Near Hermetic Air Cavity Plastic Packaging for Wireless, MEMS and Optical Applications

John W. Roman, Richard J. Ross
RJR Polymers, Incorporated
7875 Edgewater Drive, Oakland, CA 94621
tel 510-638-5901; fax 510-638-5958
jroman@rjrpolymers.com; rross@rjrpolymers.com

Abstract

This paper will detail the design and manufacturing elements of near hermetic air cavity packages produced by injection molding of low moisture diffusivity polymers. The R-Pak process uses a patented sealing methodology to take maximum advantage of the properties of the starting polymeric material. The material properties and advantages will be presented. The very low moisture diffusivity of the packages produced provides excellent environmental protection for MEMS devices and sensors or alternatively the capability to incorporate ultra clean, optically clear covers for imaging applications. The polymers also have a low microwave loss tangent which, when combined with low resistivity conductors and package bases, produce packages with outstanding microwave performance. Microwave matching structures can be also built into packages that can transform very low transistor input and output impedances to design friendly intermediate impedances. This feature minimizes package discrete components and reduces assembly sensitivity. The technology also offers cost advantages over many alternatives often with higher performance. The packages can also be designed for very high power. Representative packages illustrating each of these features will be shown and the process and equipment developed for R-Pak packages detailed.

Introduction

This paper describes the design and manufacturing processes for injection molded air cavity plastic packages. RJR Polymers air cavity plastic packages are molded with a thermoplastic material around an unpopulated leadframe. This is commonly called a premolded package. A semiconductor die is mounted into the package cavity, connected to the leads and finally sealed with a separate lid. A typical package is illustrated in figure 1. R-Pak is the name for the comprehensive system of materials, processes and equipment that produce these packages. The die and wirebonds are in a cavity rather than being embedded in an epoxy as in transfer molded packages. Traditional transfer molded packages are made by completely filling a mold a thermosetting epoxy which encapsulates a leadframe with a mounted die. This epoxy completely surrounds and embeds the die and wirebonds.

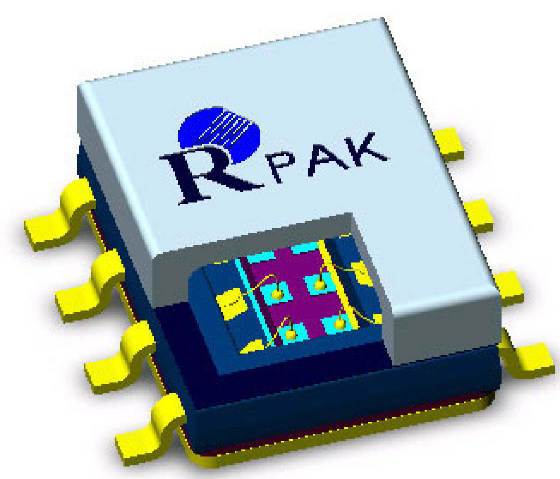

Figure 1. R-Pak premolded SOIC-8 lead package

Air Cavity Packaging

Air cavity packaging is appropriate to a number of applications. Many MicroElectroMechanical System (MEMS) devices cannot function embedded in epoxy so air cavity packaging is optimum.[1] RF and microwave semiconductors perform better in an air cavity rather than embedded in a lossy solid dielectric. Free space optical and imaging devices cannot be surrounded with an opaque material that attenuates or diffracts light.[2] Many sensors need to sense their environment to function as opposed to being isolated in a solid block of material.[3] Many devices are functional combinations of two or more of these features.

The assembly process for air cavity and transfer molded packaging is essentially the same, differing only in how the packages are "sealed". A transfer molded package is molded around an assembled leadframe that creates the package with no internal cavity. An air cavity package is sealed with a cover after component assembly into a premolded package. The RJR Polymers R-Pak injection molded packages use a modified Liquid Crystal Polymer (LCP) compound for the dielectric molded around metal leadframes. A typical package construction is shown in figure 2.

