ENABLING FLEXIBLE DISPLAY TECHNOLOGY

Barix Multilayers: a Water and Oxygen Barrier for Flexible Organic Electronics

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Organic Electronics
Is the Future of Electronics Organic?
MIT·Stanford·UC Berkeley Nano Forum

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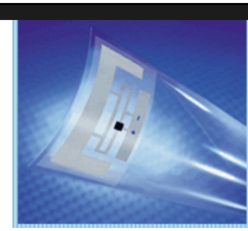
Flexible Organic Electronics

- There is not only an important future of electronics in organics, but much of that future will be **flexible** as well :

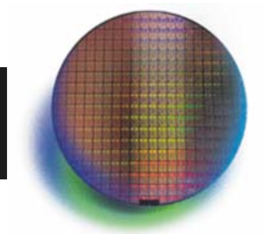
- Drivers:
  - Flexibility and form variety of applications
  - Thin, light weight and unbreakable
  - Cheaper materials
  - Large area, cheaper processes: R2R, printing techniques

Applications of Organic electronics

Smart Labels or ID Tags

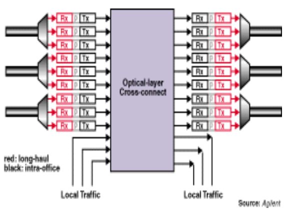


Integrated Electronics

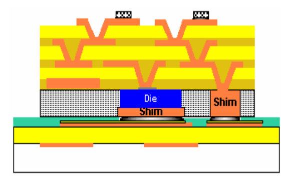


Flexible Batteries

Optical Network



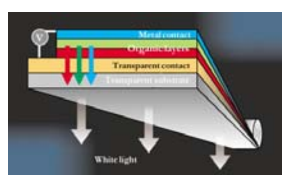
Smart Card



HDI

Digital Imaging

Display



Solid State Lighting

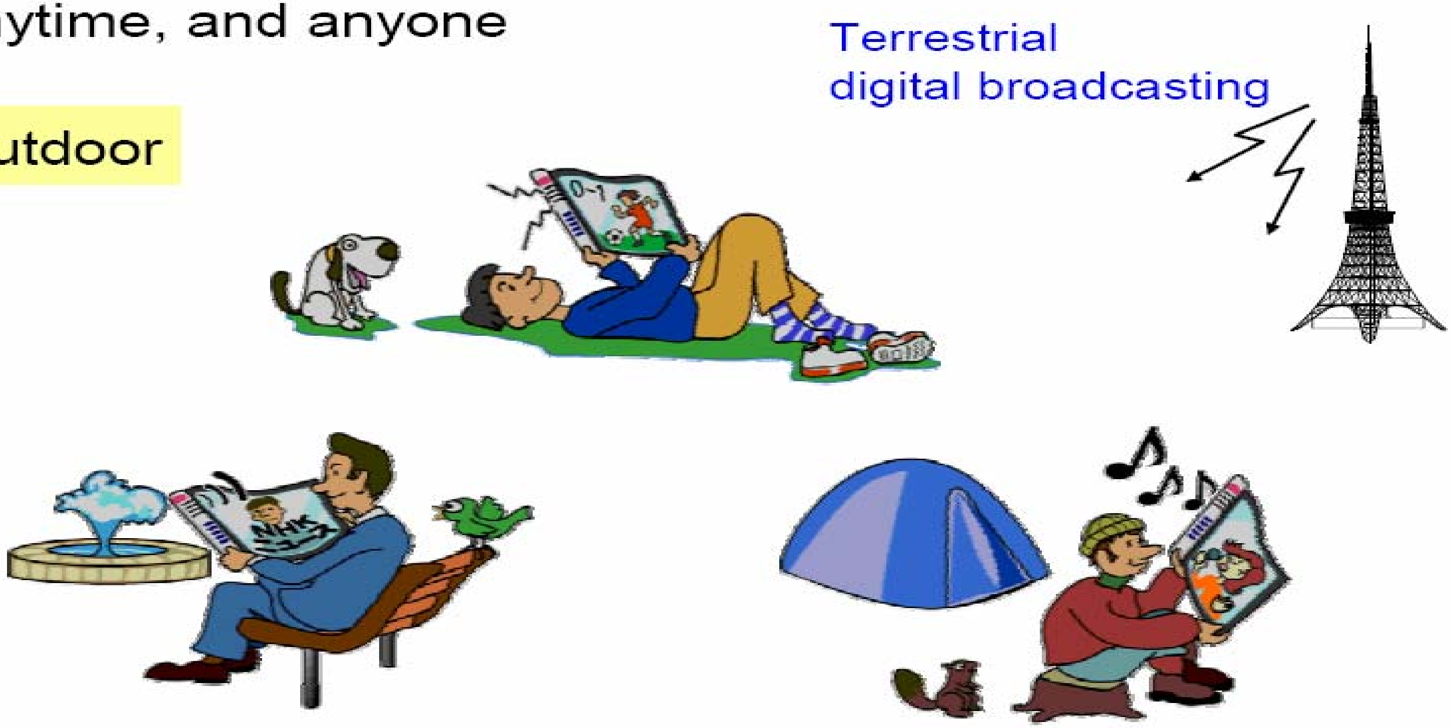
Photovoltaics

Flexible OLED display (NHK)

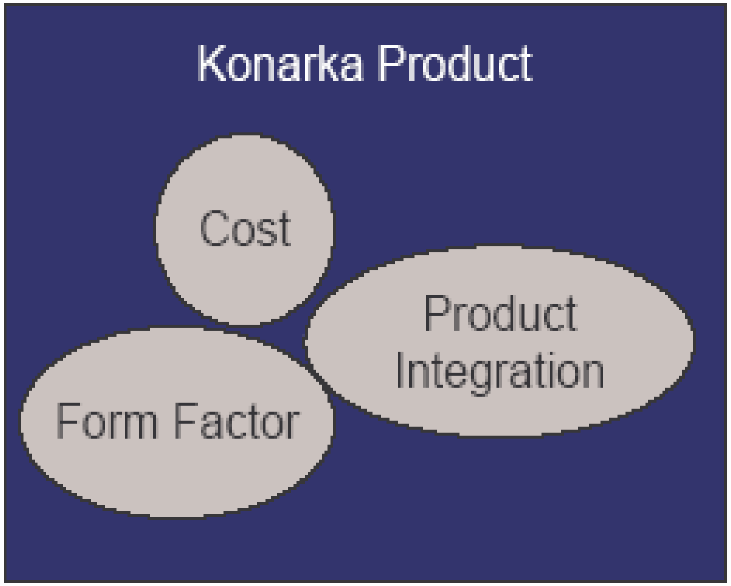
Prospects

- Barrier-free service for anywhere, anytime, and anyone

Outdoor



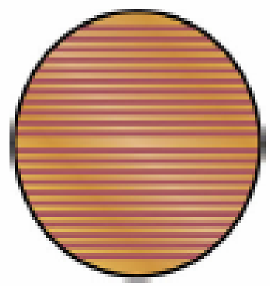
Flexible Solar cells

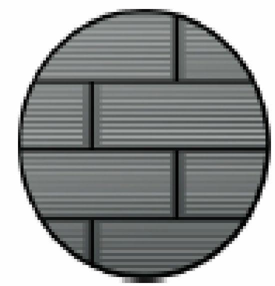


Cost: 1/3 of traditional solar

Form Factor:

