OLED & the Status of Its Development

Gary Mandle
Sr. Product Manager
Professional Display Products

SONY

What is OLED?

- Organic Light Emitting Diode
  - It is:
    - An emissive output
    - No backlight
    - No plasma gasses
    - Self luminous matrix array
    - Created by sandwiching several organic layers between conductors

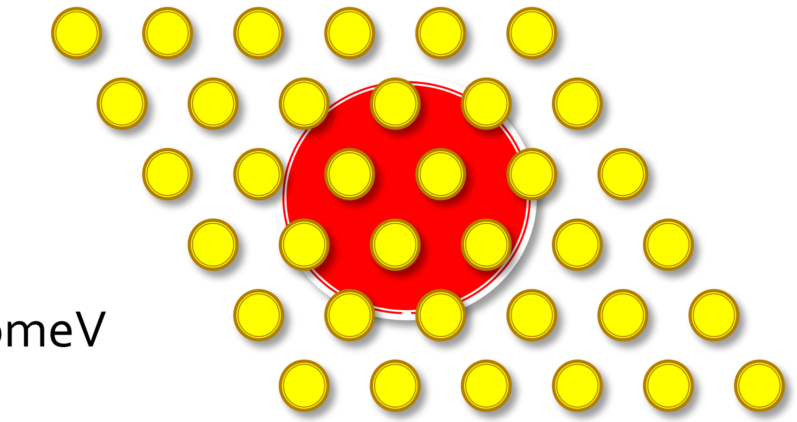
SONY

Electroluminescence

- Is an optical/electrical process
- Illumination due to electrical current passing through a material
- The result of radiative recombination of electrons and holes in a material resulting with an emission of a photon

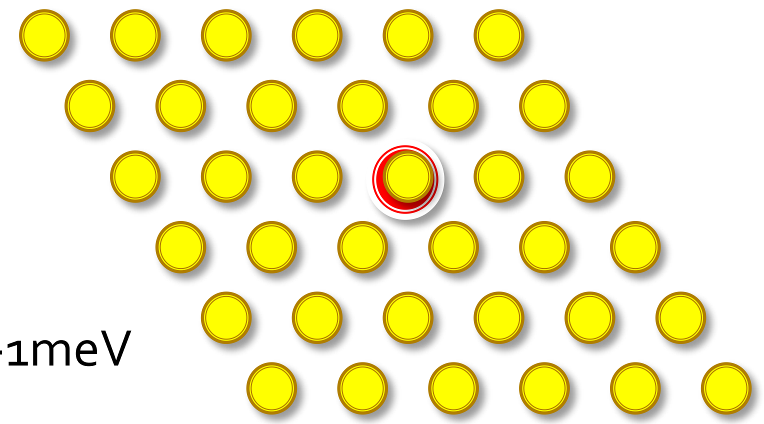
Semiconductors vs. Organic Materials

- Semiconductor
  - Wannier Excitation
    - Typical with inorganic semiconductors
    - Delocalized over many lattice sites



Binding Energy = -10meV
Field Radius = 100Å

- Organic
  - Frenkel Excitation
    - Typical with organic (molecular) materials
    - Excitation confined to one molecule



Binding Energy = -1meV
Field Radius = 10Å

SONY

Advantages of Organic Conductors

- Advantages of organic semiconductors
  - Electrons reside on P orbitals that are on the same plane and can move freely
  - Even field uniformity within the material
  - Molecules are held together by weak binding forces
  - Carrier mobility is much lower in organic materials
    - typically less than $1 cm^2/v\text{-}s$
  - High fluorescence efficiencies
  - Epitaxy fabrication is not required as is with semiconductors
  - Narrow HOMO-LUMO gap in semiconductors will quench light emission.

SONY

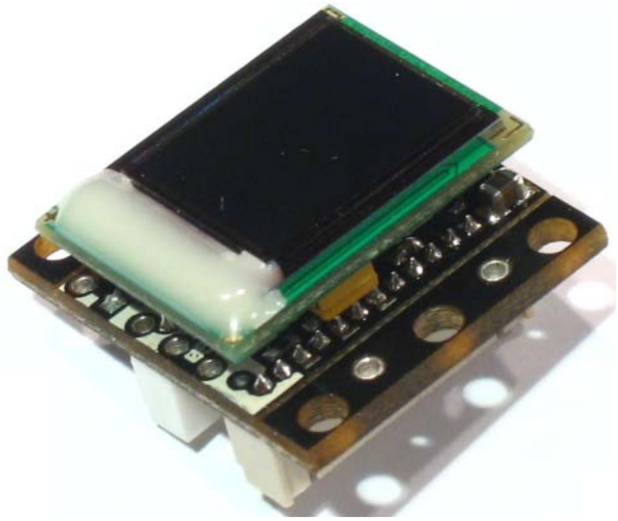
OLED from the Beginning

- 1965
  - First TFEL developed by Sigmatron
    - Thin Film Electroluminescent Display
- 1987
  - First QVGA resolution Prototype by Planar
  - Tang/Van Slyke paper on Bi-layer diode
    - Describes how an OLED would work
- 1993
  - First Multicolored TFEL Prototype by Planar
- 1997
  - First Color TDEL Prototype by iFire
    - Thick Film Dielectric Electroluminescent
  - Development of white TFEL Prototype by Planar

SONY

OLED from the Beginning

- 1999
  - First PM-OLED shown by Pioneer
- 2002
  - SVGA Micro-display Prototype by eMagin
- 2003
  - First demonstrated 20 inch WXGA aSi AMOLED by IDTech
  - 2.2 inch AMOLED installed on Kodak LS633 consumer cameras
- 2004
  - First 40 inch panel demonstrated by Seiko Epson
- 2005
  - Second 40 inch panel demonstrated by Samsung
  - AOU starts production of 2.2 inch AMOLED



SONY

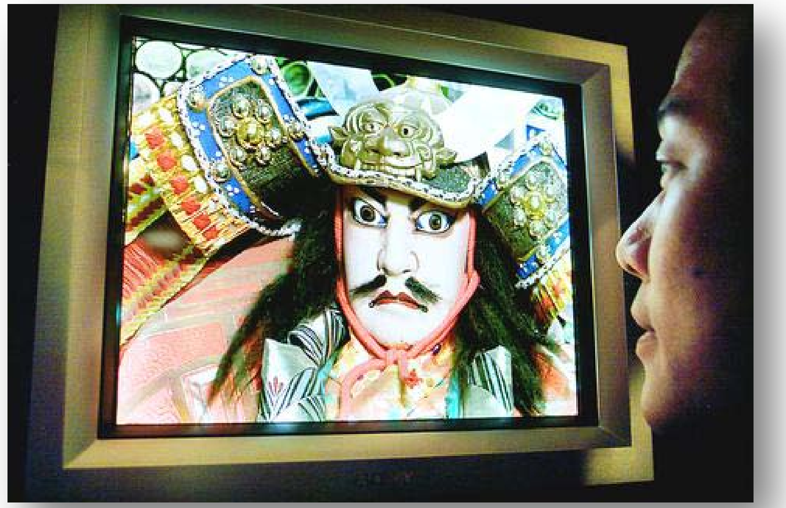
OLED from the Beginning

- 2006
  - Koizumi develops first OLED for lighting
- 2009
  - Microsoft Zune delivers with 3.3 inch AMOLED
  - Google Nexus One delivers 3.7 inch AMOLED
  - SMD develops transparent OLED
  - Mitsubishi demonstrates 155 inch AMOLED
  - Osram starts delivery of Orbeos lamps

SONY

SONY OLED Developments

- 1994
  - Start of initial development
- 2001
  - Demonstration of an SVGA resolution 13 inch at CEATEC Japan
- 2003
  - Display of prototype 24 inch at CES
  - 9B¥ investment of OLED manufacturing plant in partnership with Sony Toshiba LCD
- 2004
  - Mass production starts of small OLED (100,000 unit/yr)
  - Display of a 24 inch using tiled 12 inch panels at CES
  - Delivery of the PEG-VZ90 using 3.8 inch 480 x 320 AMOLED



SONY

SONY OLED Developments

- 2007
  - Display of 27 inch AMOLED manufactured using laser thermal printing
- 2008
  - Sales of the 11 inch XEL-1 TV
    - First OLED commercially available TV
  - Sony announces $203M investment in new OLED tooling
- 2009
  - Demonstration of 2.5 flexible display at CES

SONY

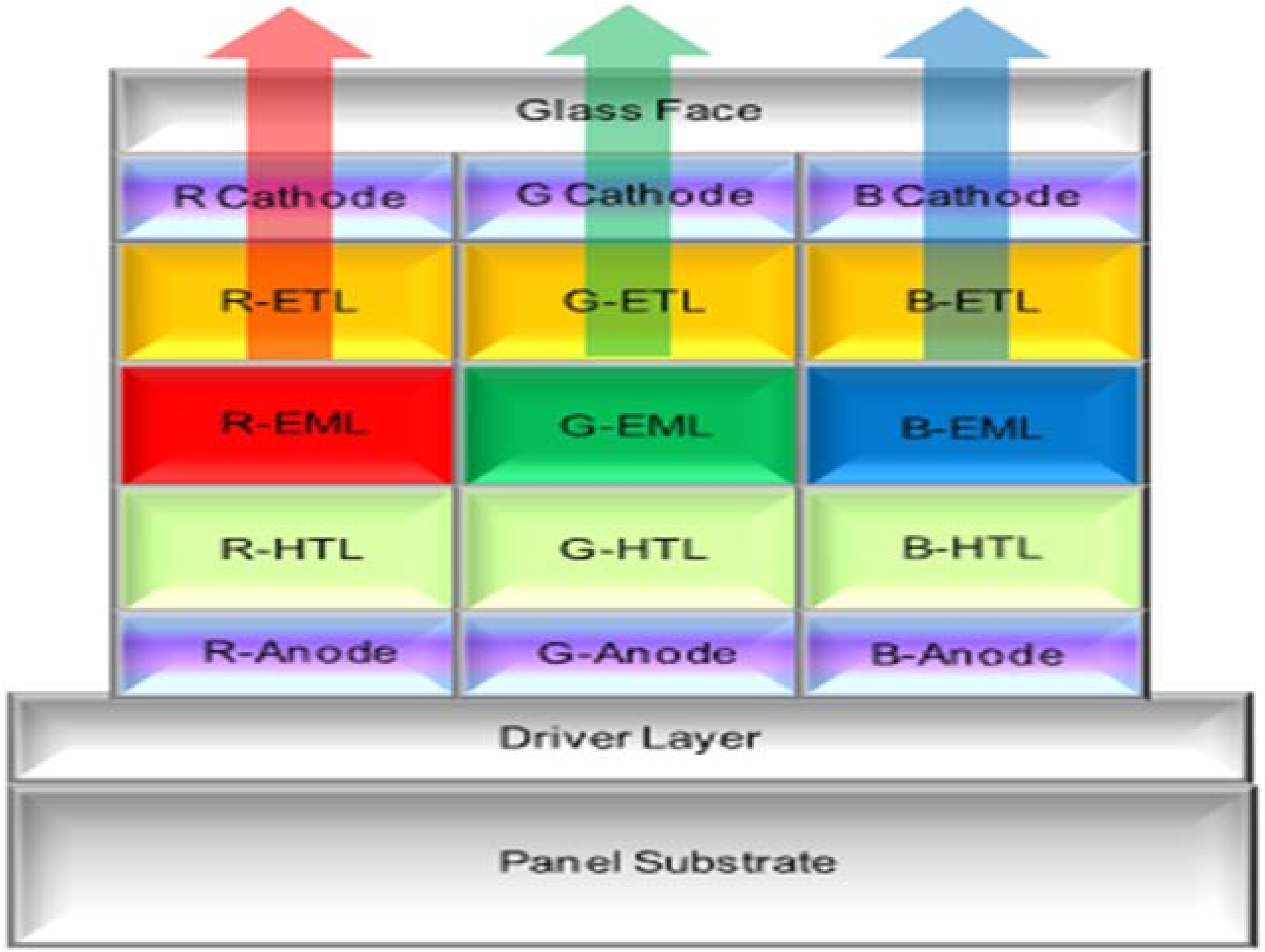
SONY OLED Developments

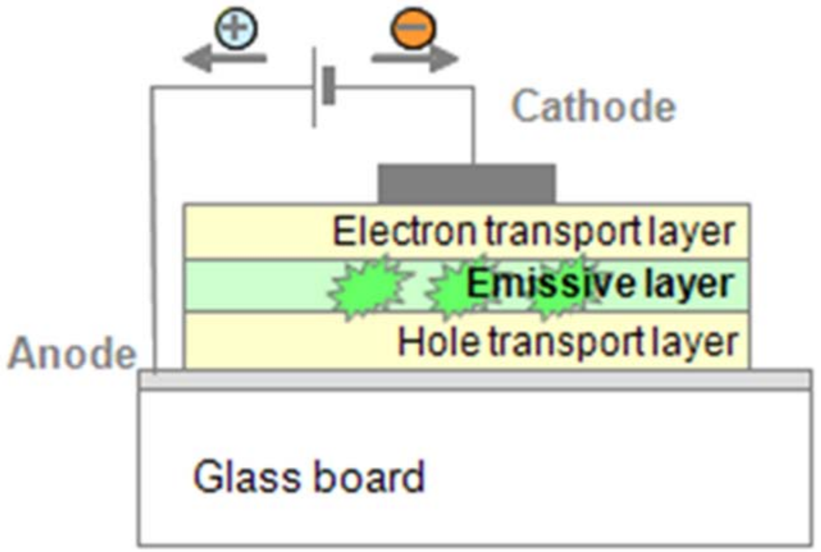
- 2010
  - Demonstrations of a 24.5 inch 3D AMOLED at CES
  - Sony shows 24.5 inch AMOLED designed for professional use at SMPTE Technology Conference
  - Sony delivers first professional OLED monitor
    - PVM 740
    - 7.4 inch 960 x 540 resolution @ 10 bit