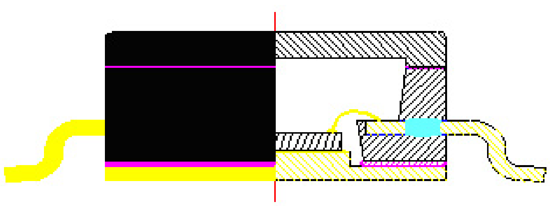

Figure 2. Representative R-Pak package cross section illustrating the internal cavity with a wirebonded die on a metal package base

Injection molding processes are very mature and take advantage of the improvements in molding hardware, controls, high temperature steels and mold design software over the last 50 years. But most significantly, there have been advances in polymer materials that are ideal for the construction and life cycles of electronic packages. The details of the injection molding process and methodology are described in "Injection Molded Surface Mount 32 Pin vision package Competes with Ceramics". [4] The advantages of RJR air cavity packages come from a combination of materials, design, manufacturing processes and dedicated equipment. All come together is what is termed "The Total Package Solution ®".

The materials used to make RJR packages are fundamental to the electrical and environmental performance advantages of R-Pak. The 3 basic components are: first, HTP 1280, an LCP thermoplastic molding material; second, custom formulated sealing epoxies that make a near hermetic cavity package; and third, metal leadframes that have specific advantages for different applications.

Liquid Crystal Polymer (LCP)

HTP 1280 Liquid Crystal polymer is a high performance thermoplastic molding material with many intrinsic advantages. The properties of HTP 1280 are summarized in Table 1.

HTP 1280 – PLASTIC BODY COMPOUND		
Physical		
Density Water Absorption	1.67 gm/cc 0.02%	ASTM D792 ASTM D570
Mechanical @ 23C		
Tensile Strength Tensile Modulus Elongation @ Break Flexural Strength Flexural Modulus IZOD Impact Strength Notched	21,000 PSI 2.5 X 10^6 PSI 1.2% 31,000 PSI 2.4 X 10^6 PSI 1.6 ftlb/in	ASTM D638 ASTM D638 ASTM D638 ASTM D790 ASTM D790 ASTM D256
Thermal		
Melting Point DTUL @ 1.8 Mpa (264 PSI)	280°C (536°F) 270°C (518°F)	ASTM D3418 ASTM D648
Electrical		
Volume Resistivity Surface Resistivity Dielectric Strength Dielectric Constant Dissipation Factor Arc Resistance Comparative Tracking Index	10^{12} ohm-cm 10^{17} ohm 766 V/mil 3.8 @ 1 kHz 3.7 @ 100 kHz 3.7 @ 10 MHz 0.007 @ 100 kHz 0.003 @ 10 MHz 165 Sec. 175 volts	ASTM D257 IEC 93 ASTM D149 ASTM D150 ASTM D150 ASTM D150 ASTM D495 ASTM D3638

Table 1. HTP 1280 Liquid Crystal Polymer Molding Compound

The crystalline domains in the LCP material result in a polymer with very low water vapor transmission and moisture absorption characteristics. The low moisture transmission rate means that packages made with LCP are more nearly hermetic than any other type of plastic package. This is shown in the comparison to other polymers in fig 3. This water vapor permeability rate of LCP shows that it is similar to glass!

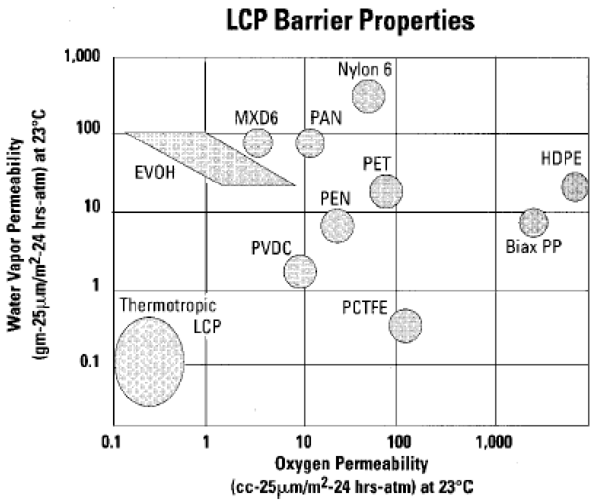

Figure 3. Water vapor and oxygen permeability of plastics [5]

