Value Engineered Wafer Level Packages for Mobile Devices

Presented by

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ASE Group
July 9, 2013
• Top Growth Drivers are Portable Consumer Devices
• Portable Devices becoming smaller, thinner, and more complex
Growth of Mobility Products

- Portable Devices have led the market
- All require small, high density packaging

Source: Prismark June 2013
Mobile Phone & Tablet Growth

- Trend towards Smartphones
- 2013 Smartphones > 50% Market
- 2017 Smartphones > 80% Market

- Tablets transforming computer market
- Tablet Sales increased 7X 2010-2012
- Changing the supplier base in the computer industry

Source: Prismark June 2013
Mobile Devices Getting Thinner

Device Thickness (mm)

- Umeox X5: 5.6 mm
- Huawei Ascend P6: 6.18 mm
- Alcatel One Touch Idol Ultra: 6.45 mm
- Sony Xperia Z Ultra: 6.5 mm
- Fujitsu Arrows ES IS12F: 6.7 mm
- ZTE Grand S: 6.9 mm
- Lenovo K900: 6.9 mm
- Motorola Razr: 7.1 mm
- iPad Mini: 7.2 mm
- iPhone 5: 7.6 mm
- Samsung Galaxy S4: 7.9 mm
- iPad 3: 9.4 mm
- Samsung Galaxy Tablet 2: 9.7 mm
Device Thicknesses

- Umeox X5 5.6mm
- Huawei Ascend P6 Ultra 6.18mm
- iPad Mini 7.2mm
- Sony Xperia Z Ultra 6.5mm
- Alcatel One Touch Idol Ultra 6.45mm
- Fujitsu Arrows ES 1S12F 6.7mm
- Samsung Galaxy S4 7.9mm
- iPad 3 9.4mm
- iPad 2 9.7mm
- Samsung Galaxy Tablet 2 9.7mm
- ZTE Grand S 6.9mm
- iPhone 5 7.6mm
- Motorola RAZR 7.1mm
- Lenovo K900 6.9mm
# WLCSP Examples in Mobile Phones

<table>
<thead>
<tr>
<th>Mobile Phone (number of WLPs)</th>
<th>Supplier (function)</th>
<th>Ball Count</th>
<th>Size (mm)</th>
<th>Pitch (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple iPhone 5 (11+)</td>
<td>Unknown</td>
<td>9</td>
<td>1.49 x 1.43 x 0.57</td>
<td>0.5</td>
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<tr>
<td></td>
<td>AJY</td>
<td>9</td>
<td>1.58 x 1.59 x 0.45</td>
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<tr>
<td></td>
<td>Qualcomm (RF power mgt.)</td>
<td>105</td>
<td>4.63 x 3.88 x 0.57</td>
<td>0.4</td>
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<tr>
<td></td>
<td>RFMD (antenna)</td>
<td>12</td>
<td>1.91 x 2.08 x 0.53</td>
<td>0.4</td>
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<tr>
<td></td>
<td>Apple/Cirrus</td>
<td>42</td>
<td>2.79 x 3.53 x 0.45</td>
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<tr>
<td></td>
<td>Unknown</td>
<td>8</td>
<td>1.96 x 2.74 x 0.47</td>
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<tr>
<td></td>
<td>NXP (LED driver)</td>
<td>36</td>
<td>2.11 x 2.14 x 0.4</td>
<td>0.35</td>
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<tr>
<td></td>
<td>Broadcom (controller)</td>
<td>72</td>
<td>3.31 x 4.39 x 0.54</td>
<td>0.4</td>
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<tr>
<td></td>
<td>AKM (electronic compass)</td>
<td>14</td>
<td>1.6 x 1.6 x 0.48</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>TI (touch screen controller)</td>
<td>99</td>
<td>4.64 x 3.81 x 0.64</td>
<td>0.4</td>
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<tr>
<td></td>
<td>SheiOP (light sensor)</td>
<td>6</td>
<td>2.4 x 1.7 x 0.8</td>
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<tr>
<td>Samsung Galaxy S3 GT-10300 (6)</td>
<td>Asahi Kasei (compass)</td>
<td>14</td>
<td>2 x 1.98 x 0.51</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Maxim (PMIC/MU/control)</td>
<td>100</td>
<td>4.52 x 4.54 x 0.69</td>
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<tr>
<td></td>
<td>Maxim (PMIC)</td>
<td>144</td>
<td>5.14 x 5.1 x 0.64</td>
<td>0.4</td>
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<tr>
<td></td>
<td>Broadcom (receiver)</td>
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<td>3.04 x 2.87 x 0.57</td>
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<td>Wolfson (CODEC)</td>
<td>90</td>
<td>4.18 x 3.88 x 0.45</td>
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<td></td>
<td>Intel (RFIC) eWLB</td>
<td>139</td>
<td>5 x 5.3 x 0.67</td>
<td>0.4</td>
</tr>
<tr>
<td>HTC One X (7)</td>
<td>Intel (RFIC) eWLB</td>
<td>148</td>
<td>5.39 x 5.03 x 0.67</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>Asahi Kasei (compass)</td>
<td>14</td>
<td>1.98 x 1.97 x 0.48</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Ti (WiFi/Bluetooth/FM tran)</td>
<td>174</td>
<td>5.7 x 5.35 x 0.64</td>
<td>0.4</td>
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<tr>
<td></td>
<td>Ti (PMIC)</td>
<td>81</td>
<td>4.82 x 4.83 x 0.52</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>36</td>
<td>3 x 3 0.7</td>
<td>0.4</td>
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<td></td>
<td>Ti (PMU for Tegra 3)</td>
<td>154</td>
<td>5.38 x 5.23 x 0.54</td>
<td>0.4</td>
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<td></td>
<td>Unknown</td>
<td>20</td>
<td>2.09 x 1.71 x 0.5</td>
<td>0.4</td>
</tr>
</tbody>
</table>