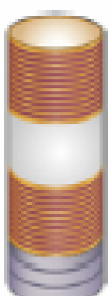
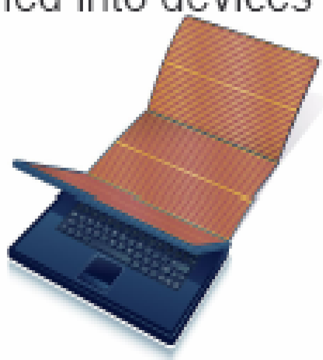
Power to Weight- 10x of traditional solar
Thickness- 100x thinner than traditional solar
Flexibility- conformable to 2 cm diameter
Aesthetic- patterns, images and colors

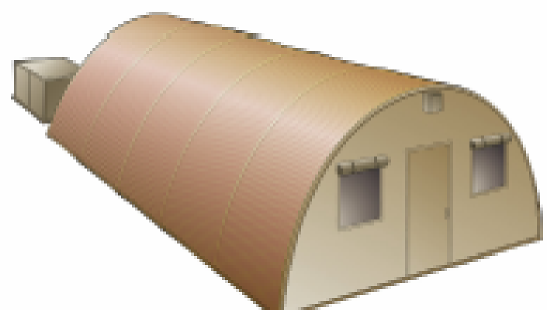
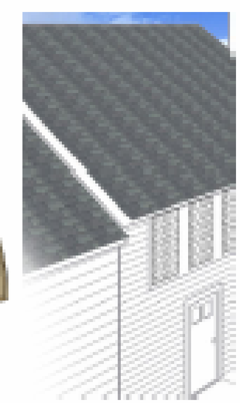




Product Integration:

Designed into devices systems, and structures

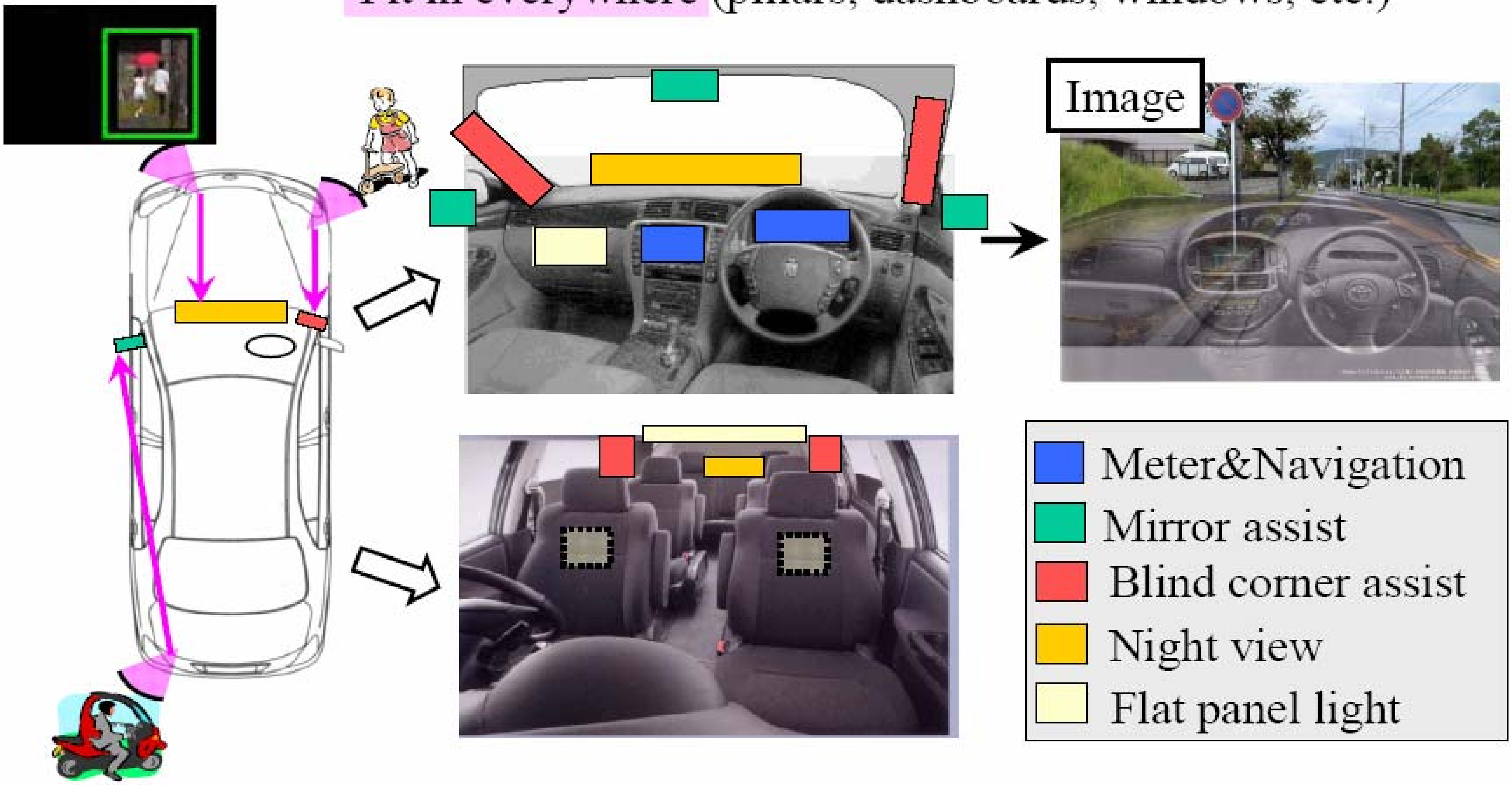



Displays and Lighting for automotive (Toyota)

Application of flexible OLED displays to automobiles

Good visibility, Quick response, Wide viewing angle,
Fit in everywhere (pillars, dashboards, windows, etc.)



The disadvantages of using plastics:

- Need low temperature processes: <100~200 C
- Higher thermal expansion coefficient, lower dimensional stability then f.i. glass.
- Substrates are not flat and have many defects
- Plastics are highly permeable for water and oxygen and offer little protection for electronic components