The associated very low water absorption percentage means that LCP packages do not create problems during soldering from the sudden vaporization of absorbed moisture that can cause package failures. The mechanical properties of HTP 1280 are a nearly ideal balance for electronic packages. This strong and tough but not brittle thermoplastic is inert and resistant to corrosives and solvents, non-flammable, and contains no halogens. Since LCP is a thermoset material it can be recycled by regrinding and remolding unlike thermoset epoxy molding compounds.

One of the most attractive properties of LCP is that the Coefficient of Thermal Expansion (CTE) is low and can be tailored. HTP-1280 is manufactured to be a close CTE match to copper, the most commonly used leadframe material for R-Pak packages. This CTE compatibility results in a highly reliable, matched system that minimizes differential thermal stresses. One of the desirable LCP characteristics for injection molding is the lack of adhesion to metals. While this results in clean release from the mold without using contaminating mold release agents, this same property means that LCP does not naturally bond to an insert molded leadframe. The RJR Polymer's solution is to use a moisture barrier epoxy to seal the leadframes penetrating through the package body that make packages near hermetic.[6][7][8]

The term "near hermetic" refers to packages that are capable of passing fine leak testing but are not exclusively made of metal and glass or ceramic. [9] Historically the term "hermetic" refers to cavity ceramic and metal or glass sealed metal packages that are welded or solder sealing to MIL STD 883, method 1013 fine leak specifications. This definition is based on the assumption that cavity plastic packages are susceptible to significant diffusion of water vapor through the plastic over time even though they can be made to pass a fine leak test. Unacceptably high levels of moisture inside of a package can cause catastrophic failure during soldering or corrosion inside of a package. R-Pak LCP material challenges that assumption with a water vapor permeability rate similar to glass, a material considered "hermetic".

The second element of the R-Pak system is the sealing epoxies used to seal he package both at the leads and at the cover that make the packages near hermetic. RJR Polymers has developed a moisture barrier epoxy that is applied to he leadframe before injection molding the package body by the patented "inverted stamping" process.[10] This epoxy is formulated to adhesively bond to the HTP 1280 molding compound and the leadframe metal, forming a leak tight seal where the leads pass through the package body. The second epoxy with similar moisture barrier properties is preapplied to package lids used to seal packages after the die is assembled.

Metal Leadframes

The third material used for R-Pak packages is the metal leadframe, which form the conductive elements of a package. Copper is the most commonly used leadframe material for R-Pak packages and the HTP1280 LCP molding compound is formulated to be a close CTE match. Copper is a very versatile choice for leadframes with great electrical and thermal conductivity at low cost. Copper can be readily plated with a wide variety of finishes to suit every application. The R-Pak process can be used to produce a package with a copper base for high power dissipation and electrical grounding.[11] This package construction is shown in figure 2 with examples pictured in figures 5 and 6. While copper is most common, the historical nickel-iron leadframe alloys can also be used where very stiff or very thin leads are desired. The R-Pak construction process versatile enough to work effectively with virtually any metal.

