RJR TECHNOLOGIES

Solutions for Low Cost, Near Hermetic Air Cavity Packages

Karen Lynch

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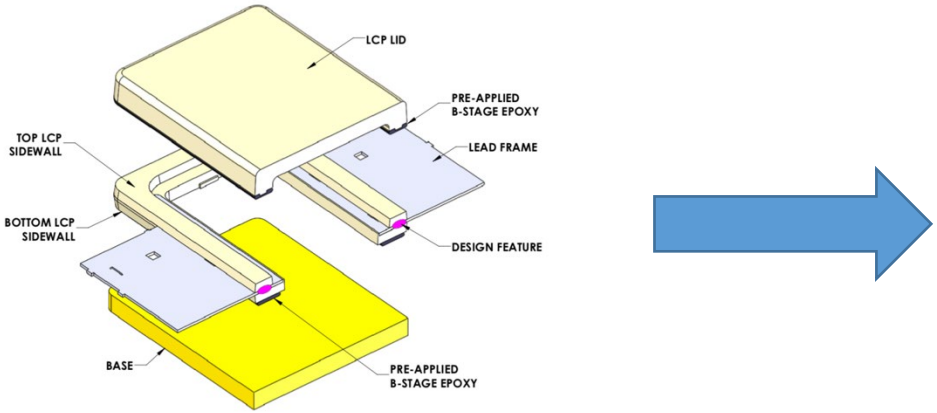
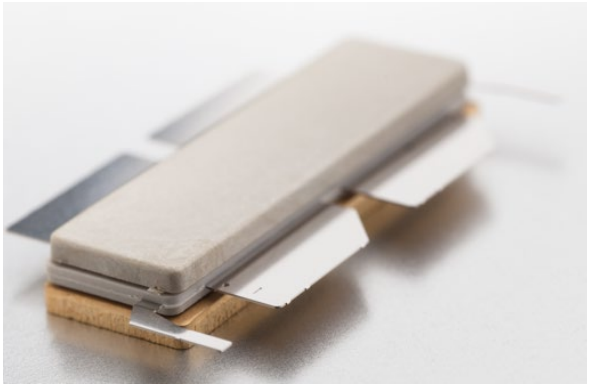
Topics

- Air Cavity Plastic (ACP) for Macro Cell Base Station
- RQFN Air Cavity Plastic for MIMO Base Station
- B-Stage Epoxy Technology
- Sealing Process

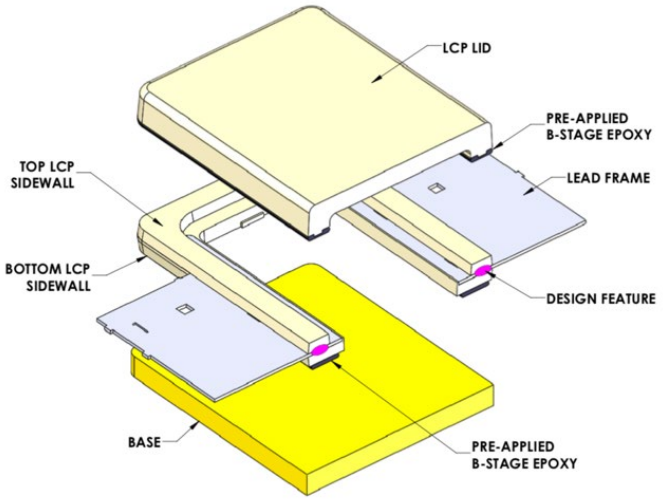
Air Cavity Package for Macro Cell





- **Base – Cu, CMC, or Super-CMC Heatsink**
- **Sidewall – Pre-applied B-Stage Epoxy**
  - **Epoxy formulated to be a Moisture Barrier**
  - **Majority of the solvent removed with Heat allowing epoxy to be “staged”**
- **Lid – Liquid Crystal Polymer (LCP) with Pre-applied B-stage Epoxy**
  - **LCP is CTE matched to the Cu leadframe**
  - **LCP has water vapor permeability rate similar to glass**

