LTCC System for High Frequency Applications

Assia Abdeslam Hanzaz

Abstract— **Using LTCC (Low temperature co-fired ceramics) system in wireless packaging applications is wide used today. The properties requirements for wireless applications are requiring low loss at high frequencies and good characteristic comparative to cost. Several designs of packaging systems are presented in various microwave packaging applications such antenna. The relative curves of dielectric constant and loss tangent vs. frequency by Giga are discussed for many types of LTCC to see the best performance using HFSS simulation.**

*Keywords- **Microelctronic technology, low-temperature co-fired ceramic (LTCC), Microstrip Antenna.***

I. INTRODUCTION

Increased performance, with reduced cost is the general trend for next generation wireless communication products, such as cellular phones. These trends in consumer end products pose increasing demands on ceramic packaging and for packaging materials suppliers. Low temperature co-fired ceramics (LTCC) are a low cost, high performance solution for ceramic packaging. LTCC systems are usually fired at 850 ° C (such as A6). High conductivity metals, such as Ag, Cu, and Au, can be used as metallization materials.

The cofired multi-layer technique enables burying components within the substrate, reducing the number of discrete components. This integration of passive components plays a critical role in size reduction of new generation of wireless products.

Low loss is the characteristic of LTCC technology. For example, the typical loss tangent for A6 is less than 0.002 at 10 GHz. Loss is directly involved in the power consumption. Low loss has implication in prolonging battery life in wireless communication products. In microwave frequency applications conductor loss is a significant contributor to total loss. Utilizing high conductivity metals and minimizing nonconducting additives in conductor pastes can further reduce total loss [1].

A typical LTCC multilayer circuit stack up is shown in Figure 1 [2].

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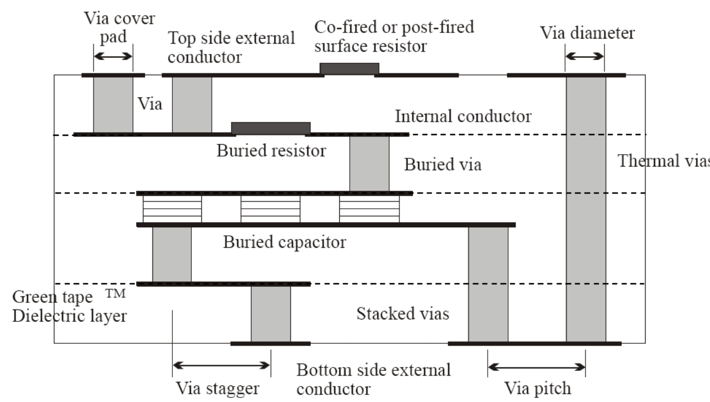


Figure 1. Typical LTCC Multilayer Circuit

Today more one company develops LTCC material to serve high frequency applications such DuPont and Ferro company.

Ferro A6 has a dielectric constant of ~ 6. The dielectric in Ferro A6 LTCC tape is a calcium boro-silicate, crystallizing glass. A typical firing consists of bakeout at 2 ° C/min ramp rate to 450 ° C for 2 hours and sintering at 850 ° C for 10 minutes with 8 ° C/min heating rate and 40 ° C/min cooling rate [3].

For high-performance LTCC MCM applications, stripline structures represent the most ideal transmission line, because dispersion and radiation are negligible and upper and lower ground planes provide effective shielding. Over there, the stripline is a valuable structure for 3-D integration of the millimeter-wave module because it is basically buried structures. Accordingly, stripline structures are commonly used as routing the signal within the module and passive devices such as band-pass filters, couplers and resonators [5].

II. A6 LTCC FERRO

A6 tape has three grades: A6-M, A6-B, and A6-C. A6-M is the preferred materials system for microwave applications. A6-M has a dielectric constant of 6 and very low dielectric loss (<0.002 @10GHz). A6-B is a similar ceramic system that fires to black appearance, while A6-C is a low cost white ceramic system. Typical physical properties are listed in Table 1[1].

