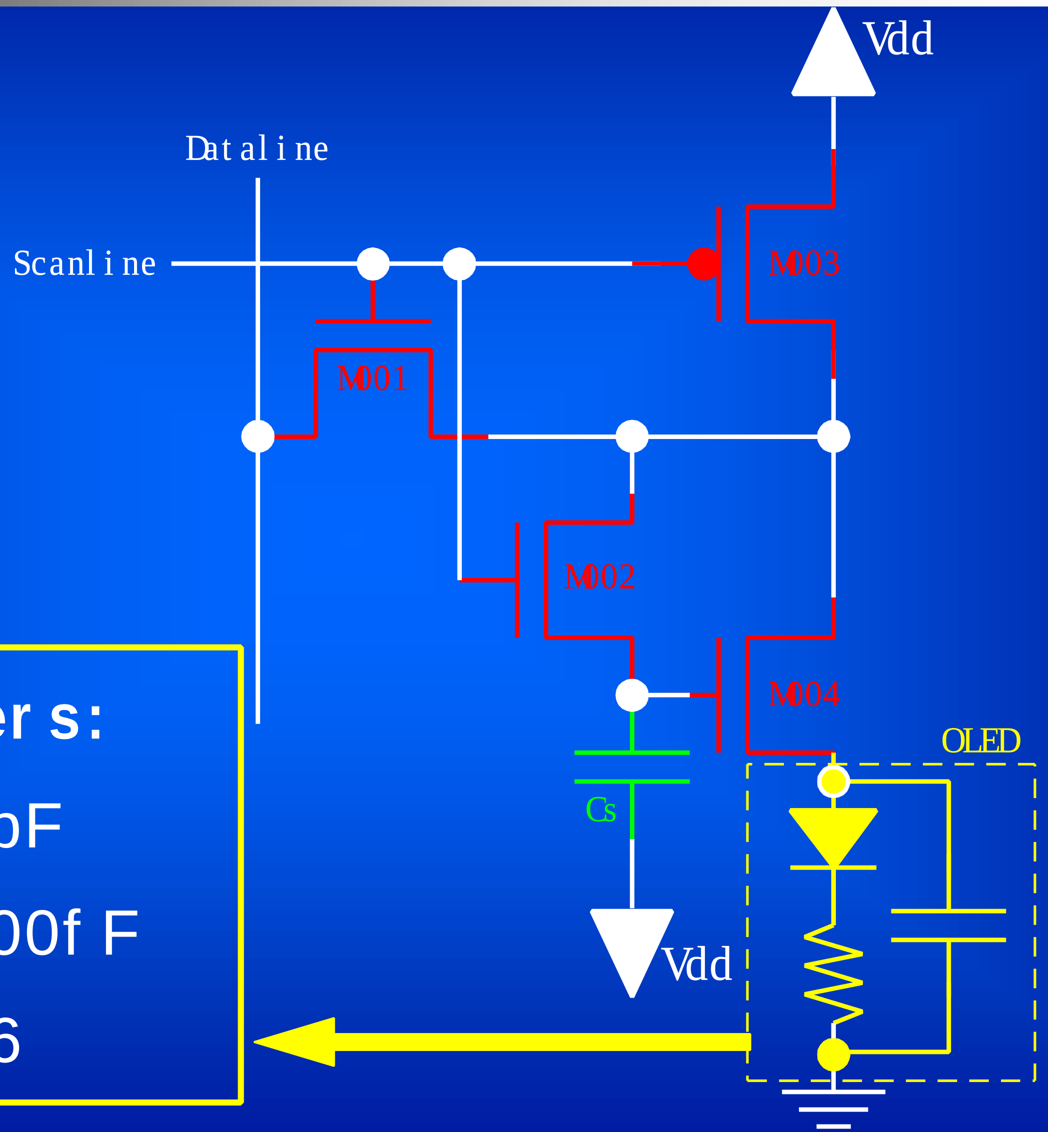
Characteristics Variation of TFT



$$I_{oled} = \frac{1}{2}\mu \cdot C_{OX} \cdot \frac{W}{L} \cdot (V_{GS} - V_{th})^2$$

Variation of μ *or* V_{th} *between pixels can result in non-uniform brightness in AM-OLED.*

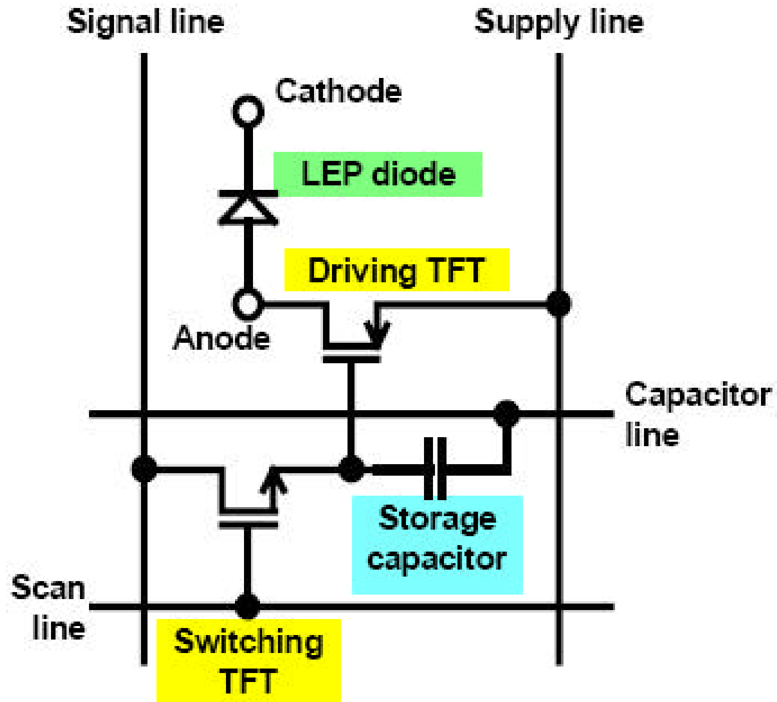
4 Transistors (4-T) Pixel Circuit



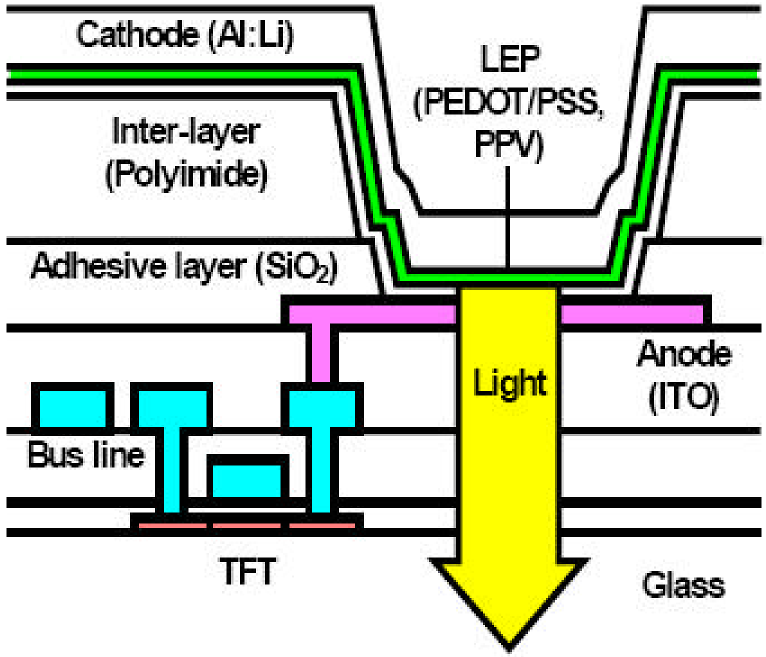
OLED parameters:

- $C_{equivalent}$ = 5pF
- $C_{storage}$ = 600fF
- R_{serial} = 36

Pixel circuit



TFT - LED layout



Note: variation in threshold characteristics causes problems with analog grey-scale - more complex circuits developed by Kodak, Sarnoff, Planar etc.