- **Barix multilayers offer a solution for the last two problems**

Permeability and lifetime of devices

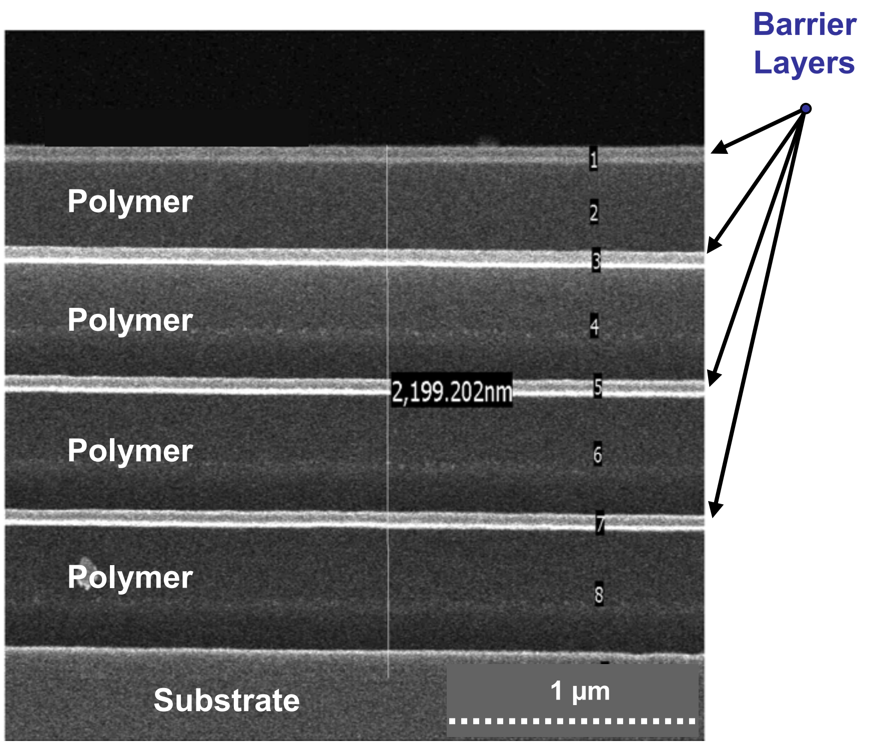
- A typical plastic film has a permeability for water (WVTR) of **1~10 gr/m²/day**

- **WVTR Needed for ~10 yr device lifetime:**
  - **Organic LED** **10^{-6} gr/m^2/day**
  - Solar Cells 10^{-4} gr/m^2/day
  - LCD 10^{-3} gr/m^2/day
  - Electroforetic displays 10^{-2} gr/m^2/day
  - RFID tags 10^{-2} gr/m^2/day

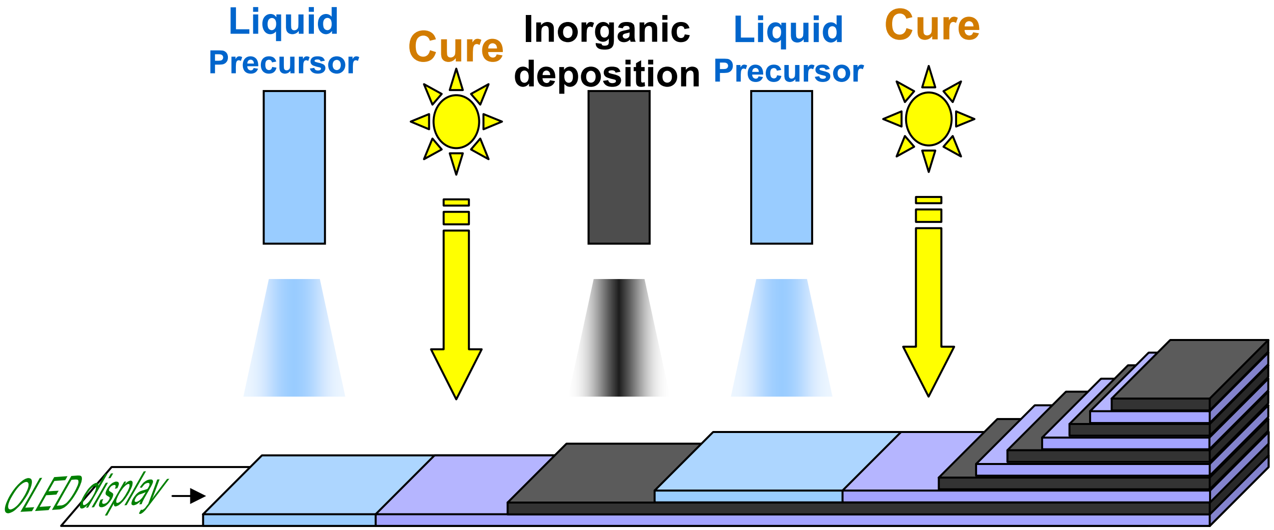
- Permeabilities and requirements for Oxygen are very similar

Barix™ Multilayer Encapsulation

- **Multilayer**
  - Redundancy
  - Tortuosity
- **Organic/Inorganic**
  - Organic:
    planarization/smoothing
  - Inorganic:
    barrier to H_2O and O_2 penetration
- **Transparent**
  - Suitable for top-emitter
  - Flexible substrates
- **Low Temperature:**
  - Suitable for organic electronics



Barix™ Multilayer Deposition

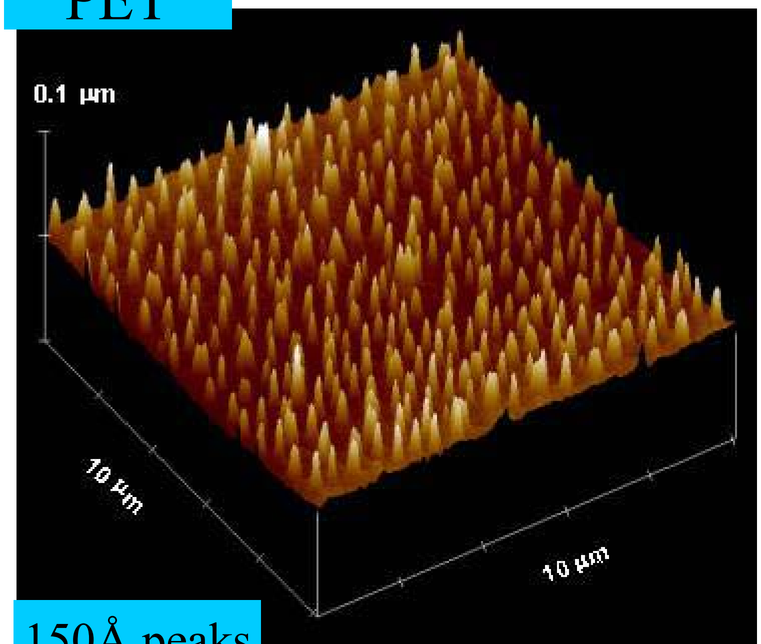


- **Inorganic:**
  - Aluminum oxide deposited by DC reactive sputtering
  - Thickness 30-100 nm
- **Organic:**
  - Monomer mixture deposited in vacuum
  - Non-conformal deposition: Liquid-Vapor-Liquid- (UV curing)-Solid
  - Thickness 0.25 – several μm
- **4-5 polymer / inorganic pairs (dyads) for encapsulation**

