Near Hermetic Packages

RJR Technologies, Inc. (RJR)

RJR specializes in the development and manufacturing of open tooled RF and Photonics packages, and proprietary B-stage epoxy adhesives engineered for sealing or attaching glass, plastic, metal, and ceramic or any other materials for conductive and non-conductive applications mainly for the semiconductor and medical industries. In addition, RJR offers manual, semi-automatic and fully automated sealing equipment designed for the customer's specific application to obtain the best seal in the industry with 99%+ yields. Besides these products, RJR services include:

- Assist customers in the design and development of custom packages and lids;
- Help the customer take the new design from prototype to mass production;
- Assist customers in defining the assembly process for new package/lid designs or lid attach;
- Solve customers' sealing or attaching issues, such as the elimination of pin holes and blow outs that occur in the assembly of air cavity products;
- Develop custom sealing processes to fit the customer's specific needs;
- Custom epoxy formulation if RJR's existing epoxy formulations do not meet the customer's needs; and
- Formulate conductive epoxies that include: electrically conductive, thermally conductive, and electrically and thermally conductive.

RJR's strength lies in combining technical expertise with product innovation. Every custom package design and adhesive are tailored to customer requirements to maximize yield and reliability.

RJR's Foundation: LCP Air Cavity Packages & B-Stage Epoxies

Air Cavity Plastic (APC) Packages:

Air-cavity packaging is used in high frequency RF and microwave semiconductor as well as photonics components, and medical application, amongst others. This is because air, as a dielectric, is lossless in comparison to traditional overmolded packages using lossy epoxy mold compound that limits performance in high frequency applications. Similarly, free space optical and imaging devices cannot be surrounded with an opaque material that attenuates and/or diffracts light. Traditionally high reliability and/or fully hermetic air cavity packages are made from using metal (Kovar), ceramic and other non-organic materials, whereas RJR's ACP packages offer a cost-effective alternative using advanced plastics with near hermetic reliability.

RJR's ACP packages consist of:

1. Liquid Crystal Polymer (LCP) compound insert-molded sidewall around metal leadframes;
2. A flange (thermal base); and
3. An LCP molded lid.

A typical package construction is shown in figure 1.

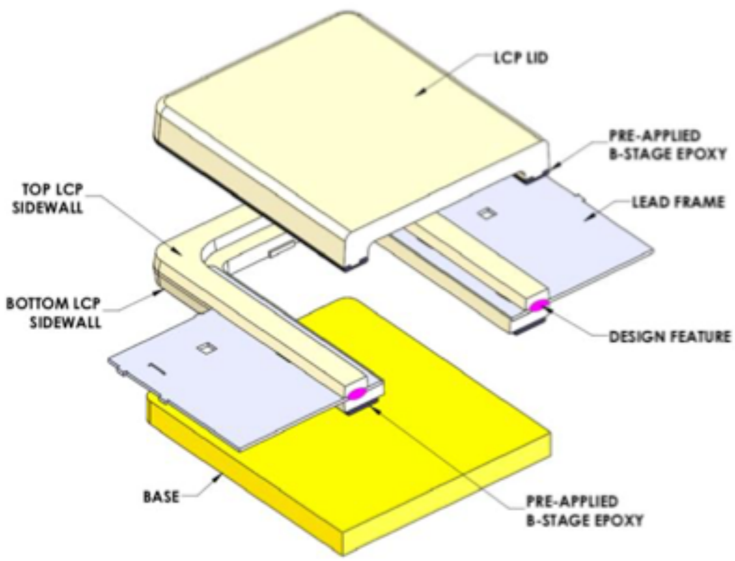

Fig 1 – A typical example of an ACP Package in cross section

The crystalline domains in the LCP material result in a polymer with very low water vapor transmission and moisture absorption characteristics comparable to glass (see figure 2). The low moisture transmission rate means that LCP-based packages, whose designs follow RJR design rules, can pass some, if not all, of the hermetic reliability tests applied to non-organic hermetic packages. LCP packages greatly outperform other plastic package materials.