OLED-display-markets

The OLED-display-family

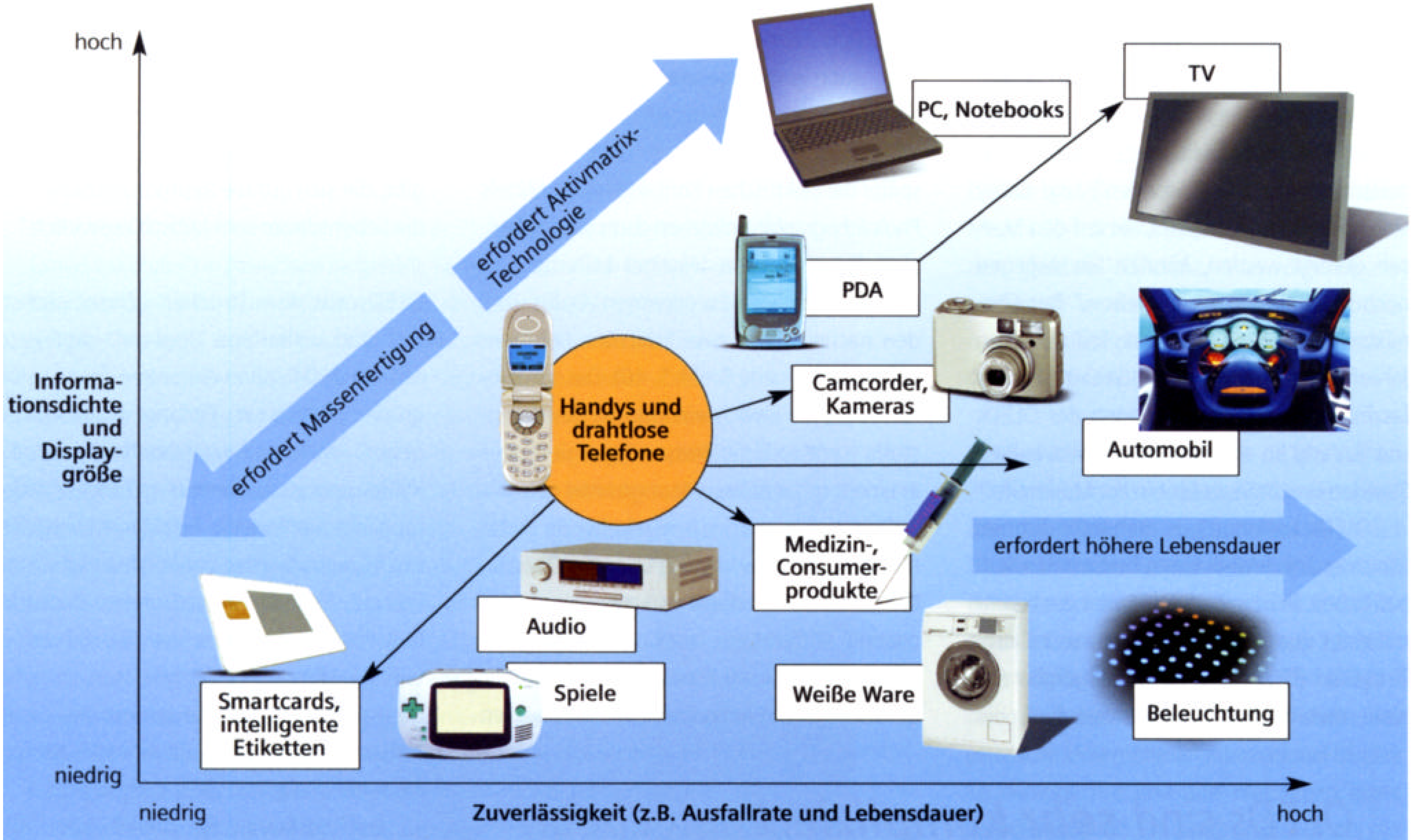
Conjugated polymers ↔
evaporated small molecules

Multichrome ↔
Monochrome

OLED-
Displays

Passive-Matrix ↔
Aktive-Matrix

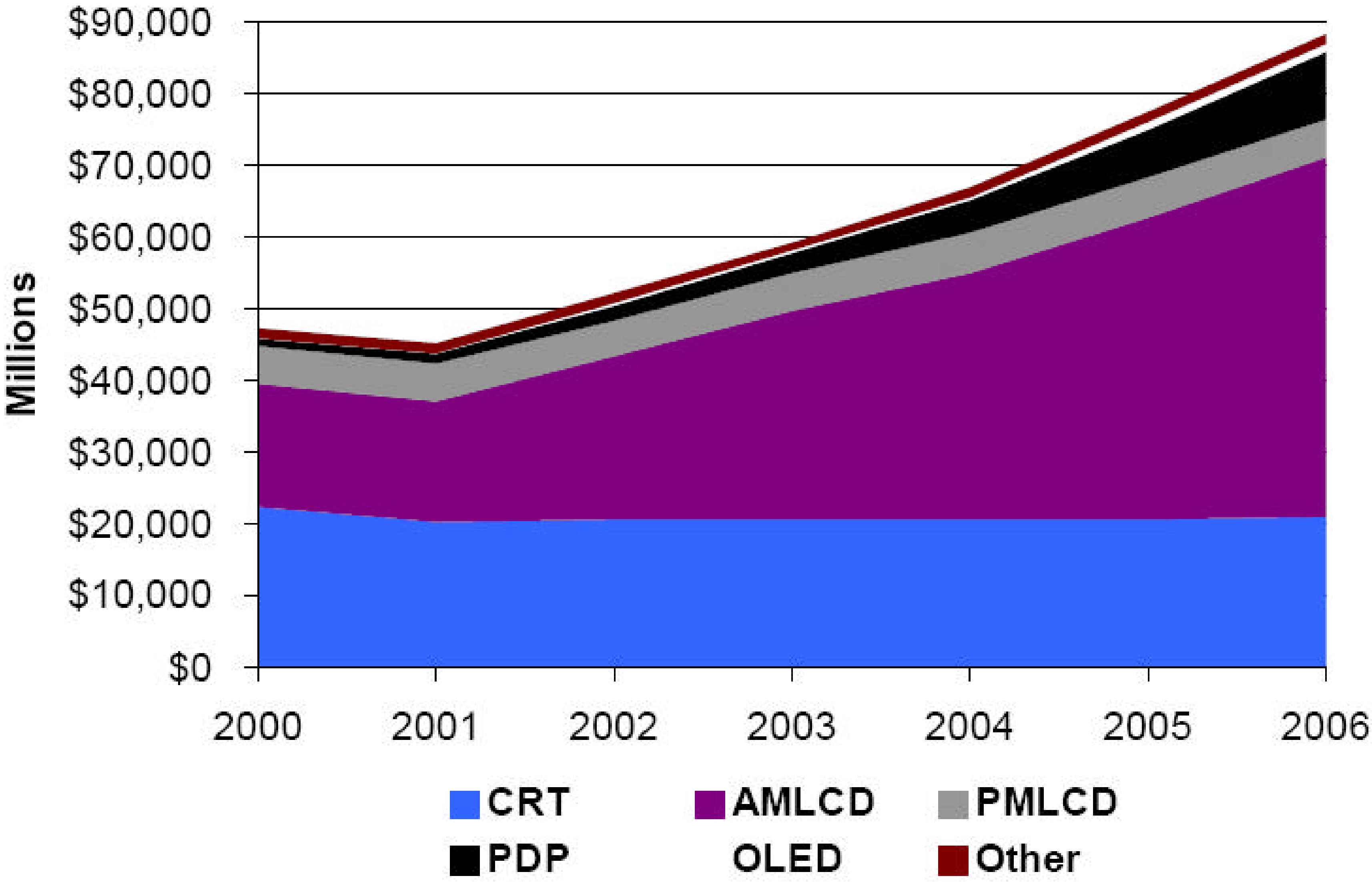
rigid substrate ↔
flexible substrate



Herausforderungen für die OLED-Forscher: Je nach künftiger Anwendung müssen organische Leuchtdioden noch verbessert werden. Für einen TV-Bildschirm ist etwa die Entwicklung von feinstrukturierten Aktivmatrix-Displays nötig. OLEDs in Smartcards erfordern die Prozesse einer Massenfertigung und wenn sie einst auch Räume erhellen sollen, müssen sie extrem lange halten.

