Frontiers in Optoelectronic Products for OLEDs

Ron Moon

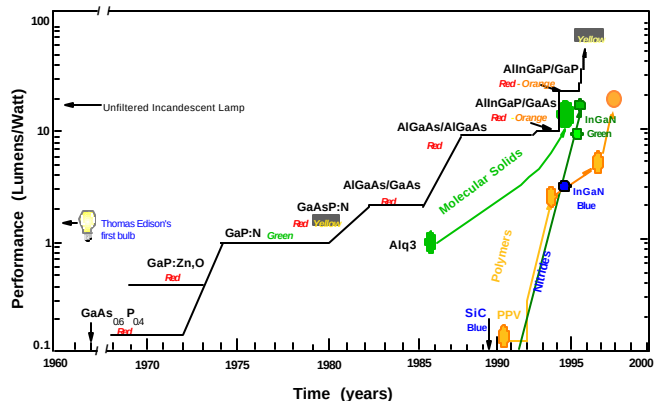
Hewlett-Packard Laboratories

Solid State Technology Laboratory

Palo Alto, CA

Evolution of LED Performance

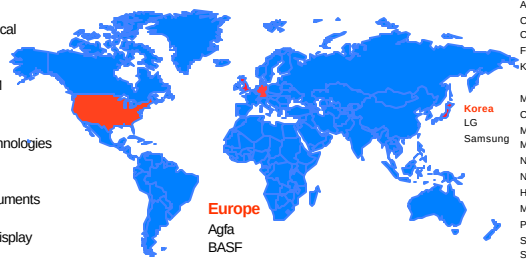
(power consumption)



Who is Who in OLED's

USA
Dow Chemical
DuPont
HP
Hughes/GM
IBM

Lucent Technologies
Motorola
Planar
Texas Instruments
Uniax
Universal Display
Xerox
??



Europe
Agfa
BASF
Bayer

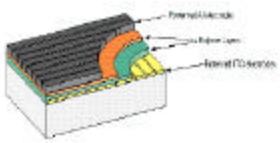
Ciba Geigy
Hoechst
Philips
Siemens
CSF-Thompson
Bosch

Korea
LG
Samsung

Japan
Asahi
Canon Inc.
Casio Computer
Fuji Photo Film
Konica

Matsushita/Panasonic
Chisso
Mitsubishi Chemical
Mitsubishi Electric
Nippondenso
NEC
Hodogaya Chemical
Mitsui Chemical
Pioneer Electronic
Sanyo Electric
Seiko Epson
Sharp
Sony
Stanley
Ricoh
Oki Electric Ind.
Sumitomo Chemical
TDK
Toyo Ink
Toshiba
Toyota

Organic Light Emitting Diodes (OLEDs): the basis for plastic, flexible, emissive, displays



Cambridge Display Technology (CDT) http://www.cdtltd.co.uk

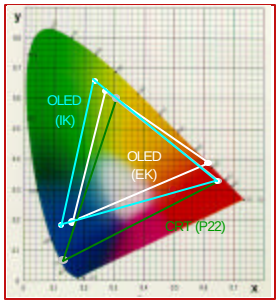
UNIAX

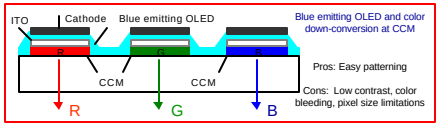
- **OLEDs rely on organic materials (polymers and small molecules) that give off light when tweaked with an electrical current**
- **OLED displays will be bright and light, ultra-thin, flexible and easier to produce than most other types of flat screens for computers and TV's**

Business Week, October 19, 1998

Characteristics of organic RGB emitters

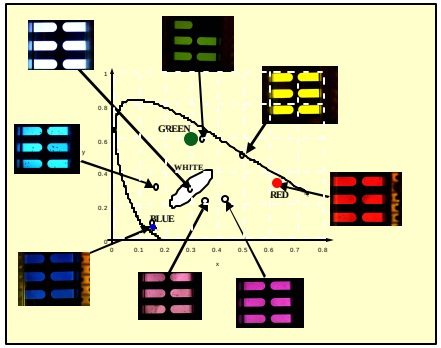
	Blue	Green	Red
Host material	Alq_2	Alq_3	Alq_3
Dopant material	Perylene	Coumarin 6	DCM2
Luminance (cd/m²) @ 20 mA/cm²	355	1980	770
Efficiency (cd/A)	1.8	9.9	3.8
Operating voltage (V)	10	8	9
Luminous eff. (lm/W)	0.6	3.9	1.3
Lifetime (hours)	2000	5000	3000





