Flip-Chip Technology

Why flip-chip?

In the development of packaging of electronics the aim is to lower cost, increase the packaging density, improve the performance while still maintaining or even improving the reliability of the circuits. The concept of flip-chip process where the semiconductor chip is assembled face down onto circuit board is ideal for size considerations, because there is no extra area needed for contacting on the sides of the component. The performance in high frequency applications is superior to other interconnection methods, because the length of the connection path is minimised. Also reliability is better than with packaged components due to decreased number of connections. In flip-chip joining there is only one level of connections between the chip and the circuit board.

Potentially flip chip technology is cheaper than wire bonding because bonding of all connections takes place simultaneously whereas with wire bonding one bond is made at a time. In practise, however, this price benefit is not always achieved due to immature processes, e.g. the cost of die bumping with current processes can be significant, especially in low volumes.

Flip-chip joining is not a new technology. The technology has been driven by IBM for mainframe computer applications. Many millions of flip chips have been processed by IBM on ceramic substrates since the end of 60`s. At the beginning of 70`s the automotive industry also began to use flip chips on ceramics. Today flip-chips are widely used for watches, mobile phones, portable communicators, disk drives, hearing aids, LCD displays, automotive engine controllers as well as the main frame computers. The number of flip chips assembled was over 500 million in year 1995 and close to 600 million flip chips were consumed 1997 [B1].

Advantages:

- Smaller size: Smaller IC footprint (only about 5% of that of packaged IC e.g. quad flat pack), reduced height and weight.
- Increased functionality: The use of flip chips allow an increase in the number of I/O. I/O is not limited to the perimeter of the chip as in wire bonding. An area array pad layout enables more signal, power and ground connections in less space. A flip chip can easily handle more than 400 pads.
- Improved performance: Short interconnect delivers low inductance, resistance and capacitance, small electrical delays, good high frequency characteristics, thermal path from the back side of the die.
- Improved reliability: Epoxy underfill in large chips ensures high reliability. Flip-chips can reduce the number connections per pin from three to one.
- Improved thermal capabilities: Because flip chips are not encapsulated, the back side of the chip can be used for efficient cooling.
- Low cost: Batch bumping process, cost of bumping decreases, cost reductions in the underfill-process

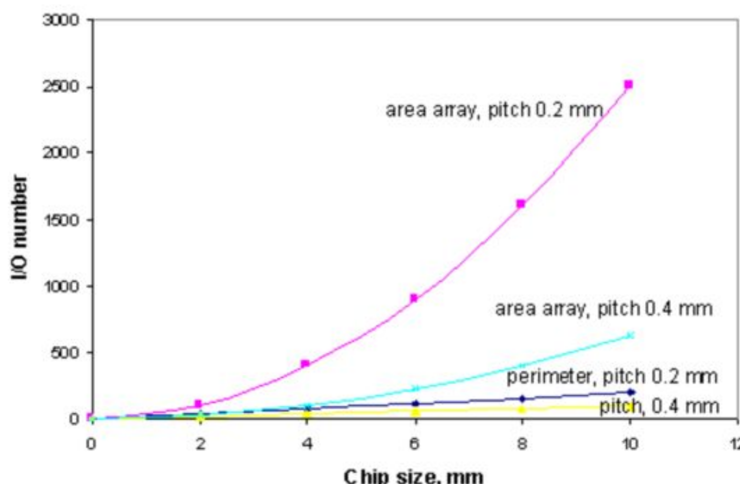

Figure B1. Comparison of the number of I/O vs. chip size between area array and perimeter array pad arrangement for pitches of 0.2 mm and 0.4 mm.

Short description of each flip chip process

There are many different alternative processes used for flip-chip joining. A common feature of the joined structures is that the chip is lying face down to the substrate and the connections between the chip and the substrate are made using bumps of electrically conducting material. Cross sections of flip chip joints without and with underfill material are shown in Figure B2. Examples of the different types of flip chip joints are schematically shown in Figure B3.