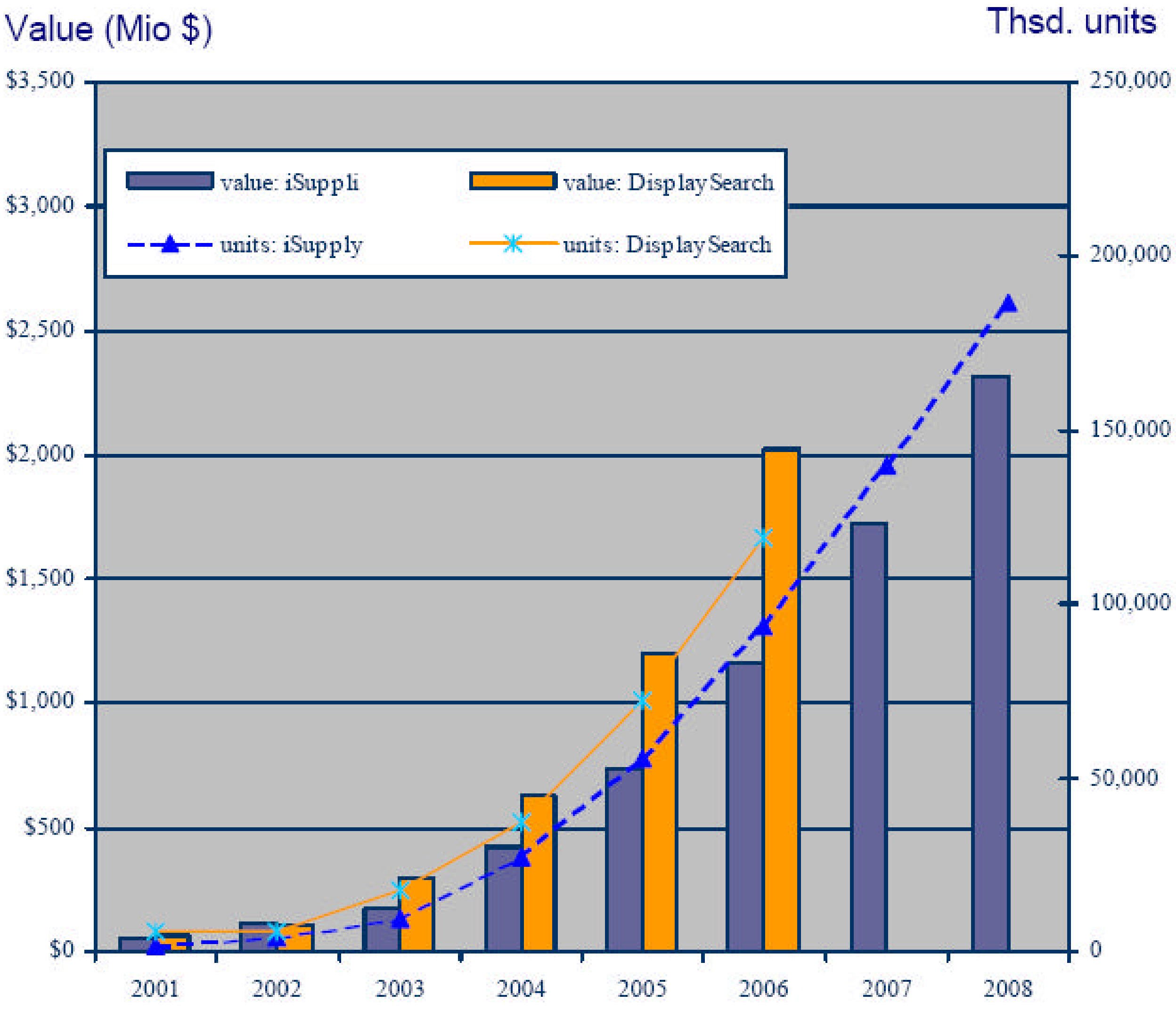
Quelle: Osram

Worldwide electronic display market



Source – iSuppli/Stanford Resources

Worldwide OLED Market, 2000-2006 F



2002 LEP/SMOLED PRODUCTION (>100K)

- 1H-2002

Product Maker	OLED Maker	Application	Display Type	Shippment	Production
Pioneer	Tohoku Pioneer	Car Stereo	4 area-color	420K	Jan-02
Radica	RiTdisplay	Game	Green	150K	Feb-02
Fujitsu	Tohoku Pioneer	Mobile Phone	4 area-color	600K	Apr-02
KTFT	RiTdisplay	Mobile Phone	Blue	110K	Apr-02
LG	Tohoku Pioneer	Mobile Phone	4 area-color	400K	May-02
Total				1,080K	

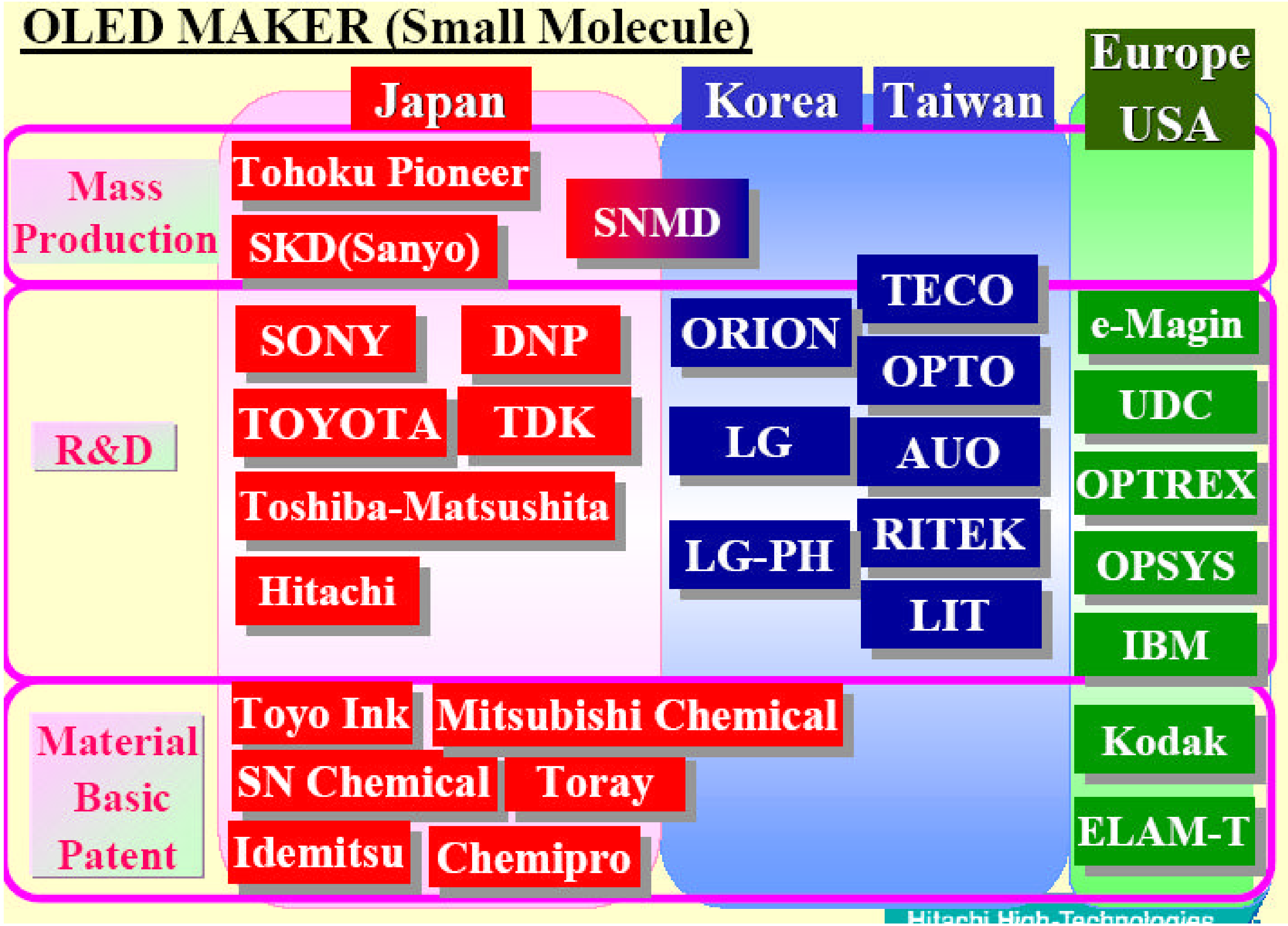
- 2H-2002

Product Maker	OLED Maker	Application	Display Type	Shippment	Production
Pioneer	Tohoku Pioneer	Car Stereo	4 area-color	420K	Jul-02
KTFT	RiTdisplay	Mobile Phone	Blue	224K	Jul-02
Appeal	RiTdisplay	Mobile Phone	4 area-color	150K	Oct-02
LG	Tohoku Pioneer	Mobile Phone	4 area-color	400K	Jul-02
Philips	Philips	Shaver	Yellow	200K	Jul-02
Samsung	SNMD	Mobile Phone	Full-color	50K	Aug-02
Giga	RiTdisplay	Mobile Phone	2 area-color	16K	Dec-02
Fujitsu	Tohoku Pioneer	Mobile Phone	4 area-color	600K	Jul-02
Total				2,060K	