Colour Tuning

- **Chemical Modification:**

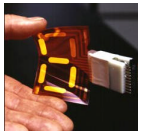


CDT

Polymer Summary

UNIAX PHILIPS

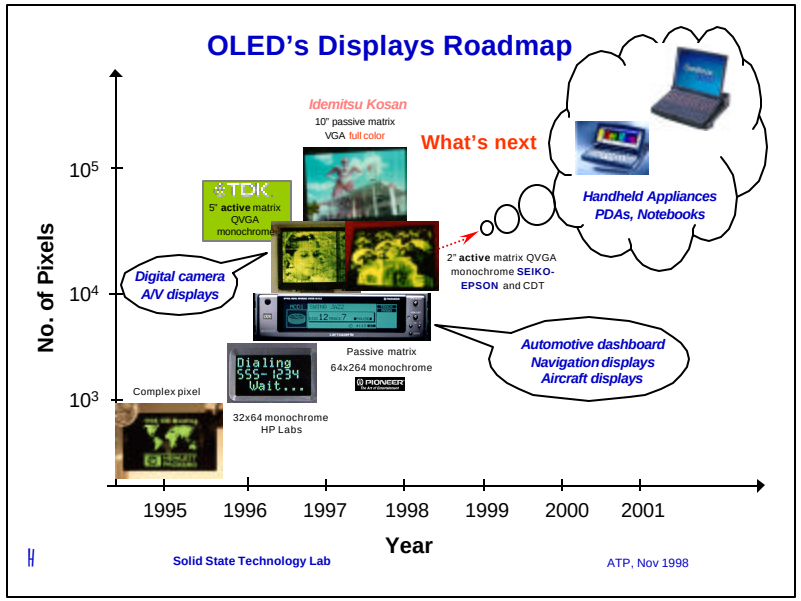
- Uniax and Philips PPV Results
  - OC1C10 (red/orange)
    - 2 lm/W
    - Extrapolated Lifetime > 20,000 hours
    - Full Acceleration Factors Determined
      dV/ dt ~ 0.12 mV/hr
  - High efficiency polymers (Yellow and Green)
    - Up to 16 lm/W

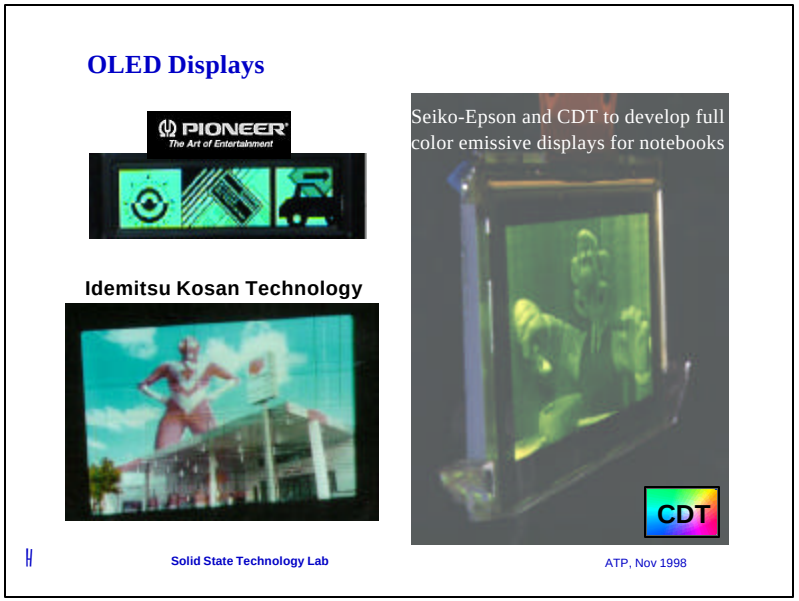


- Philips Building Pilot Line

Characteristics of Vapor-Deposited and Polymer OLED's

Device/Company	Color (nm)	Voltage (V)	Current (mA/cm²)	Brightness (Cd/m²)	Max Efficiency (lm/W)	Lifetime @ 100 Cd/m²
ITO/CuPc/NPD/Alq_3:R-QCD/Mg:Ag Eastman Kodak	530	~9	20	1400	>6	>80000
EK technology Pioneer Electronics	530	5	2	300	12	45000
ITO/HTL/distyrylarylene/L/Mg:Ag Idemitsu Kosan	475	6	3	100	~6	20000
ITO/PEDOT/DRO-PPV/Ca ITO/PEDOT/?-PPV/? Philips/UNIAX	590 Green	3 low	6.5	100	1.6 17	>10000
ITO/PEDOT/PPV/Al:Li ITO/…/DOW Mat'l/… CDT	555 Green	3 2.6	4	100 100	2.6 21.8	>2000

