TECHtips

Electronics Manufacturing Insights from ACI Technologies, Inc.

Ceramic to Plastic Packaging

As electronic products increase in functionality and complexity, there is an emphasis on affordability, miniaturization, and energy efficiency. The telecommunications, automotive, and commercial electronic markets are the leading drivers for these trends. These markets see high volume manufacturing with millions of units priced to the fraction of the cent. The choice of the packaging material for the electrical components for these markets can have a substantial effect on the cost of the final product. Therefore plastic encapsulated components are almost universally used in non-military applications over the conventional ceramic or metal electronic packages.

Traditional electronic components are hermetically sealed for environmental protection. The earliest component packages were made of glass, such as the cathode ray tube (CRT) which used a glass enclosure to seal out the atmosphere and maintain a vacuum. Today, full hermetic packages are typically made of metal, ceramic, or a combination of both. Ceramics and metals provide the only proven fully hermetic packages. While both provide a high barrier to gases and moisture, metals provide the ultimate protection. Although the raw metals can be quite inexpensive, the manufacturing methods used for metal packaging generally add substantial cost to the package. Metal packages are mostly machined, cavity style packages which are ultimately sealed with a lid. They are typically the highest cost but most reliable option for electronic packages in harsh environments.

Ceramic hermetic packages cost less than metal packages and provide most of the performance and protection of metal with a few advantages of their own. Ceramics are excellent electrical insulators and are less costly because the base material can be pre-formed before firing, forming a hard high barrier solid. Ceramics are a popular material for both hermetic and non-hermetic packages which require thermal conductivity, high temperature stability, good planarity, and smoothness. Examples of traditional ceramic cavity packages are shown in Figure 1. One ceramic packaging option, Low Temperature Co-fired Ceramic (LTCC), is a multi-layer, glass ceramic substrate that is co-fired with low resistance metal conductors (such as silver or copper) at a low temperature, typically under 1000°C. This technology provides embedded inductors, resistors, and capacitors for functional substrates.