✱ OLED products started to diversify in 2002

✱ Total quantity in 2002 is 3M

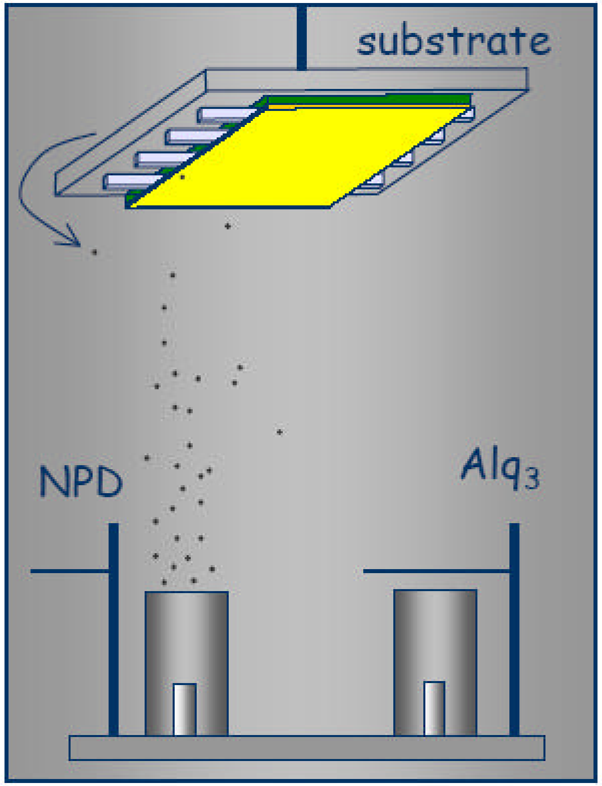
The OLED industry as seen from asia



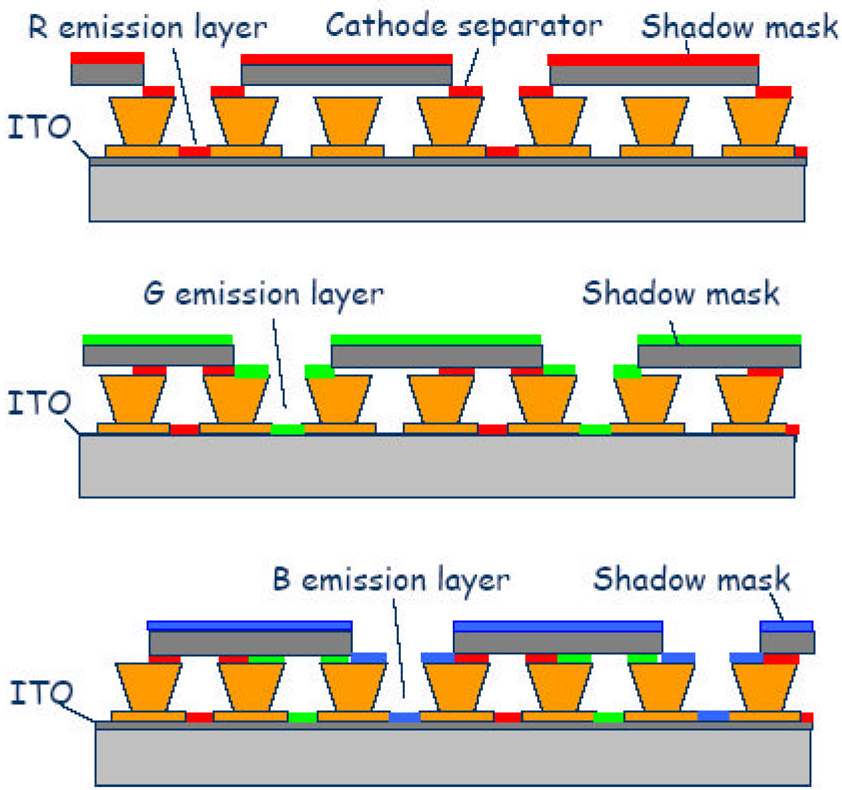
The Head-Start of Small Molecule OLEDs

- **Manufacturing started**
  - Pioneer 1997
  - TDK (Alpine, 2001)
  - Samsung-NEC Mobile Display (SNMD) (2002)
  - RiTdisplay (2003)
  - Sanyo-Kodak (2003)
- **R, G, B colors available**
  - limited lifetimes for blue
- **Shadow masking allows easy patterning for area color**
  - presents challenges with scalability and high volume manufacturing
- **Shadow masking challenging for full color**
  - high throughput and scalability is a challenge

Full color patterning with small molecules



Small molecules are thermally evaporated in vacuum



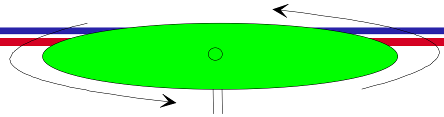
R, G, B pattering is defined by shadow masking in vacuum

Advantages of Solution Processing (Polymer) OLEDs

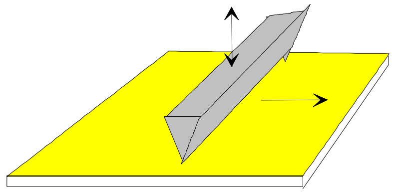
- **Lower fabrication cost**
  - fewer vacuum deposition steps - lower capital cost
  - advantageous materials usage and scalability (I/J printing)

- **Solution processing techniques**
  - compatible with printing techniques
    - lower cost for full color
  - scalable to very large substrates (high volume manufacturing)
  - better mechanical integrity
  - compatible with roll process for flex manufacturing