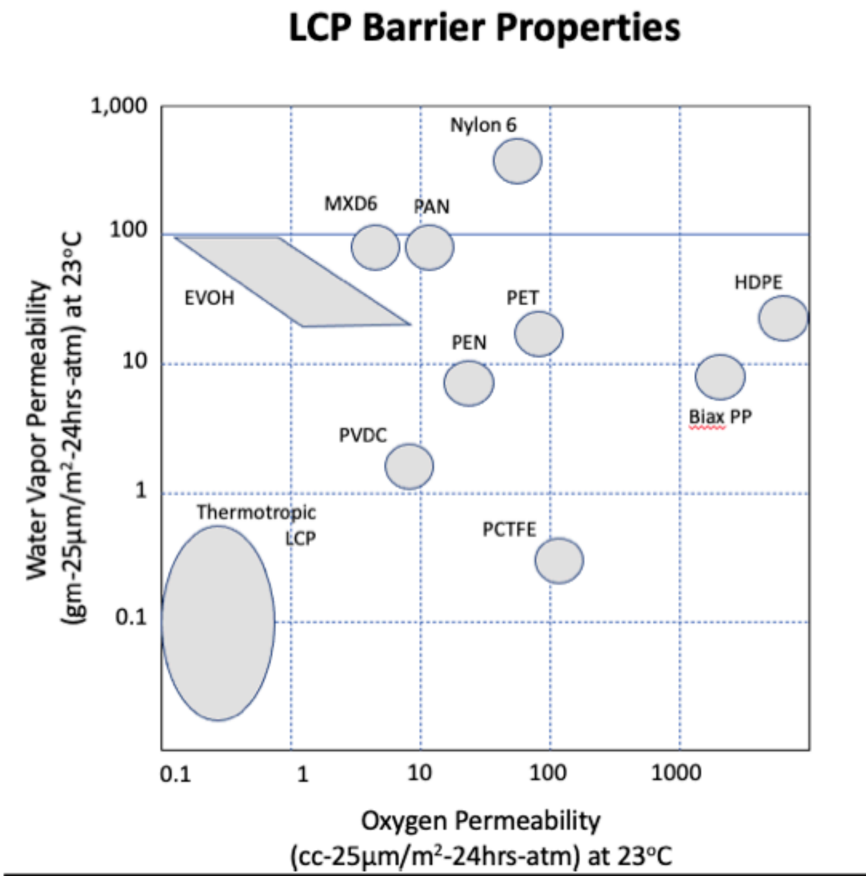

Fig. 2 – Water Vapor Permeability versus Oxygen Permeability for different LCP materials

Pham et al [1] have previously reported on the general reliability of the usage of LCP in RF packaging including a literature study. They report that LCP is an attractive material for making hermetic packages that can provide reliability in a low-cost and lightweight platform. Several authors in the literature study provide data that LCP can be used for hermetic packages with solid long-term reliability. The limiting factor in the total package is the sealing process between the different interfaces, such as LCP-to-lead frame, sidewall-to-flange and sidewall/flange-to-lid. RJR addresses all of this with its proprietary B-staged epoxy, design features, manufacturing processes and ITS (Isothermal Sealing) equipment to provide near hermetic high reliability packages.

The mechanical properties of the LCP used in ACP packages are an ideal balance of strength and toughness. LCP is inert and resistant to corrosives and solvents, and non-flammable. Since LCP is a thermoplastic material, it can be recycled by regrinding and reused to mold new packages, 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. The LCP used in ACP packages have a CTE match close to copper, the most widely used leadframe material in electronic 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 solution is to select the right LCP material and proprietary design features in the leadframe that enhance adhesion creating a near hermetic package capable of passing the most stringent semiconductor reliability requirements.

The second element of the ACP package is the sealing epoxies used to seal the package. RJR has developed a moisture barrier epoxy that is pre-applied to package lids and sidewalls used to seal packages during the backend assembly process. These epoxies are both solvent and solvent-free and RoHS and REACH compliant. For ease of use in the assembly process, RJR B-stages its epoxies to simplify handling and improve process control. B-staging an epoxy is a partial curing process where the material goes through an initial, incomplete reaction stage, resulting in a partially cured, solid or film-like material. This B-staged material is then stable for storage and later fully cured at an elevated temperature, allowing for flexible manufacturing and improved performance.

The third material used for ACP packages is the metal leadframe, which forms the conductive elements of a package. Copper is the leadframe material used for ACP packages and the 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. As mentioned before, RJR adds proprietary features in the design of the leadframe to improve adhesion to provide a near hermetic package.

The fourth material used in an ACP package is the flange (thermal base). Unlike ceramic packages that have limitations on base material choice because of the CTE mismatches, RJR's package solutions can use different base materials, CuW, CPC, Copper and diamond materials, because the thermal base is epoxied to the sidewall as opposed to high temperature brazing. RJR epoxies can easily deal with the CTE of the different materials. Also, RJR's 3-piece package design allows for any type of die attach process from the high temperature of AuSi (420 degrees C) to low temperature silver sintering.

B-stage Epoxies

RJR's B-staged epoxies simplify handling, reduce process cycles, and cut down on part rework. Because the adhesive is stable in its "beta" form, customers can treat components as if no adhesive were present, allowing seamless integration into automated assembly lines.

