ADVANCED PACKAGING'S
Step by Step

step 3

Serving a dual role, the die-attach step must provide reliable attachment of the semiconductor chip to the package and meet functionality requirements.

Die Attach

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Performance requirements for die-attach materials are continually changing. One of the industry drivers for change is the need for smaller packages that will fit into portable consumer electronics such as cell phones, pagers, medical devices, portable computers and video cameras. Another driver is at the package level — faster, higher power devices require thermal management solutions and thinner packages have rigorous moisture resistance requirements. Finally, all products are being driven by progressive material cost and processing cost reductions.

The purpose of die attach is to provide a reliable attachment of the semiconductor chip to the package while meeting the functionality requirements for the package as a whole.[1] This article will present material selection criteria for die-attach materials for various packaging options as well as an overview of some physical criteria. Measurement techniques for development and quality assurance also will be highlighted.

Packaging Trends and Material Selection

For the purpose of this article, packaging will be broken up into traditional packaging (material sets are well understood) and new packaging (material sets are still under development and optimization). Further discussion of material processing and performance criteria will lead into material selection.

Figure 1. The future of die attach is smaller, faster and less costly.

Traditional packaging. Hermetic packaging includes either glass seal, i.e., ceramic dual in-line package (CERDIP) or solder seal, i.e., side-braze and ceramic pin grid array packages (CPGA). Substrates are typically made of ceramic material. Molded plastic packages are nonhermetic packages having roughly the same package volume as their hermetic counterparts. Both hermetic and plastic packages are in widespread use today.

New packaging. New packaging developments are being driven by the requirements for portable consumer goods. Products are becoming more lightweight with higher performance. Cost reduction considerations are driving die-attach materials to be less costly, lower stress, faster curing and delamination free. Currently, thin quad flat pack (TQFP), ball grid array (BGA) and enhanced BGA or µBGA, and chip scale package (CSP) represent some of the new packages offered. These packages were developed to perform in reduced volume applications such as cellular phones and laptop computers. Other industry drivers include total unit cost pressure, thermal management performance, and moisture and delamination performance.

Material Processing

Applicability. As processes change to become more efficient, new materials are frequently required to work on old process lines as well as new lines. There is a balance between investing money to build the faster throughput lines and continuing to run status quo with lower productivity. Companies need the flexibility to run the material either way, depending on their production strategy. Material requirements are well understood, and die-attach materials need to withstand high process temperatures, generate low moisture content and exhibit high adhesion strength.

Reliability. Some of the more popular criteria for gauging material performance are measuring lamination performance as a function of moisture sensitivity and thermal mechanical cycling. JEDEC levels 1 through 6 define relative levels of moisture sensitivity where the percentage of delamination is measured as a function of thermal and humidity stresses.[2] Level 1 denotes the most robust performance and level 6 the least robust. (Please refer to quality assurance techniques such as CSAM for quantifying the degree of delamination.) Material sets for these package types must exhibit a lower modulus of elasticity (MOE), while processing at lower temperatures and still generate good mechanical integrity. Thermal cycling is dictated by MIL STD specification.[3]

Material Selection Chart. The table summarizes material requirements by package type and the new materials that have been introduced to meet these requirements (Table 1).

Development Tools

Research and development scientists have a number of analytical tools at their disposal to assist in the development and characterization of new products. These tools aid in the development of a correlation between structural properties and product performance. Following are some of the more important techniques:

Differential scanning calorimetry (DSC). This is used to characterize reaction rates of materials as a function of time and temperature.[5] The DSC can be used as a process characterization tool as well as to check for residual amounts of unreacted material at specific process conditions. The rates of reaction and degree of conversion can be calculated from the following equation:

Key equation: $d\propto/dt = k(1-\propto)^n$

Where $d\propto/dt$ = rate of reaction, $\propto$ = degree of conversion, ^{n} = order of reaction and k = reaction rate constant.

Dynamic mechanical analysis (DMA). A technique used for establishing MOE and glass transition temperature (Tg). These are key properties for mechanical modeling and process characterization.

Thermal mechanical analysis (TMA). A technique used for establishing the coefficient of thermal expansion (CTE), which is a key property for modeling. CTE and MOE must balance with the interface materials to produce a low stress environment for the package. Like DMA, these are also key properties for mechanical modeling and process characterization.