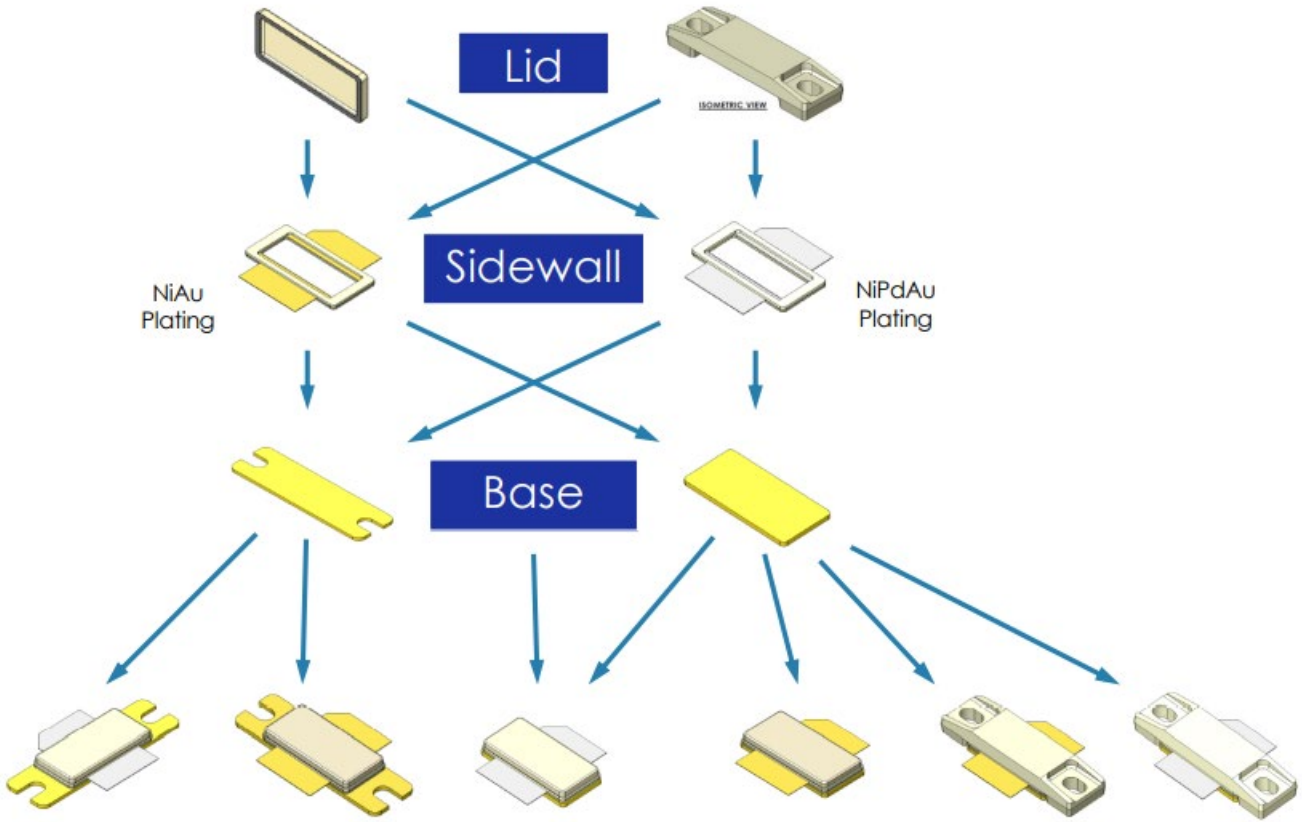
Air Cavity Advantages over Overmold



Air Cavity Package

- ✓ Air cavity eliminates signal loss caused by EMC's (epoxy molding compound) proximity to chip surface
- ✓ RF consistency - no wire sweep due to EMC material which leads to easier RF tuning
- ✓ Less capacitive feedback enables higher bandwidth
- ✓ Lead capacitance is fixed as there is no change due to EMC molding during assembly