- **WLCSPs I/Os range from 8 to 174**
- **Package area ranges from 2 mm² to >30 mm²**
- **Solderball pitches from 0.35mm to 0.5mm**

Source: TechSearch International, Inc.
Demand for WLPs remains driven by growth in mobile phone shipments
- Die sizes range from <1 x 1 mm to almost 8 x 8 mm
- CAGR of 13% is projected for unit shipments

Source: TechSearch International, Inc.
WLCSP Diversity of Structures Available

- Sputtered UBM on Nitride
- Plated Repassivation
- 3-Layer Plated Redistribution
- Cu UBM on Pad For Embedding

- Sputtered Repassivation
- 4-Layer Sputtered Redistribution
- 4-Layer Plated Redistribution
- Cu Thick RDL For Embedding

- Plated Repassivation on top of UBM
- 2-Layer Plated Redistribution
- 6-Layer Plated with 2 Redistribution Layers
- Cu UBM on RDL For Embedding
Value Engineered WLCSP Trends

- Lower Cost WLCSPs
  - Improved Reliability/Large WLCSP
    - High Power WLCSP
    - Thin WLCSP
    - WLCSP for Embedding
  - WLCSP for MEMS/TSVs
    - Improved/Low Temperature Polymers
Cost Reduced WLCSP Structures

- **3-Layer WLCSP - Elimination of UBM**
  - Solderball is dropped onto RDL capture pad, using polymer 2 for “solder definition” of wettable area
  - Eliminates second metal layer
  - Reduces Price & Cycle time

- **2-Layer WLCSP - Elimination of Polymer 1 & UBM**
  - Solderball is dropped onto RDL capture pad, using polymer 2 for “solder definition” of wettable area
  - Eliminates first Polymer layer and second metal layer
  - Further Reduces Price & Cycle time
Reliability Engineered WLCSP

- Reliability Solutions being developed:
  - High Performance Alloys & Solderball compositions
  - Polymer material property selection
  - Solderball reinforcement
  - Modified RDL & UBM Structures
  - Controlled solderball standoff height
  - Thinned die with standard solderball sizes for improved solder fatigue
  - Optimized solder shape for controlled fatigue stress reduction
  - Modeling and simulation for materials and structural optimization
Pushing the Envelope: Large WLCSP

- Drive for larger size & higher IO capability
- Current large WLCSP at ASE:
  - Production: 6x6mm, 0.4mm pitch, 220 solderballs
  - Qualified: 8x8mm, 0.35mm pitch, 324 solderballs
- Ongoing development, both internal and with customers
  - Internal test vehicles for 8x8mm & 9x9mm WLCSP
  - >30 test cells in matrix
  - > 500 I/O
  - Testing ongoing

<table>
<thead>
<tr>
<th>Device</th>
<th>w/ UBM</th>
<th>w/o UBM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Si Chip Size (mm²)</td>
<td>8x8 / 9x9</td>
<td>8x8 / 9x9</td>
</tr>
<tr>
<td>Polymer Type</td>
<td>Pi</td>
<td>Pi</td>
</tr>
<tr>
<td>Pi / P1 Thickness</td>
<td>Sum / Sum</td>
<td>Sum / 10um</td>
</tr>
<tr>
<td>PDL Thickness</td>
<td>1um/3um</td>
<td>1um/3um</td>
</tr>
<tr>
<td>UBM Thickness</td>
<td>1um/3um/6um</td>
<td>1um/3um/6um</td>
</tr>
<tr>
<td>Si Chip Thickness</td>
<td>Variable</td>
<td>Variable</td>
</tr>
<tr>
<td>Back Size Coating</td>
<td>Variable</td>
<td>Variable</td>
</tr>
<tr>
<td>Solder Ball Composition</td>
<td>Lead free</td>
<td>Lead free</td>
</tr>
<tr>
<td>Ball Pitch (mm)</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>Ball Size (mm)</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>Ball Count</td>
<td>444 / 534</td>
<td>444 / 534</td>
</tr>
<tr>
<td>PCB Finish Type</td>
<td>OSP</td>
<td>OSP</td>
</tr>
<tr>
<td>PCB Layer</td>
<td>8 Layer</td>
<td>8 Layer</td>
</tr>
<tr>
<td>PCB Thickness</td>
<td>2.35mm</td>
<td>2.35mm</td>
</tr>
</tbody>
</table>

