LCP Injection Molded Packages — Keys to JEDEC 1 Performance

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Abstract

LCP (Liquid Crystal Polymer) is a class of high performance, high temperature thermoplastic polymers which can be formulated to provide injection molding compounds having properties uniquely advantageous for electronic cavity packages. This poster paper will present thee physical, electrical, and thermal characteristics of the base materials. The packages described will include thermally enhanced LDMOS made of LCP using a three tier assembly system, partially matched RF packages based on the electrical properties of LCP and leaded packages using a 48 and 52 pin CCD/CMOS configurations as a models.

While LCP has an outstanding array of properties which make it advantageous for electronic applications, there is a notable disadvantage—adhesion. Due to it's balanced polymer structure, the surface energy of a molded or extruded part makes it very difficult to form adhesive bonds which will meet the typical electronic standards, like JEDEC Level 1 or 2 solder reflow performance.

Solutions to these deficiencies are found in the compounding and formulation of the LCP molding material, adhesives which will stick to both the LCP compound and either die or lids, and primer adhesives which can be applied to leads prior to molding to form a water vapor tight bond between the metal lead and the LCP body. Properties of two LCP materials, a typical adhesive formulation and application procedures are also shown. One of the LCP formulations will meet the requirements for lead free solder reflow.

Formulation of the compounds and process techniques and controls are the keys to LCP package performance. The steps from starting materials to assembled packages are described.

Introduction

Thermoplastic injection molding is a highly developed process used to manufacture a vast array of parts from toys to high performance automotive engine parts, medical devices, connectors as well as common consumer items. Thermoplastics are polymer compounds that can be melted and injected into a mold under pressure to form a useful part by cooling in the mold.

In the past twenty years there have been major improvements in thermoplastic compounds to perform at temperatures exceeding 200 degrees Centigrade and in high humidity conditions. Over about the last decade, a class of compounds called Liquid Crystal Polymers (LCPs) has become available. It is this polymer class, together with ancillary materials such as metal leadframes and adhesives, which combine to produce a range of cavity package configurations that can compete in the same performance arena as ceramics. Specifically, the ability to pass the JEDEC Moisture Sensitivity Level 1 (MSL1) solder reflow requirement. This involves passing a leak test after a pre-conditioning of 168 hours at 85 deg. C. and 85% relative humidity (RH) prior to three cycles through a reflow oven with a peak part temperature of 260 Deg. C.

There are a number of materials and processes that are combined in the proper sequence to achieve the MSL 1 performance. LCP is a significant contributor to this success, but it is not the magic bullet that makes everything work. LCP's high temperature performance, ease of molding, outstanding electrical properties, chemical resistance, moisture resistance, etc. all contribute to performance of a cavity package but LCP also presents a significant challenge. It is a stable, balanced molecule and is not easily adhesively bonded, especially in the presence of moisture. When molded around a metal leadframe, the LCP does not adhere to the metal. That may preclude making a leak tight package.

Among the Keys to success are materials and processes which result in a package configurations which permit standard adhesive die attach, lid attach and sealing of lead penetrations through the package body that block the entry of moisture and pass gross leak after solder reflow. They are discussed in this paper in the following sections:

1. Formulation of the LCP molding compound.
2. Design of the package body
3. Formulation and application of sealing adhesive to lead prior to molding.
4. Insert injection molding process
5. Adhesives for lid and die attach.
6. Package assembly process

Volumes can and have been written on each of these subjects This paper will 48-pin and 52 pin focal plane array quad flat packages to illustrate the important points of each section.(Ref. 1,2,3,4,5,6)

Formulation Of The Lcp Molding Compound

Table 1 shows average data on three glass filled LCP molding compounds from three different LCP suppliers. Average means adding the data sheet values of the three compounds and dividing by three. Values that show less than a 1% variation among the three materials are specific gravity, glass transition temperature (Tg), glass concentration and color. This table is representative of "generic" LCP molding compound.