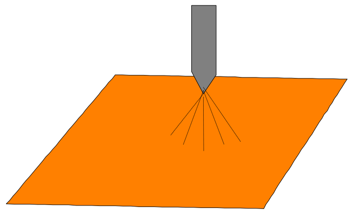
Polymer film deposition



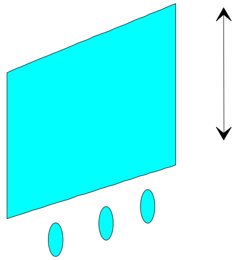
Spin Coating



Doctor Blade



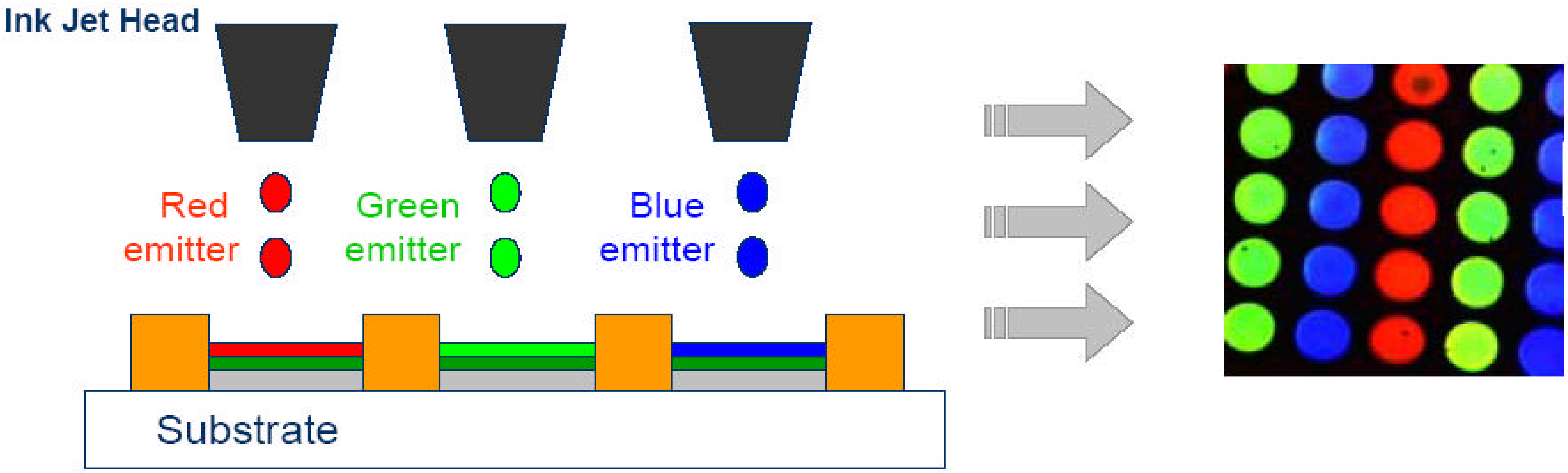
Ink Jet Printing



Dipping

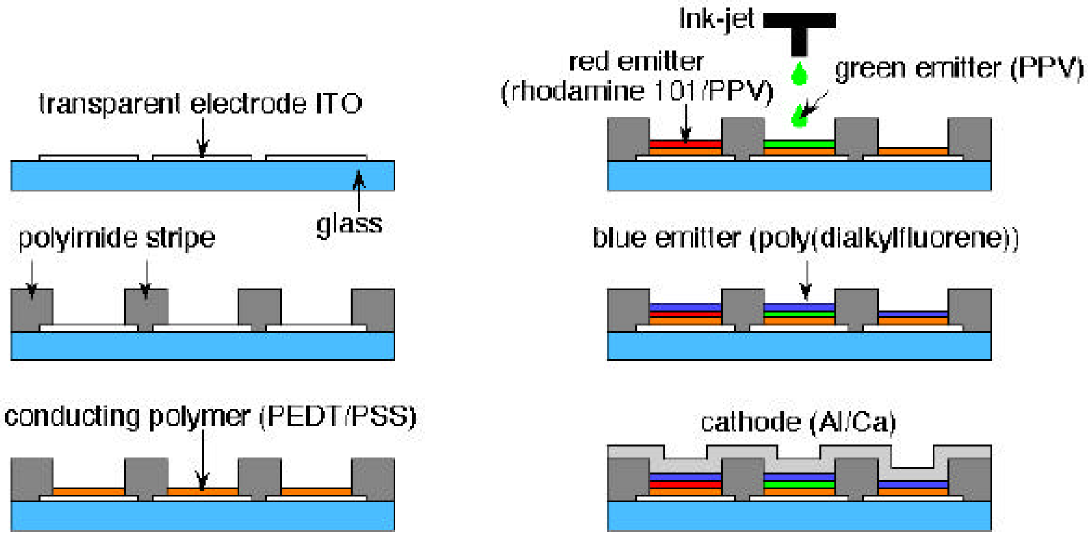
Roll printing, Micromolding, etc

Multichrome OLED-Displays: Polymere

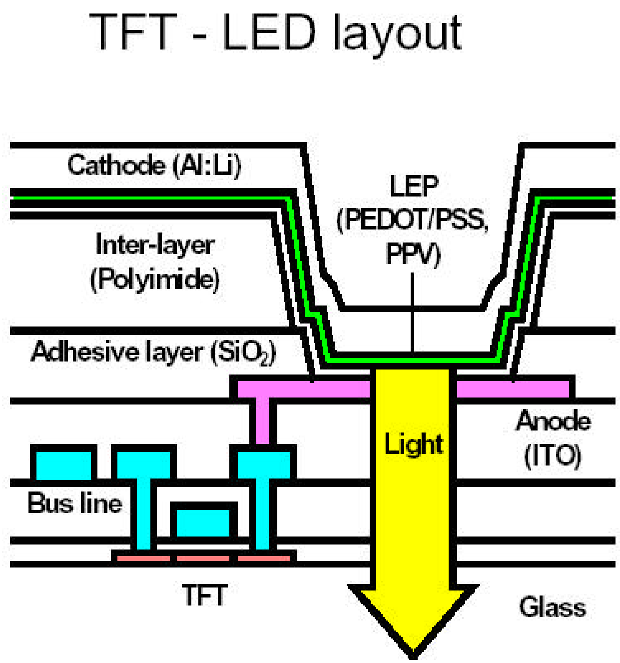


Ink Jet printing to define and pattern R, G, B emitting subpixels

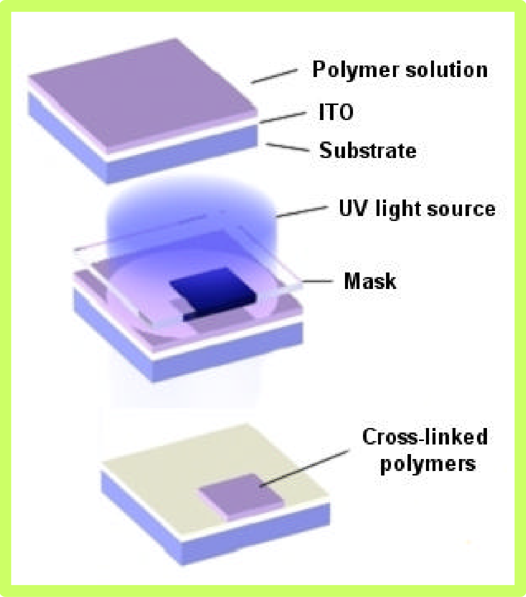
OLED displays: towards full color and active matrix displays

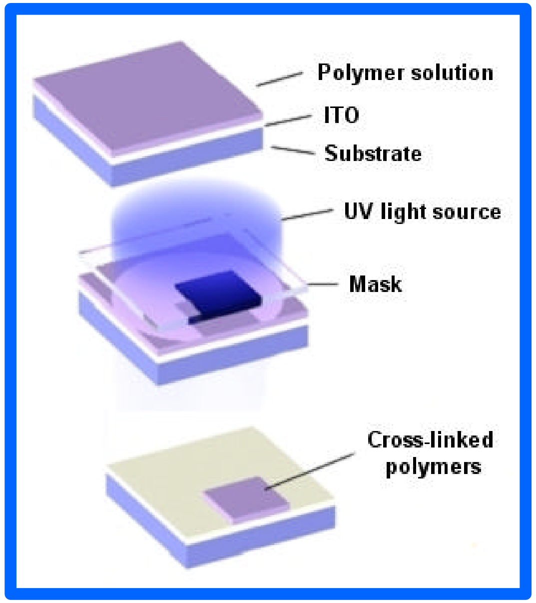


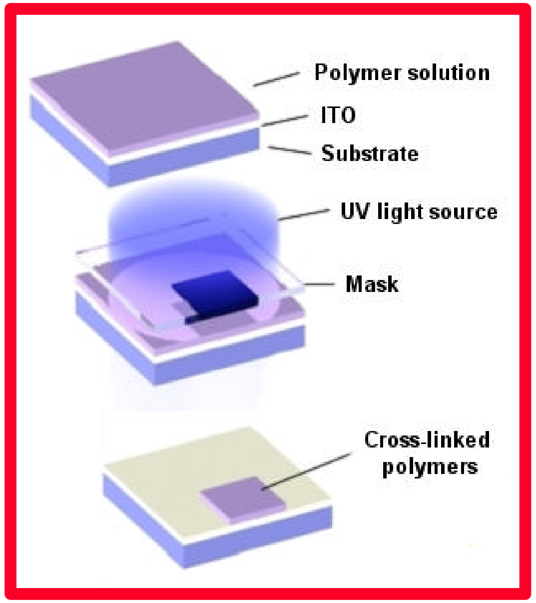
or

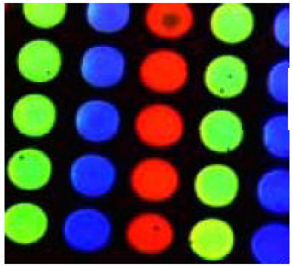


Multichrome OLED-Displays:



