High Performance of High Density and High Transparency Indium Tin oxide (ITO) and Zinc Aluminum Oxide (ZAO)

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Outline

1) Material improvements: density and microstructure
2) Bonding technique improvement
3) Transparency improvement
1) Material Density Improvements

- Target density: > 99% of theoretical

Higher density decreases the arcing events and particle emission during film deposition.

Even small differences of density have a significant impact.
1) Material Density Improvements

- Particle Emission increases with increasing arcing events
1) Material Density Improvements

- Example to quantify arcing events with respect to density over 28hr of sputtering

<table>
<thead>
<tr>
<th>Arcing (Counts/hr)</th>
<th>Low density</th>
<th>High density</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&gt; 350</td>
<td>71</td>
</tr>
</tbody>
</table>

*Data based on ZAO material

<table>
<thead>
<tr>
<th>Arcing (Counts/hr)</th>
<th>High Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
</tr>
</tbody>
</table>
1) Material Microstructure Improvements

- Microstructure uniformity (dopant distribution)

**Non-uniform (ITO)**

**Uniform (ITO)**

**ZAO Microstructure**

**Aluminum Distribution**
1) Material Microstructure Improvements

![Graph showing Arc Counts (a.u.) vs. Time (hour) for Uniform and Non-uniform microstructures]
2) Bonding technique improvement

• Source material directly affects the performance of the deposited films.

• Issues such as target cracking, contaminant substances reduce film performance.
  
  • Target cracking = bonding coverage.
  • Contamination  = target assembly

  “Issues” translate into production output decrease
2) Bonding technique improvement

- Source material assembly

- X-ray Inspection system
2) Bonding technique improvement

- Stability of source material during film deposition affects the performance of the film

Unstable (cracking is possible)  Stable
2) Bonding technique improvement

- Larger length sections reduces the number of gaps in the material

  Contamination reduction

  Arcing and Particle Emission reduction

No solder exposure on the surface
2) Bonding technique improvement

- Material Thickness also favors high performance
  - Mechanical stability: reduce cracking probability
  - Arcing and particle emission reduction

Final thickness:
- 8 mm
- No cracking
- No nodules
3) Transparency Improvements

• “Standard” ITO and ZAO films transmittance
3) Transparency Improvements

- Concept for new ITO film: ITO-X

Low film resistivity with higher transmittance at the infrared region

Graph showing the transmittance of different ITO films as a function of wavelength.
3) Transparency Improvements

- Concept for new ZAO film: ZAO-S1

Low film resistivity with higher transmittance at the infrared region

![Graph showing transmittance vs. wavelength for different compositions of ZAO and ZAO-S1.](image)
3) Transparency Improvements: ITO-X

- Accelerated aging test: 85°C – 85% RH

![Graphs showing resistivity and transmittance comparison]

- No change on resistivity over time
- No change on transmittance
3) Transparency Improvements: ZAO-S1

- Accelerated aging test: 85°C – 85% RH

Improved resistivity over time
No change on transmittance
3) Transparency Improvements: Film Stability ZAO-S1

- AFM Images/Heat Resistance

<table>
<thead>
<tr>
<th>Surface area (μm²)</th>
<th>ZAO</th>
<th>ZAO-S1 (Improved)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.058</td>
<td>1.028</td>
</tr>
</tbody>
</table>

Good humidity resistance  →  Small surface area
Summary

• Source TCO material quality and performance directly affects the performance of the TCO films

• High density material reduces arcing events and particle emission

• Microstructure uniformity improves the performance

• Target material stability reduces cracking and contamination during deposition

• High performance ITO-X and ZAO-S1 show improvement on film resistivity and film transmittance when compared with “standard” ITO and ZAO