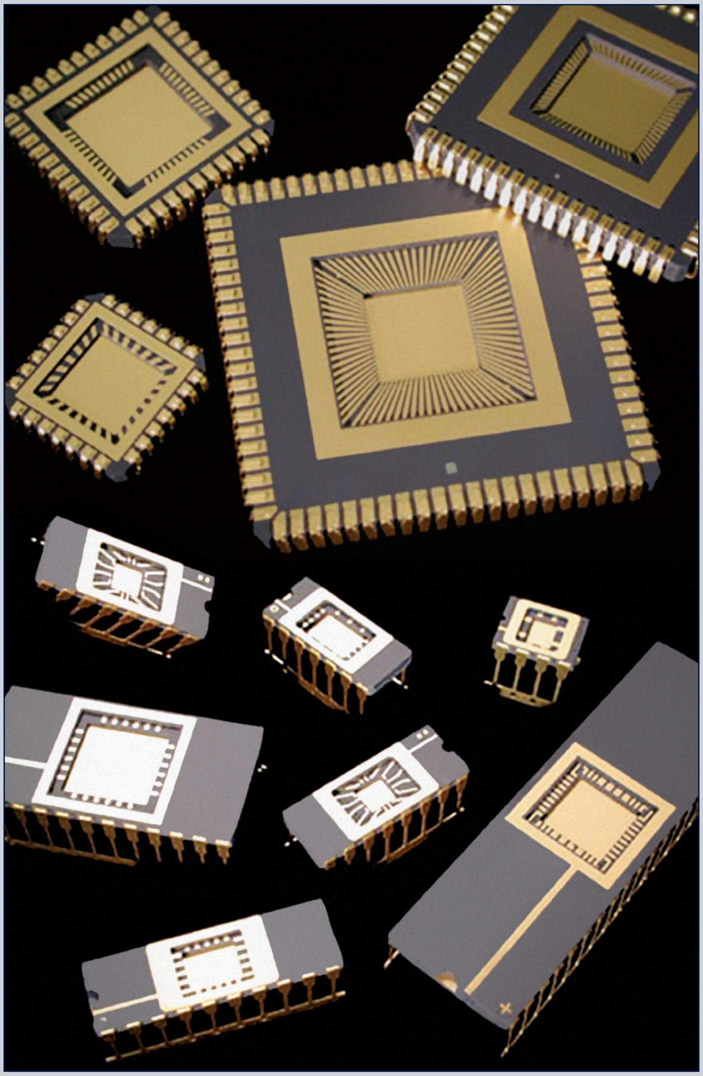

Figure 1: Ceramic Packages

Plastic packaging uses organic materials for environmental protection. In contrast to hermetically sealed packages, organic material usually contacts the active element (or a thin inorganic barrier layer) in the plastic package.

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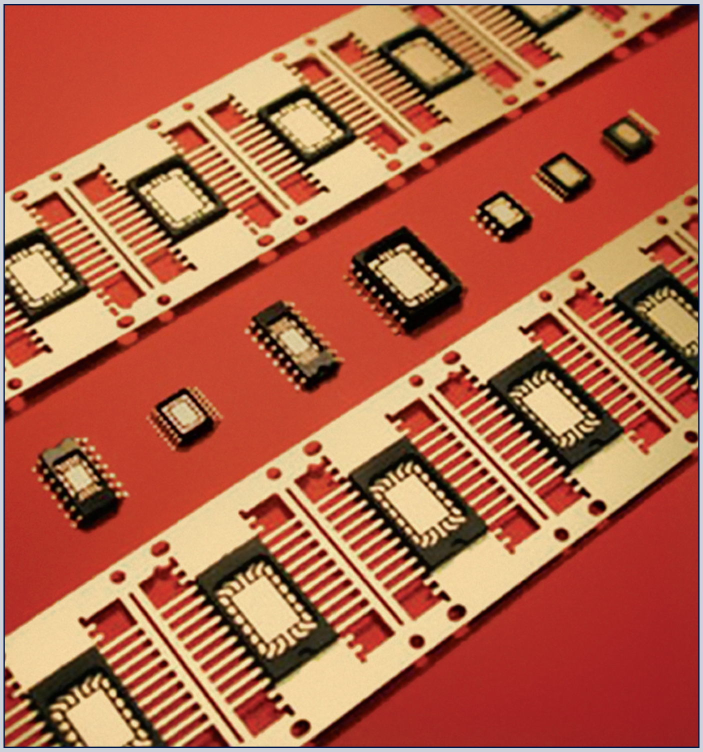

Figure 2: Pre-Molded Plastic Packages

Post molded and pre-molded plastic packaging is the dominant technology in packaging today. Post molded plastic packages are formed after chips are attached to the mounting surface, such as a metal leadframe, and electrically connected. Typically, a thermosetting epoxy resin is used to form the package body around the chip and mounting surface. There are many types of post molded packages due to the popularity and versatility of polymers. However, this process does subject the die and wire bonds of the package to the harsh molding environment.

Pre-molded packaging, as seen in Figure 2, provides a less harsh environment for packaging sensitive chips requiring a low cost assembly. The main element is that the chip and interconnects are decoupled from the molding process. The package is made by either a transfer molded process using a thermosetting epoxy resin or an injection molding process. The chip and interconnects are then encapsulated to protect them from the environment. This can be a die coating or a flow coating to fill the entire cavity. In some cases, a plastic lid is used to seal the plastic package. The injection molding process easily produces cavity style packages that are increasingly useful for newer optical and electromechanical chips (MEMS). The injection molding process allows for precise cavity packages to be manufactured automatically. Injection molding typically has a faster throughput than transfer molding and is less labor intensive.

The drive towards plastic packing in the commercial electronics industries is due to three inherent advantages of plastic packaging: cost, size, and weight. Plastic packaging designs are amenable to a high volume, automated process, which in conjunction with the low cost of the material, result in low manufacturing costs per unit. In addition, there is a well-established, high volume manufacturing infrastructure for plastic packaging technologies, which also reduces the unit cost of plastic packaging.

