Analysis Of Die Product Assembly Techniques - COB

Chip-on-board or chip-on-substrate assembly technology relies on widely available die attach and wire bond infrastructure to ensure highly reliable interconnection between the die and substrate. Assembly yields near 100% combined with the relative ease of rework and repair enhance designer confidence in both manufacturability and cost predictability. Software based programmable tooling of the chip and wire process simplifies engineering changes, particularly in wiring patterns, and provides relative immunity to redesign due to die design shrinks. COB provides the capability to perform direct chip to chip wiring that facilitates improved performance and strong functional integration in many modern high speed applications.

The variety of substrates available for COB applications allows for a wide selection of electrical, thermal and mechanical properties tailored to specific circuit requirements. Ceramic and glass ceramic substrates offer stable dielectric constant, low dielectric loss tangent and good thermal dissipation. Organic substrates can provide low dielectric constant, lighter weight and in many cases, lower cost. Ease of design, technology availability and time to market make COB the preferred choice for a high proportion of today's integration and performance module applications.

The COB assembly process flow consists of three essential steps; die attach, wire bond and encapsulation. Die attach provides mechanical adhesion of the chip to the intended substrate and requires an adhesive application followed by precision chip placement then curing of the adhesive. Once firmly in place the wire bond processing electrically connects the die bond pads to the associated wiring pattern on the substrate. The wire bond machine welds fine wires, typically of Al or Au, between each pad on the chip and the appropriate pad on the substrate. Wire bonding demands clean pads on both the chip and the substrate to ensure strong bonds as well as high production yields. Finally, encapsulation protects the die and bond wires from mechanical damage during handling and additional processing. In some cases, particularly for system in package applications, the encapsulation also provides the finished surface for component marking. Encapsulation employs either liquid dispensing or transfer molding depending on the specific application.

Designing a COB assembly process sequence can be critical, particularly for applications where die products and surface mount (SMT) components are combined on a single substrate. In principle, the COB process may either precede or follow the SMT assembly process. Generally however, SMT processing first provides a simpler process flow particularly if the COB process employs a good cleaning process. A process step such as plasma cleaning to prepare the bonding surfaces is recommended. Process characteristics and considerations for COB assembly are detailed below and provide specific information for understanding, selecting and specifying the COB process.

**Die Attachment**
Die attach adhesive provides both the thermal and mechanical interface between the die and the substrate. Although the adhesive is applicable to either the substrate or the back of the die, most manufacturers employ paste adhesives applied to the substrate. Dispensing, stencil printing or pin transfer may be used depending on die size. Most utilize dispensing except for film type adhesive. Dispense patterns depend on die size and shape but all must ensure a void free bond line. For high thermal transfer applications, a thin bond line combined with silver (Ag) filled epoxies can meet the need.

**Die Placement**
Die placement into the dispensed adhesive demands accuracy as well as proper orientation and planarity control. Over pressure to set the die into the adhesive will ensure good adhesion and establishes the bond line thickness. Orientation and accuracy of placement directly impact the bond pad to substrate wire length and the "keep out" or die spacing requirements.

**Clean**
Following die placement, adhesive curing exposes bond pads on both the die and the substrate to organic contamination by plasticizers and curing agents in the adhesive; this is particularly true when employing organic substrates. Plasma cleaning provides the best alternative, although solvent cleaning with ultrasonic assist and CO2 snow blasting find application as well. Removal of any organic contamination from the bond pad surfaces ensures high wire bond yield and strength as well as process stability and reliability.

**Wire Bond**
Thermo-sonic Au or Cu ball bonding or ultrasonic Al wedge bonding may be employed. Au ball bonding provides the highest throughput and excellent wire loop flexibility. A process temperature of 170°C for Au ball bonding may be a disadvantage particularly for temperature sensitive die. However, low pressure and time requirements reduce the exposure to potential die passivation damage when using Au ball bonding. Combined with plasma cleaning after die attach, Au ball bonding minimizes ultrasonic energy and provides very consistent bond strength.

Al ultrasonic wedge bonding offers room temperature bonding capability and minimal bond wire loop height. This low loop capability gives Al wedge bonding an advantage in direct die to die bonding. Bonding at room temperature requires higher pressures and ultrasonic energy levels, which can cause problems with mechanically sensitive die. A plasma etch clean or alumina (Al2O3) scrubbing of the bonding surfaces reduces Al wedge bonding sensitivity to organic contamination in comparison to Au ball bonding.

**Encapsulation**
Either liquid encapsulation or transfer molding may provide the physical protection for the die. For high volume applications as well as those that can be fit into standardized mold cavities, transfer molding provides the lower cost alternative. Transfer molding also ensures consistent surfaces for marking. Larger modules and die mounted to large, mixed technology substrates generally demand liquid encapsulation. Liquid encapsulants come in two types, silicone or epoxy based. Silicone systems offer excellent moisture resistance and high compliance, but remain difficult to mark and difficult to handle. Epoxy systems provide improved adhesion and marking relative to silicone as well as more consistent appearance and require smaller "keep outs" or die spacing specifications.