Creating defect free surfaces

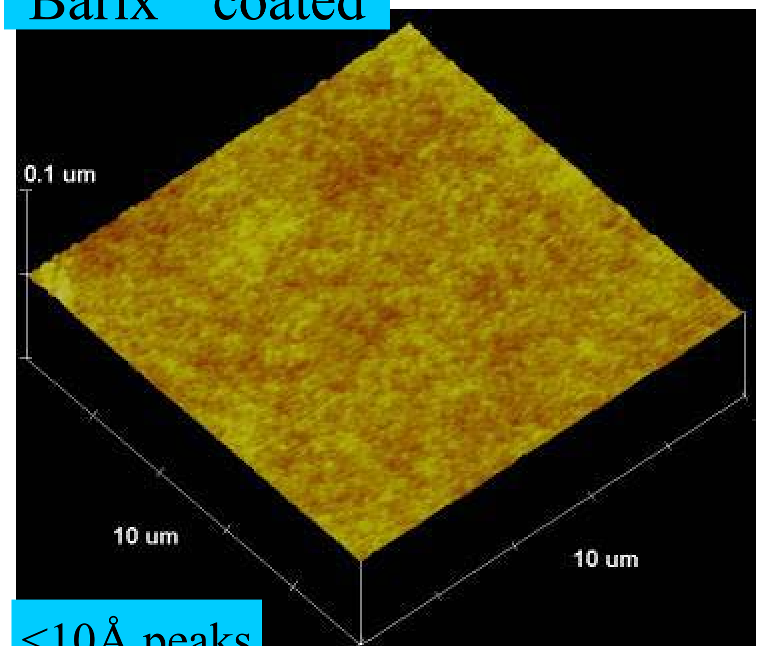
Atomic force Microscope reveals defect sites are eliminated

PET



150Å peaks

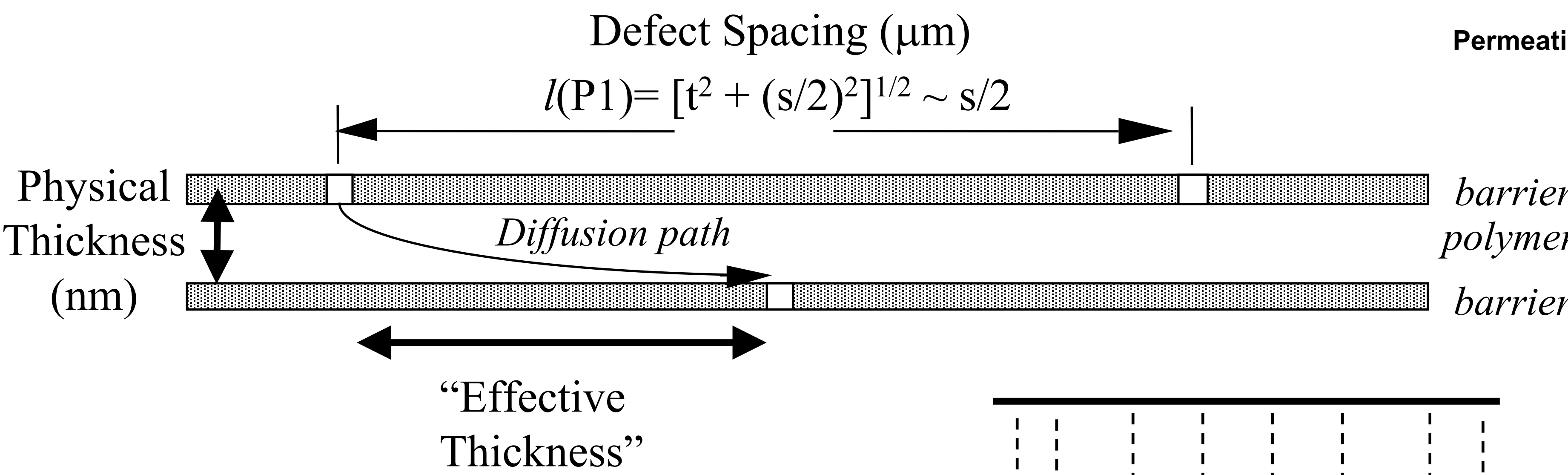
Barix™ coated

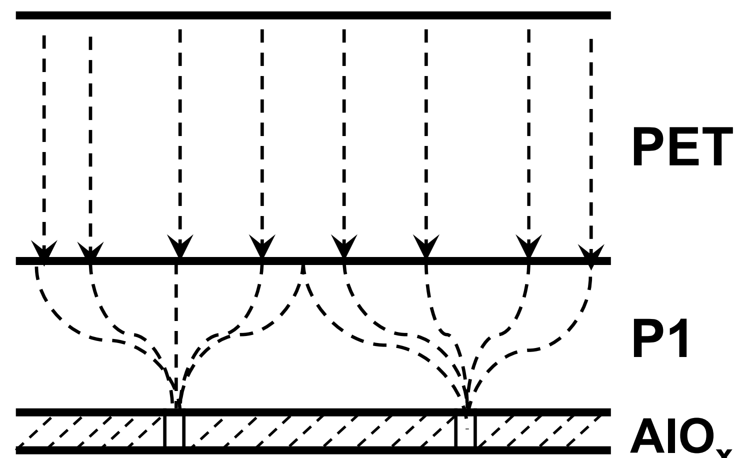


<10Å peaks

How does the multilayer barrier work?: The Role of Defects in diffusion

Permeation

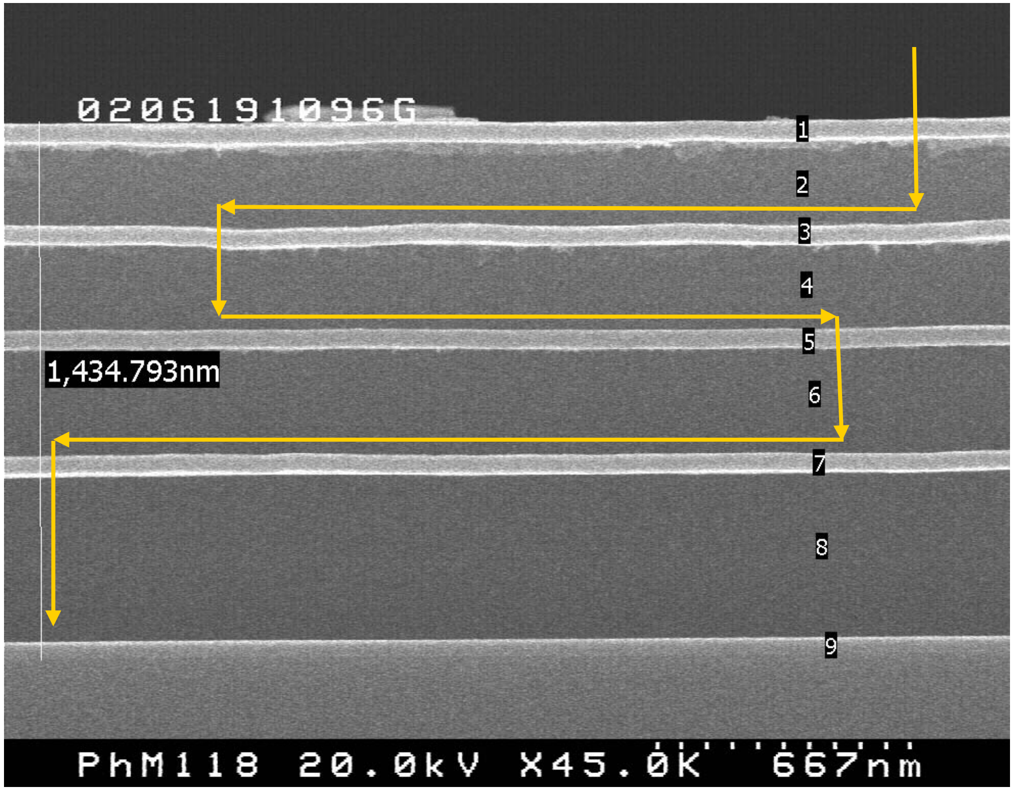




-diffusion of gas in x-y plane dominates

-results in extremely long "effective" diffusion path

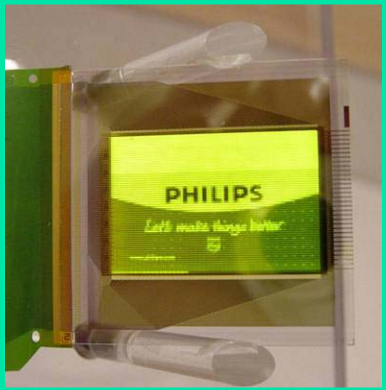
Barrier Mechanism: mainly a lag time effect