Flexible Configuration



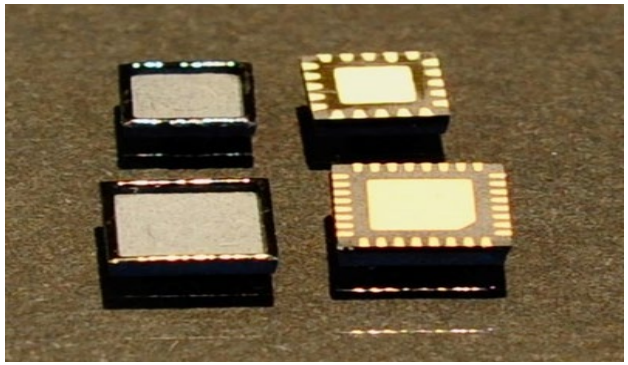
Air Cavity Plastic Reliability

	Stress	Abbv.	Ref.	Conditions	Duration/Accept**	Lot A	Lot B	Lot C
1	MSL 3	MSL3	J-STD-020D	IR = 245°C	End Point	0/100	0/100	0/100
2	Temperature Cycling	TC	JESD22-A104	-65°C to +150°C	1000 cycles / 0 Fail	0/77	0/77	0/77
3	High Temperature Storage Life	HTSL	JESD22-A103C	Condition B (150°C)	1008 hours/ 0 Fail	0/77	0/77	0/77

- Package qualified by multiple Tier 1 RF customers
- Over 80 million packages in the field
- No reported failures

RQFN Package for MIMO

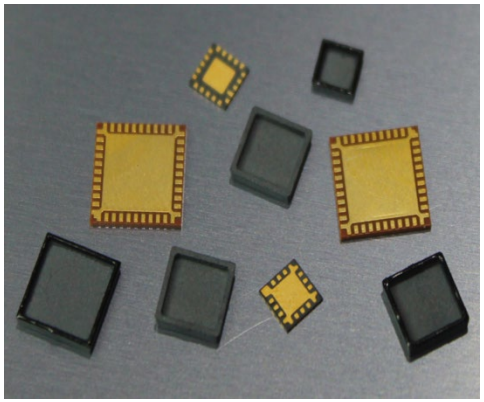
- ✓ Proprietary plastic material used on base with excellent sealing qualities
- ✓ B-stage epoxy cup lids that make the air cavity
- ✓ Liquid crystal polymer lids
- ✓ Injection molding manufacturing process
- ✓ Design features for adhesion
- ✓ Instrip design for assembly
- ✓ Proprietary sealing process
- ✓ Matrix lid seals the whole array in one process step using ITS



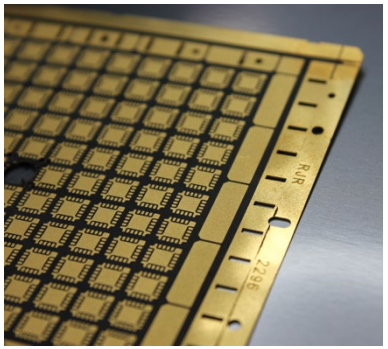
RQFN LID & BASE

RQFN

- **High Performance**
  - Air Cavity
  - Near Hermetic
  - LCP and epoxy are low loss dielectric
    - loss tangent of ~.003 @ 10 GHz
    - Dielectric at 3.8 across wide range of temperatures and frequencies
  - 77 GHz capable – A compelling product for mmwave 5G
- **Greater Functionality**
  - EMI Shield Integration option
- **Better Thermal**
  - Cu die Pad
  - AuSn Eutectic Die Attach
- **High Reliability**
  - Leak free - BLT @t0
  - Passes BLT with MSL3 precondition and 3x reflow
  - Passes 1000 TMCL (-40°C - 125°C)
- **Cost Effective**
  - 40% lower cost than equivalent ceramic packages
  - Coupon assembly for fully automatic assembly (cassette-to-cassette)
  - Low NRE for new Package designs=> $6k-10K



