High Frequency Single & Multi-chip Modules based on LCP Substrates

Overview

Labtech Microwave has produced modules for MMIC's (microwave monolithic integrated circuits) based on LCP (liquid crystal polymer) substrates for many applications ranging from Ka band to >90GHz. A wide range of structures are available to cater for a broad range of frequencies and thermal requirements. Near hermetic performance can be obtained from correctly configured LCP modules. Key properties of LCP are listed in table 1 below.

Dielectric constant	Dissipation factor	Moisture absorption	CTE X & Y
2.9	0.0025	0.04%	17 ppm ^{o}C

Table 1

Single chip modules

Single chip modules can be realised using laser based processing technology to ensure very consistent definition of mechanical features. In its simplest form the module can be based on the structure shown in figure 1.

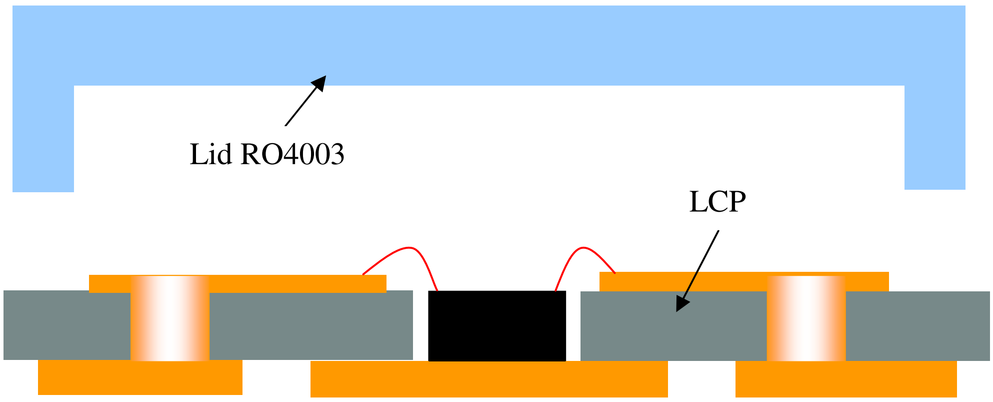

Figure 1

Via holes forming the transition from upper conductors to lower conductors are laser drilled (blind) and copper plated. The upper conductors are copper (nominally 40um thick) and the lower conductors are a sandwich of copper-nickel-copper (nominally 35um, 20um, 35um respectively). The nickel provides rigidity to the module to prevent damage to the MMIC's during handling and SMT assembly. A typical layout for such a module is shown in figure 2.

Bottom layer

Top layer with vias and cavity

Figure 2

The final finish applied to the conductor layers is Universal finish. This finish is comprised of the following layers: - Nickel 3um – 6um, Palladium 0.3um – 0.5um and Gold 0.01um – 0.05um. The main advantage of this finish is that is compatible with both gold wire bonding and soldering, thus avoid the need for expensive selective plating.

A significant amount of work has been carried out to characterize the thru hole via transitions via. This has been performed both in-house and in collaboration with Cardiff University UK. An example of one of the test pieces is shown in figure 3.

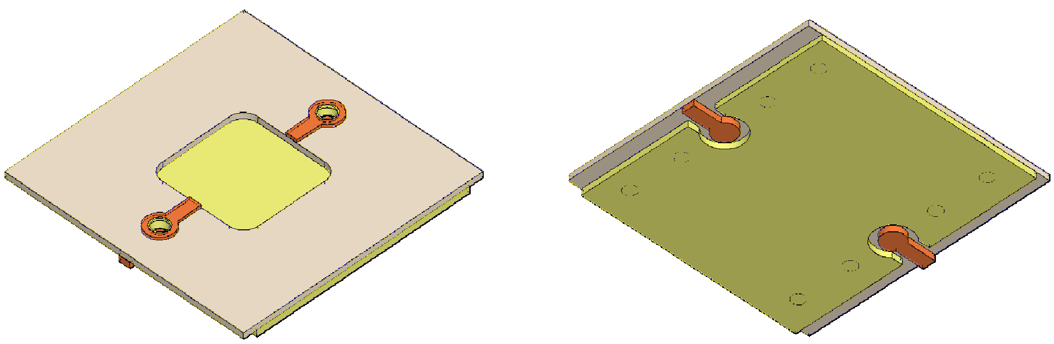

Figure 3

The package shown in figure 3 is 5mm x 5mm with a 2mm x 2mm cavity. The measurement system setup shown in figure 4 was used to measure the insertion and return losses over a range of 1GHz to 50GHz. The feature sizes of the test package were designed to be compatible with the 400um pitch of the probes. Probing the package directly involves flipping the packaging up-side-down and probing through the package coplanar lines. Measuring the package using this configuration can quickly identify the package overall performance.