PVM 740

SONY

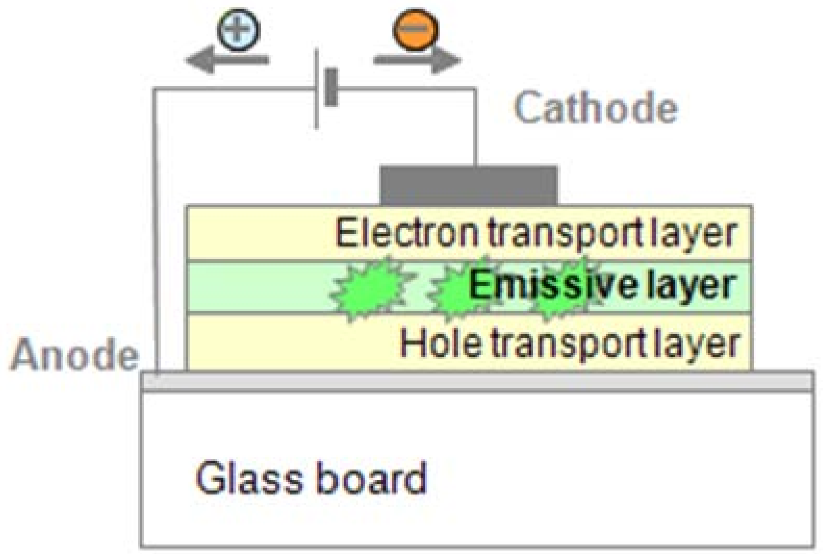
Construction

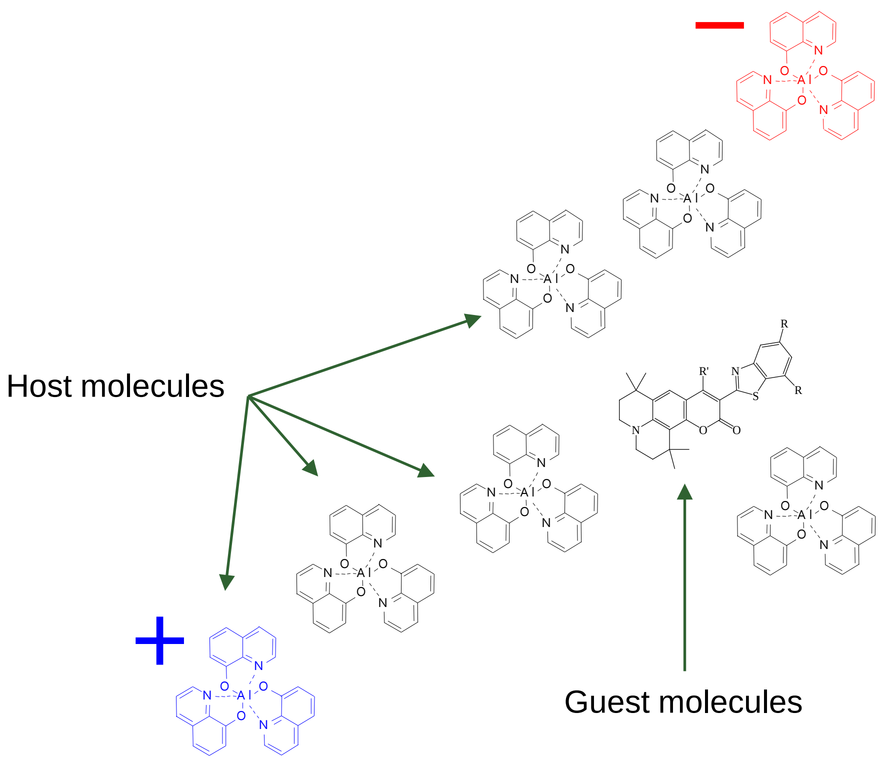




SONY

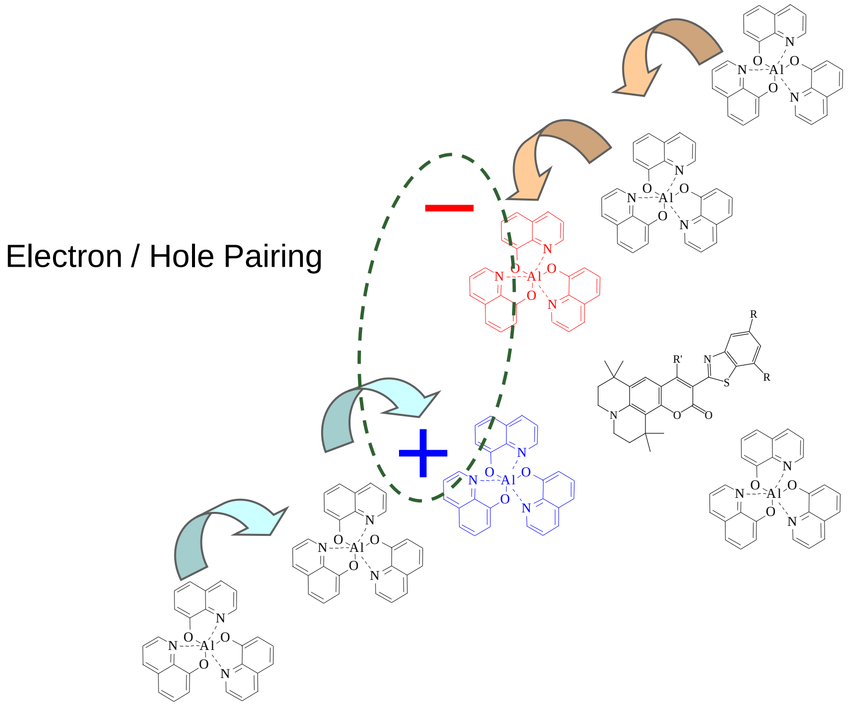
How it Works





1. Electrical charge in emissive layer

Electrons and holes are injected into the emissive layer from electrodes.

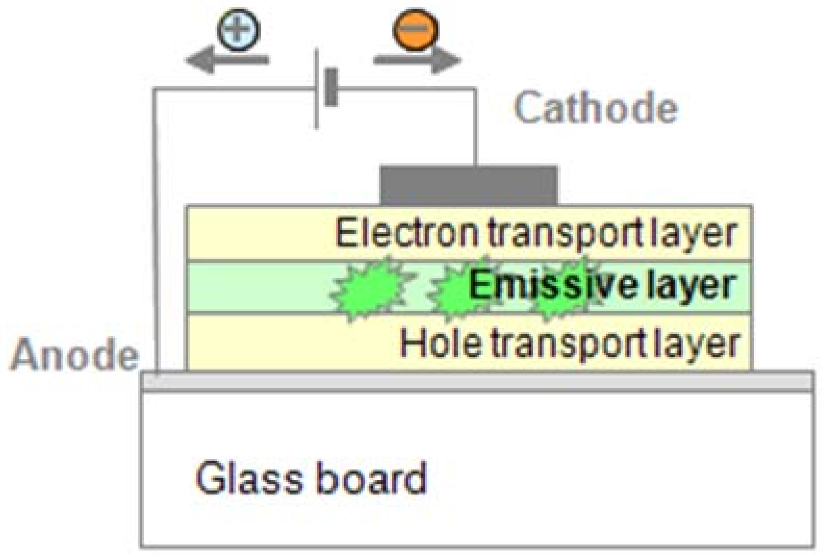


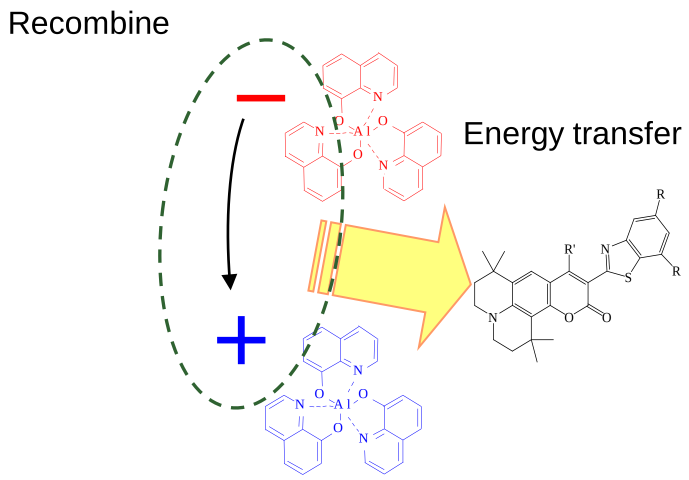
2. The formation of electron-hole pairs through charge transfer

Electron-hole pairs are formed when the injected electrons and holes approach one another while flowing through the emissive layer on host molecules.

SONY

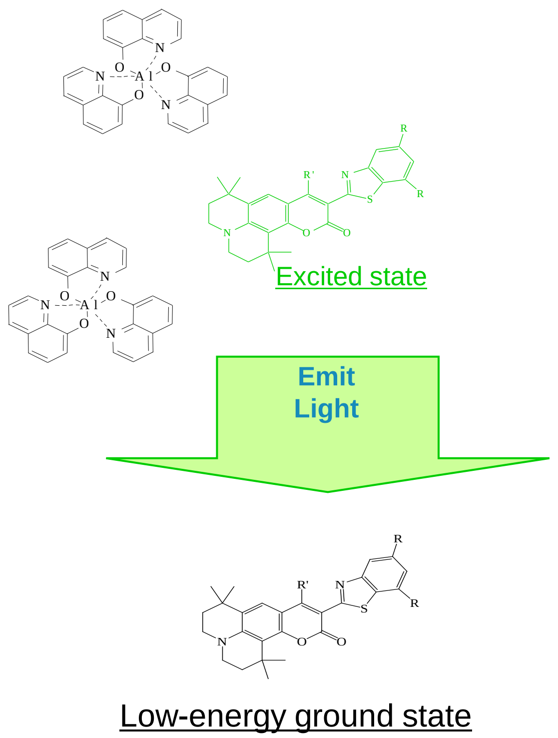
How it Works





3. Energy transfer to the emitting material (guest molecules)

When electrons and holes recombine in electron-hole pairs, energy is transferred to the guest molecules.



4. Excitation of the emitting material (guest molecules)

Guest molecules are excited by energy transferred from recombining electrons and holes, achieving a state of high energy.

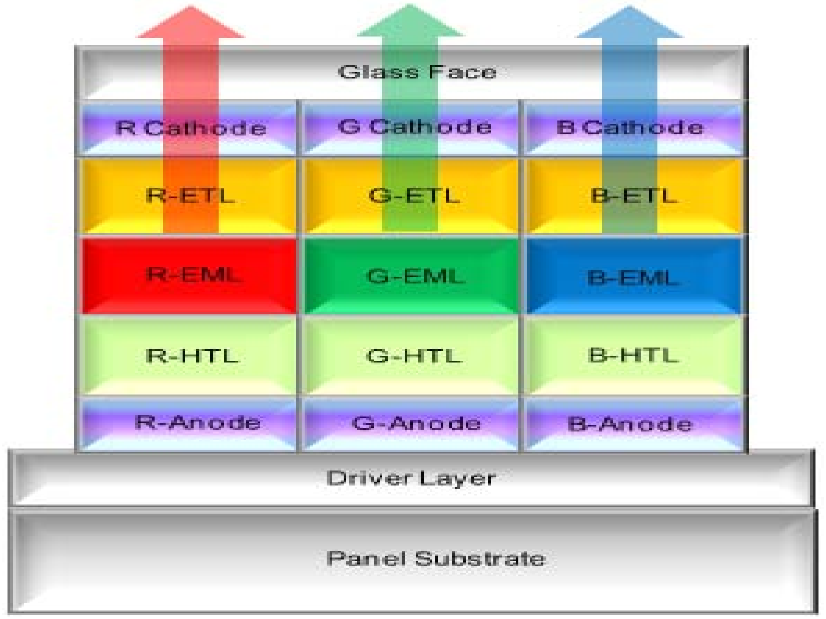
The excited guest molecules emit light, thereby releasing energy and returning to their low-energy ground state

SONY

Typical OLED Construction

- Substrate Structure
  - TFT and drive
  - SOG
- Anode
  - Conductive layer
    - Indium Tin Oxide (ITO)
- Hole Transport Layer (HTL)
  - Mixture of ionimars
    - PEDOT/PSS, CuPc, or 1-TNATA

- Emission Layer (EML)
  - Phosphor
    - ppy (green), btp (red), flrpic (blue)
- Electron Transport (ETL)
  - Electron-deficient heterocycles
    - TPBi, Oxadiazole, silole, DBzA, or BCP
- Cathode
  - If transparent , Indium Tin Oxide (ITO)
  - If not, then Mg:Ag or Li-Al