RQFN LID & SUBSTRATE

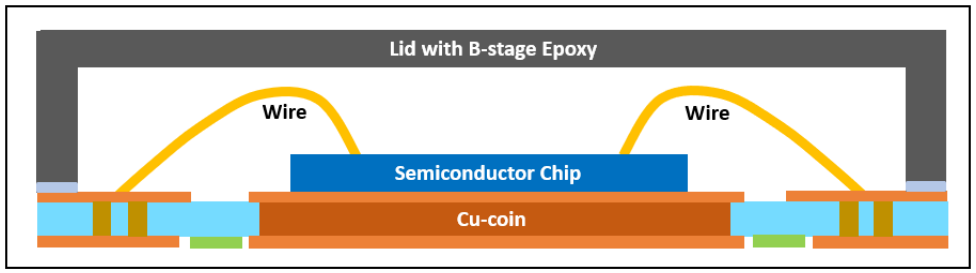


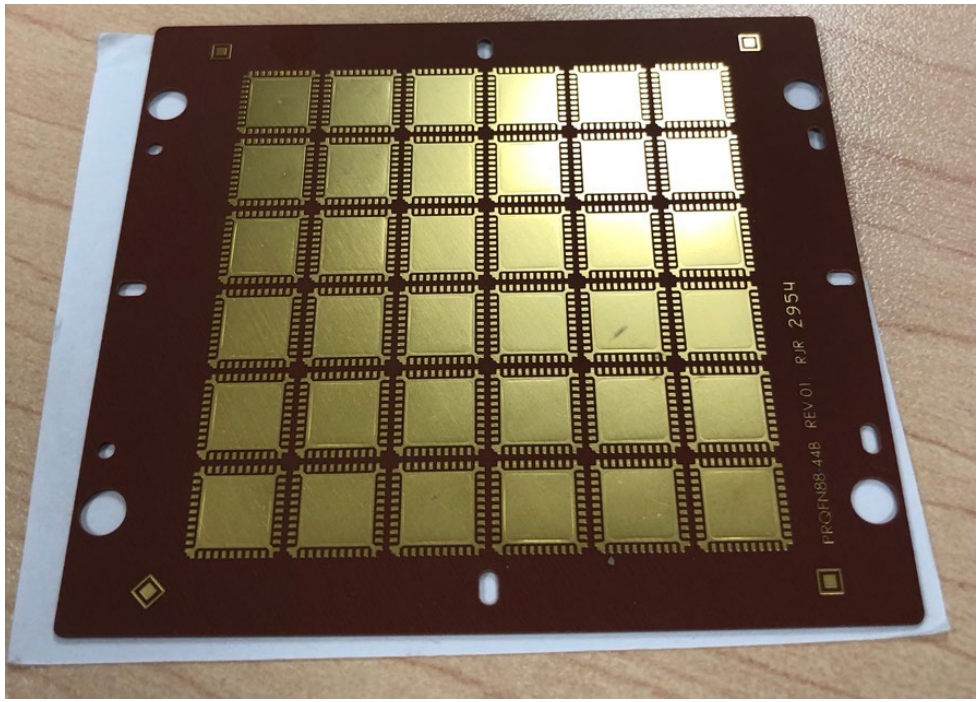
RQFN COUPON

Matrix Lid

- LCP Material with B-Stage Epoxy
- Designed for ITS sealing – one coupon sealed per ITS cycle
- Passes BLT
- Custom designs available to fit customer's 3rd party substrate as long as it meets RJR's design rules