TABLE 1
Generic LCP Molding Compound
40% Glass Filled

Physical:		
Density:	1.67 gm/cc	ASTM D792
Water Absorption	0.02%	ASTM D570
Mechanical @ 23C:		
Tensile Strength	22,000 PSI	ASTM D638
Tensile Modulus	2.5 X 10^6 PSI	ASTM D638
Elongation @ Break	1.2%	ASTM D638
Flexural Strength	30,000 PSI	ASTM D790
Flexural Modulus	2.3 X 10^6 PSI	ASTM D790
IZOD Impact Strength Notched	1.6 ftlb/in	ASTM D256
Thermal:		
DTUL @ 1.8 Mpa (264 PSI)	270°C (518°F)	ASTM D648
Vertical Flammability at 0.79mm.	V0	UL 94
CTE(parallel to flow), 0-150 deg. C.	6-16 ppm.	ASTM E228
Thermal conductivity	0.32W/mK	ASTM C177
Tg (by DSC)	120 Deg. C.	
Electrical:		
Dielectric Strength	766 V/mil	ASTM D149
Dielectric Constant	3.8 @ 1 kHz 3.7 @ 100 kHz	ASTM D150

TABLE 2
TYPICAL PROPERTIES
R-Pak LCP Molding Compound HTP 1330
40% Glass Filled

Physical:		
Density:	1.67 gm/cc	ASTM D792
Water Absorption	0.02%	ASTM D570
Mechanical @ 23C:		
Tensile Strength	22,000 PSI	ASTM D638
Tensile Modulus	2.6 X 10^6 PSI	ASTM D638
Elongation @ Break	1.3%	ASTM D638
Flexural Strength	31,000 PSI	ASTM D790
Flexural Modulus	2.4 X 10^6 PSI	ASTM D790
IZOD Impact Strength Notched	1.7 ftlb/in	ASTM D256
Thermal:		
DTUL @ 1.8 Mpa (264 PSI)	290°C (518°F)	ASTM D648
Vertical Flammability at 0.79mm.	V0	UL 94
CTE(parallel to flow), 0-150 deg. C.	6-17 ppm.	ASTM E228
Thermal conductivity	0.32W/mK	ASTM C177
Tg (by DSC)	120 deg. C.	
Electrical:		
Dielectric Strength	700 V/mil	ASTM D149
Dielectric Constant	3.8 @ 1 kHz 3.7 @ 100 kHz	ASTM D150

Also common to all three materials is the difficulty in adhesive bonding. Typical lid sealing adhesives used to seal ceramic, metal, PC board and transfer molded devices do not survive either 24 hour pressure pot exposure (121 deg. C., 100%RH) or186 hour exposure to 85Deg. C./85% relative humidity (RH) when bonded to generic LCP. The failure mode before wet exposure is mostly adhesive rather than cohesive.

Table 2 shows a formulated LCP compound designed specifically for package applications. It has the same filler concentration as the "generic" compound shown in Table 1, but it also has ingredients which provide a more active bonding surface and therefore it is more receptive to adhesive bonding. The other half of the equation is the formulation of the adhesives which are compatible with the package formulated LCP which are discussed later in this paper.

Design of the Package Body and Leadframe

Package design can be done on either a custom basis or to industry standard package outlines. Figure 1 shows three existing designs and shows the versatility of this technology. Package 1A is a 48 pin quad flatpack design for either vision applications using a glass window or an LCP plastic lid for conventional semiconductor applications. Configuration 1B shows a patented three part high power transistor package. The package mid-body and lid are injection molded using one of the LCP formulation shown in Table 2. The bottom of the package can be copper, copper/moly/copper, copper/tungsten, etc. for good heat sinking and electrical grounding. Making the metal bottom a separate item enables the use of eutectic soldering of the die to the base at temperatures of 400 deg. C. or higher since this is done before joining the bottom to the mid body prior to wire bonding. Configuration 1C is a unique partially matched microwave amplifier package. This package type takes advantage of the outstanding microwave properties of the LCP compound.