ISBN: 978-988-19251-9-0
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

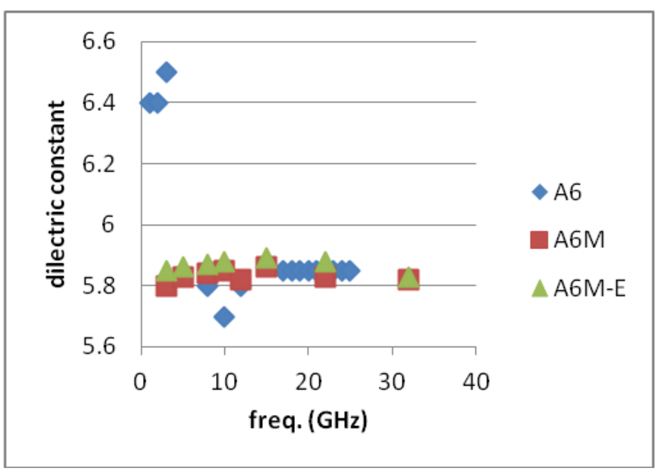
TABLE I. LTCC CHARECTRSTIC

Materials	*A6-M*	*A6-C*
Thickness (mils)	5,10	8
Shrinkage (x y, %	15.5	16
Shrinkage (z, %)	27	33
Flexural Strength (psi)	28,000	30,000

III. A6M & A6M-E LTCC FERRO

A6M is low and stable relative permittivity and low loss tangent over an unusually large and quite high frequency range. New Ferro LTCC product called A6M-E; It incorporates improvements to the physical properties of LTCC tape that improve its processing characteristics, while maintaining the excellent electrical performance of A6M [6].

High frequency electrical properties (dielectric constant and loss tangent) of A6, A6M & A6M-E are collected and drawn at figure 2. It shows the comparative between three types of ferro LTCC which describes low dielectric constant and low loss tangent at high frequency applications of A6M & A6M-E is better than A6 .



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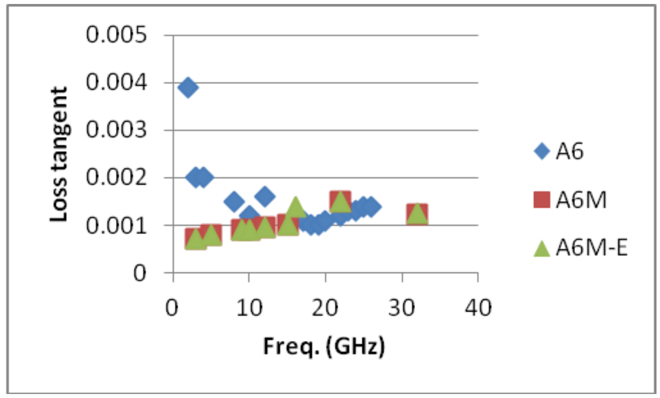

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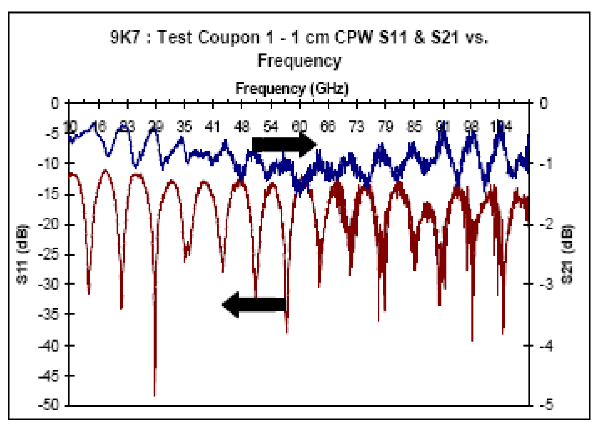
Figure 2. Electrical properties of A6, A6M & A6M-E up to 35 GHz. A) Dielectric constant vs. Frequency, B) Loss tangent vs. Frequency

IV. DUPONT 9K7 LTCC MATERIAL SYSTEM

Ability to support low-loss, controlled impedance transmission lines is of fundamental importance for a microwave Multi Chip Module (MCM) substrate. An industry standard material system is required to support the most commonly used transmission lines Microstrip and Coplanar Waveguide (CPW) [2].