Power QFN Laminate Product





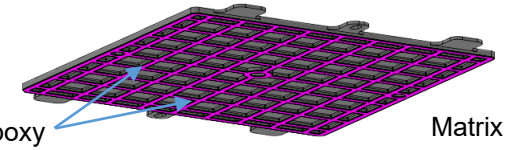
8x8 QFN Laminate

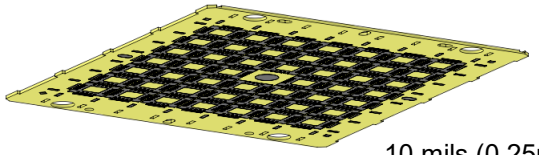
- 0.5mm coin for higher power applications
- 4-layer
- Cu coin: 20 mils +/- 2
- EM526 material
- VIPPO (via-in pad plated over)
- Solder Resist
- ENEPIG finish (Electroless Nickel Electroless Palladium Immersion Gold
- Passes gross leak test

Plating
- Electroless Nickel: 3-6 µm
- Electroless Palladium: 0.051 - 0.305µm
- Gold layer: 0.03µm MIN

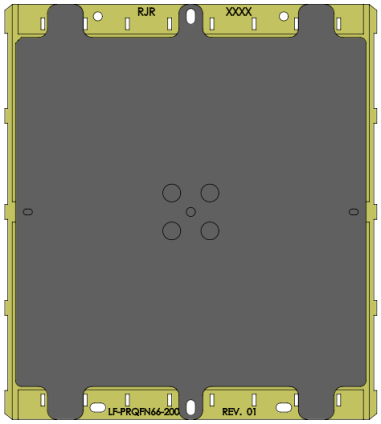
QFN Options: Leadframe and Laminate

Leadframe RQFN

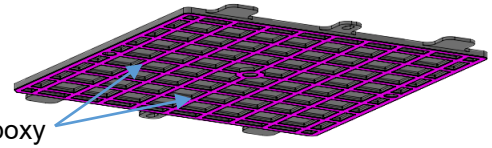


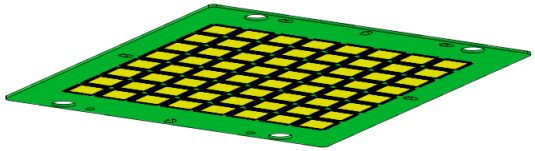


10 mils (0.25mm)
Leadframe Substrate

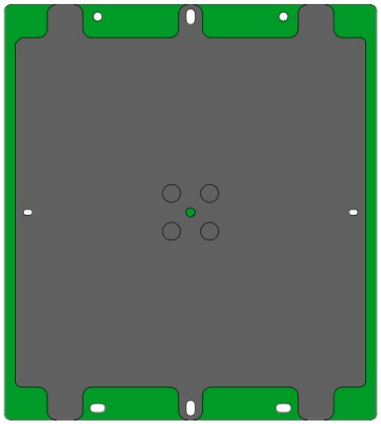


Laminate PQFN





20 mils (0.5mm)
Laminate Substrate



PQFN Assembled Coupon
Ready for Dicing

- For a given size, the same matrix lid is used for either option
- Matrix lid is shipped with RJR's B-stage epoxy
- High yield sealing can be accomplished with RJR's ITS
- This solution can be applied to 3rd party substrates if they conform to RJR's matrix lid design rules

RQFN Reliability

Tests Performed

Stress	Abbv.	Ref.	Conditions	Duration/Accept	Lot A	Lot B	Lot C
MSL 3	MSL3	J-STD-020D	IR = 260°C	End Point / 0 Fail	0/70	0/70	0/70
Temperature Cycling	TC	JESD22-A104	Condition G (-40°C to +125°C)	500 cycles / 0 Fail	0/210	0/40	
High Temperature Storage Life	HTSL	JESD22-A103C	Condition A (125°C)	1000 hours / 0 Fail	0/70	0/70	
Low Temperature Storage Life	LTSL	JESD22-A119	Condition A (-40°C)	1000 hours / 0 Fail	0/70	0/70	

