Advanced Packaging of Image Sensors

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Image Sensors: the heart of digital cameras

Images taken with Conexant SXGA (1280 × 1024)
1.3 megapixel image sensor
Outline

• Special requirements for image sensor packaging

• Traditional packaging for digital still cameras

• Additional requirements for wireless handset camera modules

• Case #1: Encapsulated package

• Case #2: Chip scale package
Special packaging requirements

- Limited process temperatures
- Optically transparent material
- Contamination control during packaging
- Alignment of image sensor package to optics mechanism
- Package Test
Limited process temperatures

• Two types of color filter materials:
  • Organic dyes
    – Maximum process temperatures can be limited to 150°C or lower
    – May require low temperature die attach process and low temperature wirebonding
    – Might not be solder reflow compatible
  • Pigments
    – Allows higher process temperatures
    – Can be solder reflow compatible
• Microlens materials can also be affected by temperature
Effect of temperature on color filters

After 250°C bake
Red:  -9%
Green: -24%
Blue:  -8%

Red - Cyan
Green - Magenta
Blue - Yellow
Optically transparent materials

- Choices are limited:

- Glass
  - 98-99% transmittance of visible light
  - expensive
  - difficult to handle

- Clear Organics
  - 90-92% transmittance of visible light
  - susceptible to degradation
  - large thermal expansion mismatch with die
Optically transparent materials, cont.

Glass lid

Organic - after 3 passes of solder reflow
Contamination control

- VGA-format image sensors contain over 300,000 pixels
- Typical pixel sizes range from 5-10 µm and are shrinking
- Contamination on die surface can be visible in image
- May be possible to correct for bad pixels in software
- Contamination far from the die surface is not in focus
Alignment of sensor to optics

- Wide range of techniques for image sensor-optics alignment:
  - Low end “toy” digital cameras: simple assembly with no real alignment
  - High-end digital cameras: precision active alignment, e.g. 6-axis robotic alignment fixtures
  - Middle ground: passive alignment of image sensor and optics to the same datum features
Package test

- Cannot contact surface of package above the active area of the image sensor, but must make reliable contact

- Must integrate a well-characterized and well-calibrated light source into the test handler (e.g. Tungsten-Halogen 3200°K)

- Must maintain flatness and parallelism if testing with optics
Traditional Imager Packaging Approach

- Ceramic or Plastic cavity package (LCC) with glass lid
- Package cost is high based on number of I/O
- LCC form factor is too large and expensive for embedding into wireless handsets
Wireless handset camera module

- Customer requirements:
- CIF or VGA format image sensor; both still and video imaging
- Integrated optics assembly and image-processing ASIC
- 2.7V power supply; power consumption < 100 milliwatts
- Complete module occupies < 1 cc
- Total price for sensor, package, optics, and ASIC < $10
- Low Z-height is one of the most critical parameters for wireless handsets manufacturers

EETimes 9/8/00
Case #1: Encapsulated Imager Package

- Modeled on Conexant’s Radio Frequency Land Grid Array Overmolded Package (used for transceivers)

Advantages:

- In-house assembly and test capability
- Low cost, high volume product
- Thin form factor

Top and bottom view of a 6x6, 40 pin RFLGA.
Optical Land Grid Array Package

- Replace overmold with dam-and-fill (clear encapsulant)
Optical LGA Process Flow

- Wafer Saw
- Die Attach to laminate substrate
- Plasma Clean
- Wire Bond
- Dam and Fill - *Dispensing or Printing*
- Branding*
- Saw Singulation of matrix*
- Electrical and optical testing*

* new process development required
Transmission through encapsulant

- Clear encapsulant material transmits 90-92% of visible light
- Solder reflow had minimal impact on image quality

Glass lid

Encapsulated - after 3 passes of solder reflow
## Optical Characterization

<table>
<thead>
<tr>
<th>Optical LGA</th>
<th>CLCC</th>
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<tbody>
<tr>
<td><strong>Sensitivity</strong> (counts/lux.sec)</td>
<td><strong>Sensitivity</strong> (counts/lux.sec)</td>
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<tr>
<td>Channel</td>
<td>Channel</td>
</tr>
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<td>Red</td>
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<td>Green</td>
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<tr>
<td>22.57</td>
<td>31.71</td>
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<tr>
<td><strong>PRNU @ 1.2lux(%)</strong></td>
<td><strong>PRNU @ 1.2lux(%)</strong></td>
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<tr>
<td>Channel</td>
<td>Channel</td>
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<tr>
<td>0.014118 counts</td>
<td>0.0100404 counts</td>
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Photosensitivity in red, green, & blue channels

Pixel Response

Non-Uniformity in flat field (no lens)

Noise (measured “in the dark”)

05-2001 18
The Optical LGA and CLCC had similar sensitivity, pixel response non-uniformity, and noise values.
Optical LGA Reliability

- JEDEC Level 4 Preconditioning
- 85°C / 85% RH
- Thermal Cycling
- 125°C High Temperature Storage
- 10,000 Lux Light Exposure

- Failures seen after 85/85 and thermal cycling

- C-SAM shows delamination of encapsulant from substrate due to CTE mismatch
Optical LGA Feasibility Summary

• Optical Performance & Characterization
  – Preliminary results show comparable performance between Optical LGA package and CLCC

• Package Reliability
  – Package delamination failures seen - due to CTE mismatch between clear encapsulant and substrate

• Future Work
  – Investigate alternate clear encapsulant materials with lower CTE
Case #2: Chip Scale Imager Package

- Wafer-level CSP
- Smaller, thinner, and lower cost than Optical LGA
Optical Characterization

• Compared CSP to CLCC performance with Conexant SXGA die
  – Photosensitivity in R, G, and B
  – Pixel Response Non-Uniformity
  – Noise
  – Power Consumption

• Expect that construction of CSP will reduce benefit of microlenses (no air gap - smaller $\Delta$ in refractive index)

• Maximum benefit of microlens in this system is 2X
Photosensitivity

- CSP has 15-20% less sensitivity than CLCC
- Red and Blue responses lower than Green for both packages
Pixel Response Non-Uniformity

- CSP has higher PRNU, but within acceptable range
- Higher Red PRNU due to higher cross-talk
Noise and Power Consumption

- No distinct difference between CLCC and CSP in column fixed pattern noise and pixel fixed pattern noise
- No difference in power consumption
CSP Reliability

- Because of limited sample size, concentrated on temperature cycling and 85/85

- JEDEC Level 4 Preconditioning
  - 85°C / 85% RH
  - Thermal Cycling

- No failures seen
CSP Imager Package Summary

- Performance is similar to CLCC package, except for some degradation in photosensitivity
- Preliminary reliability results encouraging, need more thorough evaluation
- Challenges: automated test of small, thin imager sensor package