RJR's B-stage epoxies are thermosetting, amorphous polymers with:

- Moisture vapor transmission rates are significantly lower than standard resins;
- CTE: 25–35 ppm/°C;
- Strong temperature-dependent mechanical properties;
- Strong adhesion to a wide range of materials, including LCP, gold-plated metals, ceramics, and more; and
- High glass transition points (~165 °C) for reliable performance under stress.

RJR's B-staged epoxy technology combines economics, precision, and proven reliability to meet the demanding requirements of today's electronics applications, such as:

- RF power;
- QFNs;
- Optical devices;
- Pacemakers; and
- Photonics.

Further, epoxies have been proven in tens of millions of aerospace and electronic parts since the 1950s. Today, advanced sealing compounds and processes extend their utility by offering an economical, high-performance alternative over hermetic packaging sealing.

The Sealing Process – RJR's ITS

Hot air balloons rise because heated air expands and air density decreases. That same principle, expanding gas, underlies the primary cause of blow outs and pinholes commonly referred to as "leakers" in package sealing processes that use epoxy adhesives. Unlike crystalline materials, B-staged epoxies do not have a sharp melting point; instead, they soften and flow over a range of temperatures. This behavior is further complicated by the chemical curing reaction that begins as the adhesive is heated.

In a conventional "Clip and Bake" sealing process, an epoxy-coated lid is clamped to the package at room temperature. As the assembly is heated to the curing temperature, the internal air pressure (gas) continues to build and wants to escape the package by putting stress on the epoxy bond line. If this occurs when the epoxy is soft, it will force its way through the adhesive seal creating a blowout and or pin hole. If the epoxy is still sufficiently fluid, the blowout or pinhole created by gas penetration may reflow and "heal." But if the penetration occurs near the gelation point of the adhesive, the blowout or pinhole remains open, producing a "leaker" which is detrimental to the life expectancy of the device. The epoxy curing profile that illustrates this process is shown in figure 3.

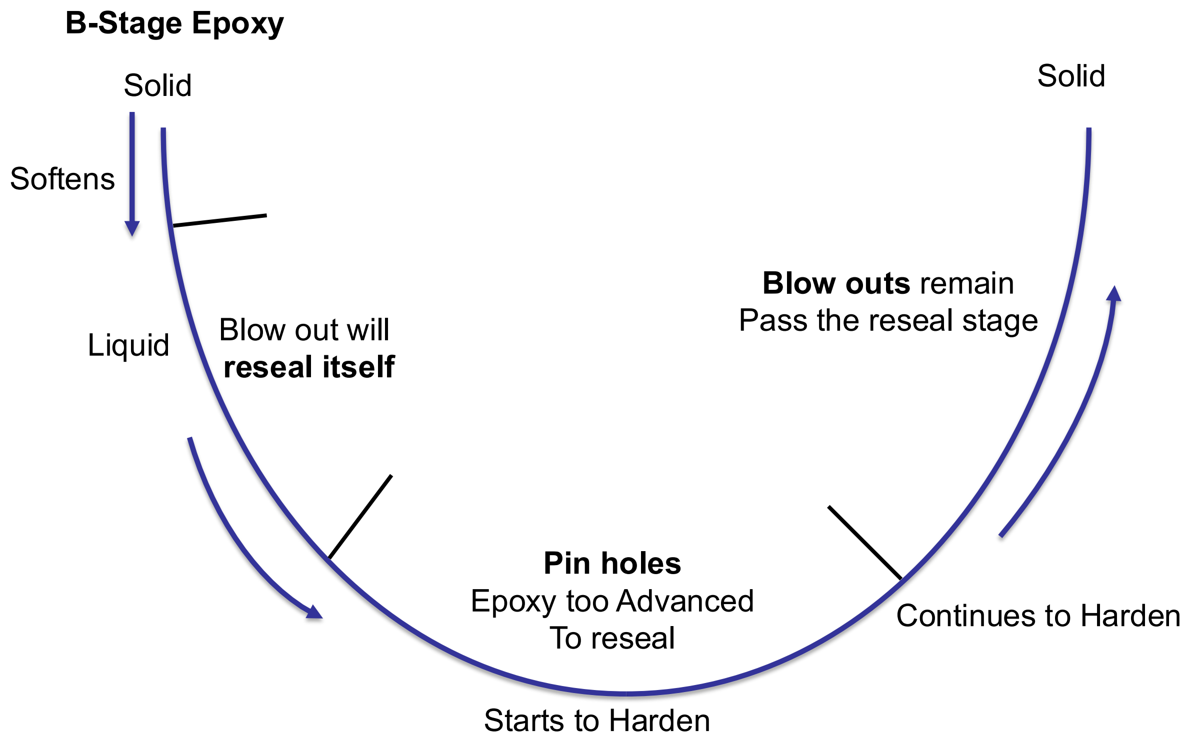

Fig 3 – Epoxy Curing Profile

When epoxies were first introduced into the semiconductor industry, a major concern was that, during curing, they might release undesirable byproducts, commonly referred to as "outgassing", from solvents in the epoxy. Such outgassing was often cited as a cause of failures in air-cavity electronic package assemblies, raising doubts about long-term reliability. While theoretically possible, RJR has shipped more than one billion epoxy-coated lids since its inception in April of 1987 without a single field failure attributable to epoxy outgassing.

