LTCC AND GLOB TOP PACKAGING FOR 24 GHZ MMIC WITH INTEGRATED ANTENNAS

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SUMMARY

A packaging method for low cost 24 GHz MMIC:s with on chip antenna using LTCC carrier substrates and glob-top encapsulation is evaluated. Microstrip ring resonators are used for characterization of single and double layers of Ferro A6-S LTCC material at 24 GHz. Quality factors close to 100 are obtained, and good agreement with the manufacturers data is demonstrated. Five different commercial glob-top, side-fill and cavity fill materials are used to cover the LTCC ring resonators. Measurements show only minor degradation in resonator quality factor when glob-tops are applied, thus indicating low dielectric losses in the encapsulation material.

INTRODUCTION

In this paper we evaluate LTCC as a packaging solution for 24 GHz MMIC's with integrated antennas [1]. The LTCC material offers passive components in the MMIC packaging as well as the ability of introducing parasitic elements for the on-chip antenna and route necessary low and high frequency connections to the chip, as shown in Fig 1.

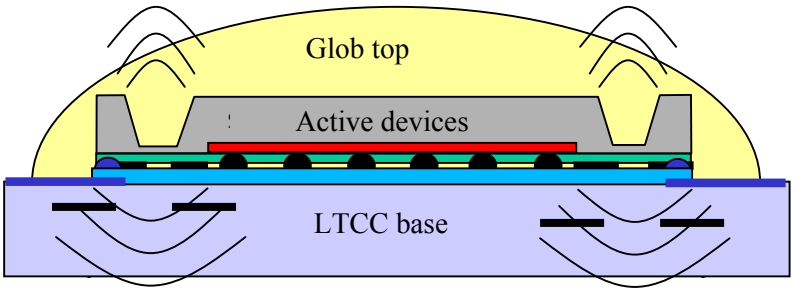

Fig. 1. Flip-chipped MMIC with micro-machined integrated antenna on LTCC carrier with glob-top encapsulation

Glob-tops offer a low cost alternative to hermetic sealing of the MMIC mounted on the LTCC carrier substrate and has successfully been evaluated at lower frequencies [2]. Glob-tops have also been suggested for packaging of flip-chip mounted MMIC [3].

In order to evaluate the combined use of LTCC as a chip carrier and microstrip substrate, and glob-top as an encapsulation method at 24 GHz , microstrip ring resonators have been manufactured on LTCC and covered with five common silicone and epoxy glob-top materials. The resonance frequencies and quality factors of the coated resonators are compared to resonators with no glob-tops.

DESIGN AND MANUFACTURING OF TEST STRUCTURES

Microstrip ring resonators are used for characterization of single and double layers of Ferro A6-S LTCC material with a fired tape thickness of 100 um. The dielectric constant of the material is 5.9 and the loss tangent is less than 0.002 according to the manufacturers data. The tape metallization is 12 um thick silver.

The microstrip resonators were designed to have second resonance at 24 GHz., corresponding to a total resonator length of one guided wavelength and a circumference of l_r = 5843 um. The groundplane was solid (not meshed) and placed one tape layer below the microstrips in the LTCC stack, yielding an effective substrate thinknesses of 100 um. A resonator and feed line impedance of 50 Ohm was selected and a microstrip width $w_{ms} = w_r$ = 141 um calculated. A second test structure was designed with double tape thickness, and a microstrip width of $w_{ms} = w_r$ = 288 um was chosen for 50 Ohm impedance. The ring resonators are lightly coupled to the microstrip feed lines by 100 um wide gaps.