Process and Equipment

The R-Pak system approach to packaging focuses on the processes involved in producing high yield packages. The epoxies and molding compounds are optimized with carefully developed processes. Processes like inverted stamping of leadframes, injection molding and the application and B-staging of epoxy applied to covers are parts of the internal manufacturing flow. Coordinated material and process optimization results in high yield package production but not all elements of the air cavity package assembly processes are internal. The package cover attach is a process performed at the end of the package assembly cycle at customer locations worldwide. Recognizing that process control and consistency is key to high yield, RJR Polymers designs and manufactures equipment to support package assembly by the customer. The IsoThermal Sealer (ITS), shown in figure 3, is an elegant solution to the challenge of keeping package assembly consistent, controlled, simple and high yielding.[12] While cover sealing with pre-applied B-staged epoxy can be done by a clip and bake method, optimum results are obtained with an ITS.

Figure 3. The IsoThermal Sealer (ITS) is used for cover sealing and metal based package assembly

The ITS is loaded with populated packages in one platen and covers with pre-applied epoxy in the opposite platen. The 2 platens are brought together accurately aligning the packages and covers which are sealed with an automatic programmed process cycle. A key feature of the ITS process is the heating of the packages and covers to the optimum epoxy curing temperature and then bringing the covers into contact with the packages graphically shown in figure 4. This process sequence virtually eliminates blowouts and pinholes caused by the increase in internal pressure when the air inside the cavity expands during heating which can result from heating the cover and package clipped together.

While this pressure equalization enhancement alone contribute to higher yields, the speed and consistency of the programmable ITS cycle further enhances yields. The programs are optimized for specific sealing materials and package configurations by RJR Polymers to provide customers with the optimum process. With the ITS equipment, the process is optimized as one component of the R-Pak system.

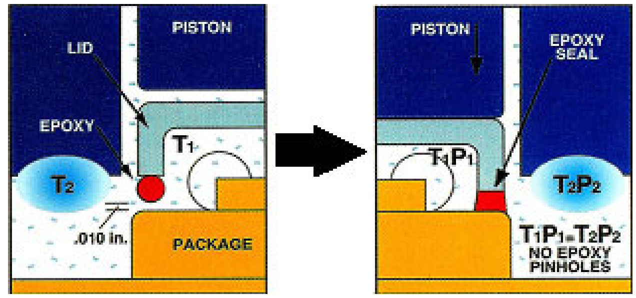

Figure 4. The ITS sealing cycle advantage

Package Design and Construction

R-Pak air cavity packages are applicable to a variety of applications as described previously. The full potential of the materials and processes can be realized by application optimized package design. The insert injection molding process allows for flexibility in placement and shaping of the package leads. R-Pak packages can be manufactured as cavity packages with plastic sidewalls and base as shown in figure 8 or as a 3 piece package as shown in figure 2. The patented 3 piece construction incorporates a metal base for high power dissipation or optimum electrical grounding.[11] The metal based package also presents the option of high temperature die attach in a plastic package.[13] High power semiconductors may be die attached first with gold/silicon or gold/tin eutectic to the metal base and then the premolded plastic package body assembled to the base. The die is then wirebonded and cover sealed to complete the assembly. The ITS is used for cover sealing and the package body to base assembly for the R-Pak metal based package.

RF and microwave Power Packages

An example of a high power package is shown in figure 5. This 2 lead package is made for high power Laterally Diffused Metal Oxide Semiconductor (LDMOS) or Gallium Arsenide (GaAs) die typically used in base station transmitters. His type of package fits historical outlines established decades ago for metal ceramic packages with wide, low inductance leads and a metal heat sink base. Where ceramic packages are constrained to use a CTE matched metal base, injection molded plastic packages can use inexpensive copper in as an alternative option to more expensive CTE matched metals or composites.

The flexibility to use less costly metal bases coupled with the lower cost of making plastic packages make these high power applications particularly attractive for pre molded LDMOS packaging.

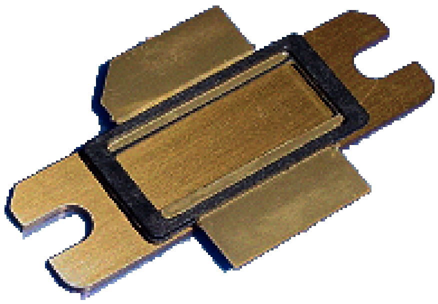

Figure 5. High power package with a flanged metal heatsink base.