The constant trend in electronics is to become smaller and lighter as evident in the cell phone and the consumer electronics industries. Plastic packages, on average, weigh approximately half of a ceramic or metal package of the same type. This reduction in weight and package footprint helps designers reduce the overall weight of their electronic product. The short lead times for plastic packages result in greater availability of the packages in the market, especially in surface mounted devices (SMD).

As with any growing technology, there are concerns with plastic packaging technologies. Unlike metal and ceramic packages, plastic packages are not hermetic. Recent advancements have developed polymeric materials that can reach nearly hermetic levels of environmental protection. These packages can pass the required helium leak tests, however, they are not considered hermetic because moisture can diffuse into the package over time. This is of concern for hermetic applications, specifically in the military. The ability of moisture to penetrate the plastic package causes reliability and storage life issues. Another concern is the long term reliability of plastic packages when exposed to the harsh environments and higher temperatures seen in military applications.

The use of liquid crystal polymer (LCP) has become a popular low cost, near hermetic packaging option. LCP is a thermoplastic which can withstand temperatures of 260°C or more without melting or distorting. Because LCPs are thermoplastic, they can be injection molded around leadframes to create a cavity. After the die and interconnects are added to the package, the air cavity can be sealed with a ceramic, plastic, metal, or glass lid. The lid can be sealed with an epoxy or some other method, such as heat or laser.

LCP has a 10 times lower moisture diffusion barrier than epoxy and absorbs only 0.02% moisture. LCP also has excellent dimensional stability when molding and creates precision parts having flat surfaces right out of the mold, without rework. Dimensional uniformity is a problem with ceramic packaging because of its high shrinkage during the co-firing process. In addition, LCP has a low dissipation factor and a dielectric constant of 3 to 4 compared to ceramics which have a dielectric constant of 4-13. LCP also has a low coefficient of thermal expansion (CTE) value. [1]

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LCP has begun displacing some of the more expensive ceramic packaging applications and typically cost about 40% less than a ceramic package of the same package type. LCP has also begun to replace some of the high performance transfer molded applications. [1] Table 1 shows some of the properties of Vectra® C115 LCP from Ticona Engineering Polymers.

Property	Vectra® C115 LCP
Density	1.5g/cc
Melting Temperature	325°C
Coefficient of Thermal Expansion (Linear)	3.0 µm/m°C
Heat Deflection Temperature	250°C
Dissipation Factor	0.020 @ 1MHz
Dielectric Constant	3.1 @ 1MHz
Water Absorption	0.005%

Table 1: Properties of Vectra® C115 LCP

Testing of LCP packages have shown that they will pass the traditional gross and fine leak testing per the MIL-STD-883E standard. However, these tests do not consider outgassing, absorption, or permeability. As a result, LCP packages are considered near hermetic packages as compared to the fully hermetic ceramic and metal packages. [2]

Hermetic packages, typically ceramic, have traditionally been used by the military. These ceramic packages provide high reliability under the severest environmental conditions. The rapid shift in the commercial industry to plastic components has caused defense contractors to evaluate the use of plastic packages in military applications. However, as the defense industry slowly makes the conversion from traditional hermetic packages to plastic encapsulated packages; it is not relaxing their expectations or specifications for performance. The defense contractor needs to know the limitations of the packages as it pertains to the specific application. Military applications that have extreme temperature variations, long storage life, hermeticity issues, or are considered mission critical should consider the proven ceramic technology. Other applications that are man-portable, ground based, or in a controlled environment can take advantage of plastic packaging technology.

References:

[1] Ross, Dick, John Roman, and Edson Ito. "Choosing the Right Material for RF Packaging." *Electronic Products*. 1 Nov. 2007. <http://www2.electronicproducts.com/Choosing_the_right_material_for_RF_packaging-article-farcrjrticona-nov2007-html.aspx>

[2] Riley, George. "Wafer Level Hermetic Cavity Packaging." *Advanced Packaging Magazine*. May 2004. <http://www.flipchips.com/tutorial43.html>

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