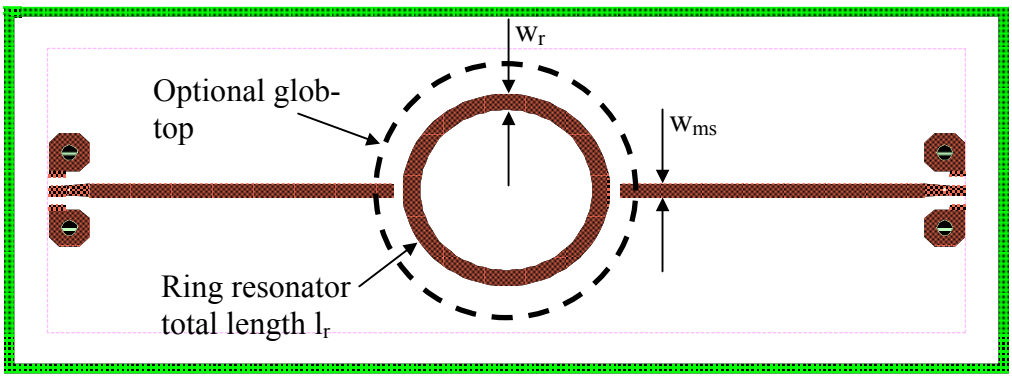

Fig. 2. Single layer 24 GHz ring resonator

The test structures were simulated with a method of moments (MoM) simulator and a resonance frequency of 24.68 GHz with an unloaded Q-value of 107 was obtained with the manufacturers dielectric data. For resonators utilizing double layers of LTCC a resonance frequency of 24.65 was simulated, and an unloaded Q of 83 predicted.

The ring resonators were covered with organic glob-top materials, side-fills and cavity fills shown in table 1.

Glob-top	**Type**	**Loss tangent**	**Dielectric constant**
Amicon S 7503	Silicone	0.0005 / 1 kHz	3.1
Semicosil 900LT	Silicone	0.005 / 50 Hz	3.0
Lord CircuitSaf ™ ME-455	Epoxy cavity fill	0.006 / 1 MHz	3.37
Lord CircuitSaf ™ ME-430	Epoxy glob top	0.006 / 1 MHz	3.7
Namics XV6841-0209	Side fill	0.008 / 1 MHz	3.5

Table 1. Evaluated glob-top materials with manufacturers dielectric data

The glob tops were approximately 2 mm in diameter and 1 mm thick and placed as to entirely cover the ring resonators.

MEASUREMENTS

The insertion loss of the ring resonators were measured with a conventional wafer probe station equipped with GSG (ground-signal-ground) probes and 40 GHz network analyzer. The resonance frequency of the resonators was determined by insertion loss measurements and the unloaded quality factor Q_u calculated from the resonator –3 dB bandwidth and insertion loss at resonance.

RESULTS

The results for the resonators covered with glob-top materials are shown in Table 2.

Glob-top	**Single layer LTCC resonance freq. [GHz]**	**Double layer LTCC resonance freq. [GHz]**	**Single layer LTCC Measured Q_0**	**Double layer LTCC Measured Q_0**
No glob-top / Air	24.67	24.85	95	75
Amicon S 7503	23.14	23.44	75	50
Semicosil 900LT	23.41	23.98	67	65
Lord CircuitSaf ME-455	22.84	23.26	95	72
Lord CircuitSaf ME-430	22.66	22.87	95	67
Namics XV6841-0209	22.78	22.96	87	71

Table 2. Measured ring resonator parameters for different glop-top materials on single layer (100 um) and double layer (200 um) thick Ferro A6-S LTCC

A resonance frequency of 24.67 GHz and unloaded Q-value of 95 was obtained for the single layer 24 GHz ring resonator without glob-top coating. These values are in good agreement with the simulated ones, indicating validity of the LTCC manufacturers dielectric data at 24 GHz. The experimentally derived effective dielectric constant 4.32 was calculated from resonator length and measured resonance frequency, and is in good agreement with the theoretical value 4.34 obtained from closed form microstrip design equations as well as with the 4.3-4.4 range reported [4]. The lower Q-value obtained for the resonators manufactured with double tape layers can be explained by increased radiation and substrate losses with the thicker dielectric.

As shown in Table 2 a reduction of 1-1.5 GHz in resonance frequency due to the increased effective dielectric constant of the microstrip resonator was seen for the silicone based materials and 1.5-2 GHz for the epoxy based ones.

The unloaded Q-value were reduced from 95 to 67-75 at 24 GHz silicone based glob tops. Small to no degradation of Q-value was seen for the epoxy-based Lord CircuitSaf materials, except for the CircuitSaf ME-430 on double layer LTCC which was possibly caused by measurement errors.

CONCLUSION

24 GHz ring resonators have been characterized on single and double layers of Ferro A6-S LTCC. Good agreement between simulated and measured resonance frequency was seen and quality factors close to 100 were obtained. Epoxy and silicone based glob-top materials have been used to cover the resonators in order to simulate glob-top packaging of an MMIC. Moderate de-tuning and negligable decrease in resonator Q-value were seen for the epoxy based resins, with slightly higher losses in the silicone based glob-tops.

The low losses and predictable resonance frequency of the embedded devices suggest that glob-top packaging could be used for low cost 24 GHz integrated circuits mounted on LTCC carrier substrates, including MMIC´s with integrated antennas.

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