Another microwave package is shown in figure 6. The partially matched package has passive network elements built into the package to transform the very low input and output impedances of microwave power die to more manageable intermediate impedances while retaining all of the good thermal dissipation and microwave grounding characteristics of the 3 piece package.[14]

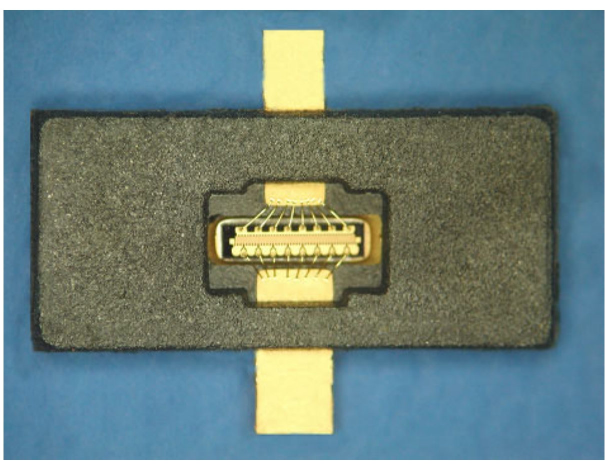

Figure 6. Partially matched microwave package.

MEMS and Sensor Packaging

Many MEMS die require a cavity package either isolated from the environment as with a MEMS switch, or open to the environment as with a MEMS (or conventional) pressure or acoustic sensor. The package shown in figure 7 is a premolded package in an SOIC-8 outline that is manufactured with a precisely defined sensing port to the outside. The die is mounted and interconnected conventionally the package is cover sealed. In this package the metal leadframe is used to define the sensing port in the base of the package but the port could also be molded into the cover. The port can be temporarily sealed to protect the die through assembly and cleaning if necessary.

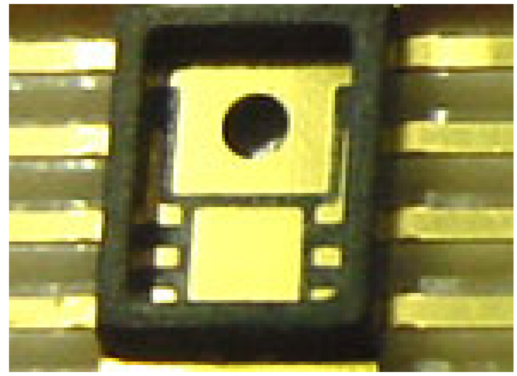

Figure 7. Sensor package in an SOIC 8 lead format.

While this package is in a standard outline, the flexibility of injection molding allows custom shapes to be produced for specialized applications. Conversely, the production of packages in standard outlines leverages the existing infrastructure of layout, tooling, handling, inspection and test. This allows easy incorporation of premolded packages where the situation demands. The flexibility of the R-Pak process allows standard package body sizes and footprints to be manufactured with a level of flexible customization by a simple change to the leadframe design.

Optical Packaging

Optical die almost always need to be packaged in a cavity as opposed to embedded in epoxy which would interfere with the sensing or transmission of light. Figure 8 shows an air cavity quad flatpack with on optically clear glass cover. This class of "imaging" or "vision" packaging houses optical sensor die which convert an optical image to electronically encoded data. This package must protect the die in its assembly and operating environments while not interfering with the optical functionality.[15] The package in figure 8 has an optically clear glass cover which is epoxy sealed to the package. The R-Pak process uses a special low outgassing cover sealing epoxy with the ITS sealing system which prevents any redeposition of volatile components that might degrade the optical clarity. The plastic of the package is compliant enough to allow attachment to glass while affording the near hermetic properties of R-Pak packaging.

