< New market survey report >

FO-WLP and RDL dielectric material
Subjects and Focal points of survey

<Subjects of survey>

◆ FO-WLP (Fan-out Wafer Level Package):
  - Chip-First type, RDL-First type
    * But RDL-first type FO-WLP not using photolithography for semiconductor is not included.

◆ Dielectric material:
  - Liquid type, Film type
  - Photosensitive (positive/negative) and non-photosensitive

<Companies surveyed>

▼ FO-WLP assembler
  - ASE, SPIL, TSMC, Amkor, STATS ChipPAC, Nanium, J Devices, Infineon, Freescale, Toshiba, Fujitsu laboratories, Others

▼ Dielectric material supplier
Focal points of survey

▼ FO-WLP

1. Main driver of Market growth
   - By application IC: AP, BB/RF, PMIC, Substitute PKG of 2.5D IC,
   - By needs: miniaturized wiring, low-profile PKG, cost reduction...

2. Technical issues for cost reduction and market expansion
   - Shift from wafer based assembly to panel based assembly, and Enlargement of assembly work size
   - Technologies and issues to realize panel based assembly and multi-RDL

▼ Dielectric material

1. Market growth of dielectric material
   - By usage (Buffer coat, FC bump, RDL, Others)
   - By form (liquid and film) of RDL materials for FO-WLP

2. Technical demands of RDL dielectric materials for FO-WLP:
   - Required characteristics for FO-WLP and the assembly process
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<td>Encapsulated base</td>
</tr>
<tr>
<td>Process type</td>
</tr>
<tr>
<td>Wafer/Panel</td>
</tr>
<tr>
<td>Work size (at present)</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Structure of TSMC's InFO-WLP</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC</td>
</tr>
<tr>
<td>Encapsulant</td>
</tr>
<tr>
<td>Redistribution layer</td>
</tr>
</tbody>
</table>

| Technical comparison for the increase of IO number in WL-CSP |
< Encap. base type >          < PCB tech. type >< RDL-First type >

<table>
<thead>
<tr>
<th>List of FO-WLP assemblers' status by type</th>
</tr>
</thead>
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<td>Assembler</td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>Amkor Technology</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>ASE</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Market size forecast of FO-WLP by application and assembly work base</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of FO-WLP</td>
</tr>
<tr>
<td>BB/RF for Mobile</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>AP</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Market size forecast of the assembled FO-WLP on wafer base</th>
</tr>
</thead>
<tbody>
<tr>
<td>(K wafer)</td>
</tr>
<tr>
<td>STATS ChipPAC</td>
</tr>
<tr>
<td>Others</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Production status of FO-WLP assemblers by # of RDL in 2014 (in volume)</th>
</tr>
</thead>
<tbody>
<tr>
<td># of RDL layer</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>STATS ChipPAC</td>
</tr>
<tr>
<td>Others</td>
</tr>
<tr>
<td>Total (K pieces)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>IC type and the combination of ICs</th>
<th>The present PKG type</th>
<th>Encaps. base</th>
<th>RDL-First</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP for Smartphone</td>
<td>PoP, FC-CSP</td>
<td>Wafer</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>2.5D (+3D) PKG</td>
<td>Panel</td>
<td></td>
</tr>
<tr>
<td>...</td>
<td>FC-CSP, FO-WLP</td>
<td>✓</td>
<td>P</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Adoption possibility of FO-WLP type by application IC</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC type and the combination of ICs</td>
</tr>
<tr>
<td>------------------------------------</td>
</tr>
<tr>
<td>AP for Smartphone</td>
</tr>
<tr>
<td>...</td>
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<tr>
<td>...</td>
</tr>
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</table>
Samples of contents (from Chapter 3)

[Types and usage of dielectric materials]

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<thead>
<tr>
<th>Type of dielectric material</th>
<th>Polymeric material</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photosensitive (Positive/Negative), Non-photosensitive</td>
<td>Polyimide (PI), Polybenzoxazole (PBO), Benzocyclobutene (BCB), Phenol, Epoxy, Others</td>
<td>Stress buffer coat, Passivation for bump, Interlayer dielectrics, Adhesive</td>
</tr>
</tbody>
</table>

[General status of manufacturers of dielectric material for semiconductor coat by type]

<table>
<thead>
<tr>
<th>Form of material</th>
<th>Photosensitive/Non-photo</th>
<th>Polymeric type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid</td>
<td>Posi</td>
<td>Nega</td>
</tr>
<tr>
<td>Film</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

[Ajinomoto Fine-Techno]

<table>
<thead>
<tr>
<th>Dow Chemical</th>
</tr>
</thead>
</table>

[Sales status of dielectric material manufacturers by use]

<table>
<thead>
<tr>
<th>Volume (kg)</th>
<th>Buffer C.</th>
<th>FC bump</th>
<th>RDL</th>
</tr>
</thead>
</table>

[Market share of dielectric materials by type of polymer]

<table>
<thead>
<tr>
<th>Chemical resistance</th>
<th>Amount by type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Others</td>
<td></td>
</tr>
<tr>
<td>PI</td>
<td></td>
</tr>
<tr>
<td>PBO</td>
<td></td>
</tr>
</tbody>
</table>

[Comparison of Spin-less coating methods]

<table>
<thead>
<tr>
<th>Slit coater</th>
<th>Spray coater</th>
<th>Ink-jet coater</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coating speed</td>
<td>~ 200mm/s</td>
<td>40mm/s</td>
</tr>
<tr>
<td>Film thickness uniformity*</td>
<td>±3 ~ 5%</td>
<td>±5%</td>
</tr>
<tr>
<td>Material utilization ratio</td>
<td>approximately %</td>
<td>approximately %</td>
</tr>
</tbody>
</table>

[Market size forecast of RDL dielectric materials for FO-WLP by form of material]

<table>
<thead>
<tr>
<th>Year</th>
<th>Liquid (Volume (t))</th>
<th>Average (USD/kg)</th>
<th>Film (Volume (m³))</th>
<th>Average (USD/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td></td>
<td></td>
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<tr>
<td>2015</td>
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<td></td>
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<td>2016</td>
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<td>2017</td>
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<td>2018</td>
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<tr>
<td>2019</td>
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</tr>
</tbody>
</table>

[Required characteristics of RDL dielectric material for FI-WLP]

<table>
<thead>
<tr>
<th>WL-CSP</th>
<th>FO-WLP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of layers of RDL dielectric material</td>
<td>1 ~ 2-Layer</td>
</tr>
<tr>
<td>Thickness of a dielectric</td>
<td>Approximately 5µm</td>
</tr>
<tr>
<td>As buffer coat layer</td>
<td>abcd</td>
</tr>
<tr>
<td>As cover coat layer</td>
<td>abc</td>
</tr>
</tbody>
</table>

[Market size forecast of liquid dielectric materials by usage]

<table>
<thead>
<tr>
<th>Form of material</th>
<th>Volume (t)</th>
<th>Average (USD/kg)</th>
<th>Film (Volume (m³))</th>
<th>Average (USD/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>2015</td>
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<td></td>
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<td>2017</td>
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<tr>
<td>2018</td>
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<tr>
<td>2019</td>
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</tbody>
</table>

[Market ratio of dielectric materials by type of polymer]

<table>
<thead>
<tr>
<th>Chemical resistance</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Others</td>
<td>0.2%</td>
</tr>
<tr>
<td>Sumitomo B.</td>
<td>14.0%</td>
</tr>
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</table>

[Market share of buffer coat dielectric materials for memory IC]
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