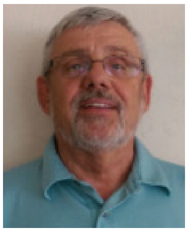

Liquid crystal polymer air cavity plastic packaging in RF applications

By Alex Elliott, Jim McDearmon [RJR Technologies]

In the highly competitive RF communications market, manufacturers need RF power transistors and packaging solutions that help them support higher linearity, higher average output power, and wider operating bandwidths. At the same time, given that the power transistor represents the single most expensive device in the power amplifier (PA), they need to find new ways to drive down costs. Together these relentless price/performance requirements are pushing designers to migrate from traditional ceramic or ceramic-metal packages or over-molded package solutions to alternative liquid crystal polymer (LCP) air cavity plastic (ACP) package options that use less expensive copper thermal bases for higher thermal performance.

ACP packages are becoming a proven, lower cost alternative to air cavity ceramic (ACC) packaging for cellular base stations and other communications systems. Moreover, the advantages of LCP packages are enabling IC manufacturers to target a host of new RF energy applications such as lighting, consumer cooking, automotive, emerging medical markets and industrial use. This article will look at why low-cost LCP packaging is driving designers to explore alternatives to over-molded and ACC packaging.

Driving down cost

Over-molded plastic packaging has for years been the preferred lower cost packaging technology of choice, particularly for commodity products such as memories or small signal transistors. The technology encapsulates the IC in a polymeric material that acts not only as a dielectric insulator, but also helps protect the device from mechanical and environmental degradation. Supported by high-volume manufacturers and suppliers, over-molded packaging is particularly attractive from a cost perspective. With a cost-per-lead running in the fractions of a cent including die and wire bonding, this approach can offer designers an order of magnitude cost advantage over traditional ceramic packages.

For RF system designers seeking to take advantage of the cost benefits noted above, the primary obstacle has been rising performance requirements. Unlike in air cavity packages, the polymer material in over-molded packages comes into direct contact with the die and bond wires, which limits package performance. Given that polymers exhibit a higher dielectric constant than air, an over-molded package will experience higher parasitics that can lower power output and gain depending upon the design and tolerance of the encapsulated die. Another issue has been reliability. The technology's high moisture absorption rate can lead to a "popcorn" effect when moisture collects and explodes in the assembly process.

Traditional alternative

Historically, device manufacturers have primarily relied on ACC packages to meet stringent RF power performance requirements. The ACC package has proved attractive because it combines a thermally and electrically conductive metal base with a ceramic ring that isolates the input and output leads. In turn, these packages deliver higher electrical isolation for the silicon die than comparable over-molded packages and are especially well-suited for high-frequency, high-power applications. Equally important, the ACC package provides excellent durability for the high-temperature soldering used in the assembly process. Widely implemented in RF applications, the ACC package is available today in a wide range of designs from multiple established suppliers.

ACC packages feature a metal base comprising a laminated structure of copper/copper-moly/copper (CPC) that is joined to a metallized and plated ceramic ring via a high-temperature brazing process. Typically, the ceramic base is gold-plated to allow the die to be attached by a eutectic process. A ceramic lid with pre-applied epoxy is typically used to seal a near-hermetic ACC package by attaching the lid to provide environmental protection.

Clearly the metal-ceramic packages widely used today offer designers a reliable, proven solution for high-performance RF applications. But they also present some distinct disadvantages. One issue is cost. In today's highly competitive base station market, designers are constantly searching for new cost efficiencies. The ACC package relies on a relatively expensive high-temperature fired ceramic and brazed assembly process to form the air cavity package. As a result, today a ceramic package represents a large portion of the total cost of a finished power RF device.

As base station design specs moved to wider bandwidths, higher power levels and higher frequencies, thermal efficiency has also proved to be a major challenge. Designers want to use a copper heat sink because it offers 30% better thermal conductivity than current CPC flanges used in ceramic packages at much lower cost with higher performance. With a coefficient of thermal expansion (CTE) approximately three times as large as current ceramic flange material, ACC packages can't use a copper flange material because the

CTE mismatch will cause the ceramic ring to crack during the brazing process.