Extremely long "Effective" diffusion path length due to large spacing between defects in AlOx layers

Vitex's Path

Today → **Tomorrow**



Encapsulation process of rigid OLED displays

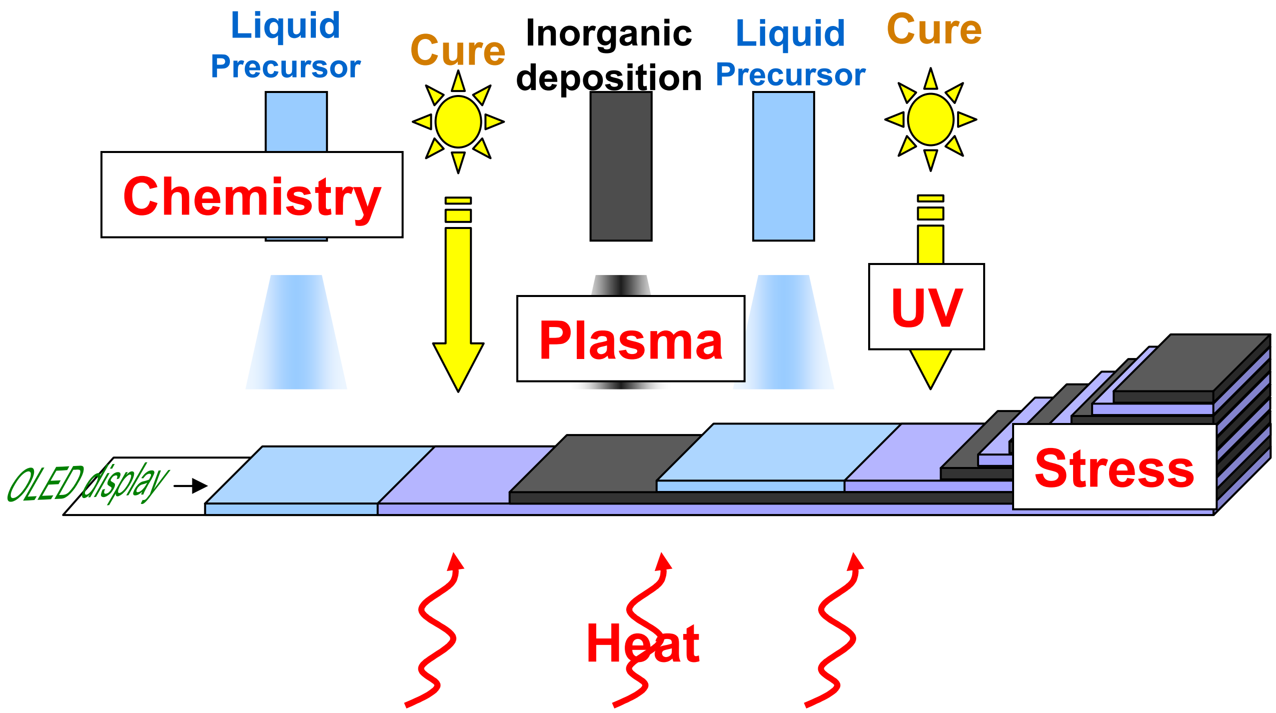
Transparent barrier substrate for flexible displays

Full substrate/packaging solution for flexible plastic displays

Encapsulation of OLED displays on a glass substrate

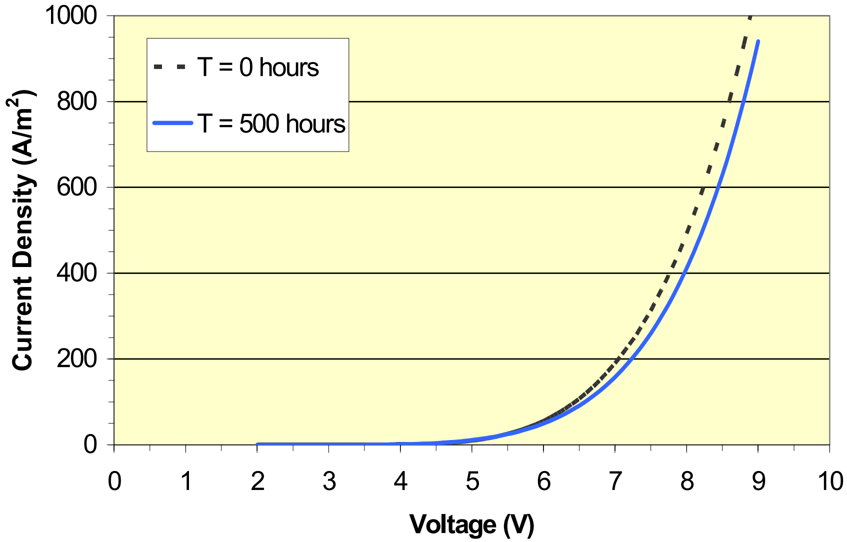
Status: Barrier layers on OLED displays meet telecommunication requirements

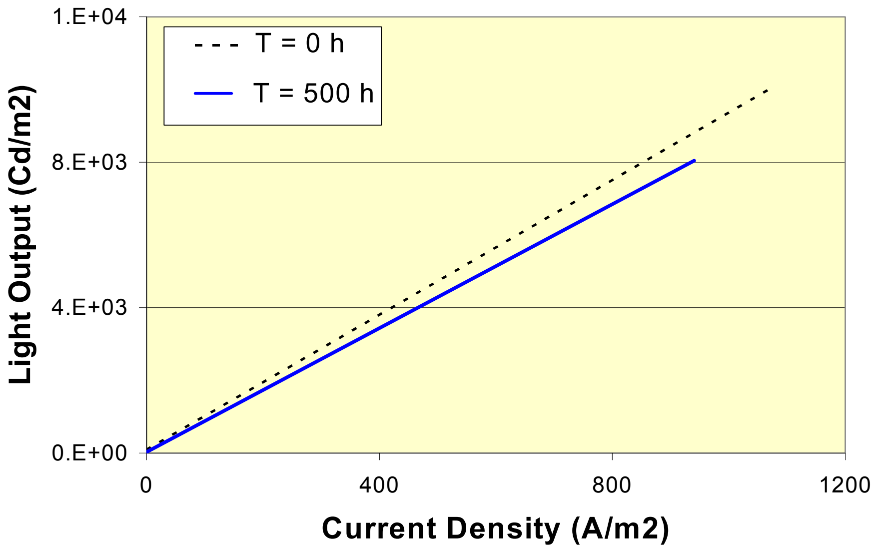
Compatibility of the process with devices