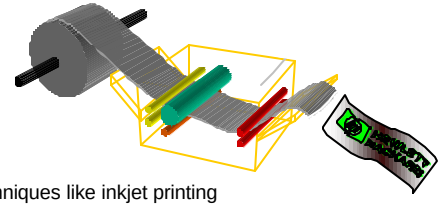

OLED's Displays Roadmap
No. of Pixels
10^5
10^4
10^3
Idemitsu Kosan
10" passive matrix
VGA full color
What's next
TDK
5" active matrix
QVGA
monochrome
Handheld Appliances
PDAs, Notebooks
Digital camera
A/V displays
2" active matrix QVGA
monochrome SEIKO-
EPSON and CDT
Automotive dashboard
Navigation displays
Aircraft displays
Passive matrix
64x264 monochrome
Dialing
555-1234
Wait...
Complex pixel
32x64 monochrome
HP Labs
1995
1996
1997
1998
1999
2000
2001
Year
Solid State Technology Lab
ATP, Nov 1998


OLED Displays
PIONEER
The Art of Entertainment
Idemitsu Kosan Technology
Seiko-Epson and CDT to develop full color emissive displays for notebooks
CDT
Solid State Technology Lab
ATP, Nov 1998

Low Cost Roll-to-Roll Process to Fabricate Emissive Organic Displays

High throughput, continuous process enables low cost displays

Flexible substrate roll

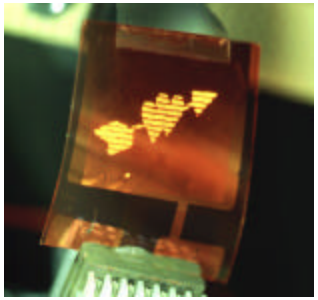


Printing techniques like inkjet printing to define the pixelated patterns

Flexible emissive display

Inkjet Printing to Define Patterns and Pixels

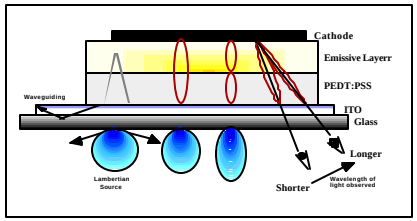
- **UCLA demonstrates glowing images patterned by inkjet printing**



Courtesy of UCLA, Prof. Yang Yang

Color Tuning (Cavity Effects)

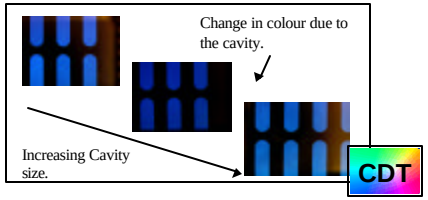
- Modify PEDT thickness



- Reflection within device structure forms cavity.
- Standing waves set-up between reflecting surfaces.

Manifested as :

- Emission directed forwards.
- Spectra narrowed around cavities resonance wavelength.
- Colour changes as viewing angle moves. **(Undetectable to the eye for these devices)**



Electronic Books and Personal Organizers:

SOFTBOOK

Major technological hurtles:

- **Rigid, fragile and heavy (liquid crystal display on glass)**
- **Short battery life (if backlit)**
- **Low contrast**
- **Expensive**

Flexible Emissive Displays Based on OLEDs

- OLED's will enable flexible displays
- Will be lighter, less complex and cheaper to make than LCD's

OLEDs Displays must compete with existing Displays

Cost of Full Color 12" AMLCD

Electronics/Drivers	$115	50%
Materials	$80	35%
(Glass, ITO, LC, TFTs,etc)		
Backlight & Polarizers	$35	15%
Total	$230	100%

Areas for Further Investigation

Materials

Red & Blue Polymers & Small Molecules

Alternative Higher Tg Materials

Reliability--several hundred cd/m2
-- >10khrs

Contact Materials both Anode & Cathode

Devices

Alphanumeric

Video Displays

Sensors ???

Active Matrix Addressing

Processes

Roll to Roll (alternative to spin casting)
- **Thickness control to 500Å to 1000Å**
- **Uniformity**

Sealing Technology
- Standard for gas permeability
- Cheap and Available

Printing Technology
- Print heads
- Correct "ink" characteristics

Microcavity Enhancements

Major Challenges for OLED Displays

- **OLED technology still in its infant stage**
- **Continuous roll-to-roll manufacturing process not proven yet for OLEDs**
- **OLED's displays are power hungry and may not be easily portable, unless they are small**
  - **They will be challenged by reflective displays**