New advances

One option to address the issues described above is to migrate to ACP packages. ACP technology uses an air cavity structure similar to a ceramic package to maximize electrical isolation of the silicon die. These ACP solutions support a wide range of applications with frequencies from L to V band. Moreover, they offer the high performance at improved cost, not only from a piece-part perspective, but also from an assembled one because ACP packages can be assembled in-strip, thereby eliminating all the non-value added labor needed to transfer singulated packages from their shipping tray into expensive Auer boats.

Packages using ACP technology employ an insert-injection molding process that combines a metal alloy lead frame with an LCP sidewall and matching lid with pre-applied B-staged epoxy as shown in **Figure 1**. Also, ACP packages can employ any eutectic die attach process used with ACC packages. The use of this lower temperature, compliant epoxy material essentially makes the package independent of the flange material. As a result, manufacturers can use any of a variety of base/flange materials to meet specific CTE matching and thermal management requirements. These base/flange materials range from ceramic LTCC and HTCC to copper alloys, OFHC copper and diamond, with thermal conductivity capabilities that range from 10W/K to 1000W/K.

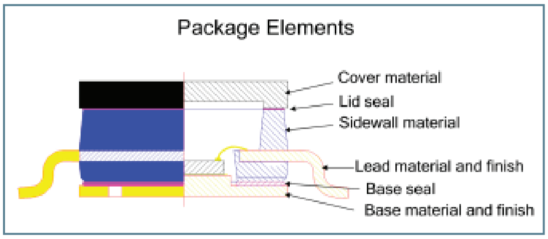

Figure 1: ACP packages use an insert-injection molding process that combines a metal alloy lead frame with an LCP sidewall and matching lid with a pre-applied B-staged epoxy.

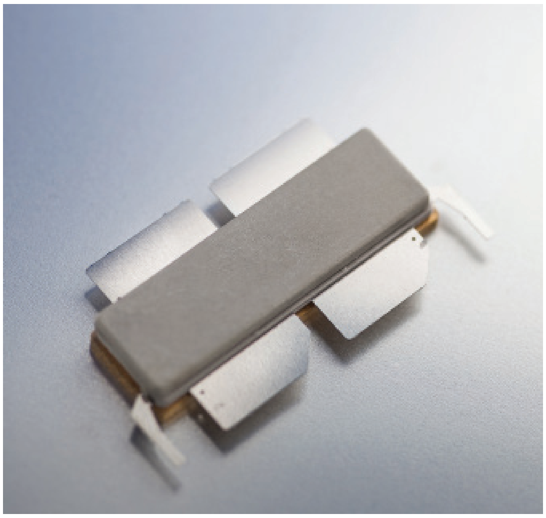

Figure 2: ACP packages allow designers to use lower cost, higher conductivity copper bases.

ACP packages, shown in **Figure 2** have been successfully used with CuW, Cu-MoCU-Cu, Al-diamond and copper flanges. It is the only packaging technology that allows designers to use lower cost, higher conductivity copper bases. Furthermore, today's ACP packages feature a flat sealing surface from lid to package and sidewall to the flange. This reduces the epoxy cross-sectional thickness between the lead and the package and increases the shear/adhesion strength of the lid to package. Another major advantage of ACP is it has one-third the dielectric constant of ceramic, therefore, providing improved RF performance. ACP technology offers the designer a fully matched CTE solution. With a low water absorption rate of just 0.02%, ACPs also offer near-hermetic reliability.

Furthermore, ACP technology makes the package assembly process easy to fully automate for high-volume production. Prior to ACP, assembly houses purchased ceramic power RF packages as singulated components, which require the use of expensive carriers to process the singulated packages. This requirement not only adds more labor to the process, it also drives up material costs. In many other types of semiconductor packaging, the in-strip or array formats let manufacturers maximize efficiency by assembling in a multi-up format.

Summary

Given the long term trend in RF power transistor performance requirements and the key role they play in the overall reliability and cost of RF systems, it seems clear that traditional ACC packaging will offer only limited utility in the years ahead. As performance requirements continue to be more demanding over time, designers will need a more reliable packaging solution at lower cost. By delivering a matched CTE solution with near-hermetic reliability at low cost and capable of supporting high-volume assembly techniques, ACP packaging offers designers a new high-performance option for today's rapidly growing RF markets.

Biography

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Jim McDearmon received his BS degree from California State U., San Diego, and is Director of Operations at RJR Technologies.