INVESTIGATION OF MMIC FLIP CHIPS WITH SEALANTS FOR IMPROVED RELIABILITY WITHOUT HERMETICITY

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Abstract

As a result of the advantages they offer, MMIC flip chips are being developed for airborne radar applications. Some of the benefits of this technology are lower wafer processing cost when Coplanar Waveguide (CPW) is used as the transmission line, surface mount compatibility, repeatable low inductance interconnect, self alignment due to solder surface tension, very high reliability, and robust 25 mil thick chips. These benefits result in lower manufacturing cost at the chip and module level, higher quality, and increased reliability. A series of recent experiments indicate that this technology may also allow for the use of sealants which provide chip protection at a fraction of the cost of welding or seam sealing at the module level. We have investigated the use of flip chips with sealants and show measured results for GaAs MMIC flip chips operating in the 5-15 Ghz range which use sealants for environmental protection.

I. Introduction

Flip chip technology was pioneered by IBM nearly 25 years ago [1]. The main advantages of this technology are high reliability and low cost chip interconnect. Since this early development, flip chip technology has been applied to a wide range of products including chips operating in the microwave range [2,3,4] and optical GaAsP LED array chips [5].

MMIC flip chips using CPW transmission line were first developed by Hughes Aircraft Company in 1986. Since that time many significant advances have been made to apply this technology to airborne applications. One such advance is the use of sealants to achieve module reliability by encapsulation of the MMIC flip chips.

Ensuring module reliability adds significant cost to microwave modules. By transferring the need for hermeticity from the module down to the die level, cost reductions can be achieved. The purpose of this paper is to review a few of the techniques that have been developed to achieve module reliability without hermeticity (RWOH).

The first approach is based on the use of glob top material, such as Dexter HYSOL FP4323, found in many commercial consumer electronics products. This material has been used for many years as a sealant for Si wire bonded chips. The effects of using this material on conventional MMICs will be discussed and test data will be shown for its application on MMIC flip chips.

The other approach uses sealgard, a silicon dielectric gel available from Dow Corning as part number Q3-6575. It has been used in commercial automotive products in the past for sealing modules containing Si chips.

Parameter	Sealgard	Glob Top
Part Number	Q3-6575	FP4323
Physical Form	Silicon Gel	Epoxy
Color	Clear	Black
Dielectric Constant	2.8	3.15
Dissipation Factor at 10 KHz	< 0.001	0.006
Volume Resistivity (ohm-cm)	$1.60x10^{14}$	$6.20x10^{14}$
Dielectric Strength (Volts/mil)	350	N/A
Temperature Range (°C)	-80 to 200	-40 to 150
CTE (in/in/ °C	N/A	$2.70x10^{-5}$
Specific Gravity (at 25 °C)	0.97	1.7
Thermal Conductivity (cal/sec-cm-°C)	N/A	$1.50x10^{-3}$
Hardness, Shore D, min.	N/A	97

Table 1. General material properties of the sealants used (vendor data).

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Although the material does allow moisture to pass through it, application of this material by Delco Electronics has demonstrated improved reliability in modules which use sealgard. Measured performance will be shown on its use.

II. Glob Top

Glob top provides a seal against the environment and also adds reliability to wire bonds. However, this material is not well suited for conventional MMIC chips. This is due to the interactions between microstrip transmission lines and the dielectric above them. Most conventional MMICs use microstrip and are designed for air dielectric (ε_r=1) over them. The glob top material which was chosen has a dielectric constant of about 3.1. This higher than air dielectric constant acts to lower the line impedance of microstrip. Thus, the performance of the MMIC will change when the sealant is added. One method to overcome this is to design the chips with the effects of the dielectric sealant taken into account. The can be done, however it complicates testing and 'known-good-die' effort. An alternative method is to use MMIC flip chips. Since the transmission lines and FETs are on the under side of flip chips, next to the board, sealant material placed over the attached chip will not cause a change in the performance of the chip.

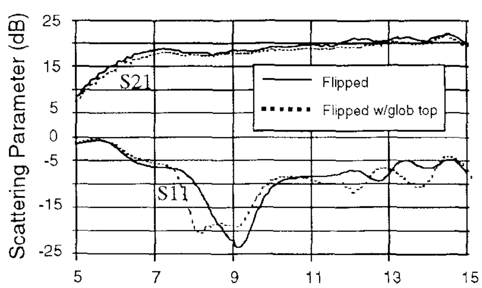

Figure 1. Measured performance of a mounted flip chip LNA before and after the addition of glob top material.