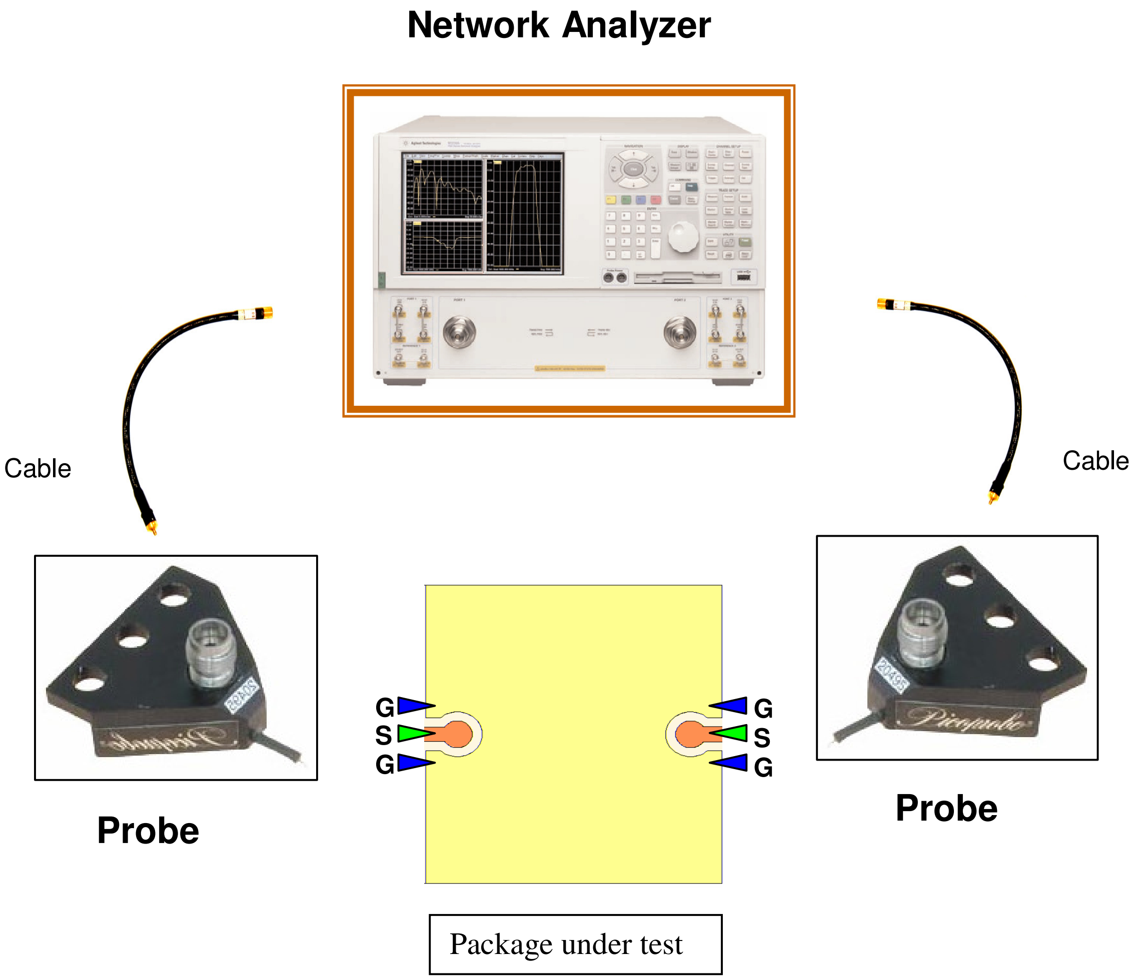

Figure 4

The simulated versus measured results for insertion loss and return loss are shown in figure 5.