RJR's Isothermal Sealing System (ITS) addresses the problem by exploiting another natural law: when internal and external pressures are in equilibrium, there is no driving force for the pressure build up to penetrate the seal. The key is to heat both the lid and package to uniform, isothermal conditions before contact is made. By maintaining separation during heating and equilibration, no pressure gradients can form. Once equilibrium is achieved, the lid is placed, pressure applied, and the system is held at isothermal conditions until the adhesive gels. This process ensures optimal sealing of the package to get the best sealing results.

At that point, the sealed parts can be removed with confidence. All process parameters, time, temperature, and pressure are independently and automatically controlled, repeatable within ±1% cycle to cycle. RJR ITS sealing systems are custom designed to the customer's application, and the system comes pre-programed with the sealing process, so it truly is a plug and play. To date, millions of packages have been sealed using ITS, consistently achieving yields greater than 99%, which is why RJR ITS sealing system is used worldwide.

Near Hermetic and High Reliability

RJR's ACP packages sealed using B-Stage epoxies can achieve helium leak rates $<3\times10^{-8}$ atm·cc/sec, meeting fine leak hermeticity standards. Accelerated stress tests (PCT, 1,000 h at 85ºC/85%RH, thermal cycle, and heat soak at 150°CC) confirm durability. Outgassing is negligible. Results demonstrate that polymer seals have been viable for decades, rivaling traditional ceramic and metal sealing methods while offering greater cost efficiency.

High reliability tests conducted at RJR include:

1. Gross Bubble Leak Test (BLT) @time zero
2. BLT after MSL3 precondition (24hours Bake@125°C + 192 hours 30°C/60% R.H. + 3 X IR Reflow @ 245 °C + 1 X Flux Immersion + DI Rinse)
3. 1000 Temp Cycles -65ºC to 150ºC.
4. High Temperature Storage Life (HTSL) @150ºC

TROSA Package – A Proof Point for Photonics Applications

RJR Technologies has developed a prototype of an innovative Datacom Transmit-Receive Optical Subassembly (TROSA) package for 200-400Gb applications, designed to redefine industry standards in cost, performance, and design flexibility. By replacing the traditional dual FAU HTCC-Kovar package with advanced materials like liquid crystal polymer (LCP) and copper-moly-copper (CMC) thermal bases, this package delivers the same high performance at just half the cost of conventional Kovar solutions, providing significant value to customers seeking both efficiency and flexibility.

This TROSA package features an internal PCB, which enables circuit design versatility and supports complex optical circuit topographies. The customizable LCP cavity design allows for intricate layouts, boosting functionality and simplifying assembly. The package is compatible with wedge bond, ball bond, and ribbon wire interconnects, making it ideal for optimizing product performance and enhancing linearity. Additionally, the CMC thermal base material ensures efficient thermal expansion compensation, enhancing the package's durability in high-performance settings. With a solderable package bottom and clamping capability to support up to 60kg on the lid, this design provides versatility for both product and board-level assembly and testing.

Reliability testing is a cornerstone of RJR's commitment to delivering robust, long-lasting products. A key aspect of this involves analyzing the internal gas composition to assess the risk of microelectronic component failures from corrosion. RJR adheres to MIL-STD-883, MIL-STD-750, Method 1018 standards, focusing on Residual Gas Analysis (RGA) to determine the actual RGA elements to do FMEA analysis on the potential effects the residual elements could have on package performance. For this testing, RJR partnered with industry renowned Oneida Research Services (ORS).

The TROSA package was subjected to rigorous testing, including a challenging 85°C/85%RH environment for 1,000 hours. The RGA results demonstrated moisture levels around 240 ppm, verifying the package's high reliability and suitability for long-term operation. This performance underscores RJR's TROSA package as a high-quality, dependable choice in datacom applications, designed to meet industry demands for cost-effective and reliable solutions in the most demanding environments.

1. AV H. Pham, M.J. Chen and K. Aihara, "LCP for Microwave Packages and Modules", Cambridge University Press, July 2012, pp. 226 - 241