There are several glob top materials available for use in electronic equipment. Most glob tops are specified in terms of, among other things, the amount of flow they have in the uncured state. To minimize the amount of flow of the material under the chip, the low flow Dexter HYSOL FP4323 material was chosen.

Figure 1 shows measured performance of a the first MMIC flip chip which was coated with glob top in our labs. It shows data for a flip mounted chip before and after application of glop top material. Notice that there is very little effect upon performance.

III. Sealgard

Sealgard is also used in the electronics industry for RWOH applications. A test was conducted in the same manner as with glob top to determine the effect of using sealgard with MMIC flip chips.

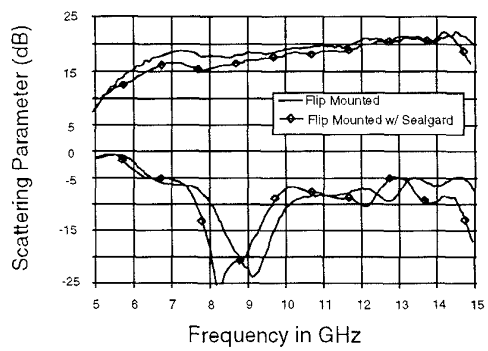

Figure 2. Measured performance of a mounted flip chip LNA before and after the addition of seal gard.

Figure 2 shows the test data for the first flip mounted sealgard protected flip chip tested in our labs. There was a small change in performance between the flip mounted performance before and after the addition of sealgard. Further experimentation has shown that this can be attributed to flow of sealgard under the edges of the chip. We have found that quick cure of the sealgard minimizes this effect. In addition, the application of a dam material around the edge of the chip may also be beneficial.

IV. Environmental Performance

After the initial electrical test, environmental testing was started. Both glob top and sealgard protected test parts were subjected to environmental testing. The chips were solder mounted on Aluminum Nitride substrates and then coated. 200 temperature cycles were performed from -55 °C to 125 °C over a one week period. In addition, the circuits were subjected to seven days of 95% humidity at

40 °C. The results are shown in Figures 3 and 4 for the glob top case. Similar results were obtained for the sealgard part and are shown in Figures 5 and 6. Notice that there is virtually no change in performance. Environmental testing will continue.

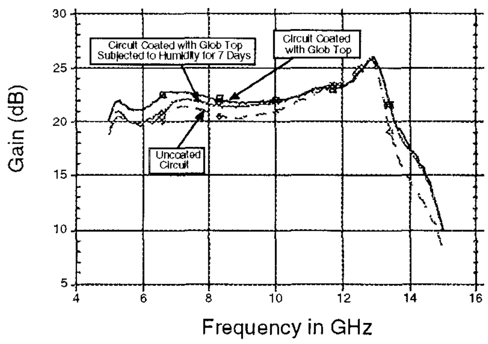

Figure 3. Small signal gain of a flip mounted LNA coated with glob top and subjected to humidity.

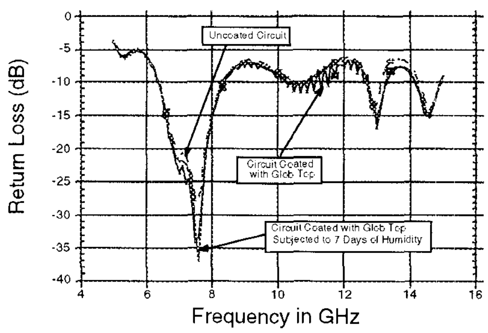

Figure 4. Return loss of a flip mounted LNA coated with glob top and subjected to humidity.

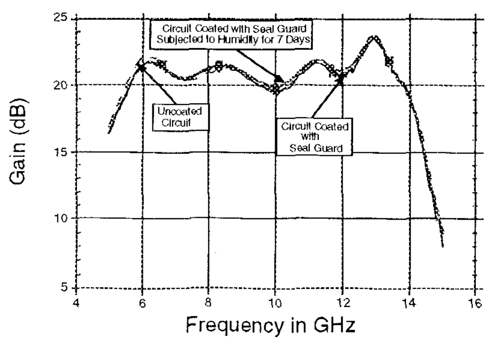

Figure 5. Small signal gain for the flip mounted LNA coated with seal gard and subjected to humidity.