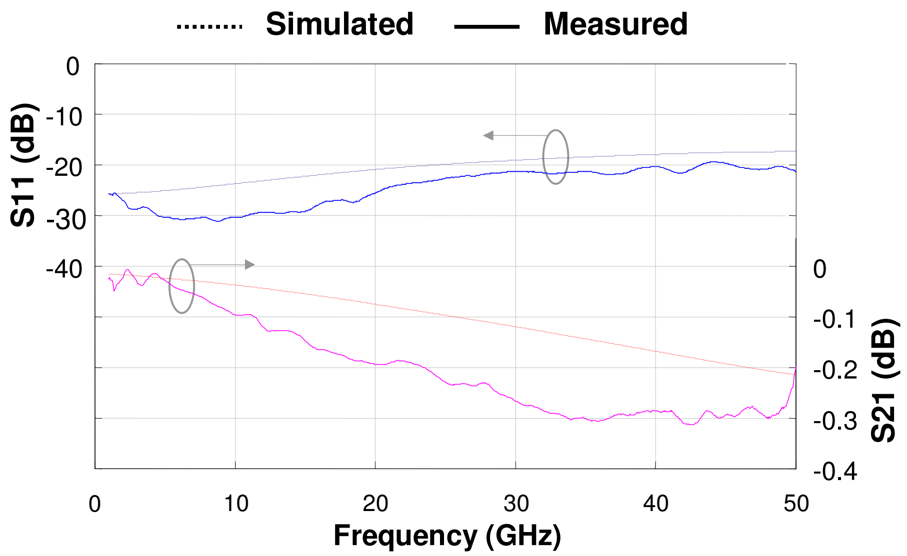

Figure 5

Isolation was also measured and the results shown in figure 6. For this measurement the package feed lines on the top layer were bonded to the cavity ground on both sides, leaving a 1.2mm gap between the two bonding wires. The resulting package isolation was found to be better than -40 dB based on 1.2mm separation distance over the entire bandwidth.

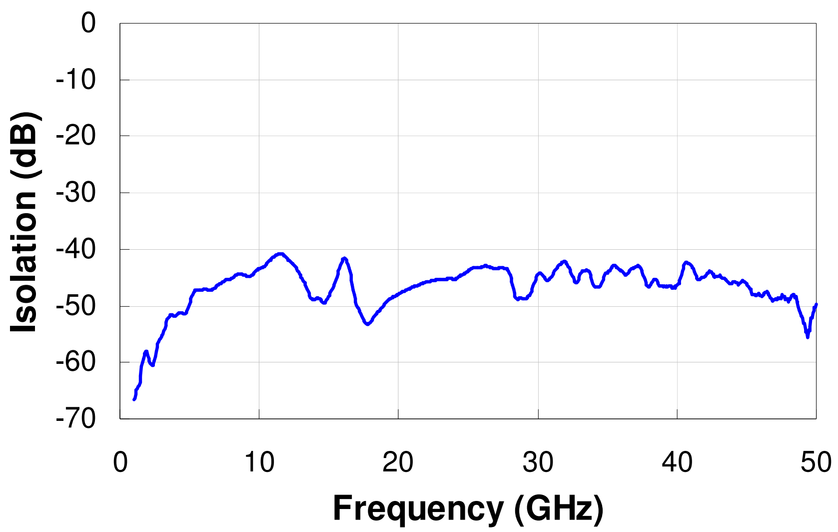

Figure 6

Thermal resistance of the module can be calculated to be <0.3°C/W from the back surface of the MMIC to the lower (solder mounting) surface of the package. This calculation is shown in table 2 below. Please note, the 2 outer layers of gold that are typically 0.03um thick have been ignored in this calculation.

Layer	**L**	**K**	**A**	**R_{th} = L/(K.A)**	
Units	**m**	**W/m/K**	**m^2**	**°C/W**	
Ag Epoxy (DieMat)	1.50E-05	60	3.00E-06	8.33E-02	
Pd	4.00E-07	72	3.00E-06	1.85E-03	
Ni	4.50E-06	91	3.00E-06	1.65E-02	
Cu	3.50E-05	390	3.00E-06	2.99E-02	
Ni	2.00E-05	91	3.00E-06	7.33E-02	
Cu	3.50E-05	390	3.00E-06	2.99E-02	
Ni	4.50E-06	91	3.00E-06	1.65E-02	
Pd	4.00E-07	72	3.00E-06	1.85E-03	
			R_{th} total	**2.53E-01**	**°C/W**

Table 2

However it must be stressed that the design of the motherboard that the module is to be mounted on will play a vital role in terms of the power that can be dissipated by the module. The most common solution for thermal management is to have a grid of via holes in the motherboard under the ground plane of the module to conduct heat down to a cold wall. An example of such an arrangement is shown in figure 7.

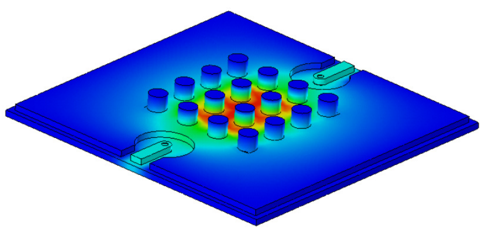

Figure 7

To obtain improved power dissipation the module should be mounted onto a solid copper "coin" that has been embedded into the structure of the motherboard.

