MCM & Hybrid Failure Mechanisms and Anomalies

The failure mechanisms found in standard microcircuits and passive components, from electrical aging, electrical, and mechanical wearout, are also found in Hybrids and MCMs. The failure rates are classified in the same manner: infant mortality, constant life, and wearout (standard “bathtub curve”). The actual failure rates can only be attained by testing; theoretical modeling values are normally used only for circuit partitioning and cost estimates. A hybrid containing a significant number of “add-on” components is more prone to interconnect defects because of this additional tier of interconnects. There are other areas of concern for Hybrids and MCMs, and they are associated mostly with the performance of very complex circuits, and the robustness of the package (substrate/ die material TCE, interconnect design, and interface integrity). These concerns are addressed in the following paragraphs.

Die Considerations

Although much of the die is standard product, the trend is toward uniquely specific designs electrically, physically, and materially. The most important aspect of the MCM die is its reliability, since to be a cost-effective product, the die yield must be greater than 99%; therefore, the establishment of a KGD (Known Good Die) source is paramount. Other items of most concern are:

a. Electrical parameter stability over time and throughout the operating temperature range. Complex circuitry can suffer performance degradation with a relative minor shift in a single parameter.

b. Duplicate die serried several times may require screening to minimize adverse performance effects of variations or drift in parameters that are normally acceptable.

c. Physically large die, common in MCMs, can be susceptible to mechanical and thermal stresses and may require careful matching of TCE and minimally stressful die attachment techniques.

d. Inspection techniques of blind solder connections need to be established for hidden die-to-substrate interconnects found in designs using flip-chip or ball grid arrays.

e. Junction temperatures need consideration in power applications and high speed logic chips when die is located in a confined area with limited heat-sinking potential. This is a condition common in many MCM designs.

MCM Substrate Considerations

Typically, the MCM substrate design plays an integral part in the circuit behavior. The layout geometry, the material selection, deposition results, and processing controls all effect this behavior. Common concerns are:

a. Texture and surface quality variations in raw substrates from different suppliers, can cause problems in the deposition of consistent metallizations essential to producing reliable conductive traces, and accurate values of the passive elements.

b. The effects of thermal cycling/shock can result in metallization defects both physical and chemical, which are essentially the same problems encountered with standard microcircuit designs. With multi-layered designs, this environment is a potentially significant problem as open or very high resistance may occur in the vias due to the differences in material TCEs.

c. Moisture ingression, with organic substrates in plastic encapsulated designs, is a potentially significant failure mechanism, as they are inherently more susceptible than hermetically sealed designs. These defects, somewhat similar to standard microcircuits, can result in opens or shorts in the metallization due to delaminations, mealing, intermetallics, dendritic growth, etc. In addition, residual moisture or ingression through defective seals in hermetically sealed designs can cause corrosion problems with the substrate metallizations.

d. Un-packaged, coated substrates can be used effectively in limited applications, and several types of coatings are available. These coated substrates, however, may be damaged by chlorinated solvents, etching/plating solutions, flux residue, and contaminants from other chemical processes, resulting in delamination and mealing of the substrate. Coated substrates are also more susceptible to physical abuse and damage during routine handling or later during servicing or repair.

Other Failure Mechanisms

Both Hybrids and MCMs have failure mechanisms peculiar to the specific package designs, either hermetically sealed or encapsulated, and are essentially the same that occur in standard microcircuit packaging. Basic failures include hermetic seal leaks, encapsulant popcorning from moisture ingression, leads corroded from atmospheric contamination, and markings deteriorated from poor handling and processing practices.

When passive structures are used in microwave applications, the factors that affect the performance of transmission lines include: microwave dielectric constant, frequency dependence of the dielectric constant, surface finish and flatness, dielectric loss tangent, thermal expansion and conductivity, dimensional stability with time, and surface adhesion properties for the conductor coatings. Electromagnetic coupling between transmission lines can be significant. Because of this, transmission lines are normally separated by two or three line widths in order to minimize coupling effects. The backside grounded co-planar waveguide has additional problems, due to the excitation of parasitic modes that severely degrade circuit performance.

Via fractures have been observed due to thermal expansion differences between the die attach alloy and the GaAs monolithic device. This problem poses an inherent reliability risk, and processing parameters must be optimized to minimize and control fracture occurrence. Pulsed RF conditions have resulted in fatigue failure of airbridge structures; however, improved metallization systems, that include a multi-layer structure of different metals, eliminate this type of failure.

Thermal dissipation difficulties and electromigration failures are a concern with thin-film resistors. NiCr resistors are especially susceptible to degradation due to moisture, and care must be taken to ensure that they are passivated.
The largest concern with MIM capacitors are electrical shorts caused by pinholes in the dielectric material or sharp points on the metal plates. It is very difficult to eliminate pinholes, but manufacturers can limit the problem by exercising care during the fabrication process.

Spiral inductors are no more than a combination of transmission lines and air bridges. There are no special failure mechanisms to consider with inductors, other than those previously identified with transmission lines and air bridges.