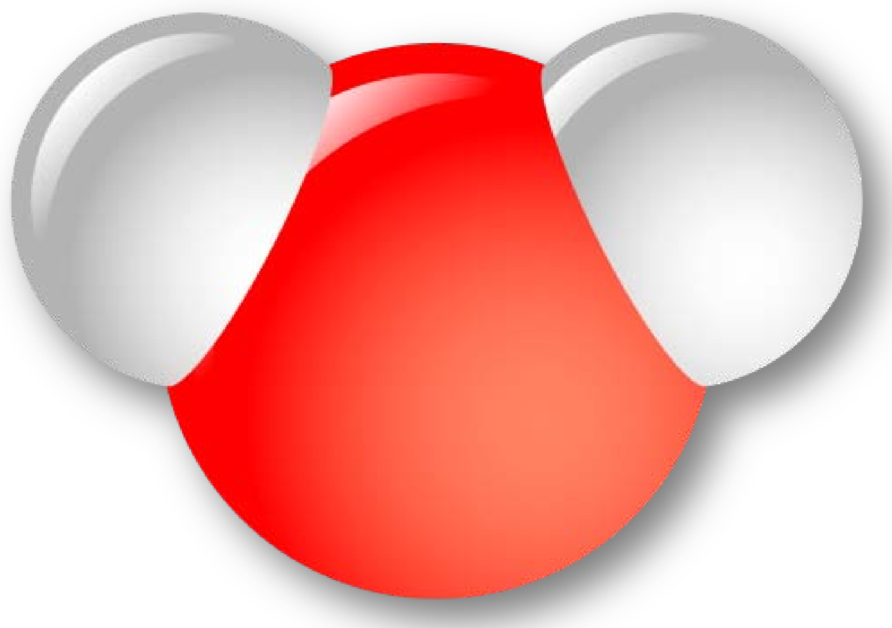
A matter of scale

- OLED Module
  - All layers
  - 1.4mm (1/16 inches)
- Substrate Structure
  - 2000Å
- Anode
  - 1800Å
- Hole Injection/Transport
  - 1200Å

- Emission Layer
  - 800Å
- Hole Blocking Layer
  - 20 - 40Å
- Electron Injection/Transport
  - 1200Å
- Cathode
  - 3000Å

1Å = 1.0 x 10^{-10} meters
Or = .1nm

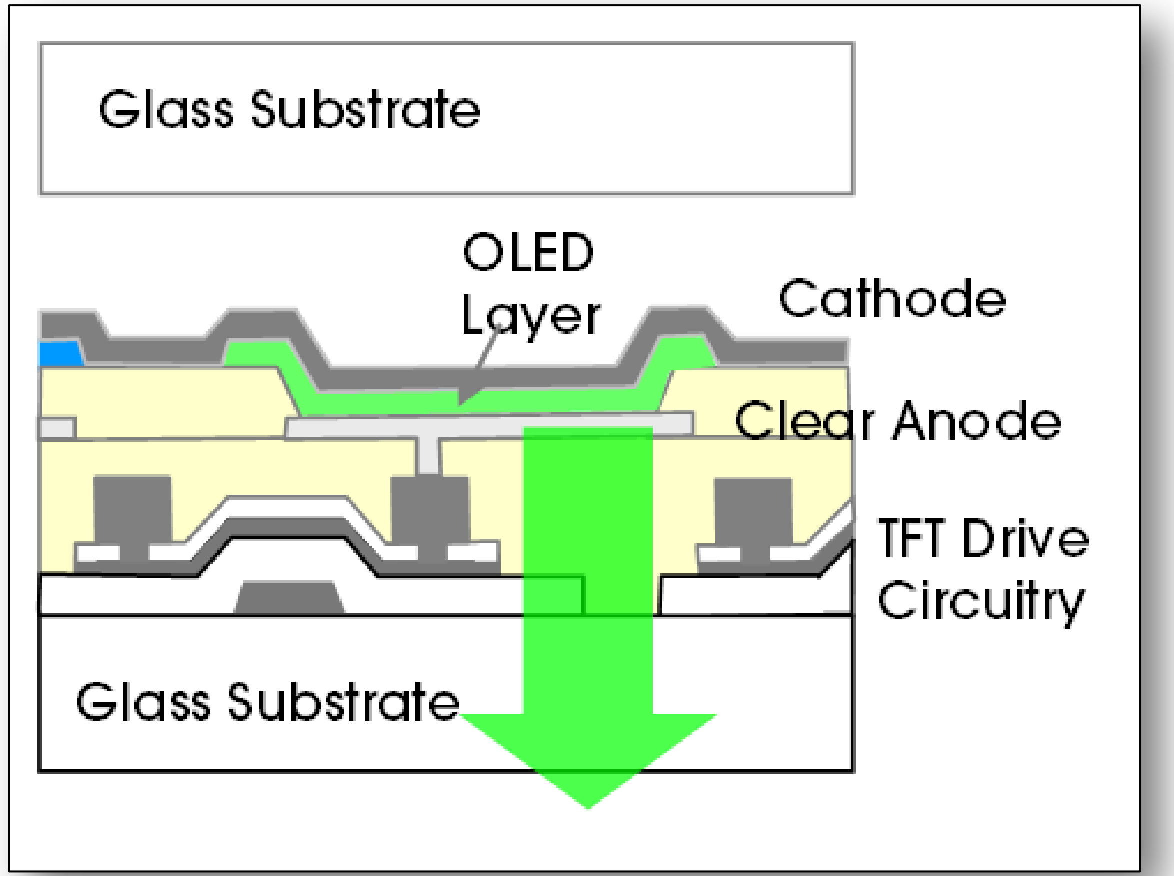
In reference
The diameter of a water molecule is 29Å

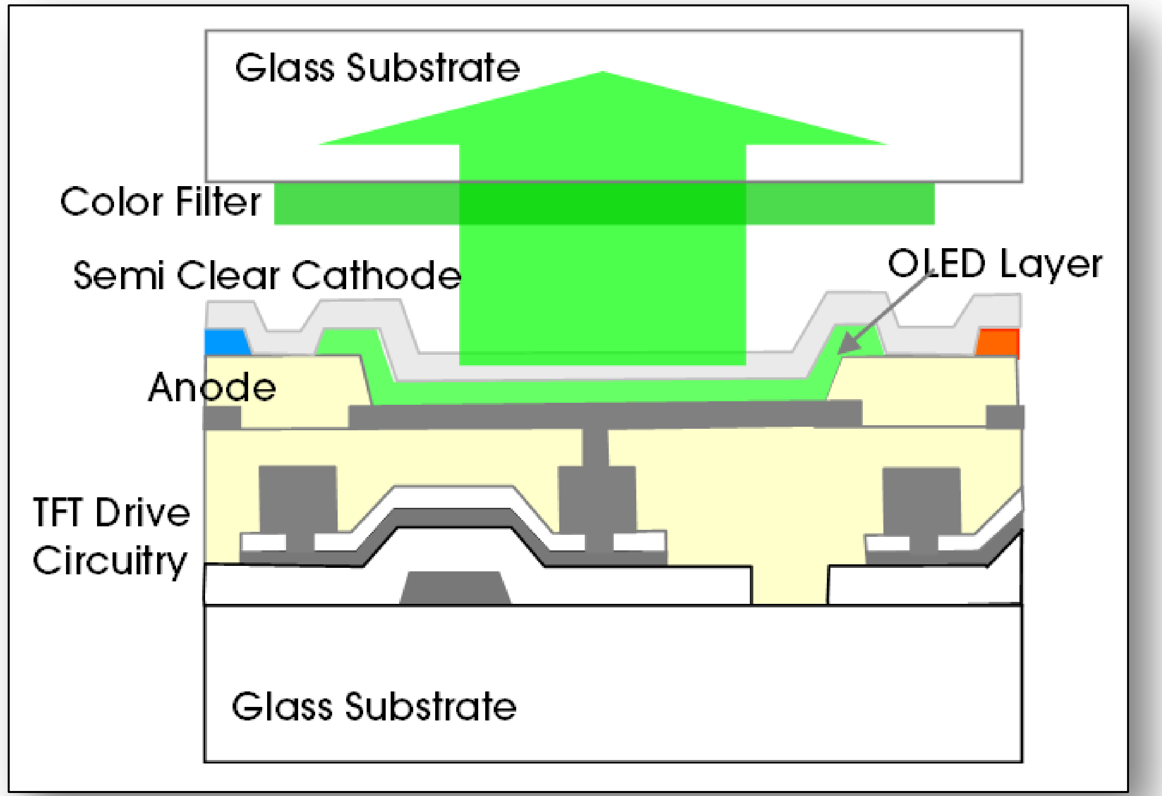


SONY

Architecture

- Bottom Emission
  - Limited aperture
  - Issues with driver density
  - More complicated driver fabrication
- Top Emission
  - Simpler driver design
  - Larger emission area
  - Much higher emission efficiencies

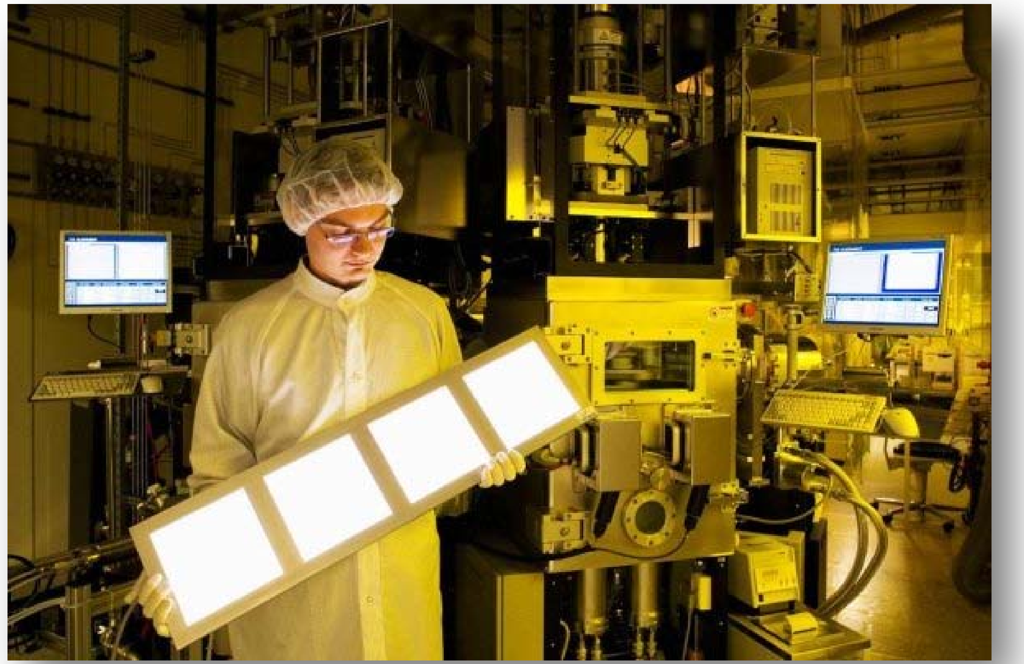




SONY

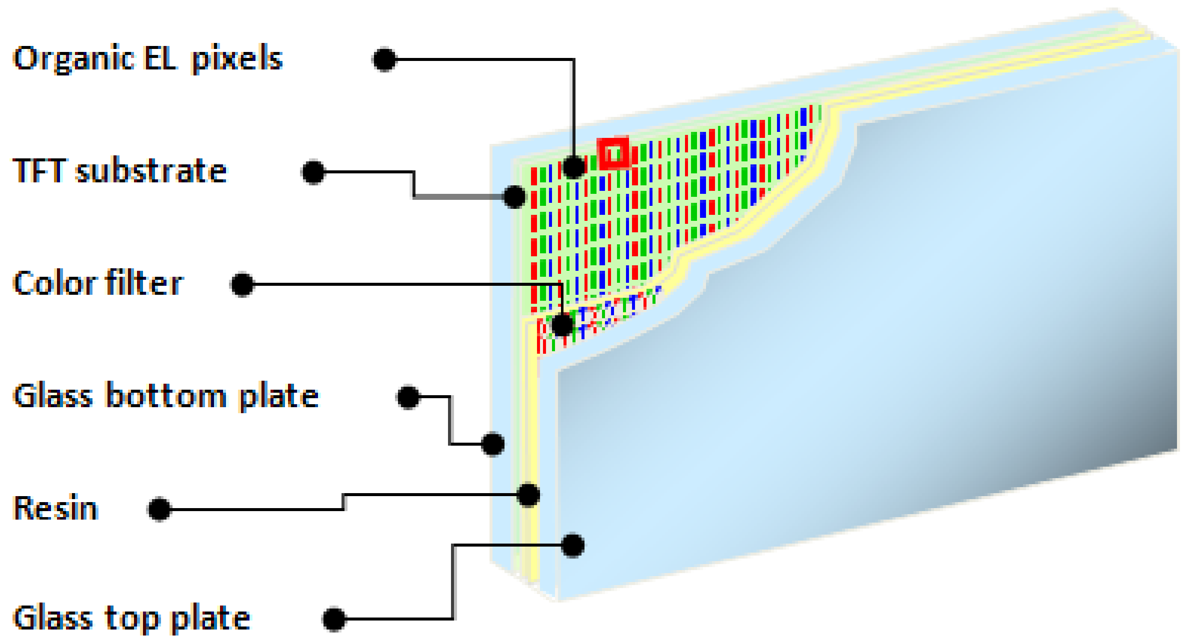
Types of OLED

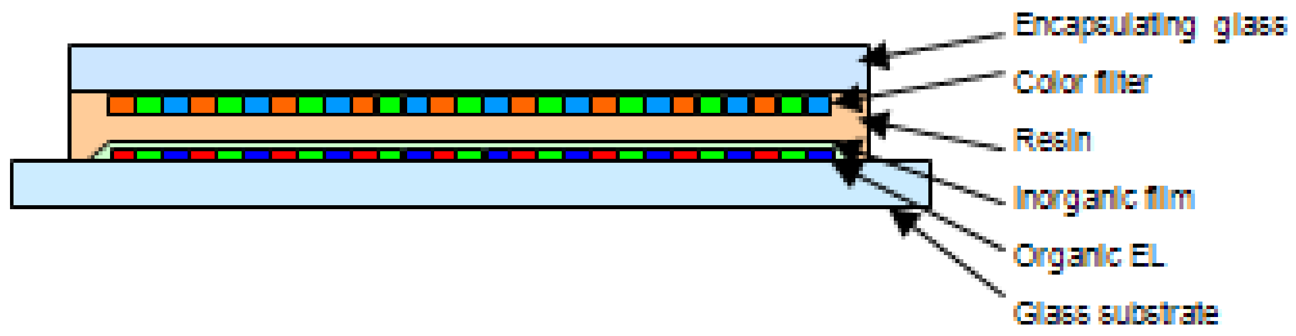
- TOLED
  - Transparent OLED
- SOLED
  - Stacked OLED
  - used for lighting
- P-LED
  - Polymeric based OLED
  - Flexible
- AMOLED
  - Active matrix displays