Near hermetic results can be obtained when using LCP modules. To achieve this, a metal lid is soldered into place using a high melting point (e.g. AuSn) solder. A grounded metal trace must be placed around the active features of the module for the purpose of lid mounting. Fine leak tests have been conducted using an 8mm x 8mm LCP package with a metal lid. The measured helium leak rate was less than 3×10^{-8} atmospheres/cc/second. This meets the requirements of Mil-Std 883 for a module of the volume under test.

Moisture absorption results for the test structure shown in figure 8 have been supplied by Rogers Corporation.

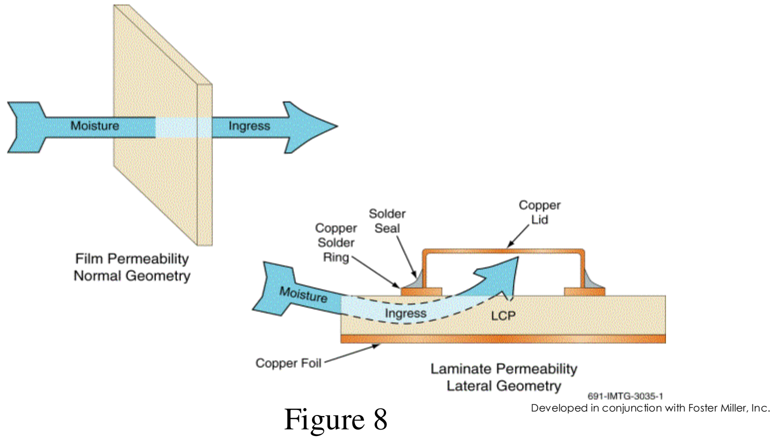

Figure 8

The test was conducted at 85°C / 85% RH. Results from test this structure are shown in table 3. Internal moisture levels at the noise limit of 100ppm, other elements (N2 etc.) were not flat lined, indicating a good test.

Actual time in 85/85 (hours)	Part description	Moisture content (ppm)
0	Copper control cavity	100
0	LCP test cavity	100
172	Copper control cavity	100
172	LCP test cavity	100
1000	Copper control cavity	100
1000	Copper control cavity	100
1000	LCP test cavity	100
1000	LCP test cavity	124
1000	LCP test cavity	100

Developed in conjunction with Foster Miller, Inc.

Table 3

If high power dissipation is required then drop-in style modules offer the best solution. An example of such a package is shown in figure 9.

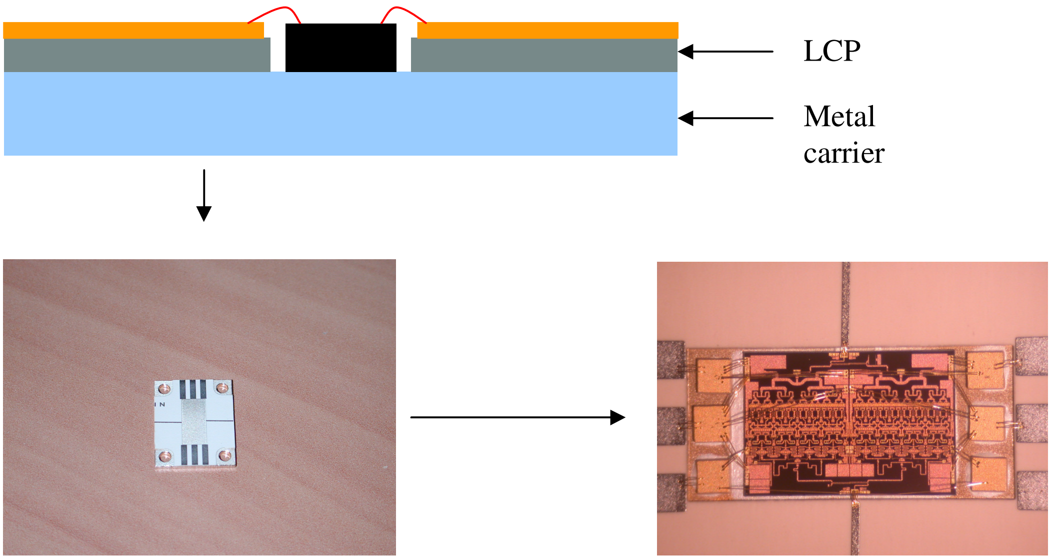

Figure 9

Multi-chip modules

Multi-chip modules can be readily tailored to meet a wide range of applications and can comprise multilayer structures. In this section a number of MCML sample structures based on LCP technology are illustrated.

