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

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

Robert Jan Visser

Vitex Systems, Inc.
3047 Orchard Parkway
San Jose, CA 95134
tel 408-519-4400  fax 408-519-4470
www.vitexsys.com
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

- Integrated Electronics
- Optical Network
- Digital Imaging
- Display
- Smart Labels or ID Tags
- Flexible Batteries
- Smart Card
- HDI
- Solid State Lighting
- Photovoltaics
- Display
- Digital Imaging
- Optical Network
Prospects

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

Outdoor

Terrestrial digital broadcasting
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.)

Image:

- Meter & Navigation
- Mirror assist
- Blind corner assist
- Night view
- Flat panel light
The disadvantages of using plastics:

- Need low temperature processes: <100~200°C
- Higher thermal expansion coefficient, lower dimensional stability than, for example, 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 $1 \sim 10 \text{ gr/m}^2/\text{day}$

<table>
<thead>
<tr>
<th>WVTR Needed for ~10 yr device lifetime:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic LED</td>
<td>$10^{-6} \text{ gr/m}^2/\text{day}$</td>
</tr>
<tr>
<td>Solar Cells</td>
<td>$10^{-4} \text{ gr/m}^2/\text{day}$</td>
</tr>
<tr>
<td>LCD</td>
<td>$10^{-3} \text{ gr/m}^2/\text{day}$</td>
</tr>
<tr>
<td>Electroforetic displays</td>
<td>$10^{-2} \text{ gr/m}^2/\text{day}$</td>
</tr>
<tr>
<td>RFID tags</td>
<td>$10^{-2} \text{ gr/m}^2/\text{day}$</td>
</tr>
</tbody>
</table>

- Permeabilities and requirements for Oxygen are very similar
Barix™ Multilayer Encapsulation

- **Multilayer**
  - Redundancy
  - Tortuosity
- **Organic/Inorganic**
  - Organic: planarization/smoothing
  - Inorganic: barrier to H₂O and O₂ 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

\[ l(P1) = [t^2 + (s/2)^2]^{1/2} \approx s/2 \]

- 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
Today

Encapsulation process of rigid OLED displays

Transparent barrier substrate for flexible displays

Tomorrow

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
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
Ca buttons can be used to test barrier performance
Long Ca Lifetimes with 2-sided thin film barrier

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

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

No pinholes
Encapsulation of Plastic pixels and PM Displays

60°C/ 85% RH Shelf test


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
Acknowledgements

- Vitex Staff whose work appears in this presentation: Lorenza Moro, Xi Chu, Todd Krajewski, Teresa Ramos, Cara Hutchinson, Nicole Rutherford, Marty Rosenblum, Steve Lin
- PNNL Staff whose work appears in this presentation: Mark Gross, Wendy Bennett.
- Flexible substrate and encapsulation of plastic displays funded in part by USDC contracts RFP98-37 and RFP01-63
- Encapsulation of flexible displays funded in part by subcontract no. 070102.10 to UDC on ARL DAAD19-02-2-0019.
- Samsung SDI
- Universal Display Corporation.
- Philips
- DuPont Teijin Films
- Techni-Met, Inc.
- Tokki Corporation