8x8mm 444 I/O

9x9mm 534 I/O
WLCSP Geometries

- **Dual RDL**
  - Dual RDL required for higher I/O, High density WLCSPs

- **Fine Solderball Pitch**
  - Production
    - 0.5 & 0.4 mm pitch 0.3 & .25 balls
  - Technically qualified
    - 0.3 mm pitch & 0.17 mm ball
  - Engineering/Qualification
    - 0.2 mm pitch & 0.1 mm ball

- **Qualified Fine-Pitch L/S’s**
  - RDL L/S :
    - 8/8
    - 10/10
    - 12/12
    - 15/15
Power Applications

- Power Management WLCSPs require higher currents
- Current capacity to \( \leq 2 \text{A} \) per solderball
- Industry asking for 5 Amps

Activities
- Thicker Copper RDL & UBM development
- Thermal dissipation study
- EM model and test vehicle for high current designs
  - Solder alloy, Barrier layer composition, UBM & Interconnect line thickness & width, and Via connection
- EM & Current testing ongoing for 4-layer and 3-Layer WLCSPs

EM Test Die

40\(\mu\)m UBM
Power WLCSP - Requires EM Study

- Electro Migration Study
- Study factors:
  - Polymer 1 vias, RDL dimensions, UBM dimensions, structure, and Solder alloy
Evolution of Thin WLCSPs

- Thinner Devices requires thinner WLCSPs
- New Process flows, materials and equipment being developed for thin wafer processing
Embedded WLCSP

- Thick (≥10µm) Copper UBM required for Laser Processing after embedding
- Die thinning required down to ≤50µm
- Total embedded die solutions being developed
  - Thick Copper UBM & Thin Die
  - Industry developing embedded die in strip and panel formats for packages & modules
  - Production with SIP Assemblies on Embedded packages

![ASE Materials Embedded Die](image1)

<table>
<thead>
<tr>
<th>Plating thickness (6.5-11.5µm)</th>
<th>MAX</th>
<th>MIN</th>
<th>AVG</th>
<th>STDEV</th>
<th>U%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10.86</td>
<td>10.10</td>
<td>10.42</td>
<td>0.32</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>10.78</td>
<td>9.71</td>
<td>10.09</td>
<td>0.42</td>
<td>0.05</td>
</tr>
</tbody>
</table>

![ASE Panel Fanout](image2)
Wafer Level Integrated Passive Devices

- System Integration benefits from IPDs
- Resistors, Capacitors, Inductors and integrated arrays
- Modeling, simulation, measurement
- Wafer Level or Modules
Wafer Level MEMS

- WL MEMS in production as single WLCSP or as Die to Wafer Assemblies

Oscillator MEMS on ASIC - DTW
3D Wafer Level Packaging

- 3D TSV available for 200mm & 300mm Wafers
- Die on die with thin die mounted on face of WLCSP, between perimeter solderballs
- Used for WLCSP and WLCSP MEMS
- TSVs for Backside connectivity for Power packages, including High Frequency Analog Amplifiers

Double sided WLCSP
Evolutionary Paths for FOWLP

- Single Die FOWLP
- Multi Die 2D FOWLP
- Multi Die 2D with Passives FOWLP
- Double sided 3D FOWLP
- Double sided 3D FOWLP Module Assembly
- Double sided 3D FOWLP Package on Package (FOPOP)
Fanout Multiple Die Packages

- 13x13 3-Die Test vehicle
- 2-Die Test vehicle
- 39 Embedded Components:
  - 3 Active Die
  - 28 - 01005
  - 6 - 0201
  - 2 - 0402
- 3D WL Fanout POP

3D aWLP Bottom
3D aWLP Top
3D aWLP Stacked POP
Summary

- WLPs used for all Phones, Smart Phones and Mobile Devices

- Industry is expanding menu of offerings:
  - Very Thin WLCSPs
  - Enhanced WLCSP Structures and capabilities
  - Improved materials including low temp cure polymers
  - WLP Fanout Packaging
  - WL Integrated Passives
  - 3D WLPs
  - WL MEMS
  - Embedded Die Packaging
Thank You

www.aseglobal.com