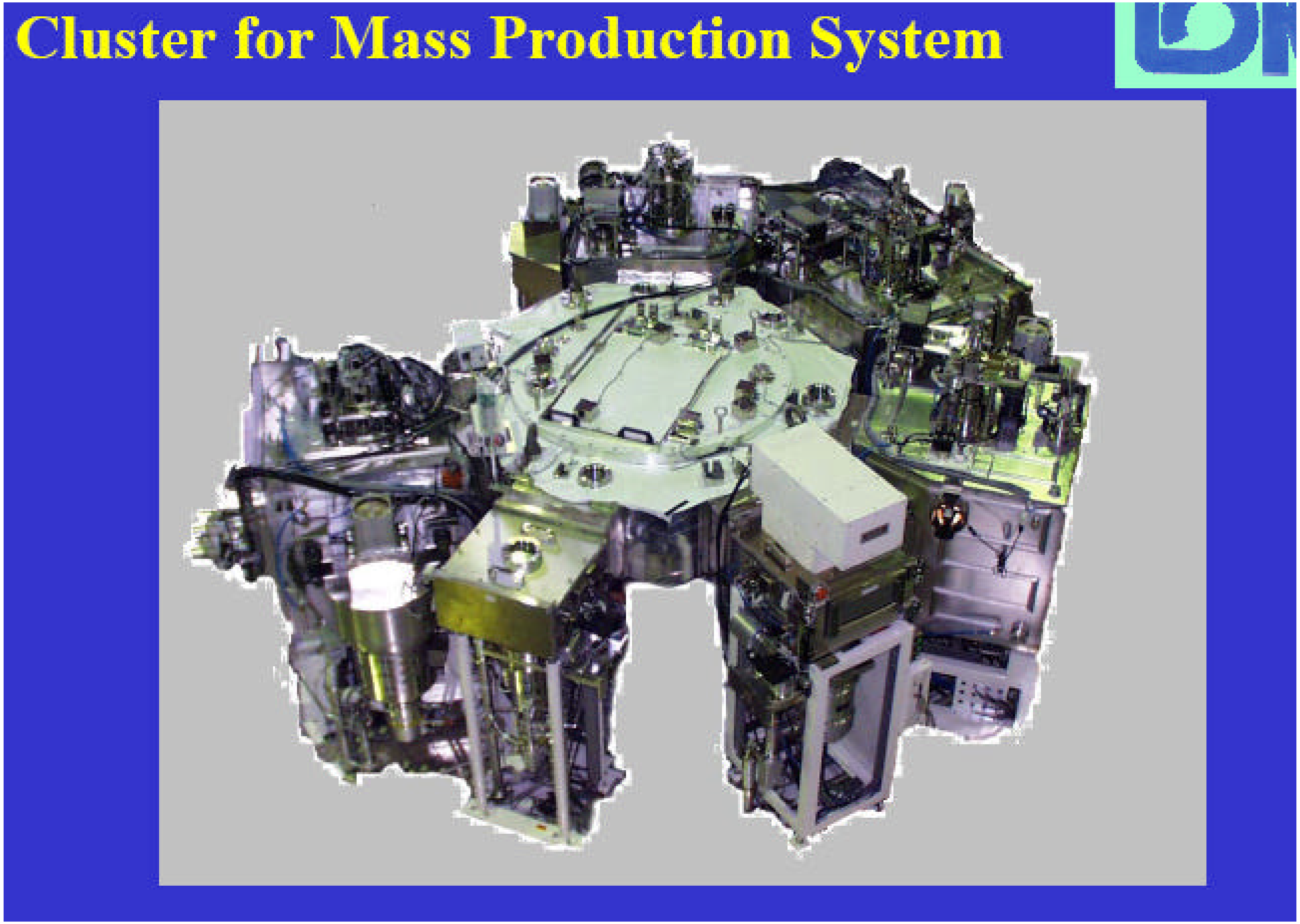




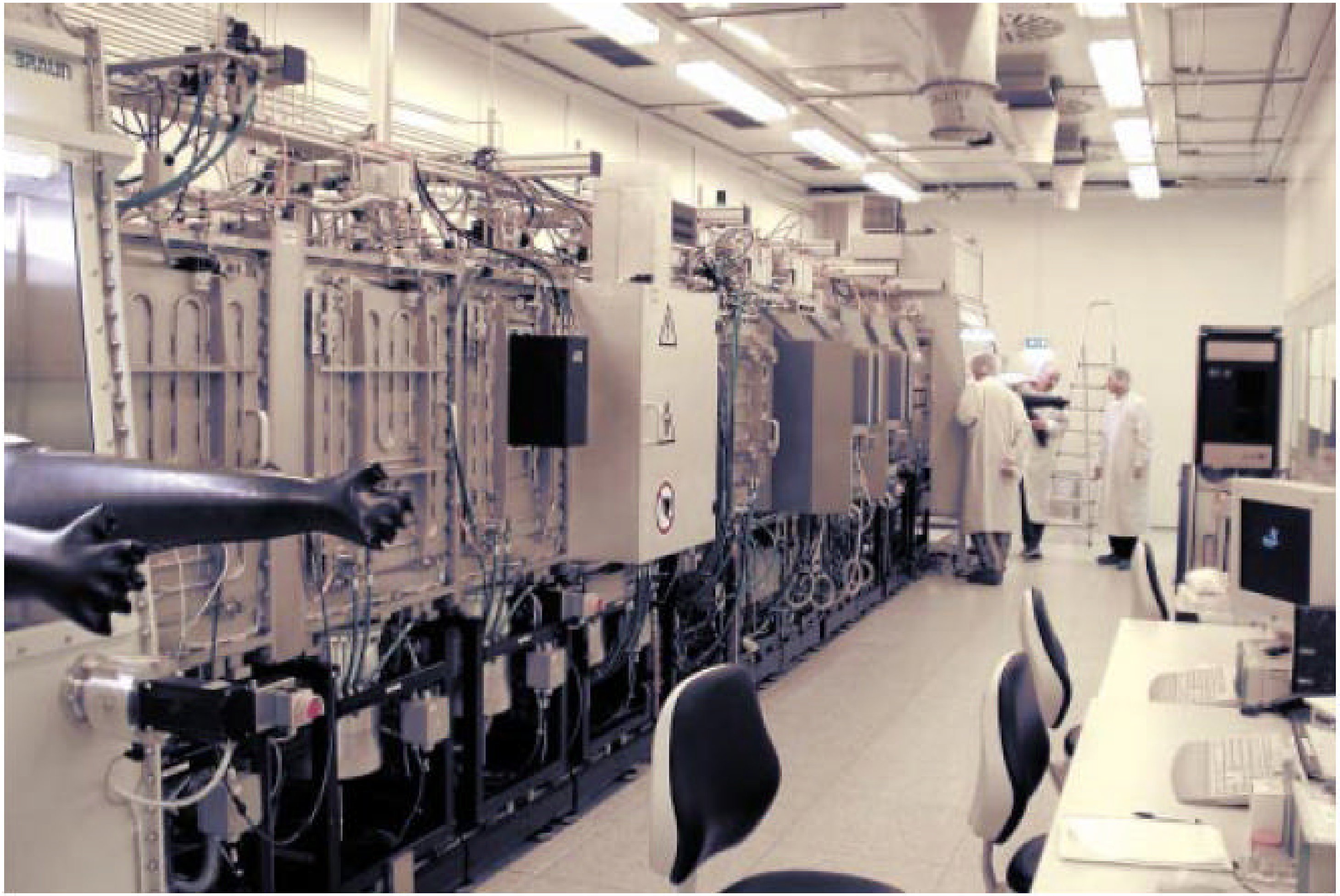


- the polymer is a semiconductor *and* a photoresist

OLED-fabrication: Cluster tools

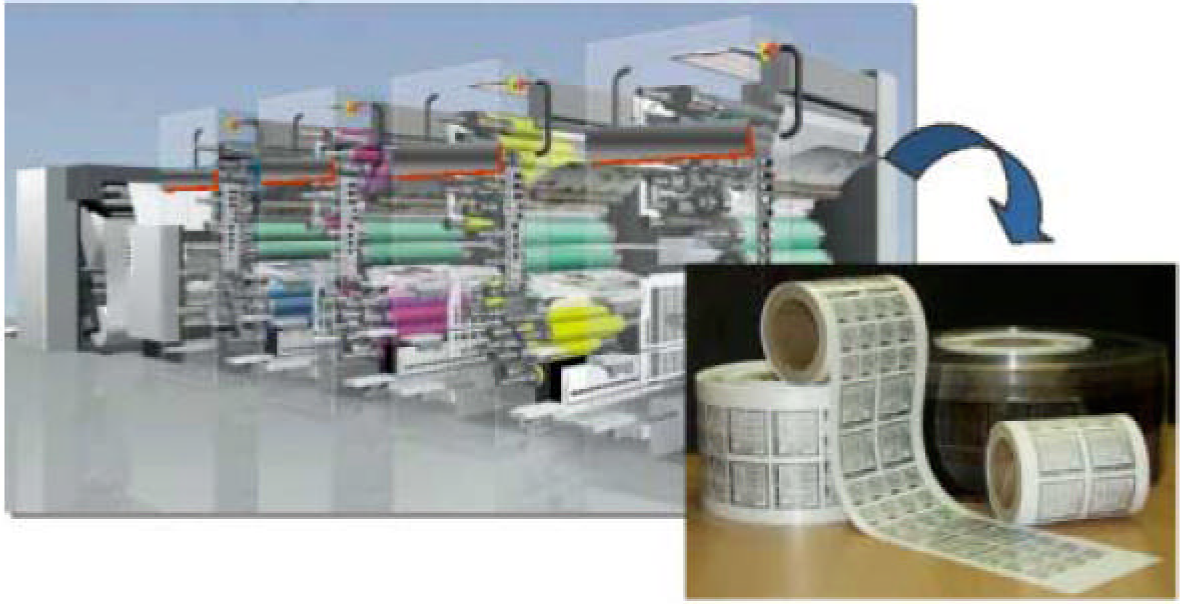


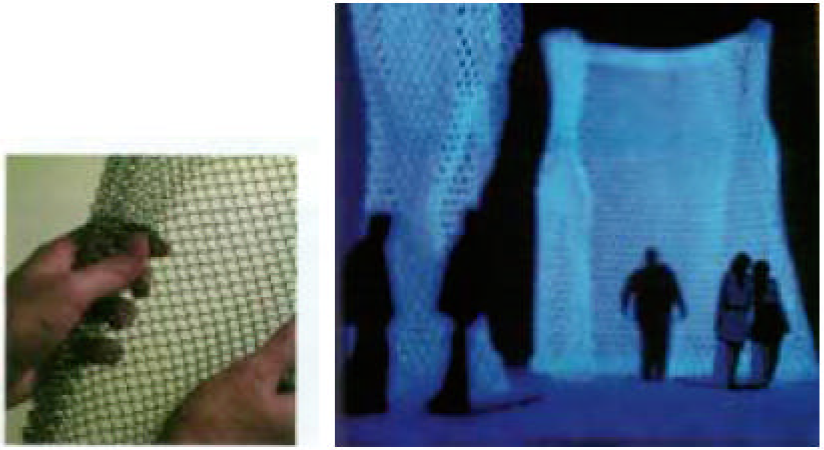
OLED-fabrication: in line equipment



Die ca. 11 m lange Inline-Anlage am Fraunhofer IPMS wird von sogenannten Handschuhboxen zur Bestückung bzw. Entnahme eingerahmt. Foto: © Fraunhofer VμE

The Holy Grail: Flexible OLEDs





Sheila Kennedy, Harvard Univ., 1999

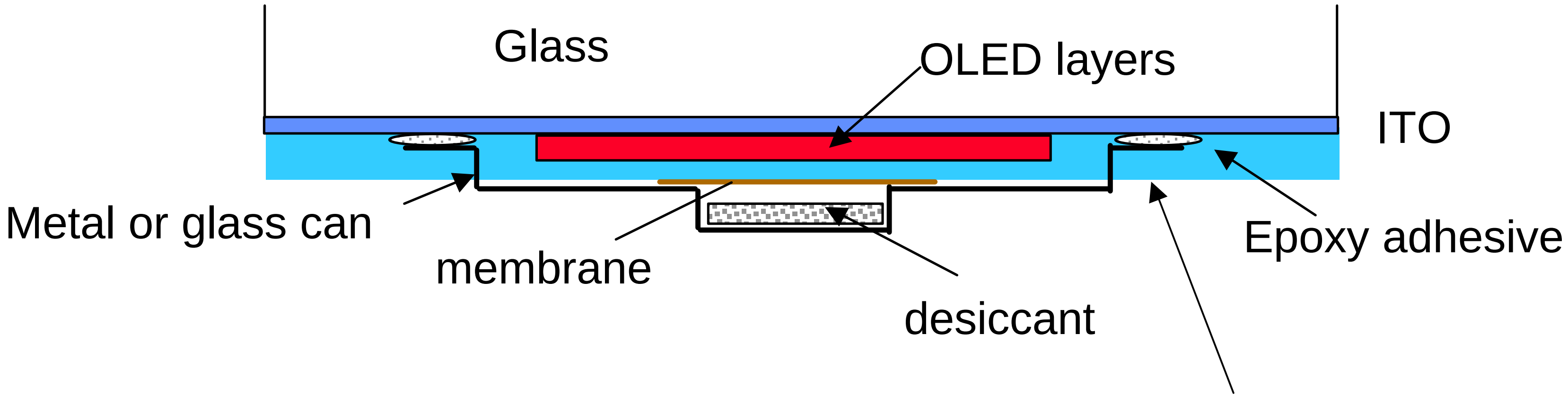
Thin film barrier layers for creating ultra thin OLED displays on glass and plastic