To characterize the ability of the new tape system to support low-loss, controlled impedance transmission lines and interconnects; the most typical transmission lines used in high frequency MCM circuits; The first test coupon was designed, fabricated, and tested during the initial phase of GreenTape™ 9K7 material development, test coupon of 9k7 is shown below in Figure 3.



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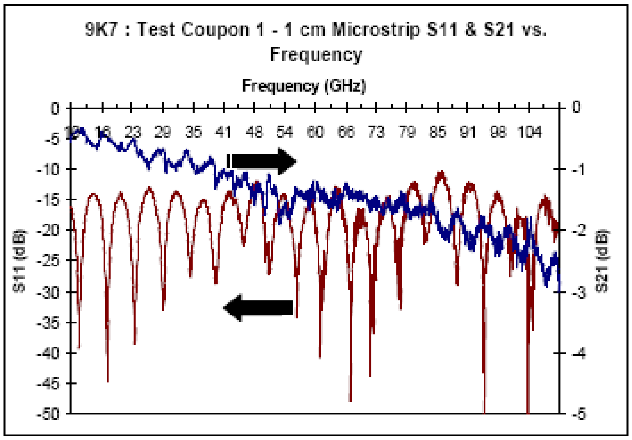

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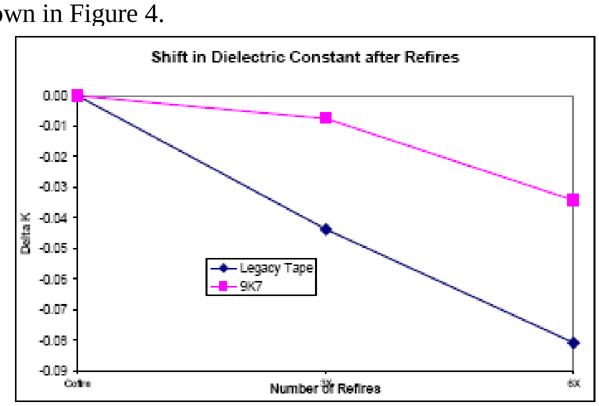
Figure 3. Transmission line performance data from TC1 up to 110 GHz. A) CPW S11 and S21 vs. Frequency, B) Microstrip S11 and S21 vs. Frequency

Stability of Dielectric Properties

One of the important considerations for assessing the manufacturability of an HF/Microwave MCM substrate is its ability to withstand reprocessing through critical process steps. It is must choose material which imperative that their dielectric properties remain unchanged. While legacy LTCC systems meet this requirement sufficiently, 9K7 has significantly stable dielectric properties when subjected to multiple refirings, owing to specific improvements in its material composition. Stability of properties through multiple re-firing steps is important because it allows for customization of the top or external layers for subsequent post processing [4].

To establish the dielectric stability, multiple GreenTape™ 9K7 tape lots were fired under similar initial conditions of 850°C and 26.5 hr temperature profile. Each of the test lots were refired at 850°C and 30 minutes. Dielectric properties were measured with a split cylinder cavity method at 9.5 GHz after three and six refires. A legacy tape sample was also included in the testing as a control sample. Observed variation of dielectric constant and loss tangent are shown in Figure 4.



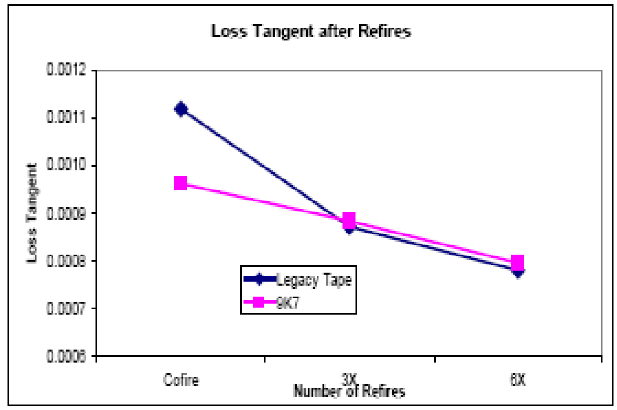


Figure 4. Distribution of dielectric constant – 150 individual samples

It is clear from the chart that GreenTape™ 9K7 has a smaller shift (less than 0.03) in dielectric constant even after six refire steps which are sufficient to accommodate most of the manufacturing requirements. Both for the legacy tape system and GreenTape™ 9K7 the loss tangent decreases with refire while it is observed that the change in the loss tangent for GreenTape™ 9K7 is smaller than that for the legacy tape.