FIGURE 1A

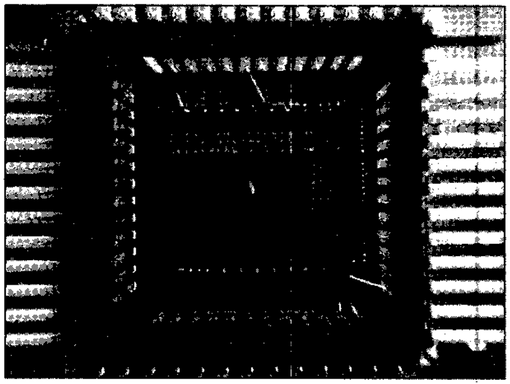


FIGURE 1B

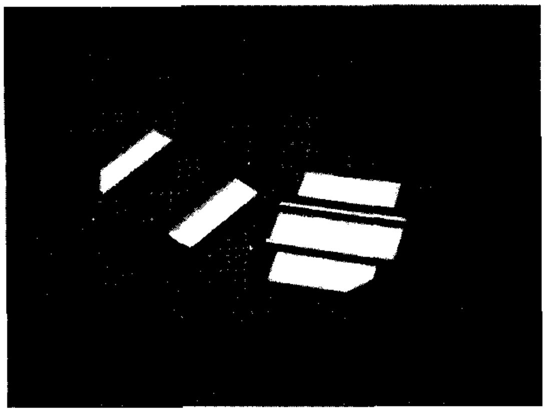
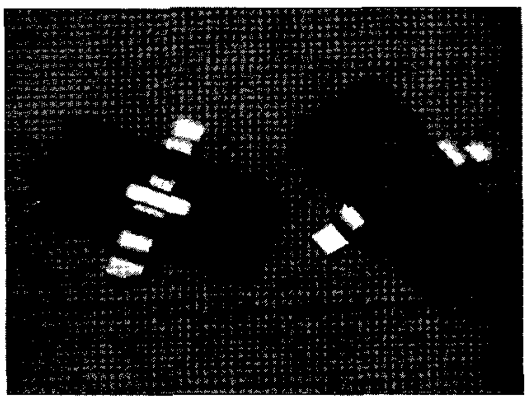


FIGURE 1C



In all of the cases above, the injection gate location, dam bars and lead supports are designed to maximize the anisotropic mechanical properties and CTE of the LCP compound.

3. Lead primer adhesive formulation and application

Well sealed packages like those described in Figure 1 have 4 primary paths for moisture intrusion:

A. Diffusion through the lid adhesive
B. Along lead penetrations through the package body.
C. Outgassed from the plastic body or adhesive
D. Diffusion through the package body plastic

The contribution Items A, C and D to package interior moisture is normally small compared to item B. If the package body material is not tightly adhered to the penetrating leads ***on all four sides*** there will be a direct and open moisture path to the package interior and a gas leak path to the exterior of a sealed package during gross leak testing.

The adhesive formulation used for coating the leads is termed "primer". Dip coating the leadframe to apply the primer was ruled out for economic reasons. The best process is to apply the moisture barrier adhesive primer precisely and locally forming mini-gaskets around each lead. The package wall captures the gaskets during molding where the moisture barrier gasket forms a leak tight bond with both the molding plastic and the metal leadframe. Formulating the family of primer adhesives was a major program that required years of investigation and the application process represented the greatest challenge.

The answer was found in the ASAP2000 inverted stamping process. This system (U.S. Patent # 5,826,158) takes a totally new approach to adhesive application. The stamping die is immersed in a bath of the material to be applied, raised out of the liquid, and then the die is brought into close proximity or into direct contact with the surface to be coated or "stamped". Proper design of the die permits application of the primer to the vertical sides of the leads. A representation of this process is shown in Fig. 2.

