Single chip packaging was the dominant means for incorporating integrated circuits into an end systems during the early 1990's. At that time desktop computers and workstations were the driving force of the semiconductor industry in both product and package technology development. Today the driving force of the semiconductor industry has shifted to wireless and personal communication products. The packaging requirements for these applications has changed according to the new need for smaller, lighter, better performance and higher integration. Die products provide utility in meeting these requirements and at the same time are leading to system cost reductions.

Die products are essential in meeting this new level of integration and size. The associated assembly technologies play a key role implementing successful manufacturing processes. In our last issue of DIEmentions (Volume 6), we provided an overview of the standard die product assembly techniques associated with die attach, die to substrate interconnection and die encapsulation. In this issue we will discuss in more detail wire bond interconnects with respect to multiple die applications and improved integration.

**Wire bond interconnect**

The chip and wire assembly process flow consists of three primary steps: die attach, wire bond and encapsulation. The wire bond process electrically connects the die bond pads to the associated wiring pattern on the substrate. The wire bond machine essentially welds a fine wire, typically gold (Au) or aluminum (Al), between each die pad and the appropriate pad on the substrate. Wire bond technology used for chip-on-board (COB) and chip-on-substrate (COS) assembly relies on widely available wire bond infrastructure. The wire bond technology and equipment is very mature and offers a highly reliable interconnect from die to substrate when proper processes are utilized. Assembly yields approaching 100% combined with the ability to rework and repair enhance the designers confidence in both the manufacturability and the cost predictability.

Wire bonding demands clean pads on both the die and substrate to insure strong reliable bonds as well as high production yields. Software based programmable tooling of the wire bond process simplifies engineering modifications and provides immunity to die size changes.

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Designing the COB assembly process sequence is critical, particularly for applications where die products and surface mount (SMT) components are combined on a single substrate. In principle, the wire bond process may either proceed or follow the SMT assembly process. Generally however, SMT processing first provides a simpler process flow especially if a good cleaning process is employed. A process step such as plasma cleaning to prepare the bonding surface is highly recommended for quality and reliability assurance.

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 when die is temperature sensitive or the substrate material will not tolerate the temperature extreme. However, the low energy and time requirements for this bond process reduces the potential damage to the die itself. Combining a plasma clean after the die attach process minimizes the ultrasonic energy needed and results in consistent bond strength.

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**Au ball bond with 1 mil wire**

Al ultrasonic wedge bonding offers the advantage of room temperature bonding and a minimal bond wire loop height. This low loop height capability gives Al wedge bonding the greatest utility in die to die bonding. The wedge bond is also capable of finer bonding pitches than the ball bond process. Wedge bonding at room temperature does however require higher pressure and ultrasonic energy levels. This can be a concern with mechanically sensitive die. As with Au ball bonding clean surfaces are essential to strong reliable bonds.

**Aluminum wedge bond**
For both ball bond and wedge bond process success, the use of high quality wire is essential. Specific wire properties (hardness, elongation, tensile strength) are selected based on the requirements of the bonding process and parameters employed. Sufficient analysis and evaluations needs to be performed to insure a robust process set-up.

Fine pitch aluminum wedge bond

Despite the maturity of the wire bond process, it often constrains the overall assembly process flow. The wire bond process requires significantly more floor space than the other assembly processes given an equal volume of production. These wire bond constraints worsen as the number of bonds per die and/or substrate increase. The wire bond process and equipment also typically require the largest amount of manpower and resources to run and maintain in the assembly area.

Process and manufacturing engineers must remain mindful of their I/O counts as substrates go through design revisions and become more complex.

Well designed processes are essential to a good wire bond process. Efforts to meet throughput increases, yield improvements and reliability demands, process and manufacturing engineers need to focus on three specific areas in their wire bonding operation:

- Material consistency and repeatability; including bonding surfaces on the die and substrate along with their cleanliness.
- Process consistency and repeatability; including control of the prior processes especially adhesive dispense, die attach, cure and clean. Attention needs to be paid to operator handling and the assembly area environment.
- Equipments set up and maintenance; including bond parameters, program control, SPC, documentation, calibration and preventive maintenance.

The wire bonding process is extremely flexible in meeting the needs of today's multi-die applications. The maturity of the technology, equipment and processes coupled with established infrastructure makes it possible for wire bonding to remain the dominant die to substrate interconnect technology. We expect wire bond technologies to maintain the largest share of die to substrate interconnect through 2004, by which point flip chip will become a major force in multi-die systems. National Semiconductor supports manufacturers employing wire bond technology by offering over 600 die products ready for ball or wedge bonding. These products can provide the building blocks for creating smaller, lighter, better performing, highly integrated applications.