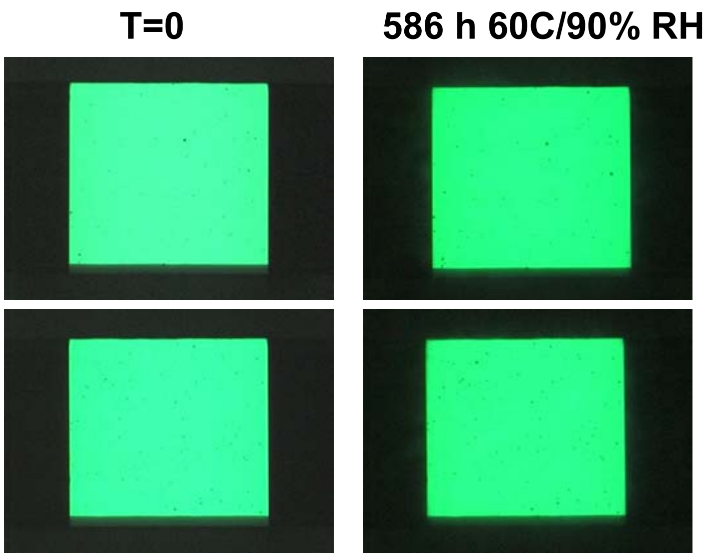


- **Many potential sources of damage**
- **With the right type of chemistry and process conditions they can be overcome**

Encapsulation of Bottom Emission Test Pixels on Glass

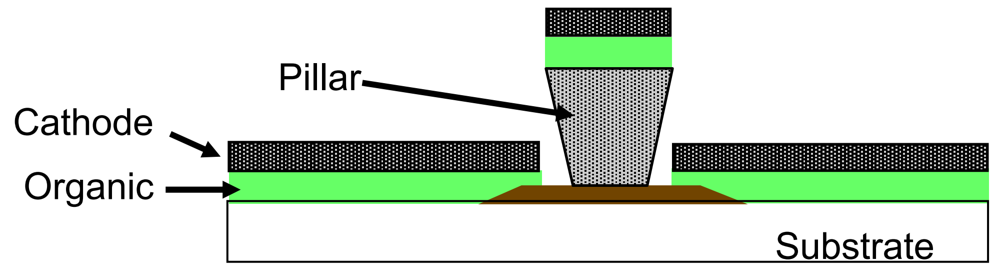


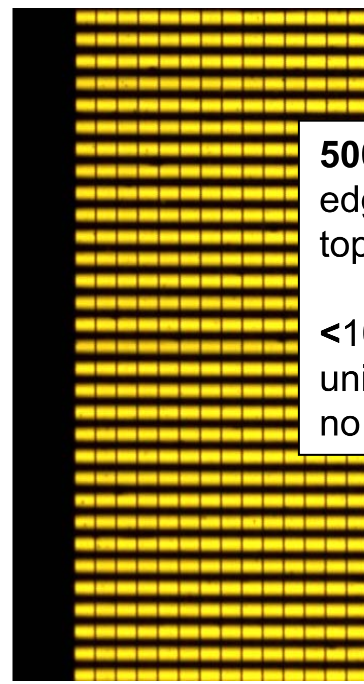




Pass requirements for
60C/90% RH, passive, 500 h
80 C, passive, 500 h
-40 to +80 200 cycles
80C, 100 h energized

