OLED Encapsulation

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Introduction

• Objectives of today’s remarks
• Encapsulation choices
• Edge sealing choices
• Application of frit sealing to OLED lighting
• Encapsulation research needs
Encapsulation targets

• Performance
  – Permeability* < 1x10^{-6} \text{g}_{\text{water}}/\text{m}^2/\text{day}
  – < 1x10^{-5} \text{g}_{\text{oxygen}}/\text{m}^2/\text{day}

• Cost
  – $10-20/\text{m}^2$

• Reliability >40,000 hours active / 20 years lifetime
  – Damp heat degradation
  – Mechanical stress
  – Thermal stress

*DoE Manufacturing Roadmap - 2013
<table>
<thead>
<tr>
<th>Material</th>
<th>Pro’s</th>
<th>Con’s</th>
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</thead>
<tbody>
<tr>
<td>Metal can</td>
<td>• Low cost</td>
<td>• Poor CTE match</td>
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<tr>
<td></td>
<td>• Easy to pocket for desiccant</td>
<td>• Stamping costs</td>
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<td></td>
<td></td>
<td>• Edge seal required</td>
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<tr>
<td>“Thick” Glass (&gt;0.2 mm)</td>
<td>• Excellent moisture, oxygen and thermal resistance</td>
<td>• Rigid</td>
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<tr>
<td></td>
<td>• Low cost</td>
<td>• Pocket required for desiccant if frit seal is not used</td>
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<tr>
<td></td>
<td>• Transparent</td>
<td>• Edge seal required</td>
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<tr>
<td></td>
<td>• Expansion match to substrate</td>
<td></td>
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<tr>
<td>Polymer film</td>
<td>• Flexible</td>
<td>• High cost</td>
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<tr>
<td></td>
<td></td>
<td>• Damage sensitivity</td>
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<tr>
<td></td>
<td></td>
<td>• Edge seal required</td>
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<tr>
<td>Deposited coatings</td>
<td>• No edge seal</td>
<td>• High cost</td>
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<tr>
<td></td>
<td></td>
<td>• Additional (complex) deposition step</td>
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<tr>
<td></td>
<td></td>
<td>• Damage sensitivity</td>
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<tr>
<td></td>
<td></td>
<td>• May require backup glass</td>
</tr>
<tr>
<td>“Thin” glass (&lt;0.2 mm)</td>
<td>• Flexible/conformable</td>
<td>• Fragile and may require polymer backup</td>
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<tr>
<td></td>
<td>• All other glass advantages</td>
<td>• Flexible edge seal required with flexible substrate</td>
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## Edge sealing technology options

<table>
<thead>
<tr>
<th>Technology</th>
<th>Pro’s</th>
<th>Con’s</th>
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| Laser glass frit seal    | • Established OLED sealing technology  
                          • Hermetic seal  
                          • Capable of sealing over electrical leads  
                          • Narrow seal band | • Multiple process steps  
                          • Expensive  
                          • Stress buildup with larger sizes  
                          • Anticlastic bending stress |
| Polymer seal             | • Low temperature  
                          • Inexpensive process steps  
                          • Supports flexibility | • May degrade under aggressive environmental conditions  
                          • Not hermetic  
                          • Wide seal band  
                          • Requires desiccant  
                          • Best performing materials are expensive |
Corning developed a hermetic sealing solution using a low Tg glass frit

- Developed a low Tg frit with unique absorption characteristics tuned to a specific wavelength region (IR)
- Designed frit with a selective filler material to adjust the CTE
- These unique features offered sealing compatible with OLEDs

Deposit required width and thickness frit line on cover glass
Frit uniquely designed to absorb required energy

Align cover glass with backplane / OLED stack and seal with localized heat source

Pattern with frit line
Localize heat source
OLED laser frit sealing process flow

1. Wash Cover Sheet
2. Make Frit Glass
3. Paste Formulation
4. Dispense Paste
5. Pre-Sinter cover glass
6. Deposit OLED stack on base substrate
7. Align substrate with fritted cover glass
8. Laser seal process
9. Singulate
Seal performance was demonstrated with different lead configurations and with live OLEDs

- Sealing tests performed successfully over various lead materials/passivation layers
  - Mo, W, Ti, Cr, ITO, multi-layer metals
  - SiN\textsubscript{x}, SiO\textsubscript{2} passivation materials
- Sealing performance – sealed over lead material,
  - Ca test at 85C/85% RH passes 8,500 hrs with glass package
  - Successfully demonstrated over active and passive backplanes
- Successfully sealed many hundreds of live OLED samples without damage to leads or to the OLEDs
  - Sealing confirmed hermetic
  - No electrical issues with display performance
- AM OLED displays exceeded 2000 hours under 85C/85% RH testing
Technology wishlist

- Stress modeling of hermetically sealed glass laminate
- Reduced cost of sealing polymers
- Greater flexibility of polymers after curing
- Lower permeability to reduce desiccant load
- Solid state polymer encapsulant with inorganic layers and glass or polymer barrier
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