IMOLA Workshop – Smart Lighting 2014

Technology development for a flexible, low-cost backplane for lighting applications

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Overview

- Application requirements
- Technology specifications
- Process flow
- Technology developments
- Technologies for increased flexibility
- Conclusions
Application requirements

Interactive, modular, flexible, large-area, OLED-based lighting system on low-cost foil with built-in intelligent light management
Technology specifications

PI: € 20 per m²
Cu: € 6 per kg
PET: € 2.0 per m²
Al: € 1.4 per kg
Technology specifications

- **Integrated power converter**: 40V DC to 0...1A DC
- **Embedded inductor**
- **OLED**
- **Ferrite**
- **Backplane**

**Glass/Foil**
- \( I \leq 500 \text{ mA} \)

**Backplane**
- 250 \( \mu \text{m} \) PET
- 50 \( \mu \text{m} \) Al (2x)
- \( < 100 \text{ m\Omega} \) vias

**OLED**
- 3 mm x 3 mm, 400 \( \mu \text{m} \) pitch

**Technology specifications**
- 3 mm x 3 mm,
- 400 \( \mu \text{m} \) pitch
- 250 \( \mu \text{m} \) PET
- 50 \( \mu \text{m} \) Al (2x)
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Process flow

1. Al-PET-Al laminate
2. Structuring Al
3. Via drilling
4. Via filling
5. Ferrite printing
6. Chip mounting
7. OLED mounting
Via drilling

- Via drilling by laser
  - Aluminum is used as hard mask for CO₂ laser drilling
  - Additional UV laser desmear after CO₂ drilling
  - Optimize via tapering for filling process
  - Design compensation to match foil deformation

![Diagram of Via drilling process]

*Images of via drilling results*

200 µm
Via drilling

- Desmear after CO\textsubscript{2} drilling
  - Pulsed KrF laser desmear
  - Oxygen plasma desmear

Deposit after CO\textsubscript{2} drilling

Area cleaned with KrF

Before plasma cleaning

After plasma cleaning
Via filling

Via filling by stencil printing
- Enclosed print head (Dek ProFlow) for high-aspect ratio via filling
- Design of experiment on Cu-PET-Cu with CE 3103 WLV
  - Minimize entrapped air bubbles
  - Improve contact between ICA and copper
- Results
  - Single print stroke with medium speed
  - High ProFlow head pressure
Via filling by stencil printing

- Histogram of via resistance ($\Omega$) for 135 vias (9 samples over two printing runs) with an aspect ratio of 4:5 (350 $\mu$m depth and 450 $\mu$m diameter)

> 95% of vias are below the 100 m$\Omega$ target
Chip mounting

- Flip-chip mounting using stencil printed ICA bumps
  - Two test chips
    - IZM28 (2.5 mm x 2.5 mm, 300 µm pitch, 20 contacts)
    - IZM41 (0.9 mm x 0.9 mm, 500 µm pitch, 4 contacts)
  - Bonding parameters: 3 min @ 180 °C and 0.5 N pressure
  - Small contact pads on IZM28 incompatible with ICA printing
Chip mounting

- Flip-chip mounting using stencil printed ICA bumps
  - Low and reproducible resistance on PET-Cu
  - Large variation in contact resistance on PET-Al

| COPPER | 1 | A | 62,2 | 62,2 | 57,5 | 57,5 |
|        | B | 67,4 | 67,4 | 63,9 | 63,9 |
|        | A | 61,5 | 61,5 | 61,1 | 61,1 |
|        | B | 61,8 | 61,8 | 55,9 | 55,9 |
|        | A | 71,5 | 71,5 | 57,5 | 57,5 |
|        | B | 59,7 | 59,7 | 60,2 | 60,2 |
|        | A | 67,4 | 67,5 | 61,1 | 61,1 |
|        | B | 59,2 | 59,2 | 58,5 | 58,5 |

| ALUMINUM | 1 | A | 295,7 | 297,4 | 12085 | 11900 |
|          | B | 5000 | 15700 | 9856 | 10170 |
|          | A | 89,5 | 89,6 | 97,7 | 97,4 |
|          | B | 672,1 | 675,6 | 332,9 | 330,8 |
|          | A | 110,9 | 111 | 145,5 | 144,9 |
|          | B | 1214 | 1219 | 503,4 | 499,6 |
|          | A | 1718 | 1759 | 808,1 | 807,6 |
|          | B | 3706 | 3760 | 782,3 | 782,4 |
|          | A | 306,2 | 307,3 | 464,5 | 465,1 |
|          | B | 465,1 | 465,1 | 11065 | 10900 |
OLED mounting

- Structural film adhesive combined with printed ICA bumps
  - Very high bumps required to bridge glass encapsulation
  - Even distribution of OLED contacts for optical uniformity
  - Pre-structured film adhesive applied to backplane before printing
  - Dek PumpPrint technology for printing >1.5 mm high bumps
  - Optimized stencil design and print process make it possible to reliably print pyramidal dots with a 1:2 aspect ratio
  - Higher aspect ratios are possible with optimized material
Increased flexibility - OLEDs

- Flexible OLED technology (Holst Centre)
  - Bottom emission type, fabricated on PEN foil
  - Efficiency of up to 47 lumens per watt (white light)
  - SiN-OCP-SiN barrier stacks (Holst Centre IP) on cathode and anode sides
  - Customized design for IMOLA applications
Increased flexibility - OLEDs

- Flexible OLED technology (Holst Centre)
  - Honeycomb shunt lines for uniform current distribution over large area (> 10 cm x 10 cm)
Increased flexibility - UTCP

Once the backplane is flexible ....

... flexibility is limited by the rigid components

A solution:
- Thin down chips, down to foil-thickness (± 30 µm, by grinding)
- Make a flexible interposer (e.g. based on polyimide)
- Embeddable in or on the flexible backplane
Increased flexibility - UTCP

- Small I/O pitch (< 100 µm)
- 300-700 µm thickness

- PCB I/O pitch (~ 500 µm)
- Flexible

- UTCP interposer
- Flexible
- Known-Good-Package
- 60-80 µm thickness
Increased flexibility - UTCP

10 µm
Conclusion

Al etching

Ferrite printing

Via filling

Adhesive selection

OLED mounting

Chip mounting