Encapsulation of Passive Matrix Displays on Glass: Edge Seal

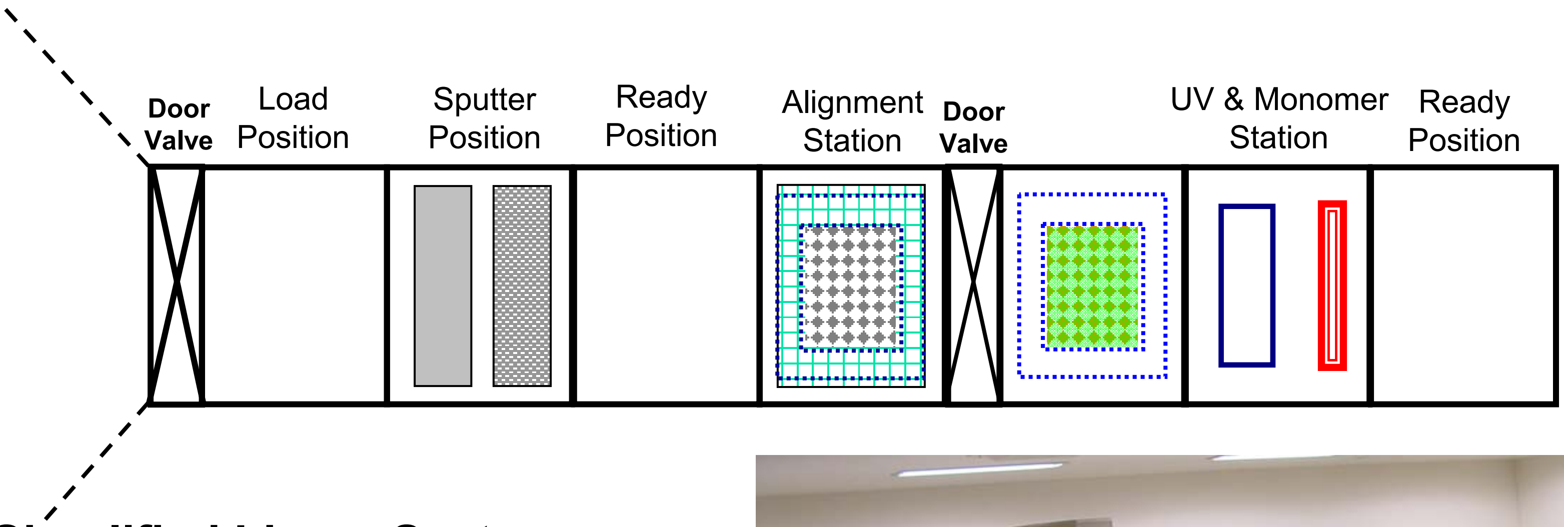




500 h 60C/90% RH
edge sealing over severe topography

<10% pixel shrinkage
uniform illumination
no increase in leakage current

Guardian System – Linear Tool for R&D



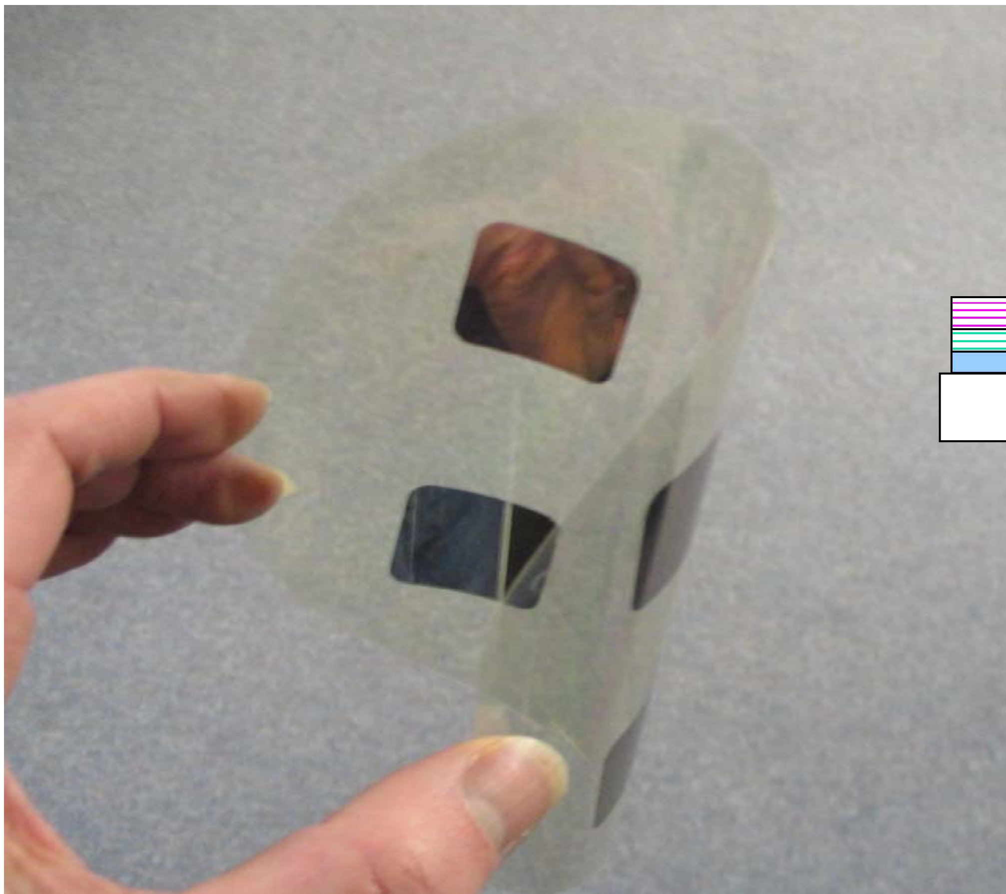
Simplified Linear System

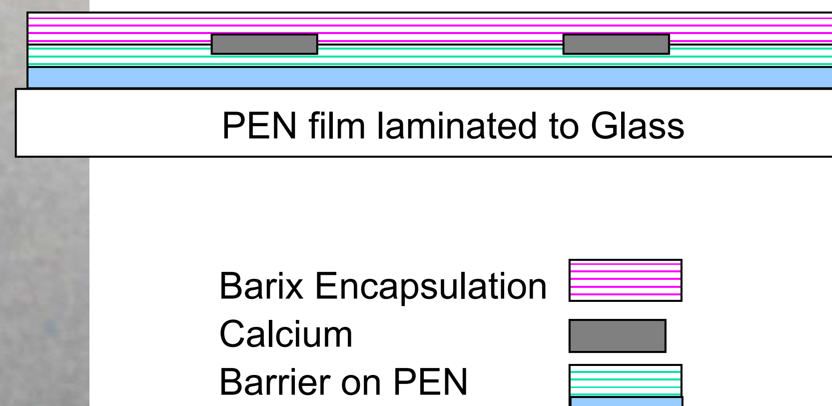
The first systems have been sold

Flexible Devices

Barrier Results for Plastic Substrate

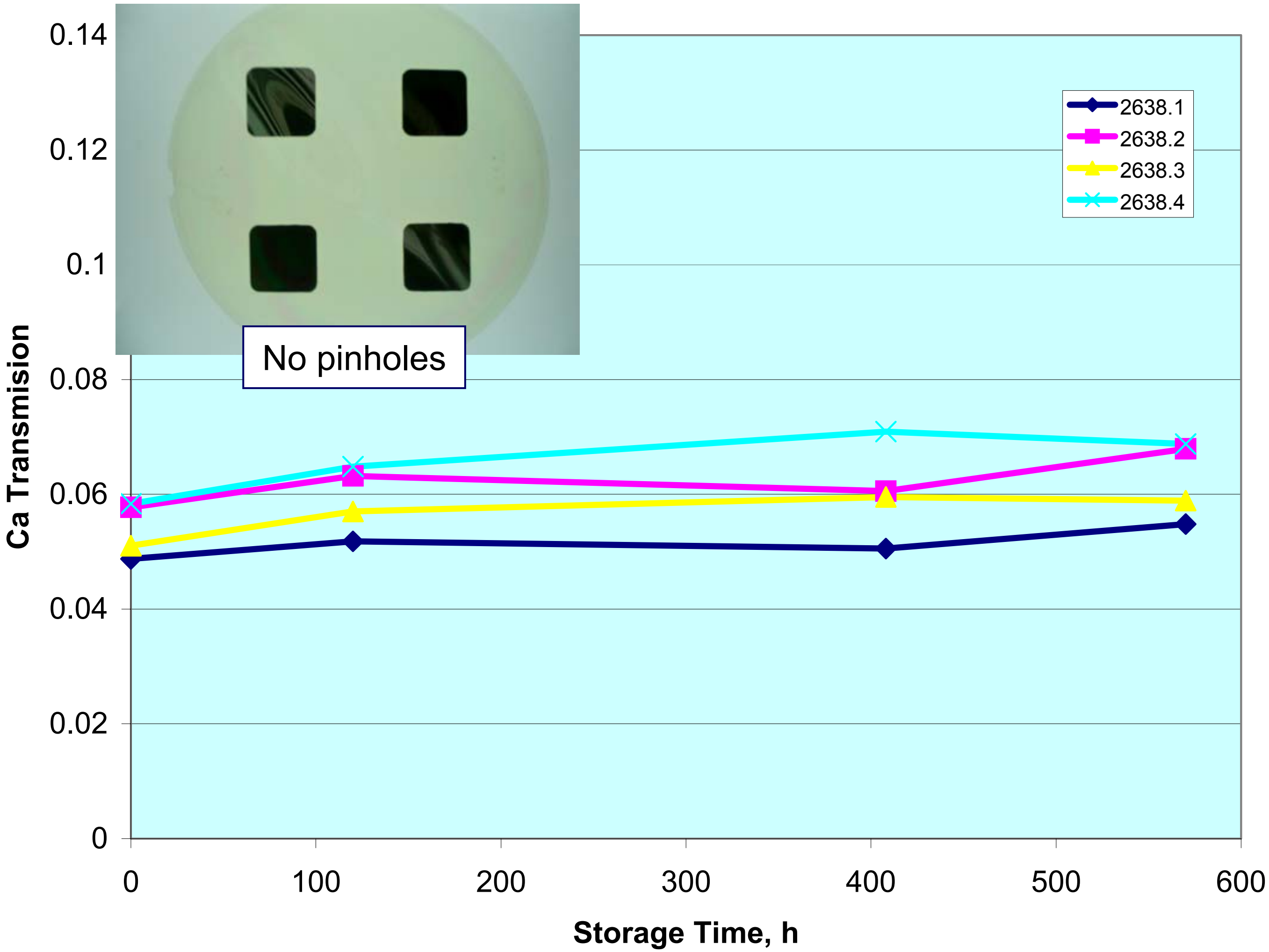
Ca buttons can be used to test barrier performance