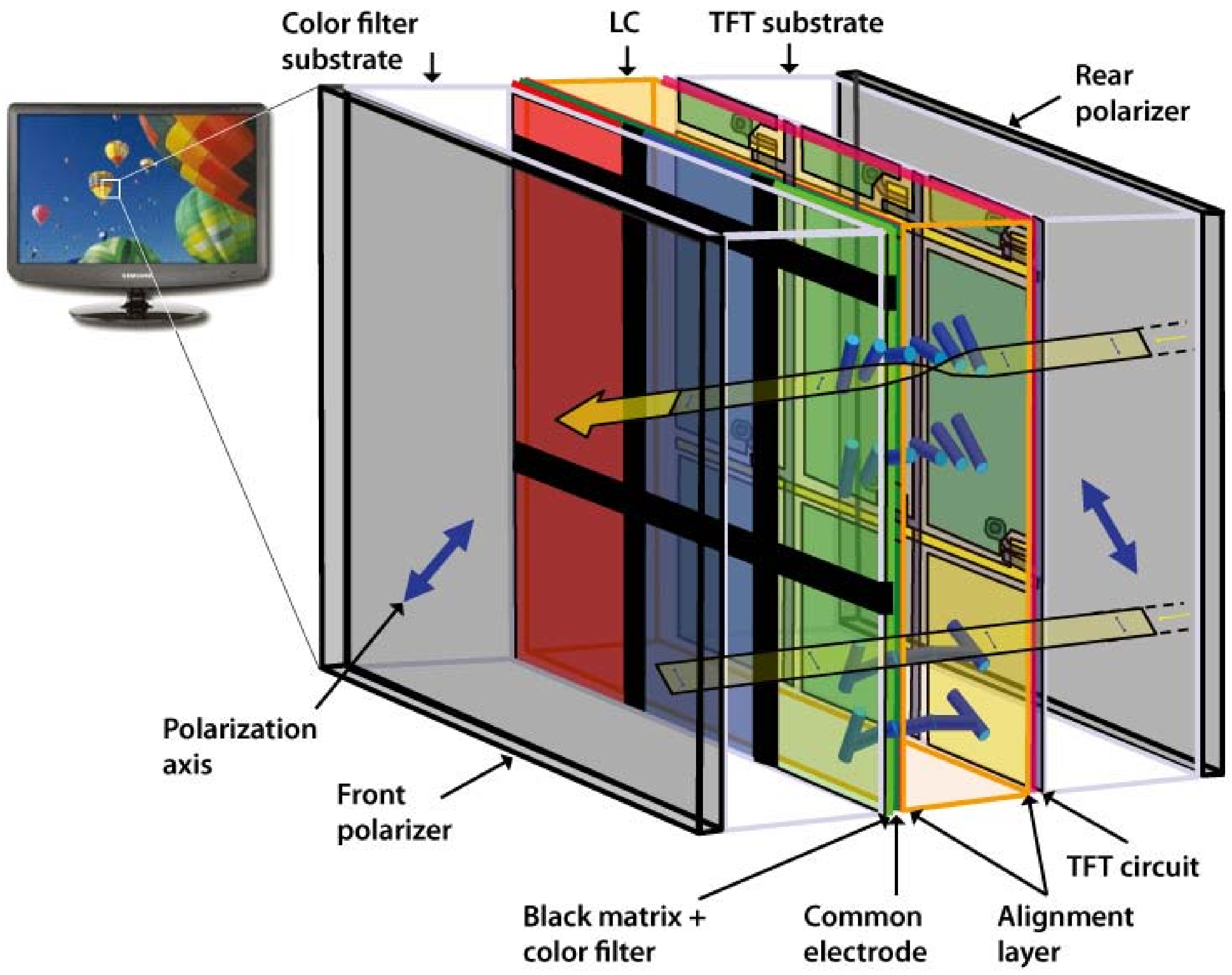


SONY

OLED compared to LCD

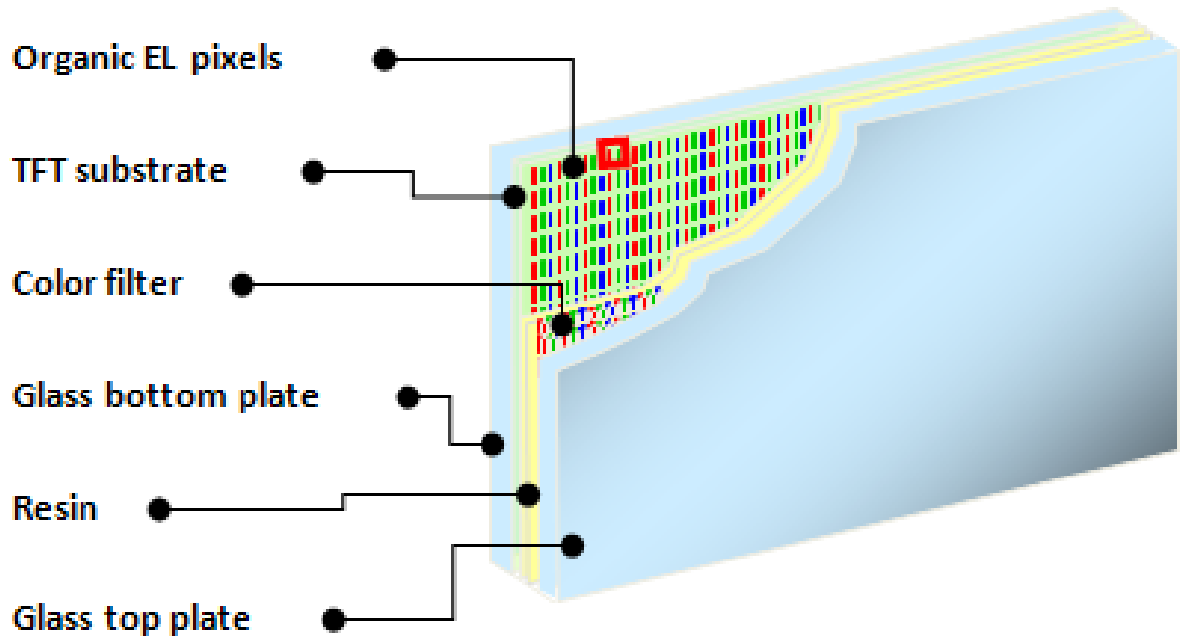


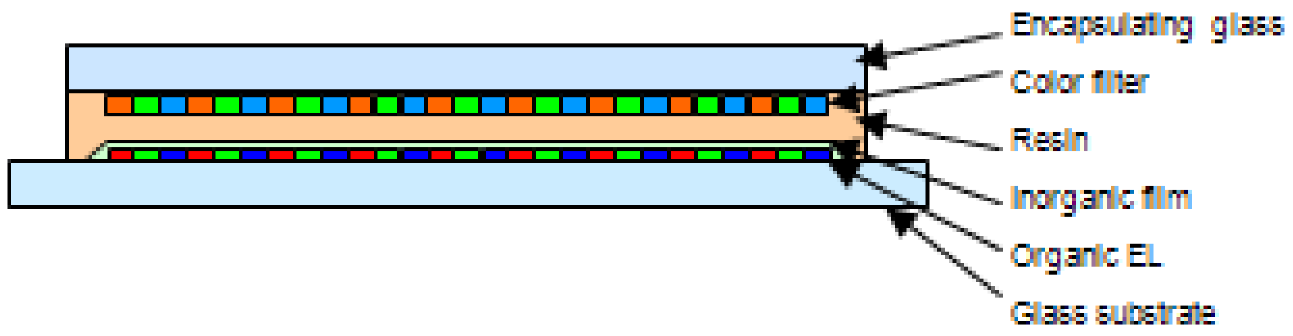


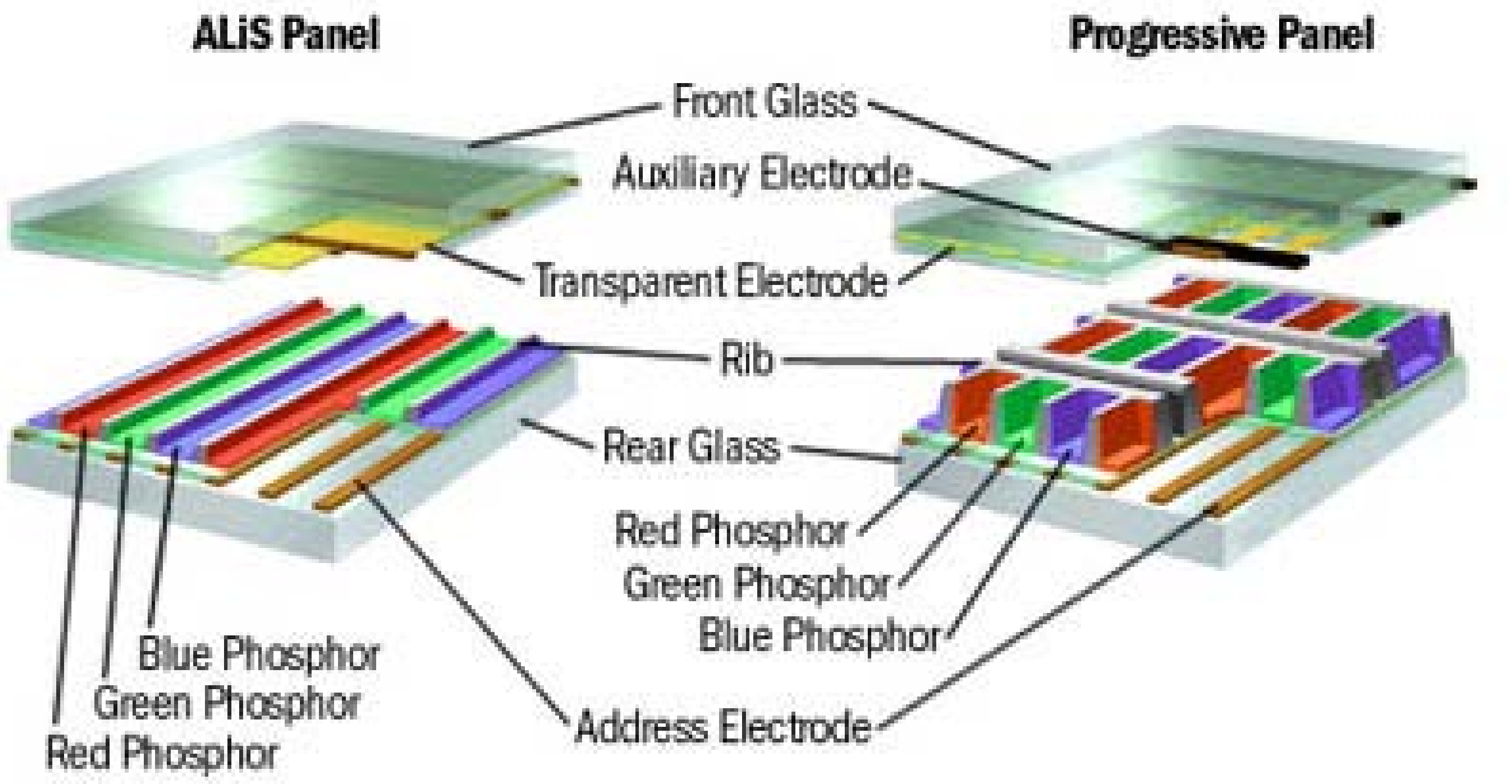


SONY

OLED compared to Plasma

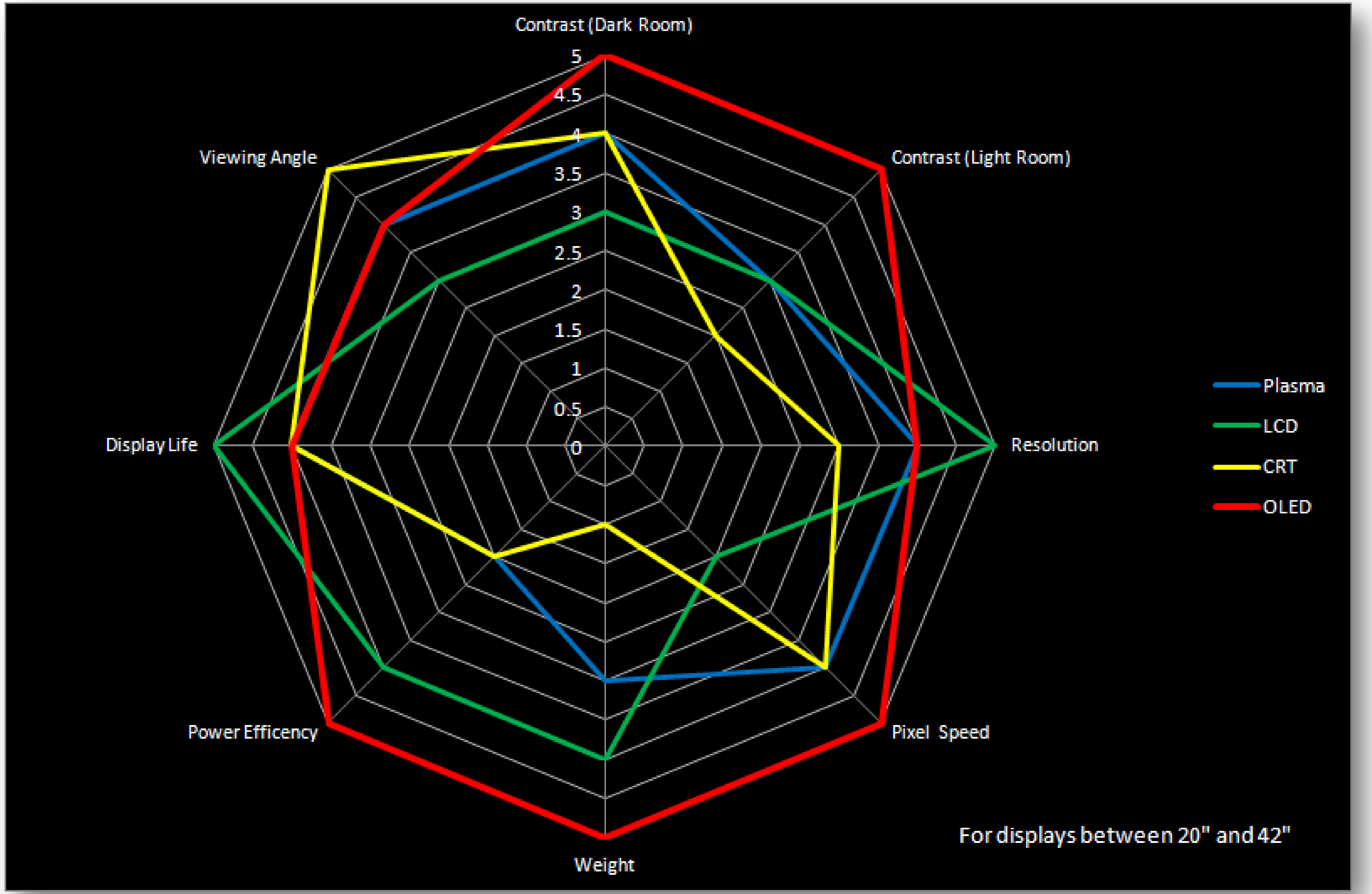






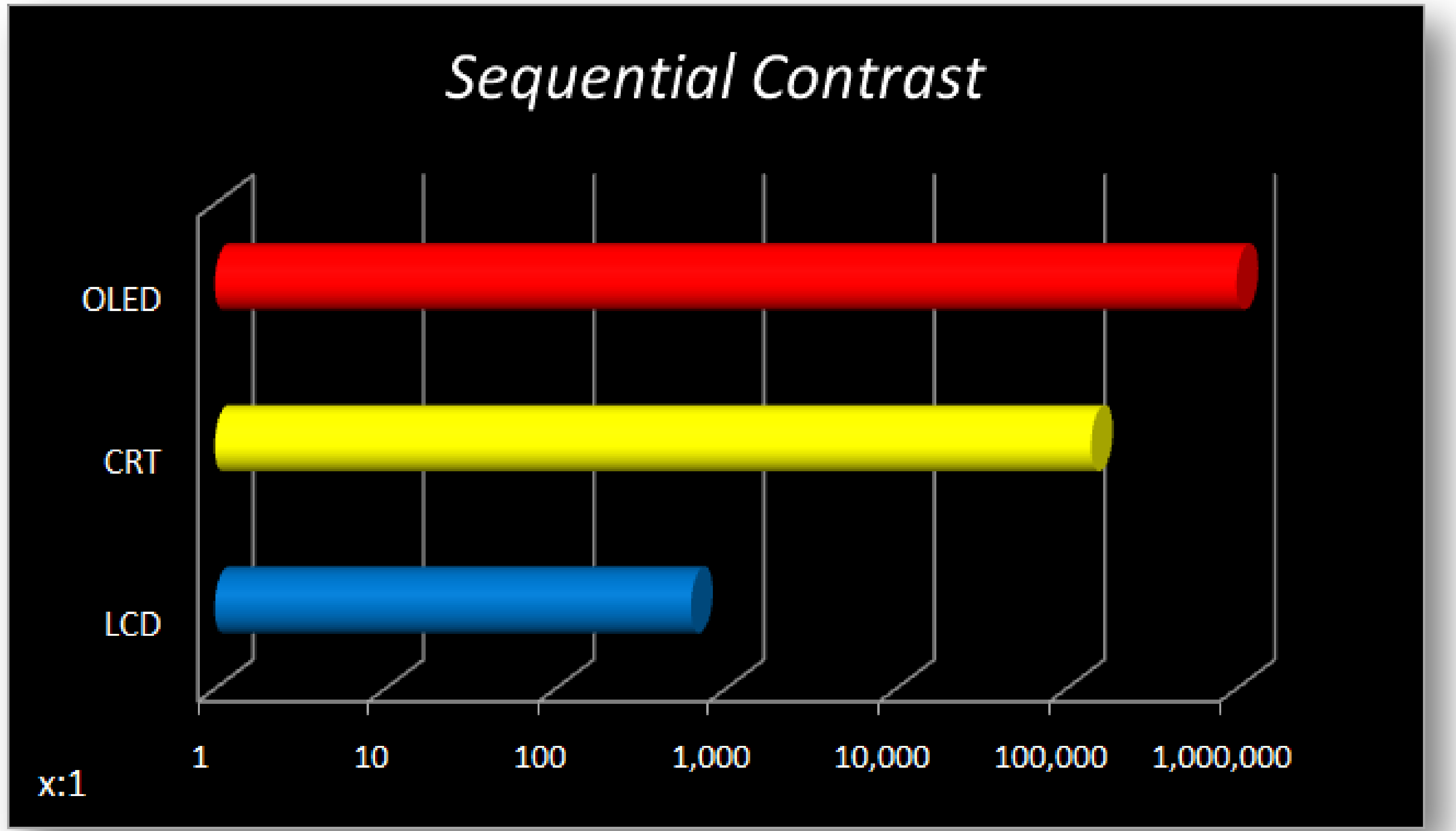
SONY