L.L. Moro, N.M. Rutherford, R.F. Praino, O. Phillips, M.Clauson, R.J.Visser

M. E. Gross*, P.E. Burrows*, G.L. Graff*

OLED: an ideal display but extremely moisture sensitive

The market seeks a solid state solution



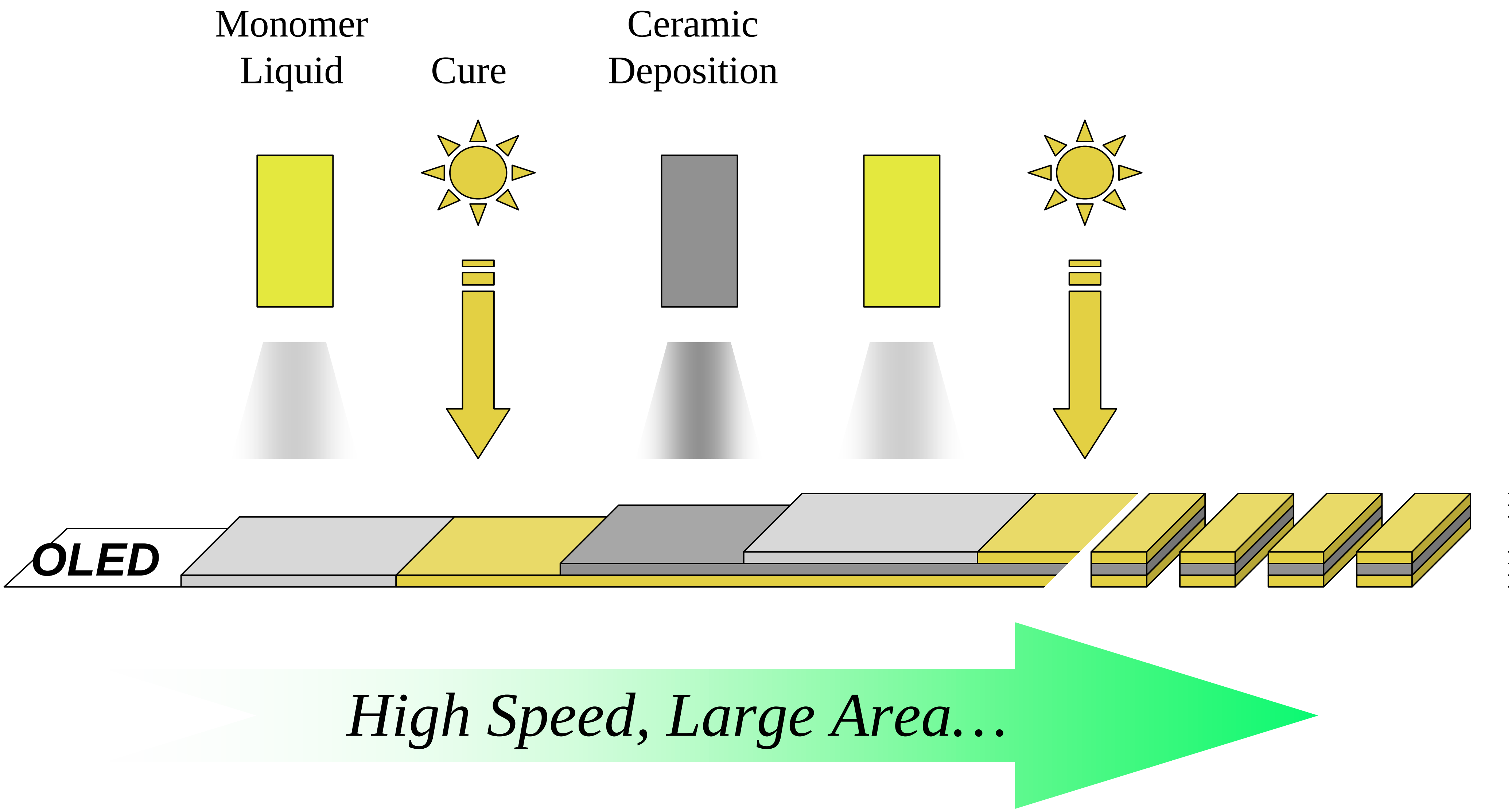
Vitex goals:

1. **Replace metal can**
2. **Replace glass substrate with 'Flexible Glass' ™**

Barix™ encapsulation

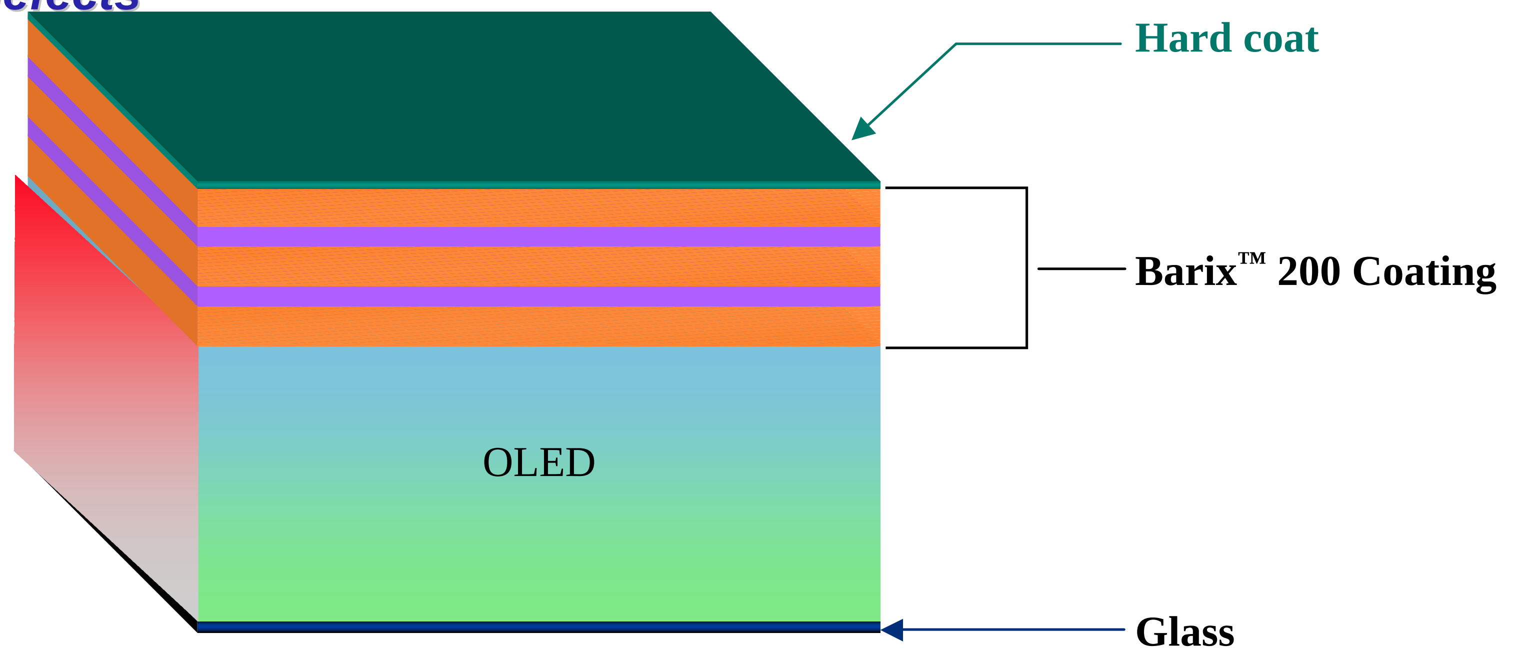
- Transparent
- Ultra-high barrier
- Applied at low temperature

Multilayer Barrier Deposition:



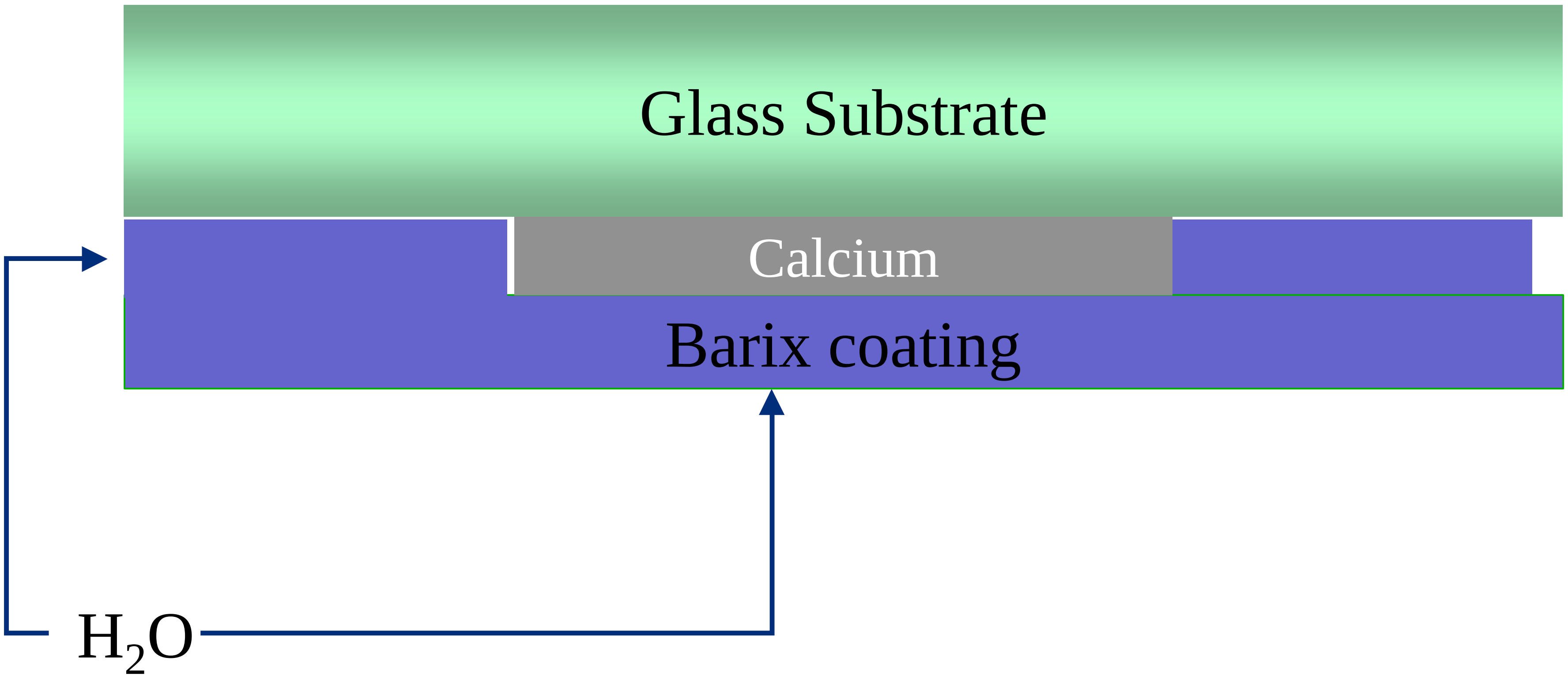
A transparent Multilayer barrier: suitable for top emission OLED's