* Reports available for 4x4, 5x5 and 6x6

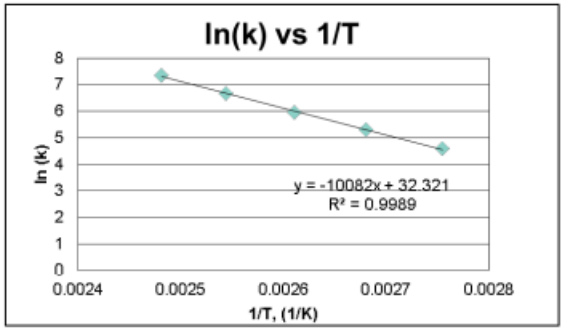
Note: MSL3 pass/fail criteria is BLT after precondition: 24hours Bake@125+5/-0 °C + 192 hours 30°C/60 R.H. + 3 X IR Reflow @ 245 °C + 1 X Flux Immersion + DI Rinse

B-Stage Epoxy Summary

- **B-stage epoxy** is a system wherein the reaction between the resin and the curing agent/hardener is not complete. Due to this, the system is in a partially cured **stage**. When this system is then reheated at elevated temperatures, the cross-linking is complete, and the system fully cures.
- Eliminates the needs to deal with “wet” materials in their assembly process by supplying a **B-stage** solution for ease of handling
- Epoxies adheres to – Metals, Composites, Ceramic, Plastic, and Glass
- Epoxy with low chloride contents improve package HAST/UHAST performance
- Solvent free – epoxies have no residual solvent and are more environment friendly
- RJR’s epoxies are RoHS and REACH compliant

B-Stage Epoxy Science

- ✓ **Proprietary coating process** – provides high speed epoxy application with high throughput
- ✓ **B-stage control** – through the use of Kinetics, RJR has developed a method to control the quality of the b-staged epoxy and predict shelf life by measuring gel time



Shelf life prediction with initial gel time = 2000 s

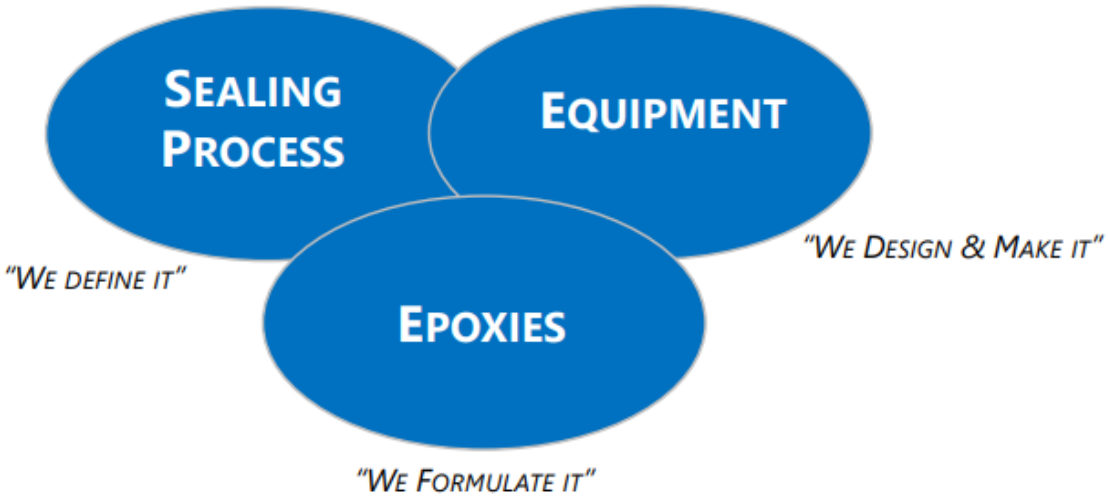
T, °C	K(T)	Days	Gel time prediction, seconds
30	0.38561	28	1740
8	0.02850	365	1750
3	0.01488	365	1870

$$t_{gel} = -K(T)t + t_0$$

$$K(T) = Z\, e^{-\frac{E_a}{RT}}$$

- RJR ships with Gel time: 2000 – 2500 s
- Material Storage Temperature = 3 – 8 °C

