Making the Connection with Wire Bonding

Wire bonding is a means of first-level interconnect, which is the initial interconnection to the actual die surface or the logicon a device. This interconnect takes that logic, or the power of the chip and connects it to the outside world.

Other methods of first-level interconnect include flip chip and tape automated bonding (TAB). However, wire bonding is the prevalent means of doing interconnects with more than 90 percent of total first level interconnects. Of this figure, gold wire bonding represents approximately 90 percent of the interconnects while the remainder is aluminum and other noble or near-noble metals.

Wire Bonding Types

Wire bonding is done to interconnect a chip to a substrate, substrate to a substrate, or substrate to a package. There are two types of wire bonding- ball bonding and wedge bonding.

The method of wire bonding that is most popular today is gold ball bonding, a process that melts a sphere of gold on a length of wire, bonds that down as a first bond, draws a loop out, and then connects the wire bond (the second wedge bond) down by means of a crescent and then reforms another ball for the subsequent first ball bond.

The second method of wire bonding that is performed is the wedge bonding process. This process is primarily used with aluminum wire but also can be used with gold wire. Usually performed at ambient temperature, wedge bonding involves putting two wedge bonds down.

No ball is formed in this process which can be done at room temperature. This aluminum bond process is characterized as an ultrasonic wire bond, meaning only ultrasonic energy, force and time is used to create the bond. Gold wire bonding is characterized as a thermosonic process, meaning that heat (typically 150°C), ultrasonics, force and time are all used to effect the bond.

When you would use each of these types of processes depends on the specific type of application. For example, gold wire bonding is used in most high volume applications because it is a faster process. Aluminum wire bonding is used in situations when packages or a printed circuit board cannot be heated. In addition, the wedge bonding process can attain a finer pitch than gold wire bonding. Presently, the pitch limits of gold wire bonding are as fine as perhaps 60 micron. Aluminum wedge bonding with fine wire can be performed at pitches finer than 60 micron.

Applications

The applications for wire bonding are diverse. The source of products that these eventually end up in range from personal computers, to video cassette recorders, automobiles, aircraft, microwave ovens, defense systems, radar, guided missiles, etc.

The automatic wire bonder industry has matured considerably in the last 20-25 years. The speed and accuracy of the equipment and its capabilities for handling different types of materials have risen tremendously. Conversely, manual wire bonding equipment is used in specific applications where the parts cannot present themselves adequately for an automatic wire bonder. The biggest applications for manual wire bonders is in the assembly of disk drives.

When purchasing a wire bonder, a potential user needs to determine several things. First of all, will the bonder build the required product? To determine this, a user normally submits an application to be performed by the supplier. The wire bonder supplier has to know not only how to make the application run, but also understand metallurgy and electronic manufacturing.

A user also needs to determine the reliability level of the equipment and the degree of support that will be provided at installation and subsequently when the machine is put in production.

In general, problems to be aware of with wire bonding fall into three categories. First is material and whether it is suitable for a high yield wire bonding process. Gold wire bonding, for example, requires smooth, clean bond surfaces. Typically, gold wire is bonded to an aluminum pad on the die and thick or thin film gold metallization on the substrate. The cleanliness of the substrate affects whether the bond can be made reliably.

Gold wire bonding is one of the most sensitive processes in microelectronic assembly. It could be characterized as a "litmus test" which determines if materials and processes are under control. If they are not, there likely will be problems with the wire bonder. Material problems can range from organic to inorganic contamination of the bond surfaces to microcracks in the die structure. Organic contamination usually can be removed with a cleaning process such as argon plasma cleaning. Other material problems usually need to be solved in one or more upstream processes, such as die and substrate fabrication.

The second area where problems may occur is in the manner in which the bonding process is performed. Questions to ask include: Is the material being presented correctly to the equipment? Is the bonding program correctly written and constructed? It is often difficult to maintain a high degree of control and repeatability with materials and processes, however these are the chief sources for yield and throughput loss at wire bond.

The third area to examine is the equipment itself- specifically, the calibration and operation of the machine. In the normal process of troubleshooting a wire bonding problem, this should be the last area to check. With well maintained equipment and good material and process control, the wire bonding operation can run with a defect rate significantly less than 100 ppm.

Even with the problems identified above, wire bonding is still the most flexible for performing first-level interconnects. It is a very well understood and highly refined process. There is a substantial infrastructure consisting of equipment, supporting materials and process expertise to support an efficient wire bonding operation for even a small company.

Alternatives

With the continued growth of flip chip technology, some of the limitations of wire bonding are amplified, notably I/O pitch and bond pad configuration. Wire bonder suppliers have continued to drive down the minimum pitch capability of their equipment, however flip chip still enables higher I/O density per chip.

As mentioned earlier, the predominant alternatives to wire bonding are flip chip and TAB. A decision to use any of these methods depends on the specific application, production volume and frequency of design changes in the product.

The wire bonding of hybrid circuits, MCMs and similar packages have some special requirements that are not found in monolithic devices. Primarily, the unique challenges for these types of products are custom handling with large area and deep access requirements.

When there are step heights within a product such as bonding to die, substrate, package pins, a rectilinear Z-drive bond head has the capability to address bond surfaces over a range from 0-250 mils or greater with a single setup.

With hybrids and MCMs, the other special requirements include the variety of chips that are contained in the packages and the particular properties of each of the surfaces. This requires capability within the bonder for programming force, time and ultrasonic parameters for each bond.

Also, special looping capability for forming the shape of the wire interconnecting first and second bond is necessary. In microwave applications, the shape of the loop is critical for tuning of the circuit.

The wire bonding future

Primarily because of its established infrastructure and proven capabilities, wire bonding will remain the predominant means of first-level interconnect will into the next millennium... By Bruce Hueners - Palomar Technologies