FIGURE 2

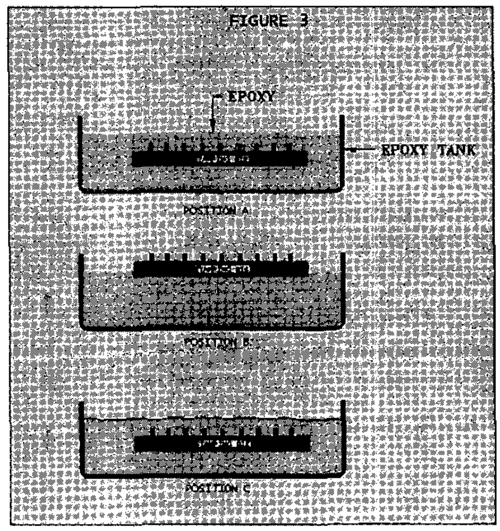
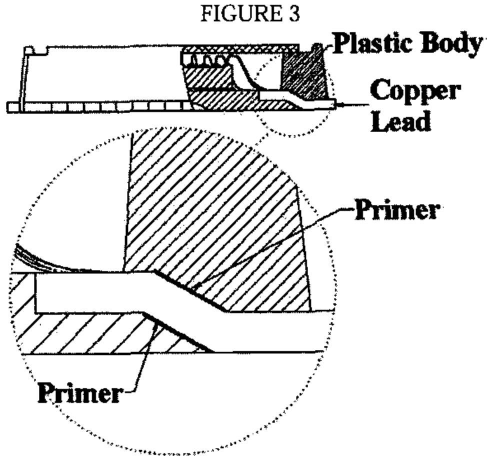


FIGURE 3



The uniformity of distribution can be seen from the picture of a 48-pin leadframe segment in Fig. 3 which has been stamped with the appropriate moisture barrier primer. After the stamping, the stamped parts are cycled through a linear oven to advance the primer to the appropriate molecular weight (B staging). The operating window for B staging is governed by the molding cycle and the adhesion integrity with the molding compound.

4. Insert Injection Molding Process

The importance of the barrier primer and molding compound has been discussed but making good packages requires a good molding process. The keys in the molding process are the mold design, and the time/temperature/pressure parameters of the molding cycle. All electric molding presses are preferred because of the fine control of the injection rate, pressure cycle and shot size. A schematic picture of the mold and leadframe configuration is shown in Figure 4. Process cycles will vary with the size of the part, the number of sites per leadframe and the thickness of the LCP in various parts of the package. A major advantage of LCP is the extremely low mold shrinkage making thickness variations in electronic packages minimal.

Figure 5 shows a completed package after lead trimming, forming and singulation. This unit has 52 pins as well as a down set metal die pad as an example of the versatility of the technology.

5. Adhesives for assembly and lid attach

There is a family of adhesives designed for these die attach and lid sealing. Selection depends upon the material composition of the die pad and the lid. A glass lid for sealing vision packages uses a formulation specific to the combination of glass and LCP while attachment of a metal base to a package sidewall uses a different formulation even though they look the same and process in the same thermal cycle. A typical formulation for vision packages is shown in Table 3.