- ⇨ *Polymer film planarizes surface to reduce substrate defects*
- ⇨ *Inorganic film provides barrier properties*
- ⇨ *Organic film protects barrier layer from mechanical damage*
- ⇨ *Multiple Barix layers yield an enhanced barrier by decoupling defects*

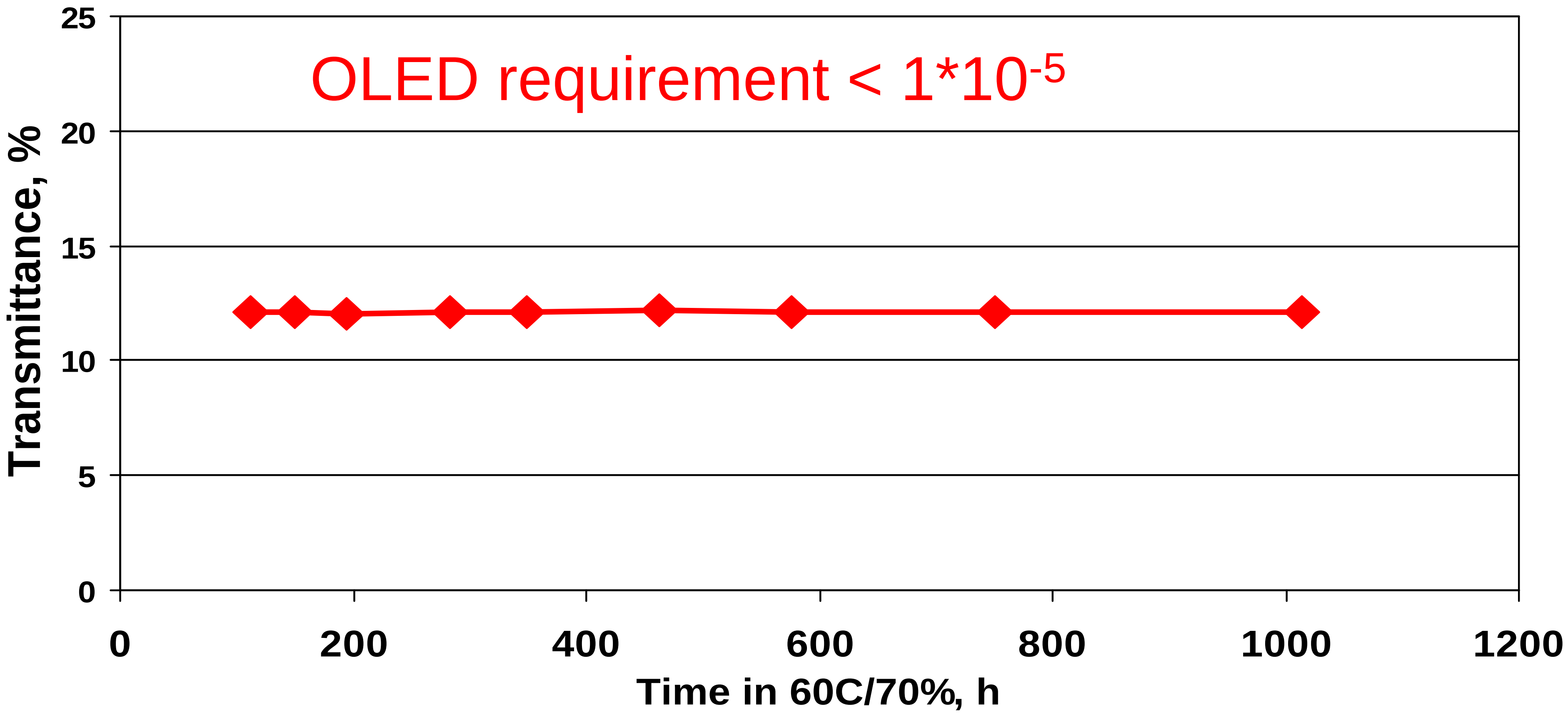


The Calcium Test

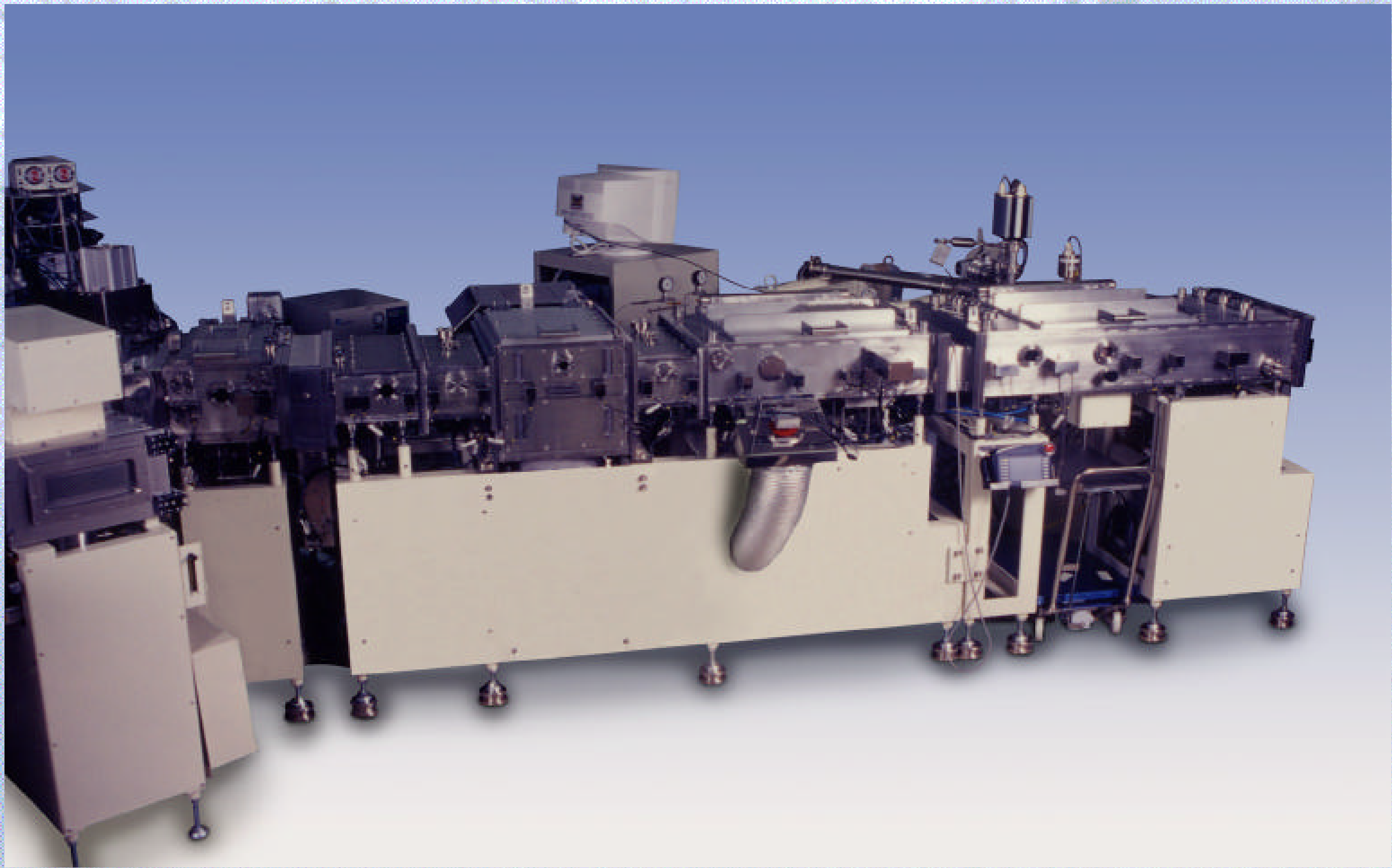
$$2Ca + O_2 + H_2O \rightarrow Ca(OH)_2 + CaO$$



Basic Barrier performance: Calcium test transmission coefficient at RT: <2 10^{-7} gr/m^2/day



Tokki and Vitex have developed an encapsulation tool: G200



Cost - Materials

Based on a 2" diagonal display