Our Value Proposition - B-Stage Epoxies



- We provide the ***best seal in the industry*** by formulating our own adhesives from scratch, which allows us to control the sealing process
- Our epoxies have minimal moisture transmission, low Ionics for ***higher reliability***. Our epoxies are designed to work with our ITS sealing system to cure in minutes
- We have a ***broad range*** of standard adhesives that have been used in the semiconductor market for 35 plus years – from nonconductive to thermally and electrically conductive
- If our standard adhesives do not meet our customers requirements, we can develop a ***custom formulation*** that will

Summary

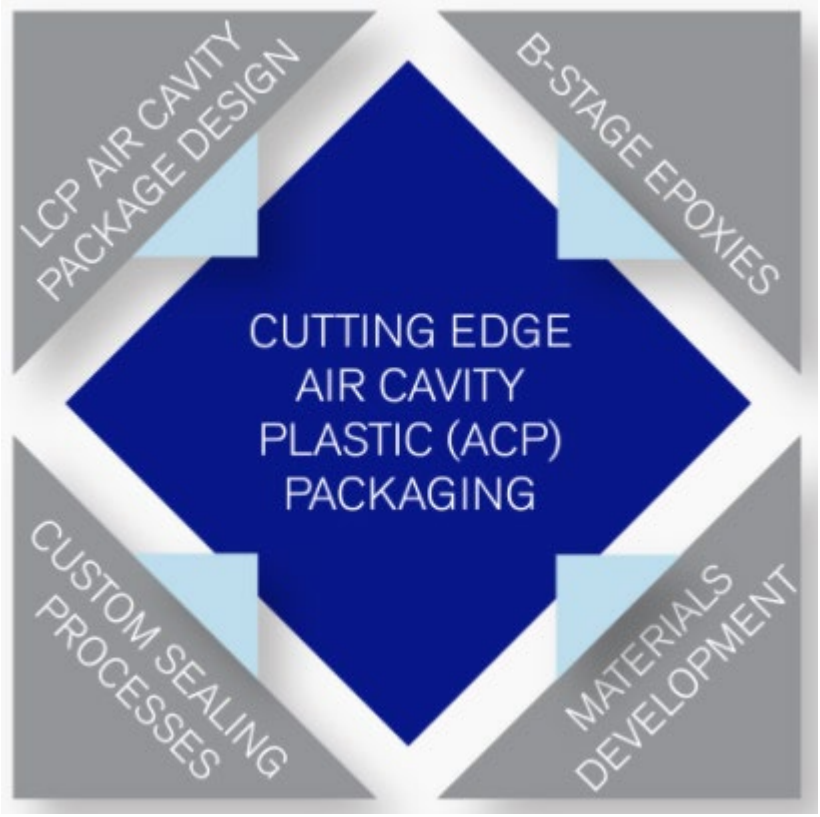
- Air Cavity Plastic packages provide a cost reduction over ceramic packages and a performance advantage over overmold packages. B-stage epoxy enables ease of use in assembly.

- Air Cavity Plastic is available in two platforms
  - **ACP** for Macro Cell base stations - consists of base, sidewall and lid
  - **RQFN** Air Cavity Plastic for MIMO Base Station supports both leadframe and laminate packages

- RJR's **B-Stage Epoxy** tailored and formulated to support both ACP and RQFN packages

- RJR provides the Total Solution to support Air Cavity Plastic – **Components, B-stage Epoxy**, **Sealing Process** and **Sealing Equipment** for high-volume Production

THANK YOU


LCP AIR CAVITY PACKAGE DESIGN
B-STAGE EPOXIES
CUTTING EDGE AIR CAVITY PLASTIC (ACP) PACKAGING
CUSTOM SEALING PROCESSES
MATERIALS DEVELOPMENT