**Marking**
Laser, ink jet, stencil or stamp marking techniques may be employed although laser and ink jet simplify serialization of parts. Key factors include permanence, visibility and contrast.
silicone based liquid encapsulants laser marking works best. With epoxy liquid encapsulants and mold compounds ink based marking with either ink jets or pin printing provide maximum clarity and contrast.

Failure to perform a thorough clean following die attach cure not only reduces yields, but significantly reduces mechanical reliability of wire bonds. Solution: Incorporate a clean step or use suppliers with post die attach cleaning capability. Plasma cleaning methods are preferred.

- Liquid encapsulation increases risk of wire loop exposure. Solution: Specify epoxy based materials when liquid encapsulation is required.
- High I/O counts can force long wire bonds (> 2500 microns) increasing susceptibility to wire wash or wire sag during encapsulation.
  Solution: Use higher strength wire alloys when bond wires exceed 2500 microns in length.

Design Guidelines
Many design rules depend on the manufacturer's equipment and process capabilities. Those presented here represent nominal capabilities industry wide. If there is a need to violate any of these guidelines be certain you work with your assembler as early in the design phase as possible to avoid major cost and quality implications.

- Keep Outs
  Function of die geometry, I/O count and substrate pitch limitations.
- Escape Routing
  Since bond pads are peripheral, only fan out required.
- Bond Line
  10 - 75 microns typical. Die attach cured adhesive thickness specification impacts thermal transfer as well as attachment strength.
- Pad Size/Geometry
  Width = 100 microns (typical)
  Length = 100 - 150 microns (typical), function of I/O count, die size and rework requirements. Rounded corners may enhance reliability (pad adhesion to substrate).
- Pad Finish
  Au ball bond: >50 micro-inch Ni, >40 micro-inch Au
  Al wedge bond: >50 micro-inch Ni, 8-10 micro-inch Au
  Pd or Ag may replace Au in certain situations
- Electrical Properties (typical values)
  Au
  R = 0.03 Ohms
  C = 0.006 pF
  L = 0.65nH
  Al
  R = 0.035 Ohms
  C = 0.0006pF
  L = 0.65nH

<table>
<thead>
<tr>
<th>Wire Length</th>
<th>Au</th>
<th>Al</th>
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<tbody>
<tr>
<td>Wire bond length(max)</td>
<td>2500 microns</td>
<td>3000 microns</td>
</tr>
<tr>
<td>Bond diameter(ball)</td>
<td>2 - 4x wire diameter</td>
<td>N/A</td>
</tr>
<tr>
<td>Bond length(wedge)</td>
<td>3 - 5x wire diameter</td>
<td>2x wire diameter</td>
</tr>
<tr>
<td>Bond width(wedge)</td>
<td>1.5 - 2.5x wire diameter</td>
<td>1.2 - 2x wire diameter</td>
</tr>
<tr>
<td>Wire diameter (typical)</td>
<td>25 microns</td>
<td>25 microns</td>
</tr>
<tr>
<td>Pitch (typical min)</td>
<td>100 microns</td>
<td>140 microns</td>
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Substrates
Substrate selection, particularly for system in package applications, control a great many aspects of a successful COB design. These include thermal management options, electrical performance, mechanical integrity and long term reliability. The table below presents several important properties of various substrate alternatives, most of which demand consideration in the design phase and have important impacts on cost and manufacturability as well.

<table>
<thead>
<tr>
<th>Substrate Properties</th>
<th>FR-4</th>
<th>Polyimide</th>
<th>Ceramic/Glass</th>
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<tbody>
<tr>
<td>Dielectric Constant (1MHz)</td>
<td>4.0 – 5.5</td>
<td>4.0 – 5.0</td>
<td>5.0 – 9.5</td>
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<tr>
<td>Dielectric Loss Tangent (1MHz)</td>
<td>0.02 – 0.03</td>
<td>0.01 – 0.015</td>
<td>0.00015 – 0.0002</td>
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<tr>
<td>Coefficient of Thermal Expansion (ppm/°K)</td>
<td>17 - 22</td>
<td>14 - 16</td>
<td>3.0 – 6.6</td>
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<tr>
<td>Thermal Conductivity (W/m°K)</td>
<td>0.2</td>
<td>0.2</td>
<td>18 - 20</td>
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<tr>
<td>Moisture Absorption (%)</td>
<td>0.3</td>
<td>0.15 – 0.4</td>
<td>~0</td>
</tr>
<tr>
<td>Line/Space Geometries (microns, typical)</td>
<td>100/100</td>
<td>75/75</td>
<td>100/100</td>
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</tbody>
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