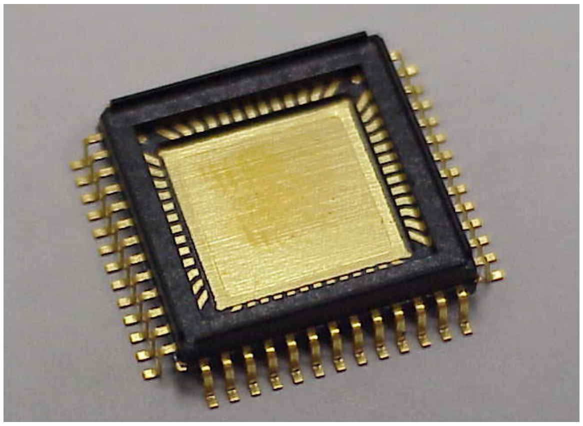

Figure 8. Quad flatpack optical package with a transparent glass cover

Summary

This paper has given an overview of the design and manufacturing processes for RJR Polymers R-Pak injection molded air cavity plastic packages. The R-Pak process uses patented sealing methodology to take maximum advantage of the properties of the starting polymeric material. The material properties and advantages of the system were described but more in depth information can be found in the references or by contacting the authors.

References

[1] Jacobs, Josh, Malone, Josh, "Suitability of an Epoxy Seal for a MEMS Package", Proceedings of the International Microelectronic and Packaging Society Symposium, Boston, Massachusetts, 2000

[2] Xu, Frank Y., "Quasi-hermetic Photonic Packages with Polymer Sealants in a Central Office Environment", Proceedings of the Electronic Components and Technology Conference, New Orleans, Louisiana, 2003

[3] Rentsch, Arno, Wilde, Juergen "Use of Alternative Materials for Packaging of Sensors and MCMS", Proceedings of the Micro Materials Conference, 2000

[4] Louie, Wayne, Li, Norman, Shaffer, Tony and Ross, Richard, "Injection Molded Surface Mount 32 Pin Vision Package Competes with Ceramics", Proceedings of the Surface Mount Conference, San Jose, California, 2002

[5] Lusignea, Richard, "Liquid Crystal Polymers: New Barrier Materials for Packaging", Packaging Technology, October 1997

[6] Ross, Richard J., "New Hydrophobic Materials and Process for Sealing Microwave and Vision Packages", Proceedings of the Wireless Design Conference, London, England, May 15-17, 2002

[7] Ross, Richard J., "Elimination of Moisture in Adhesive Sealed Packages", Proceedings of the European Conference on Wireless Technology, London, England, September 24-28, 2001

[8] U.S. Patent Number 6,214.152: "Lead Frame Moisture Barrier for Molded Plastic Electronic Packages." April 10, 2001

[9] Roman, John W., Ross, Richard J., "A Moisture Resistant Air Cavity Plastic Microwave Power Package Capable of Eutectic Die Attach" Proceedings of JEDEX Conference, San Jose, California, 2003

[10] U.S. Patent Number 5,816,158: "Inverted Stamping Process." October 6, 1998

[11] U.S. Patent Number 6,511,866: "Use of Diverse Materials in Air Cavity Packaging of Electronic Devices", January 28,2003

[12] U.S. Patent Number 5,056,296: "Iso-thermal Seal Process for Electronic Devices", October 15.1991

[13] Ross, Richard J., "Plastic Packages for Microwave Devices using Standard Eutectic Die Attach", Proceedings of the Wireless Design Conference, London, England, May 15-17, 2002

[14] Evangelista, Steven C., Roman John W., "A High Performance 5.8 GHz Power Amplifier Design Enabled by a New Microwave Power Package", Proceedings of the International Microelectronic and Packaging Society Symposium, Denver, Colorado, October 2002

[15] Ross, Richard J., Humid Aging Performance Testing of Ceramic, Thermo Plastic And Transfer Molded Vision Packages", Proceedings of the IMAPS Conference, Tokyo, Japan