Figure 10 shows an example of a metal cored module that features coaxial via holes and exposed core for thermal management. Chip and wire microwave components assembled to the upper surface and SMT components mounted on the lower surface. It should be noted that multiple MMIC cavities can be accommodated on this design.

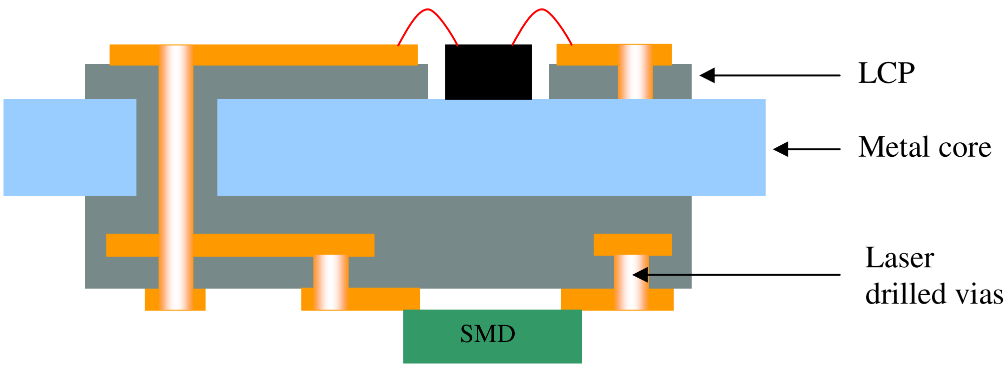

Figure 10

Figure 11 again shows a module with a metal core and coaxial vias but in this case we have an additional conductor layer with chip and wire technology employed on both sides of the metal core. This module was designed for controlling signals and power to enter via the lower surface. Microwave, transmit and receive being handled in the upper side with an antenna connecting directly to the upper surface. Mounting of the module was realized using solder balls.

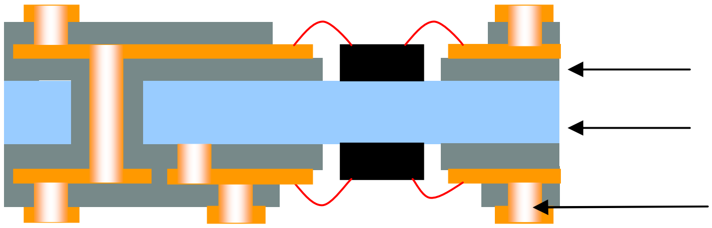

Figure 11

The example shown in figure 12 has been used in >90GHz application where the microwave signal does not have to transition through any via holes. The signal is carried via the stripline and launched by a probe into a waveguide. The stripline structure is bonded using a conductive bond film to a metal carrier that has a waveguide aperture machined through. Due the thickness of conductive bond film a CuMo shim is used under the MMIC to make it coplanar with the stripline conductors.

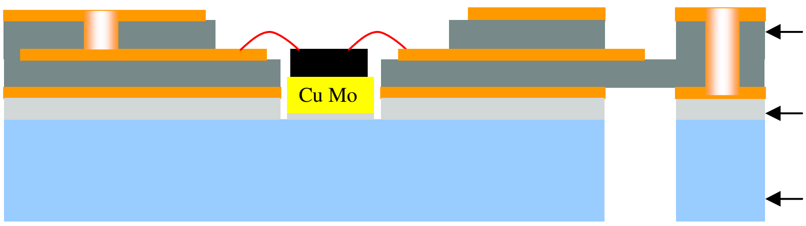

Figure 12

As an alternative method of supporting the LCP for larger modules, FR4 or similar materials can be used with the microwave signals confined to the outer LCP layer. The supporting board can either be a simple double sided or a multilayer circuit. The lower surface providing the mounting footprint to accommodate either SMT or BGA formats.

In this application the microwave signal is taken directly from the microstrip layer. An example of this type of structure is shown in figure 13.

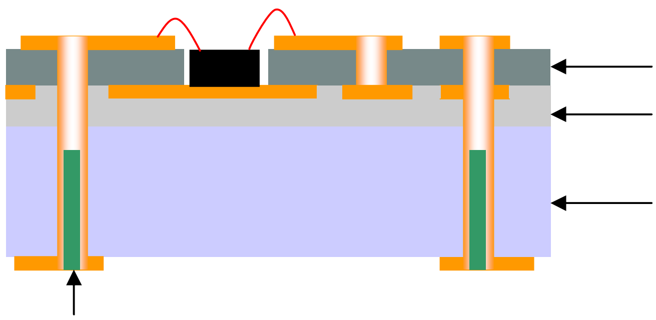

Figure 13

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