From the analysis of A6 LTCC and 9K7 LTCC; above 9GHz applications the dielectric constant of A6 is 5.6-5.8 while of 9K7 is 6.975-7.275, and the dissipation factor of A6 is 0.0014-0.0015 while of 9K7 is 0.0010-0.0011. Here we can say A6 is better at applications which need low dielectric constant but not at multi frequency because it has some change in dielectric properties when the frequency increased.

Ferro develop LTCC A6M has better loss tangent than A6 and there A6M-E. A6M-E is an improved version of Ferro's A6M LTCC tape which combines industry leading high frequency performance with enhanced green tape properties. Ferro A6M-E's stable low dielectric constant (5.6 ±0.2) and unique low loss over a large frequency range (0.0002) at range 1-100 GHz makes it the material of choice in a myriad of advanced packaging applications up to 110 GHz, also 9K7 have low loss tangent which give the benefit for wireless communications.

V. LTCC 94 GHz Antenna Array

An antenna array is designed in low-temperature cofired ceramic (LTCC) Ferro A6M for mm-wave application.

The antenna is designed to operate at 94 GHz with a few percent bandwidth. A key manufacturing technology is the use of 3 mil diameter vias on a 6 mil pitch to construct the laminated waveguides that form the beamforming network and radiating elements.

The methodology for designing the antenna array is to divide the array into its major components and transitions, optimize each component and transition and subsequently

ISBN: 978-988-19251-9-0
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reassembling the entire system for resimulation and eventual fabrication.
The LWG (laminated waveguide) is rectangular dielectric-filled waveguide using vias for the side walls and solid planes for the top and bottom walls. The via size and pitch must be sufficiently small to meet the stringent requirements for isolation between the inside of the LWG and outside of the LWG [7].

The measurement of the loss in LWG is taken for real coupon . Figure 5 shows the HFSS model of a 1 inch LWG coupled to WR-08 waveguide at both ends. The model incorporates the nominal material values. Figure 5 shows the comparison between simulation and measurement for insertion loss and return loss, respectively. The simulated insertion loss has similar characteristics as measured data, but is under predicting loss by 2 to 3 dB. The simulated return loss on the other hand agrees extremely well with measured data.

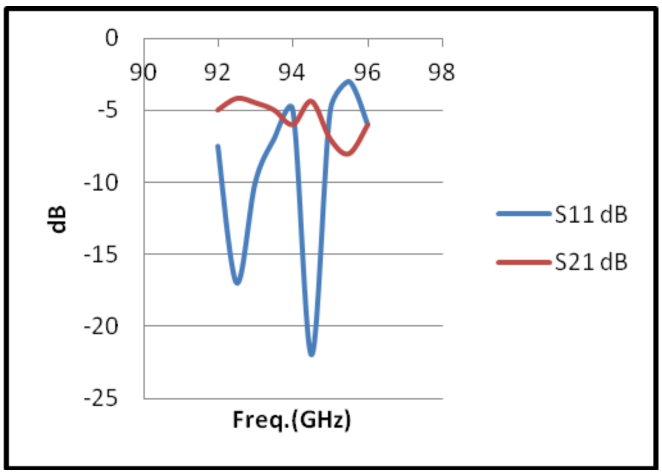

Figure 5. LWG mesurmenst of S11 and S21 vs. Frequency

CONCLUSION

To enable and extend applications of LTCC technology to millimeter frequency subsystems, many companies have developed a new low dielectric constant materials system, which is compatible with microwave loss properties. The ferro A6M-E and DuPont 9K7 low temperature co-fired ceramic system is designed to enable advanced high frequency circuits up to 100 gigahertz and beyond.

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