Thermogravimetric analysis (TGA). A technique used to establish the temperature range for thermal stability. It also can spot potential problems with outgassing as related to process condition. This is a key test for establishing process applicability.

Thermal interface testing, interface and bulk conductivity testing. Interface testing is performed routinely for high power applications. Thermal performance is a function of not only the bulk material properties but also the degree of contact at the interfaces between the material and the joined surfaces. Degradation of interface contact as a function of environmental stress can be quantified using this technique.

Mechanical Modeling. Material modeling is playing a major role in new materials design. Mechanical modeling using finite element analysis is becoming more important as packaging becomes thinner and more flexible. It is important to balance the adhesive with the interface properties, including CTE and MOE. Tg is an important consideration from a users temperature requirement. Most users want the Tg to fall outside post-assembly thermal exposures to assure that the die-attach material is stable for the life of the device.

Molecular Modeling. Another computer technique playing a major role in material design. Programs exist that can model new material candidates for bleed, creep, wetting and other properties.

The following list highlights some of the more common measurements that can be used to quantify the reliability of a die-attach material. These techniques also can be used for process monitors and process characterization and optimization.

Adhesion measurements. Adhesion is a fundamental test for measuring die-attach performance. The purpose of adhesion testing is to assure there is a reliable and functional bond between the die and the substrate.

Internal imaging techniques (scanning acoustic microscopy [CSAM] and X-ray). Both X-ray and CSAM are nondestructive techniques for examining internal defects. X-ray is a radiation technique in which large discontinuities can be seen, and is a powerful tool for looking at structures such as large outgas voids. CSAM is used for measuring interface voiding and delamination performance on cured and environmental test units. Unlike X-ray, ultrasound will not transmit across an air gap. This property allows the user to detect air spaces and thin voids and is a powerful tool for looking at interface voids or delaminations. This technique also is popular for process characterization and process monitor.

TABLE 1. *Summary Chart*

Package Type	Typical Key Requirements	Material
Hermetic (CERDIP, CPGA, Sidebraze)	• High adhesion strength • Low moisture content • High process temperature (above 320°C)	• Silver glass die attach • Silver filled cyanate ester[4]
Molded plastic, smaller die sizes (PDIP, QFP)	• High modulus • Lower temperature processing moisture resistance (sub 250°C)	• Silver filled epoxy • Modified cyanate ester blends
TQPF/thin outline plastic	• Lower MOE, stress • Lower temperature processing	• Epoxy • Cyanate ester blends
PBGA, thermally enhanced BGA	• Low MOE, stress • Thermal performance	• Epoxy blends • MCOT (modified cyclo-olefin thermoset) • Conductive fillers
CSP	• Ultra low MOE, stress • Moisture resistance • Good mechanical integrity	• Epoxy blends • Cyanate ester blends • MCOT • Silicone materials

CSAM can help confirm delamination as a contributor to poor thermal performance. (Refer to the section on thermal interface testing.)

Cross sectional analysis. This is a destructive technique where units are physically cut at a location where a defect is suspected, and is used to confirm a suspected defect, based on electrical performance or indicated by the non-destructive imaging techniques previously mentioned.

Optical microscopy. A traditional technique that can be used to spot material mismatch problems such as part warping. Also useful for spotting fillet cracks, outgas voids, resin bleed and fillet quality.

Environmental testing. Key environmental tests include thermal cycling, thermal shock, HAST, 85/85 and pressure cooker testing. These tests are designed to expose package materials to thermal, mechanical and humidity environments that would exceed the real world environment and assure reliability of passing units.

Moisture absorption tendency. Measurement of moisture absorption is a key property in measuring new materials. The amount of moisture absorbed by the material may translate directly to device moisture sensitivity and subsequent delamination.

Viscosity and pot life. Viscosity and rheology is routinely measured with a viscometer and readings may be done either statically (fixed test speed) or dynamically (variable test speed). Material viscosity can be read over time and pot life can be established as a function of percent change per unit time. Dynamic viscosity gives an indication of how the paste will perform under various shear conditions and is useful for predicting dispense performance.

Conclusion

We continue to be challenged by new products and associated material solutions. Scientists and engineers will continue to develop new product solutions for die attachment. For new materials, attention must be paid to many elements, including thermal conductivity, mechanical stress on the device, moisture sensitivity and delamination performance, and cost. Die attach solutions will help pave the way for future products yet to be developed. **AP**

References

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