V. Buried Transmission Lines

In a practical module, where sealgard would be used, transmission lines are on the surface of the substrate. Since sealgard usually fills the module, any transmission lines on the surface of the substrate would be exposed to the sealant. In addition, sealgard has a dielectric

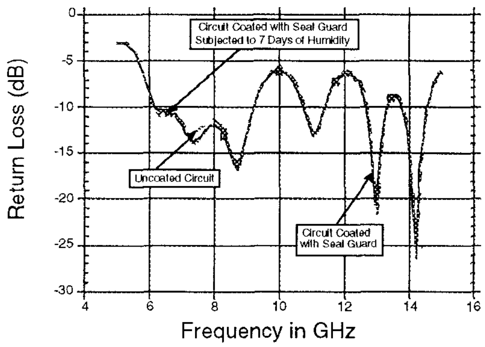

Figure 6. Return loss gain for the flip mounted LNA coated with seal gard and subjected to humidity.

constant different from air and a high dielectric loss tangent which causes module level test data before and after the addition of sealgard to be significantly different. This is not the case for glob top since it is only used locally over the chips within the module. A method to overcome this problem in sealgard modules is to bury the transmission lines within the substrate and use vertical vias and pads to connect to the MMIC flip chips. Figure 7 shows the substrates and MMICs used to generate the data shown in Figures 3-6. Notice that CBCPW lines are buried in the substrate as they approach the active device.

VI. Conclusions

We have shown that glob top and sealgard material can be used with MMIC flip chips with very little effect on performance. In addition, environmental test results have been shown. Further, buried transmission lines have been presented as a method to reduce the effect of the sealant upon the transmission lines feeding the active device.

These techniques leverage the advantages of MMIC flips chips to allow for the use of sealants on GaAs MMICs at X and Ku-band.

Further environmental testing is needed to verify the ability of this method to survive significant environmental conditions.

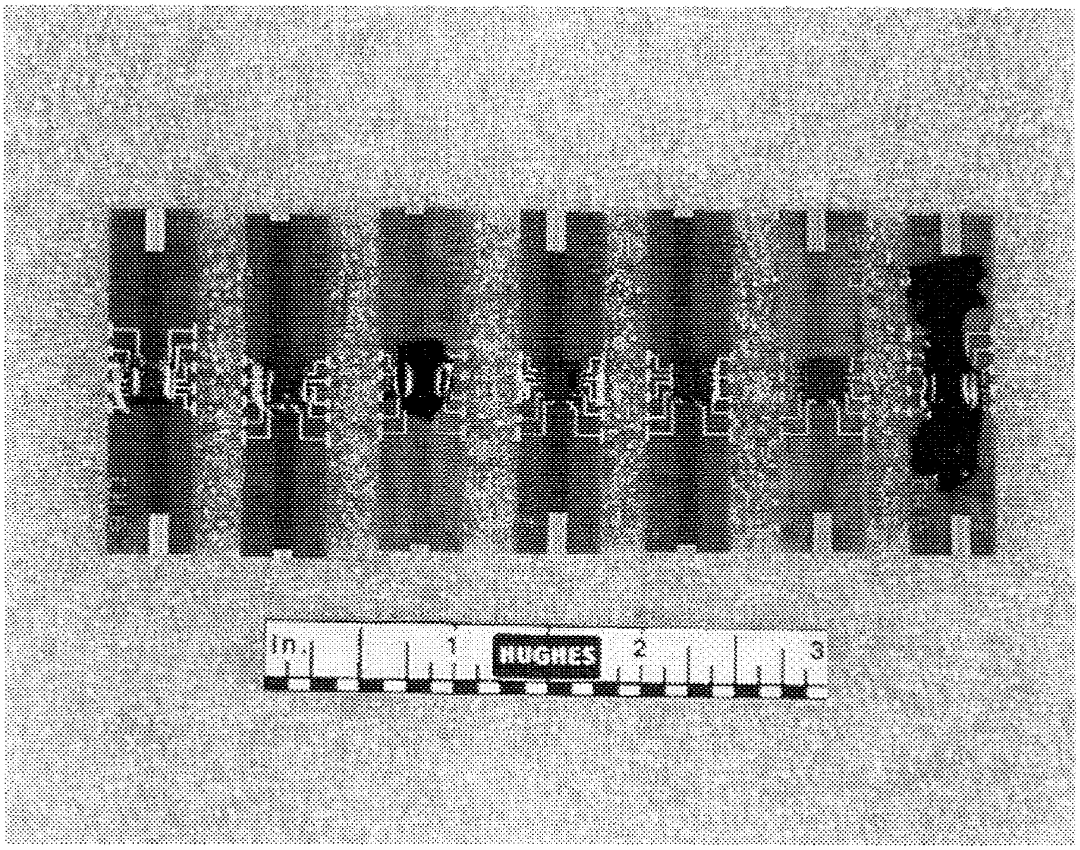

Figure 7. Test pieces used in the tests show the use of buried transmission lines to minimize the effect of the sealant upon the input and output transmission lines.

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