FIGURE 4

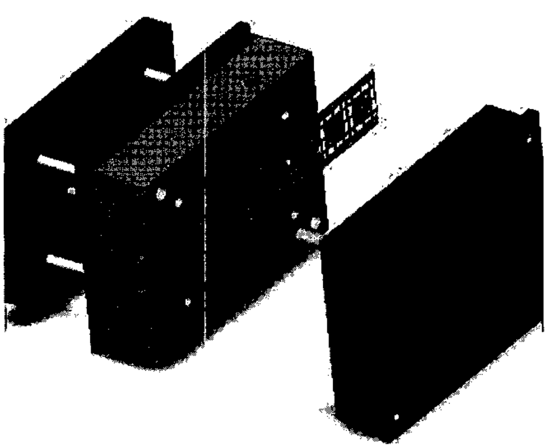


FIGURE 5

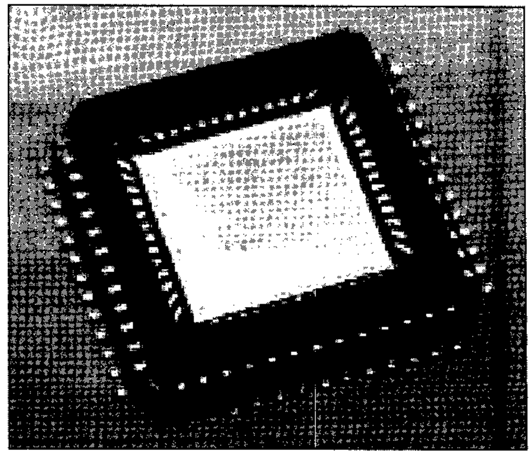


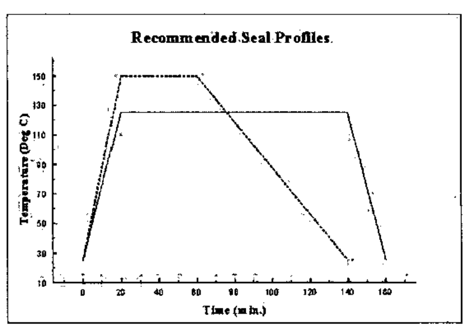
TABLE 3
TYPICAL PROPERTIES
FORMULATION RJ9F CCD

Extractable ions	less than 10 ppm
Moisture Absorption @ 85/85 Temp, Humidity	<2.5%
Ultimate Tg by DSC	100°C
CTE	30×10^{-6} in/in/°C

TYPICAL SEALED PACKAGE PERFORMANCE PROPERTIES*

Humid aging (168 hrs @ 85/85 conditions)	Zero Failures
Thermal shock (MIL-STD 883E)	Zero Failures
Thermal cycle (MIL-STD 883E)	Zero Failures

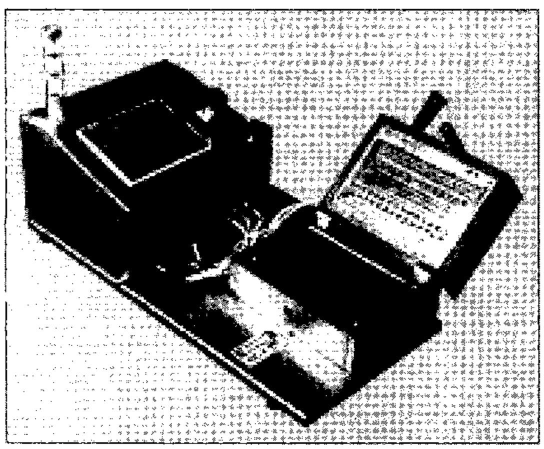
SEALING AND CURING



6. Package Assembly Process

The historical method of clamping packages and lids together either with individual clips or in multiple fixtures will work for sealing. But there may be a substantial variation from part to part or fixture to fixture which can decrease yield due to leaks and misalignment. RJR Polymers manufactures the IsoThermal Sealer (ITS) that elegantly controls the process conditions and increases efficiency. Yields of 99% or greater can be commonly achieved by using the Isothermal Sealing System and equipment. This system uses precise locating plates for all the components and the individual plates are temperature controlled. Package component parts are not joined until their temperatures are equilibrated and each package is provided with accurately controlled pressure. A picture of the standard model 400 ITS sealing unit is shown in Figure 5. Cycle times will generally be in the range of 4 minutes to 12 minutes followed by a 30 to 60 minute post cure (no pressure required). This type of unit is semi-automatic. The parts are charged to the unit manually or with transfer tools. When the unit is closed and the start button is actuated the rest of the cycle is automatic.

FIGURE 6



Conclusions

There is no single magic material or process step that is the key to success in producing high performance injection molded cavity packages. All of the Keys listed must be coordinated to produce an efficient process. The six specific keys outlined in this paper are as follows:

1. Formulated, molding grade LCP compounds receptive to adhesive bonding.
2. Design of specific package configurations.
3. Formulation and application of adhesives which bond to LCP.
4. Controlled, insert injection molding process.
5. Adhesives for lid and die attach.
6. Controlled package assembly process with adhesives.

If all 6 steps are performed correctly the results are packages which pass JEDEC MSL1 solder reflow performance.

Acknowledgments

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References

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