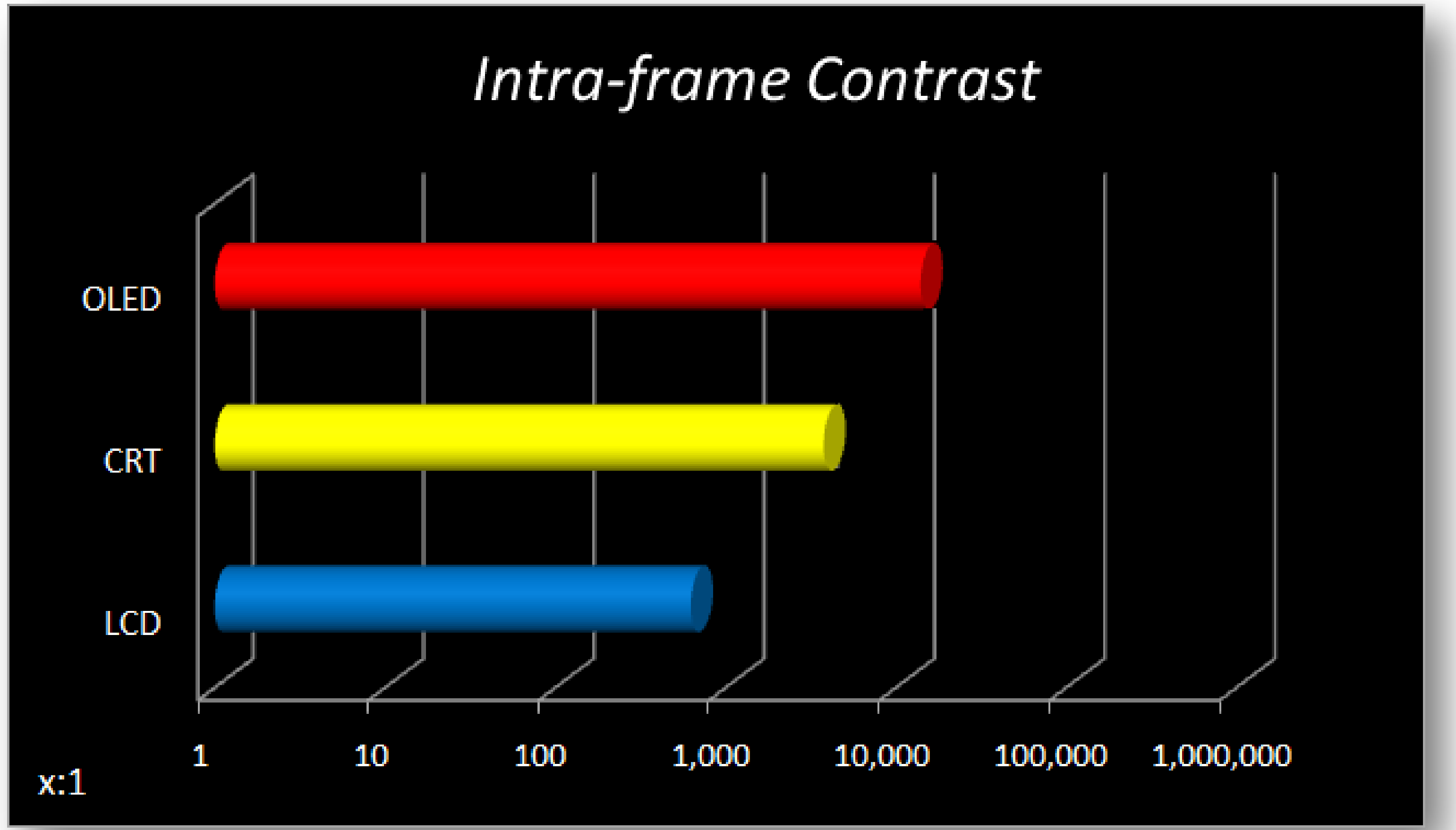
Advantages of OLED

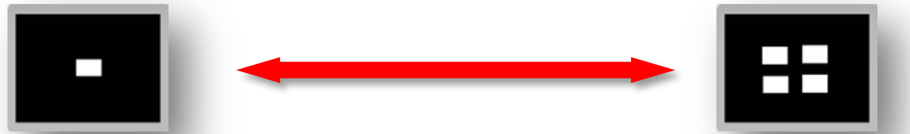


SONY

Advantages of OLED





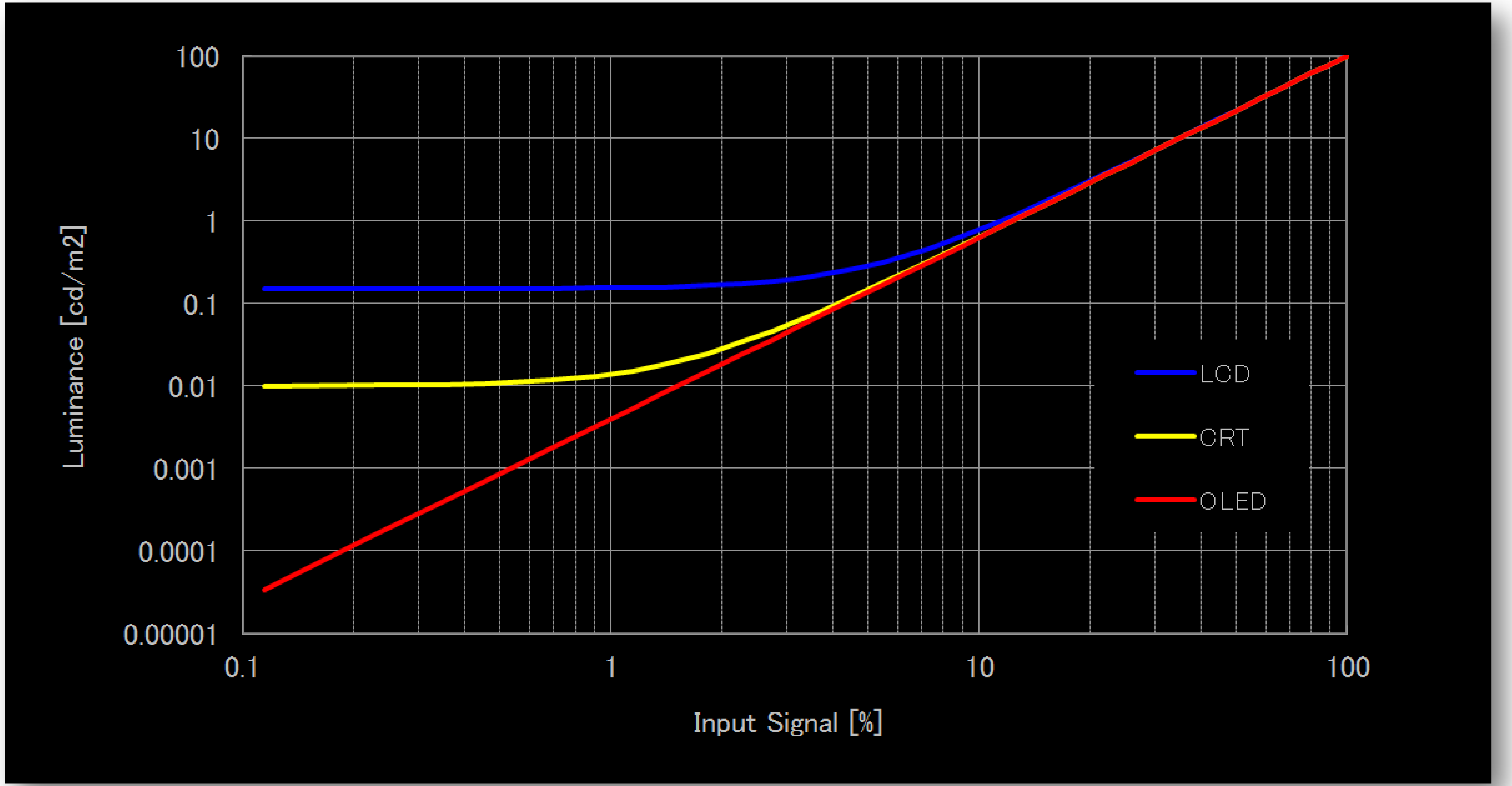


IEC 62341

Contrast Performance

SONY

Advantages of OLED



LCD

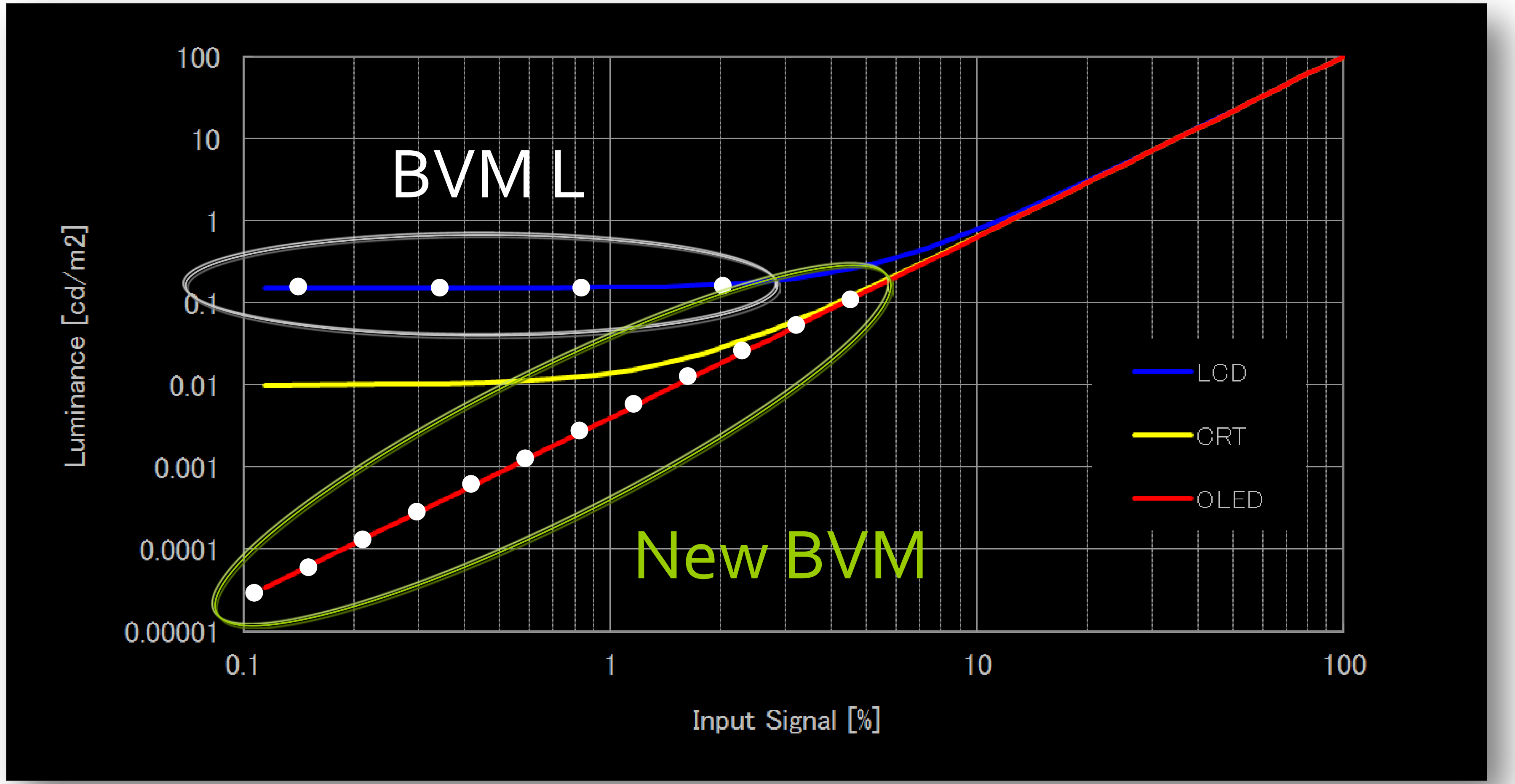
OLED

Black Performance

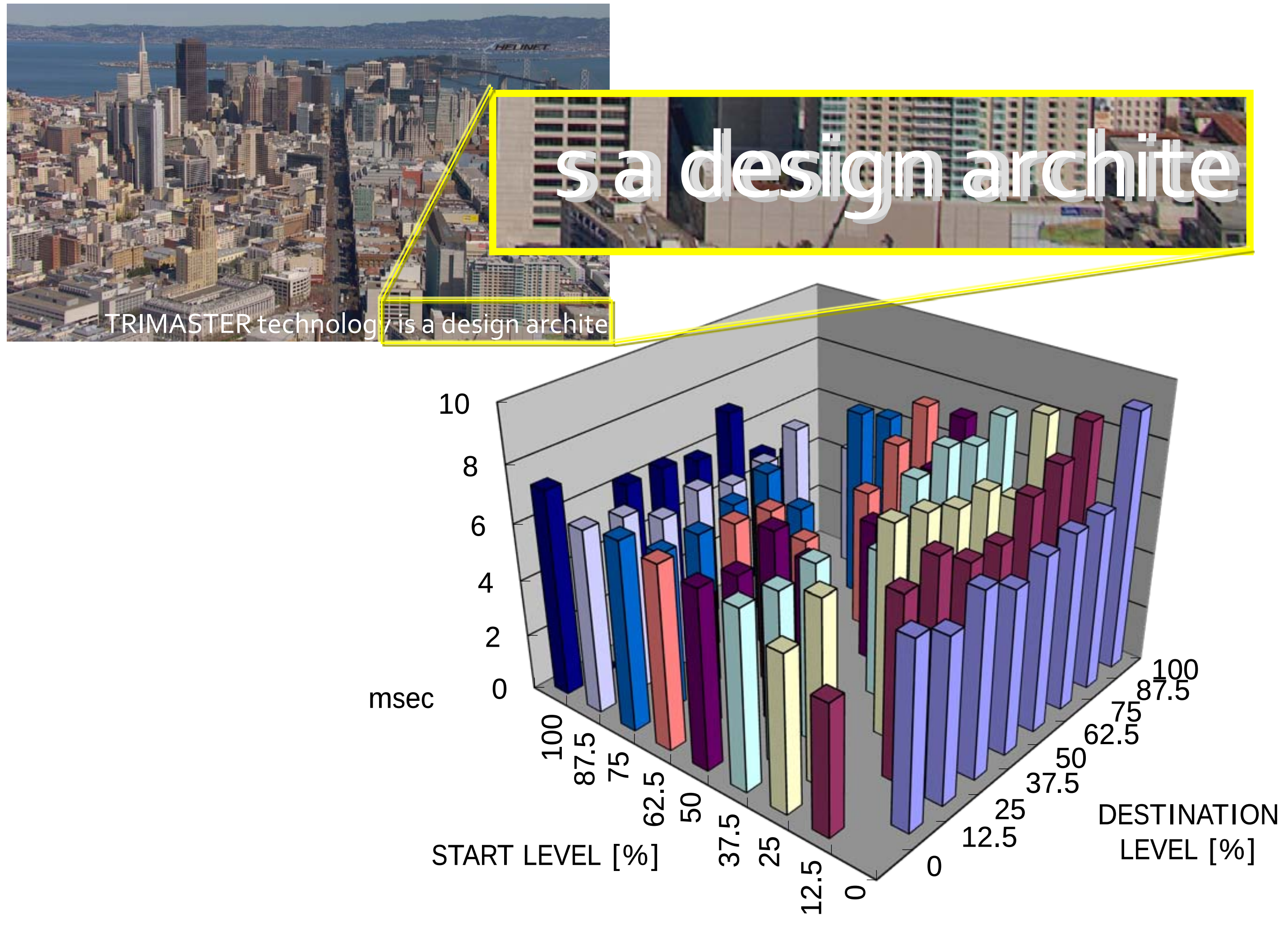