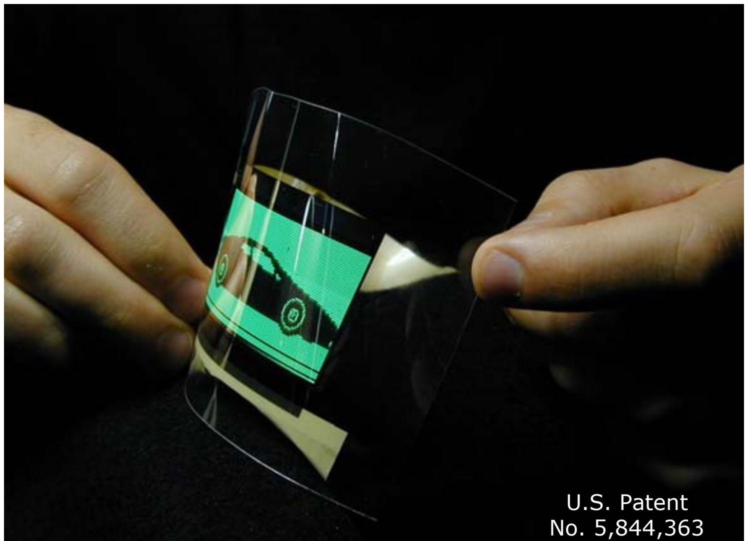
Long Ca Lifetimes with 2-sided thin film barrier

Almost no change after 570 h 60C 90% RH!

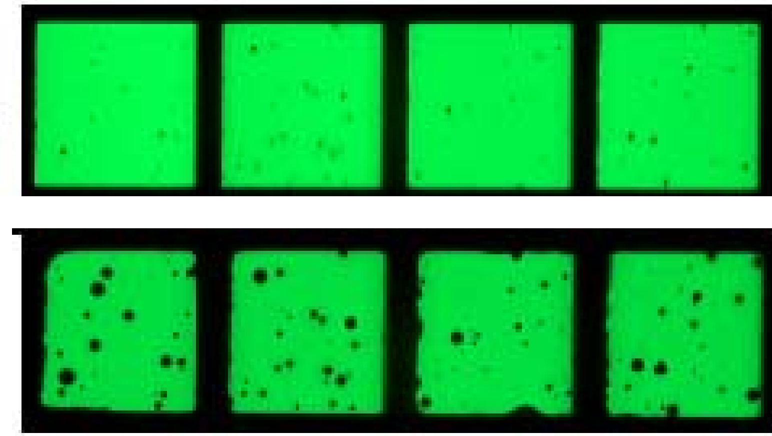


Permeation rate of ~1x10^{-6} for the combination of encapsulant and barrier substrate at 21C

Encapsulation of Plastic pixels and PM Displays



60C/ 85% RH Shelf test



0 h

140 h

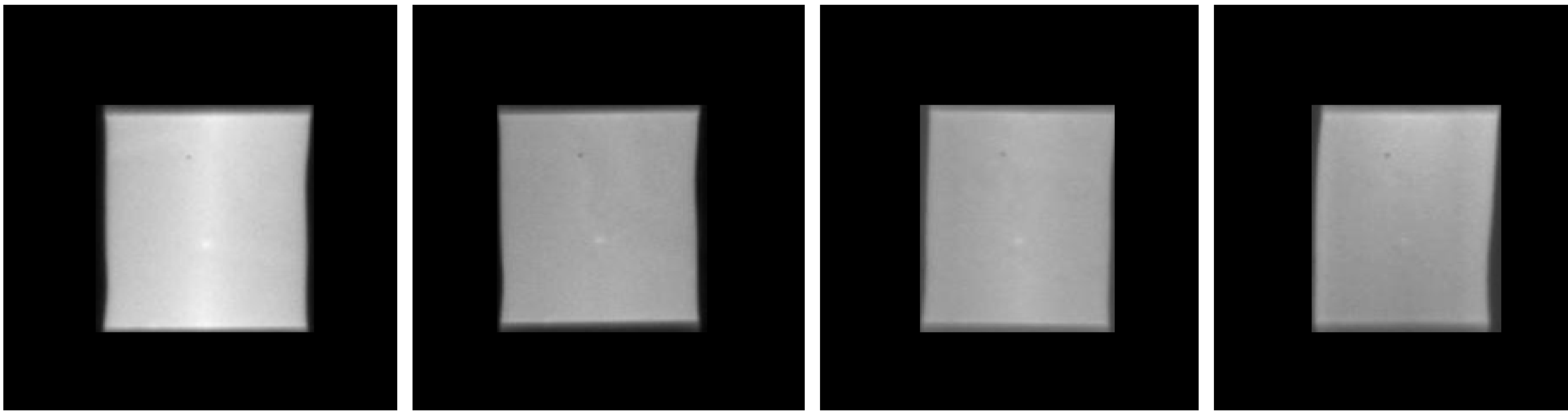
Chwang, et.al. *Appl. Phys. Lett.* (2003), **83** (3), 413-415

RT Lifetime on plastic is ok

Acceleration at higher T/ RH show poorer performance than on glass

Plastic Test Pixels after Encapsulation

0 h | 48 h Drybox | 48 h 60/90 | 400 h 60/90



PLED Test Pixels. No black spot growth!

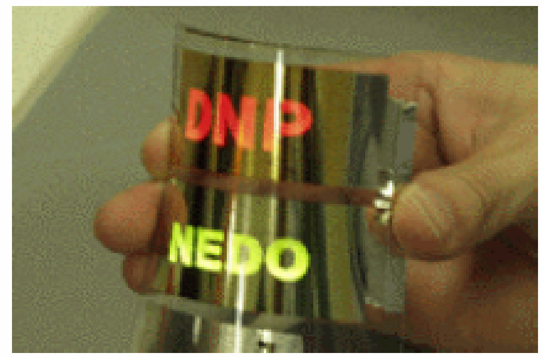
Champion data: a lot of know how about processing on plastics needs to be developed

Examples of flexible OLED displays

- Mono-color display
- Passive display

First products expected in 2006

Dupont



DNP

UDC

Color display Pioneer

Flexible Substrate R2R Pilot Line

- Large scale manufacturing of plastic barrier substrate.
- Process Control and Process Improvement remain key focal points
- Continue analysis to identify failure modes:
  - Mechanical abrasion
  - Impact of particles
  - Sources of particles
- Co-operation with TMI (CT)

Conclusions

- Barix thin film encapsulation can meet requirements for OLED’s in telecom applications
- Vitex Encapsulation tools are entering the market
- Barix multilayers successfully solves two problems of plastic substrates:
  - Provide a microscopically flat surface
  - Protection of devices against the environment
- Flexible Organic Electronics is just around the corner

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