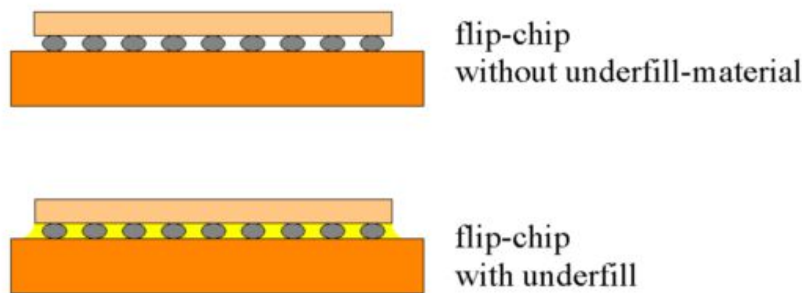

Figure B2. Cross sections of flip chip joints without and with underfill material.

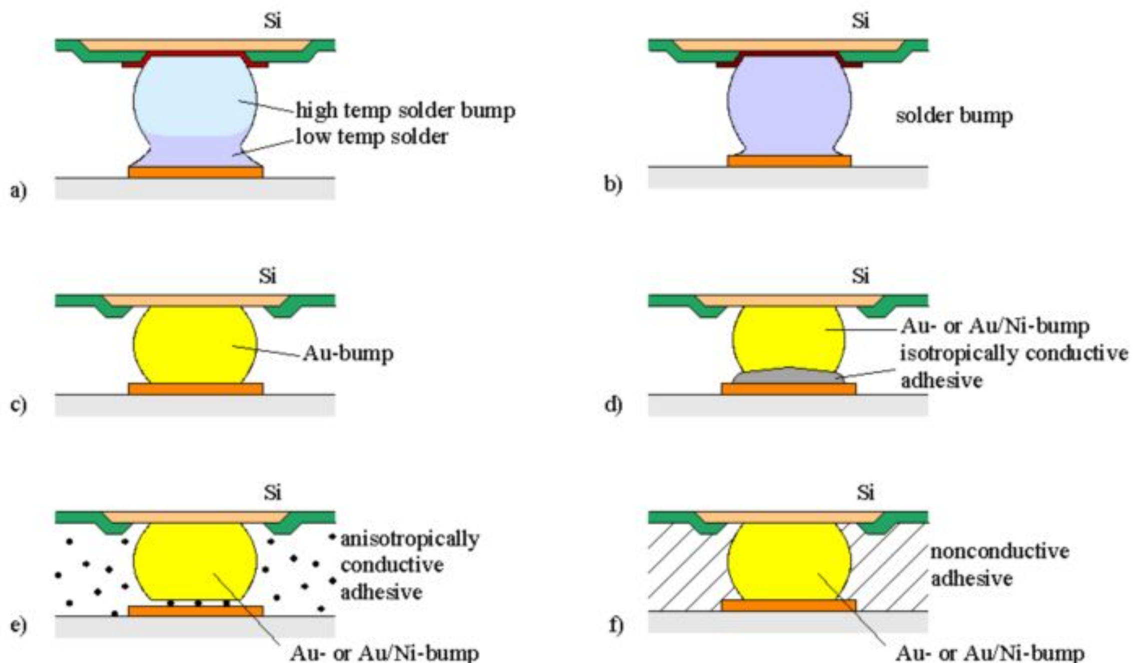

Figure B3. Examples of different types of flip chip joints.

Reliability

The different flip chip processes have different aspects concerning the reliability. However, one key factor which has drastically increased the reliability of flip chip structures against temperature variations is the use of underfiller between the chip and the circuit board which, when properly selected and applied, may increase the reliability by more than one decade. The underfill materials, usually filled epoxies, are stiff enough to take part of the forces developed by different thermal expansion coefficients of the chip and substrate. An underfill material also protects the face of the chip against moisture and impurities and makes the structure mechanically stronger.