SONY

New Signal Processing

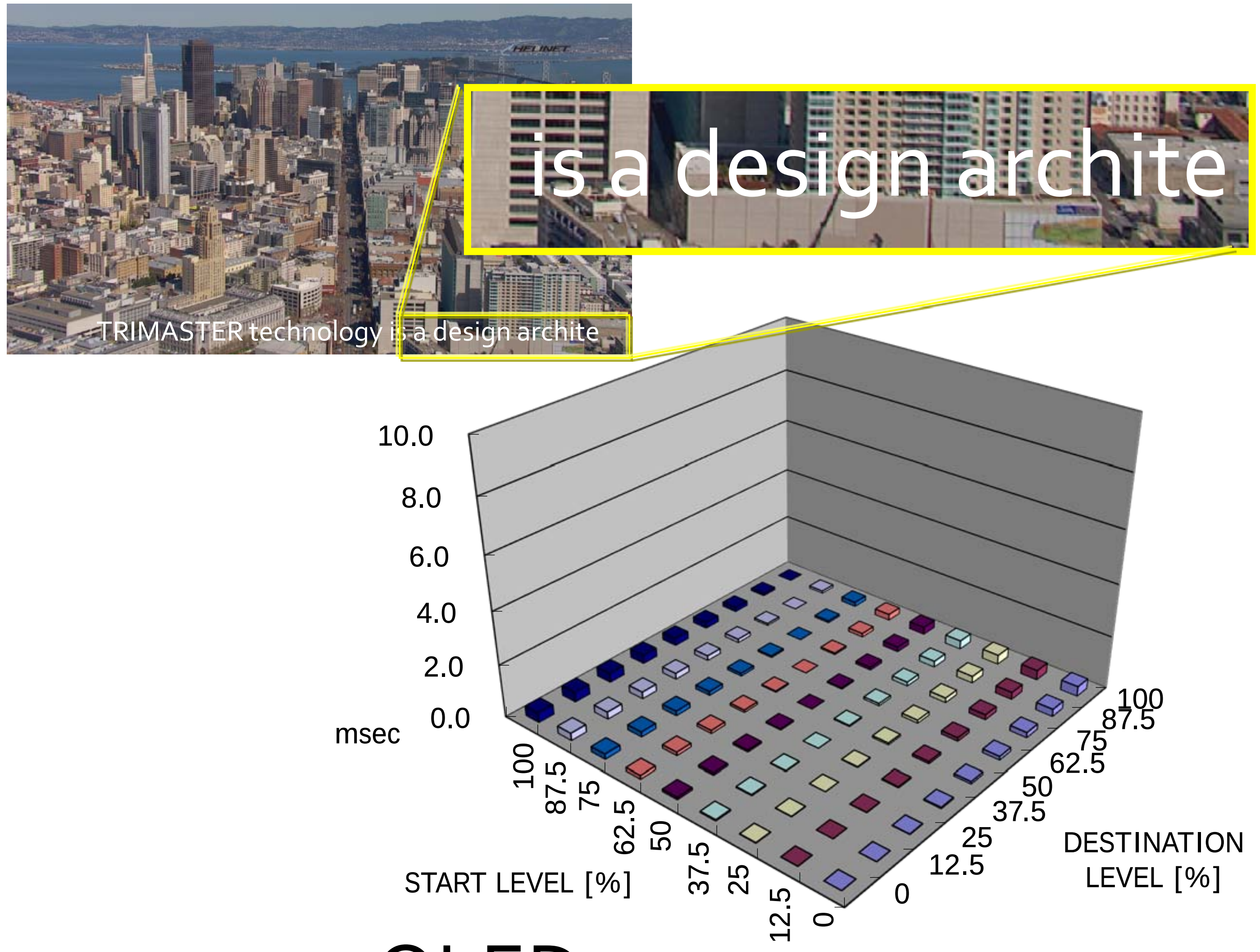
- Improved black accuracy
  - Increased process bit depth
- New uniformity correction system
  - 3 Dimensional correction
- More accurate color management system for CRT emulation
- New I/P Conversion system
  - Faster through-put from 11ms to 3ms for 1080/60i



Advantages of OLED



LCD



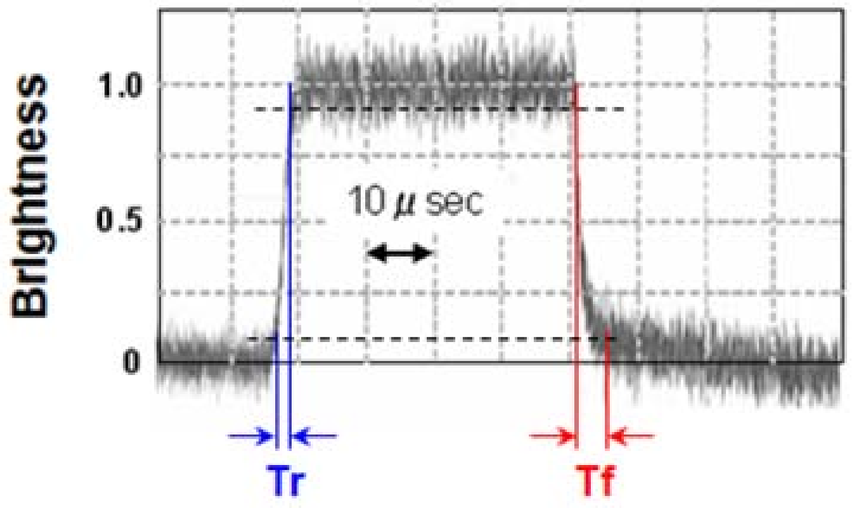
OLED

Pixel Speed

SONY

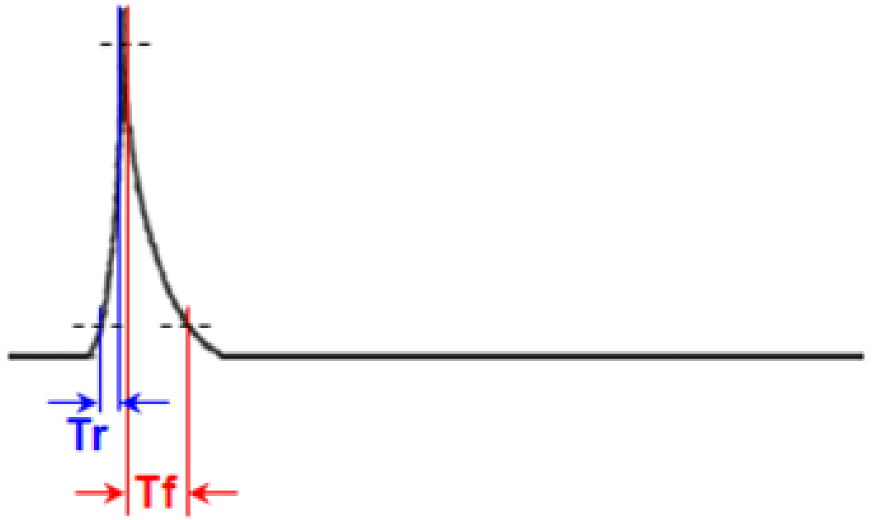
Advantages of OLED

OLED

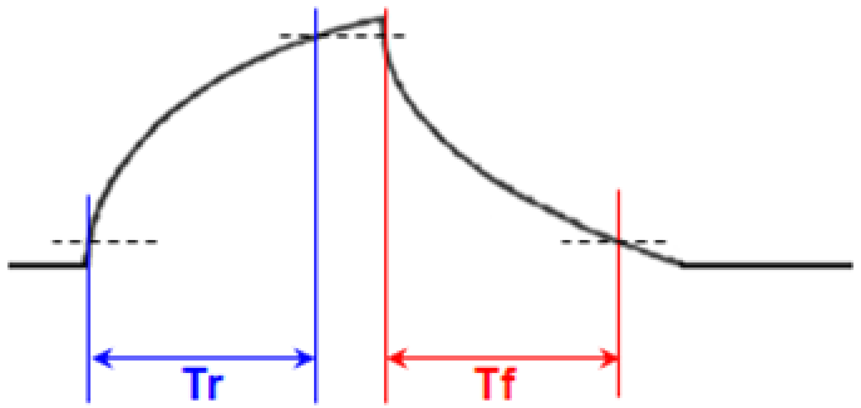


Response Time	Tr + Tf (typical)
OLED	6 us
CRT	Green/Blue: 100 us Red: 1 ms
LCD	12ms to 16 ms

CRT



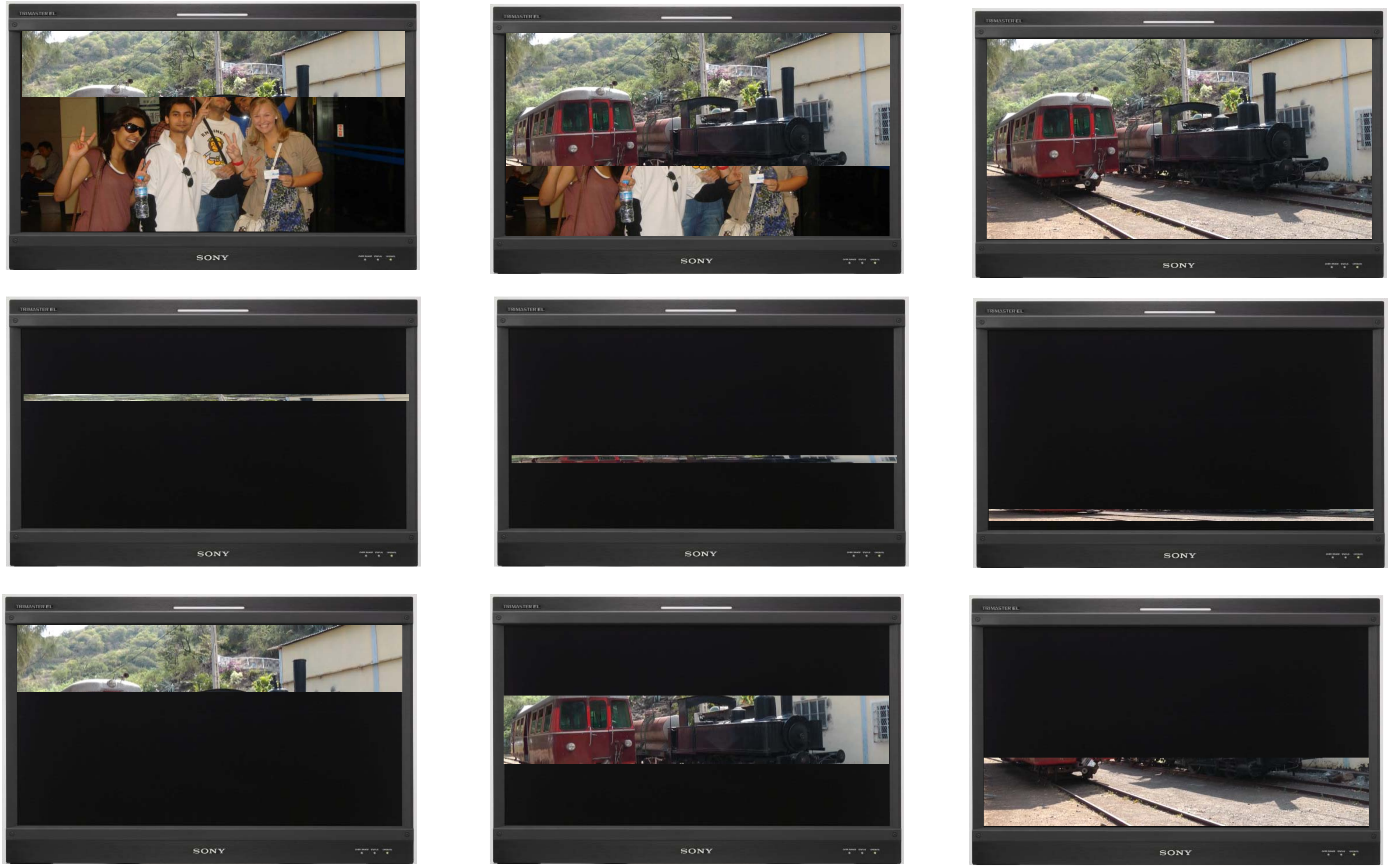
LCD



Pixel Speed

SONY

Panel Write Operation



LCD

Smearing issues
No flicker

CRT

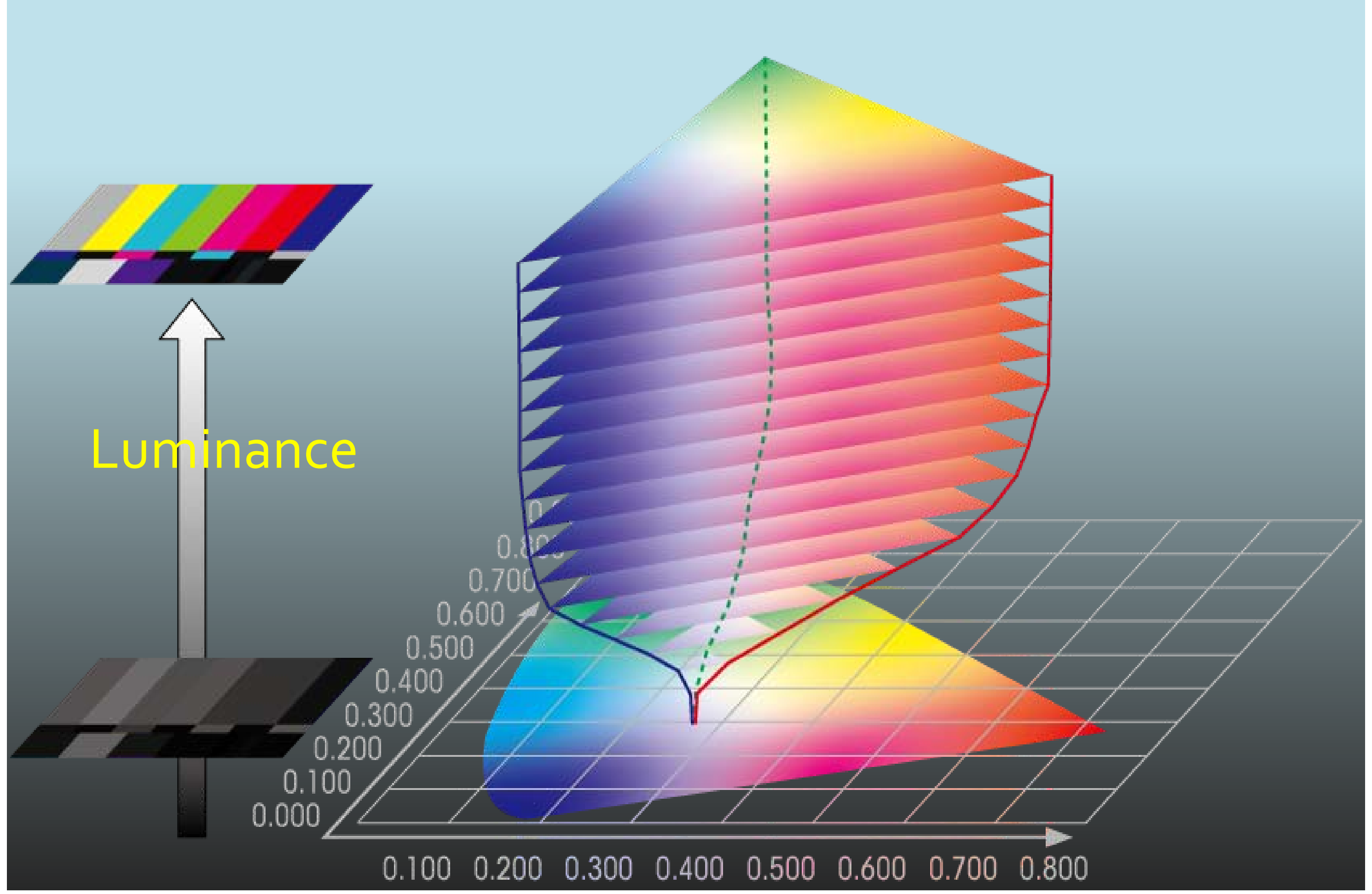
Good motion performance
Flicker

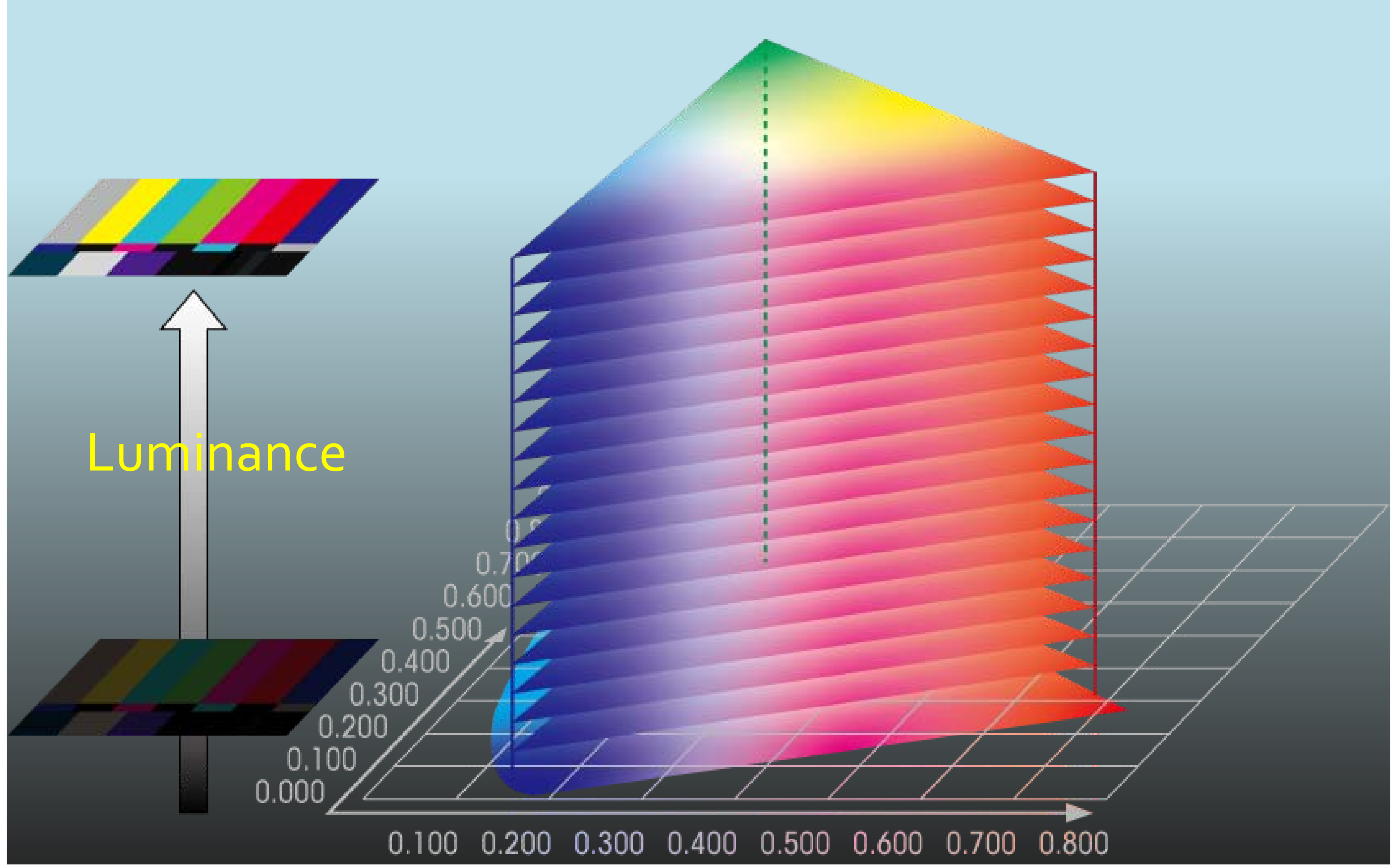
OLED

Balanced performance

SONY

Advantages of OLED





LCD

OLED

Gamut Accuracy

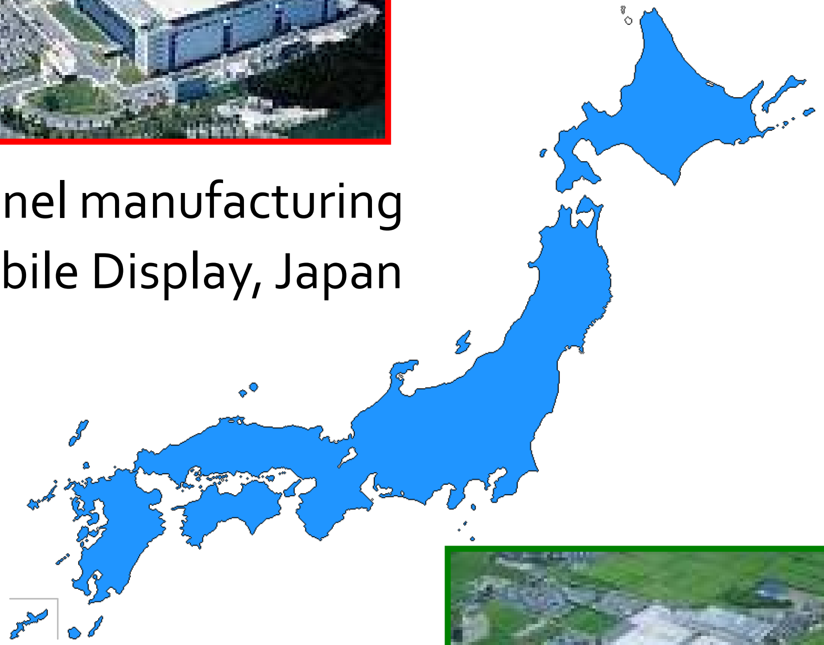
SONY

The Latest Panel Design

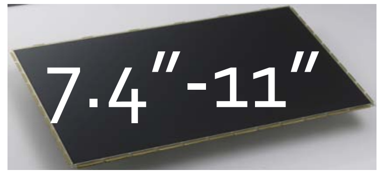
2009
- 7.4 & 11 inch volume production

2011
- 17 & 25 inch volume production

OLED panel manufacturing
Sony Mobile Display, Japan



Final product manufacturing
Sony EMCS Factory, Japan



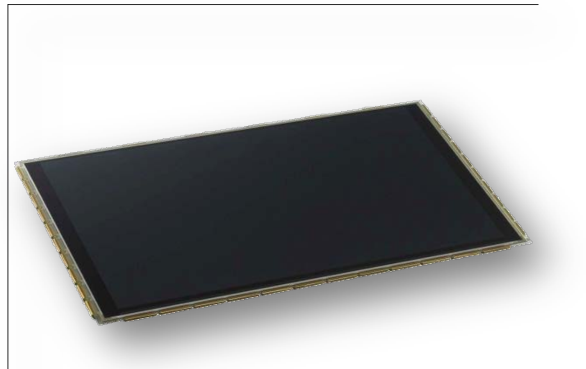
2009-2010

2011

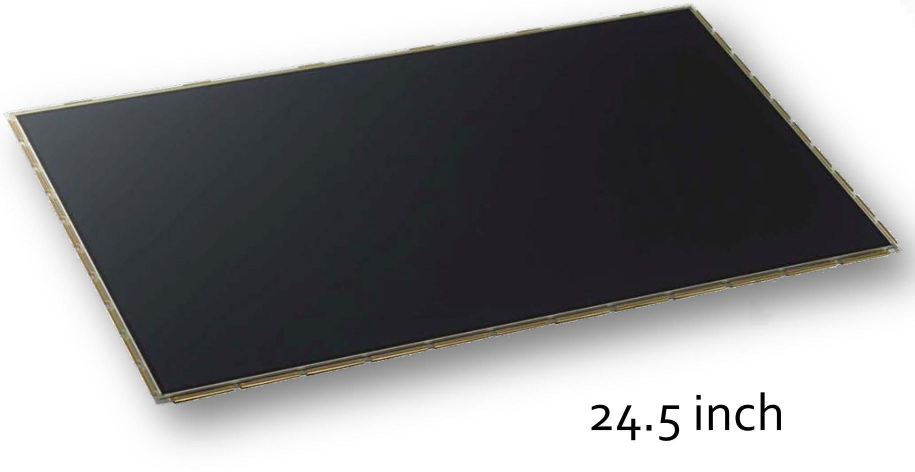
SONY

The Latest Panel Design

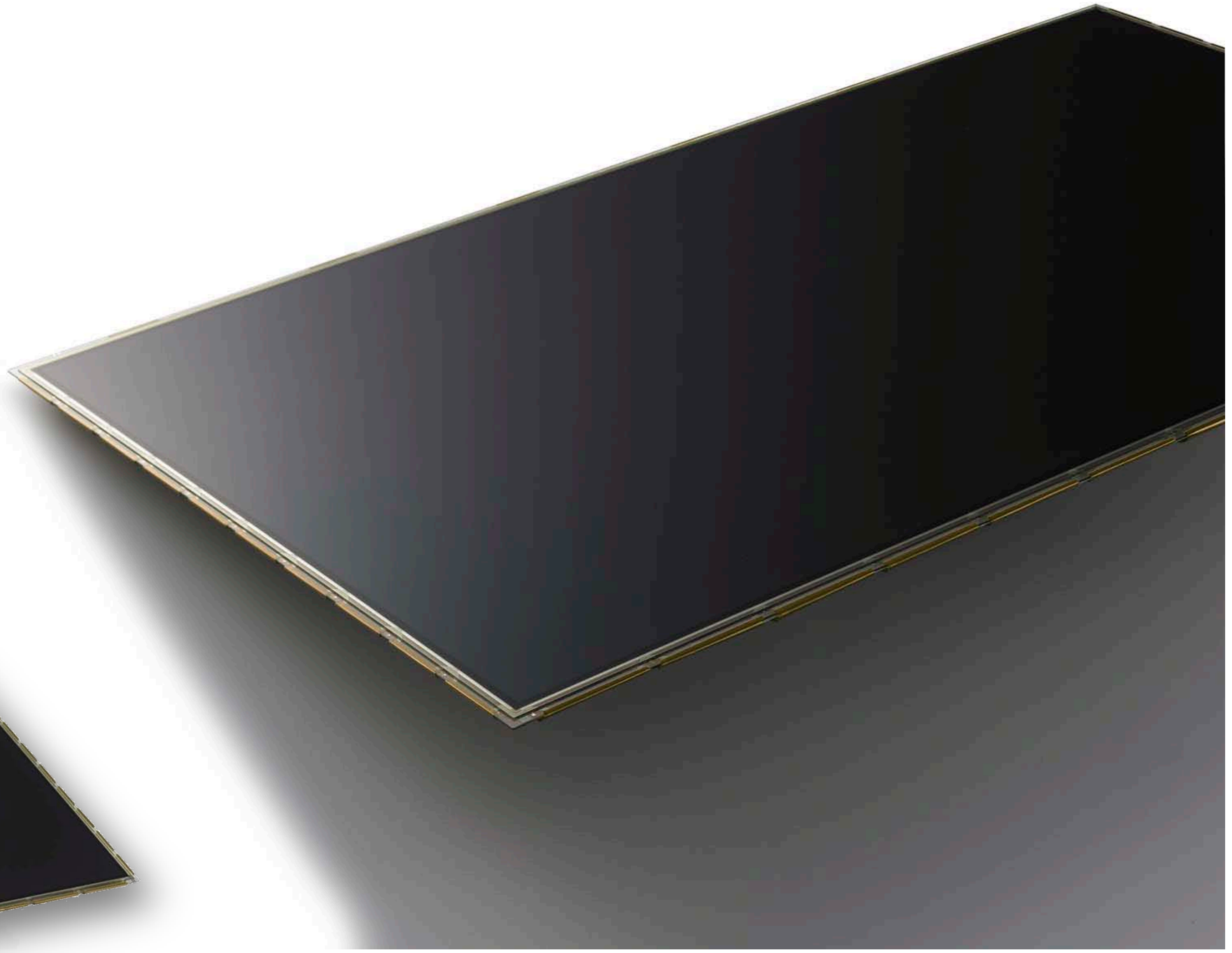
- 17 inch & 25 inch AMOLED panel
  - 16.5 & 24.5 inch diagonal
  - 10 bit drivers
  - 1920 x 1080 resolution
  - Top emission architecture
  - P3 color gamut
  - Panel life equal to BVM CRT



16.5 inch



24.5 inch



SONY

Mechanical Advantages

BVM E250
29 lbs.

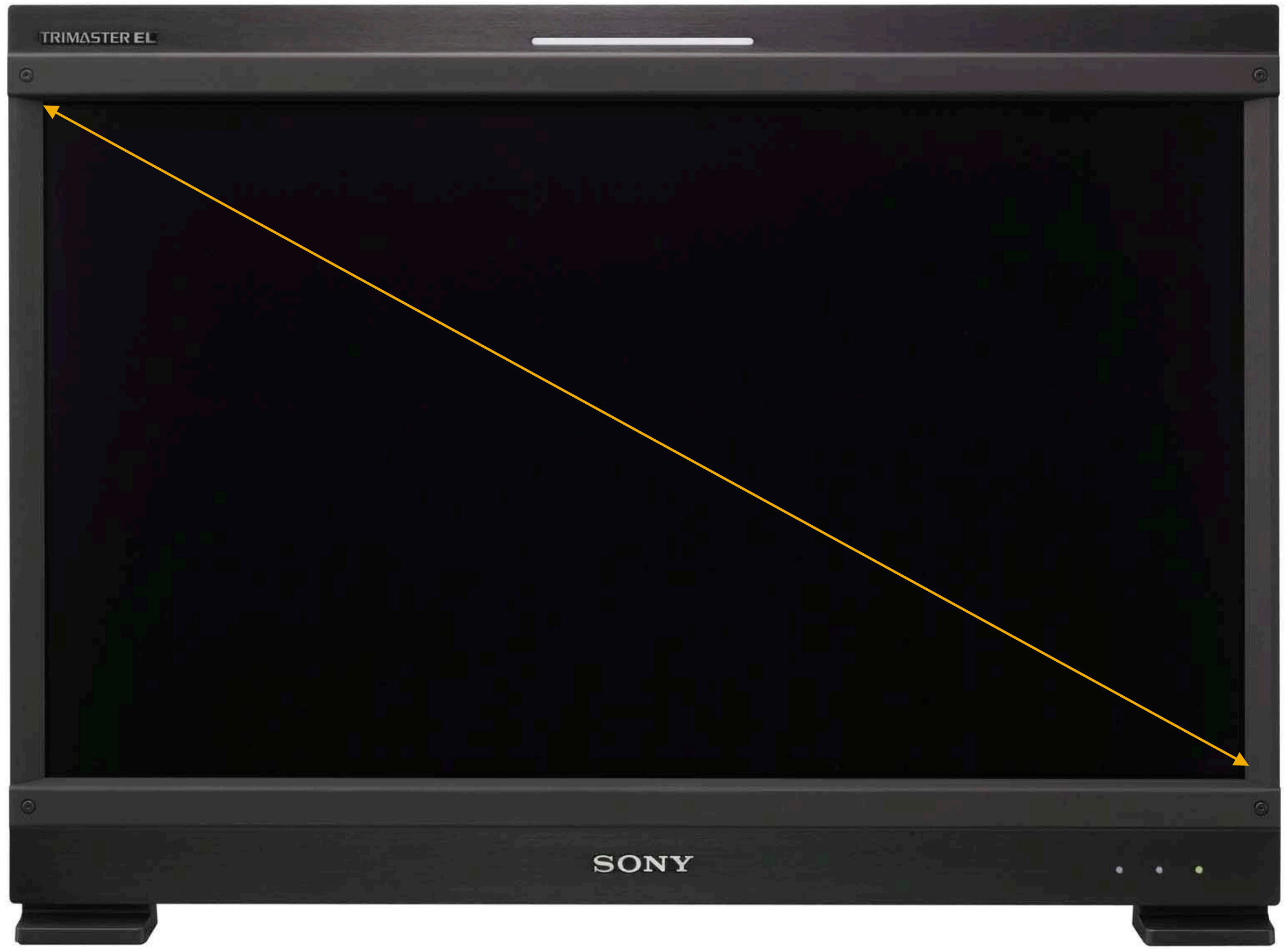
BVM L231
47 lbs.

SONY

Mechanical Advantages

BVM E250
25 inch

BVM L231
23 inch



22 ¾ inch

22 ¼ inch

Resulting Product Lineup

TRIMASTER EL

BVM E Series

SONY

Resulting Product Lineup

TRIMASTER EL

BVM F Series

SONY®

Resulting Product Lineup

TRIMASTER EL

PVM Series

SONY