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COMMUNICATIONS

LTCC BASED TECHNOLOGY FOR 3D FORMED MODULES

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This paper is oriented on the overview of possibilities which are given by LTCC based materials. The accent was oriented to the three-dimensional (3D) electronic modules, their electrical and mechanical properties and their possible influence to the quality and reliability of final product. The authors present selected results of their research work at TU FEI, Department of Technologies in Electronics.

K e y w o r d s: thick film, LTCC, 3D formed modules

1 INTRODUCTION

Generally, the highly developed electronics systems capitalize conductive and dielectric materials in three- dimensional layout in combination with advanced assembly and interconnection technologies for IC chips and other electronics components.

Most of the necessary interconnection attributes for high powered and sophisticated chips are offered by Multichip Technologies (MCM) which combine the latest assembly and interconnection techniques for universal and for high frequency applications. The three basic concepts depend on the material and technology basis: MCM-C modules designed on ceramics substrates by thick film technology, MCM-L modules based on printed circuit boards, and MCM-D modules constructed via thin film technology on several various substrates. Low Temperature Cofired Ceramics (LTCC) which offers exclusive properties and allows to create non-standard 3D structures can be exploited in the MCM-C technology. Besides MCM-C, the LTCC is often used in sensoric applications for its flexibility, its ability simply to create various shapes and multilayer structures. The processing temperature of the LTCC (approx. 850 °C) accelerated production makes it simpler and more economical in confrontation with standard thick film processing. The specific properties and advantages of the LTCC can be profitably included into MCM production technology, sensoric and three-dimensional applications using multilayer structures (Fig. 1) [1].

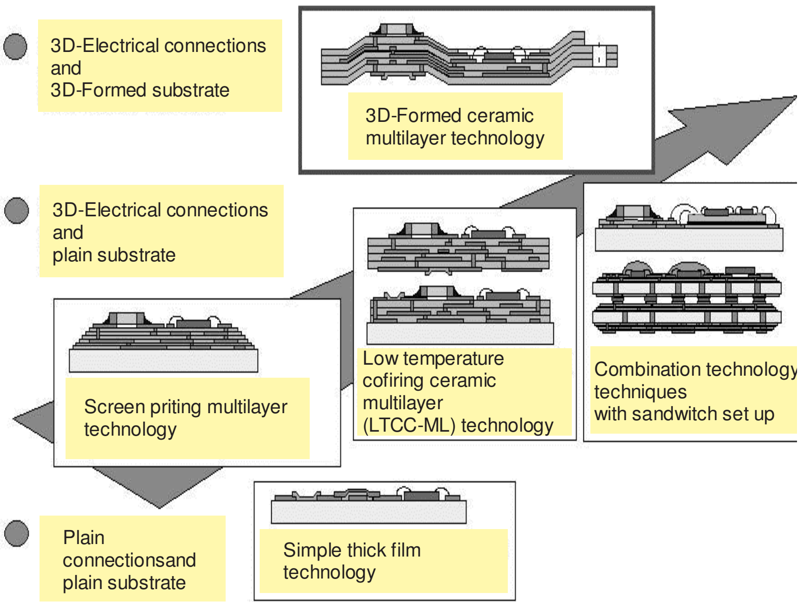

Fig. 1. General trends and overview in the hybrid technology progress.

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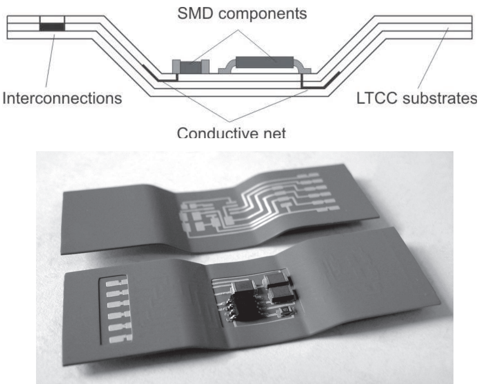

Fig. 2. Samples of the 3D formed LTCC structure — schematic drawing and photo of the final device for thick film pressure sensor application.

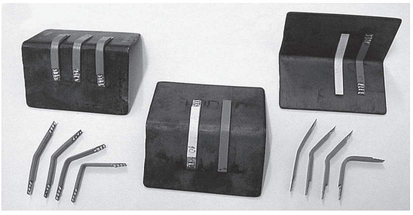

Fig. 3. Samples of the LTCC bended strips with an example of the difference between inside and outside bending angles.

2 EXPERIMENTAL ANALYSIS OF THE 3D FORMED MODULES AND THEIR PRODUCTION TECHNOLOGY

Materials based on the LTTC are processed by technology that allows to create structures up to 60 ceramics layers.

The particular technology adjustments of a common production process were used for experimental LTCC (GT 951 and GT 851) samples production.

The used technology steps are briefly described and listed below:

1. Substrate dimensions and orientation definition respecting the material shrinking during LTCC processing (*ie* cofiring) followed by the cutting of the designed strips.
2. The conductive layout screen-printing employing the LTCC compatible silver paste DuPont 6158.
3. Drying of the printed conductive net at 120 °C for 5 minutes.
4. Layers deposition and arrangement for the next processing.
5. Planar isostatic pre-lamination at temperature 70 °C and pressure 20.7 MPa for 10 minutes.

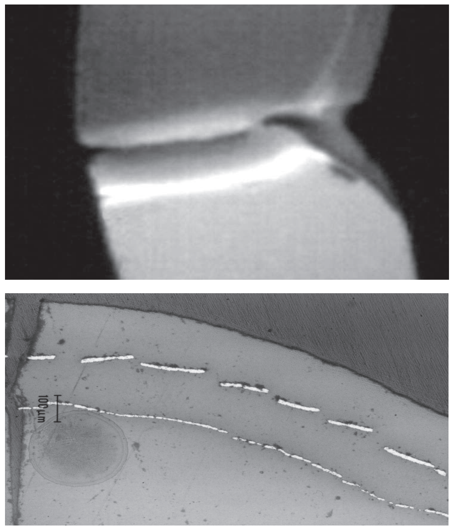

Fig. 4. a) Outer micro crack at the bending vertex, b) Illustration of the inner micro-cracks in the bend conductive layers.

6. Three-dimensional bending and re-lamination using a special tool and isostatic laminator (temperature 70 °C, pressure 20.7 MPa, time 10 minutes).
7. Standard co-firing process of the laminated 3Dmultilayer ceramics structure including the conductive net.
8. Measurement, testing and diagnostics of the processed and burned samples.

Finished 3D samples (Fig. 2) were subjected to the following analysis:

- Analysis of the mechanical properties depending on the number of layers and folding angle.
- Measurement and evaluation of some electric properties signal cross-talk and impulse response.
- Inside conductive layers analysis at the bend location.

3 MECHANICAL PROPERTIES OF THE 3D TESTING SAMPLES

Ceramics based (DuPont GT 851 and GT 951) strips with dimensions 10 × 50 mm were used for the analysis of mechanical properties. The used strips were equipped with a conductive route across the whole length and with soldering pads placed on the both narrow ends. Specific bending tools were used for the re-lamination process and bending of the raw ceramics strips. This supporting equipment allowed to prepare samples with inside and outside angles 20, 40, 60 and 80 degrees (Fig. 3) and it is suitable for using and application up to 10 layers of raw ceramics.

The performed tests following the basic analysis show that the inside angle bending brings more significant results and has a notable influence upon the possible failure. Considering this fact, the results of this way sample bending are listed and evaluated in the next passages.

Bending process optimization was performed and evaluated via mechanical tests following detailed visual inspection [4]. The failure process was activated in the most

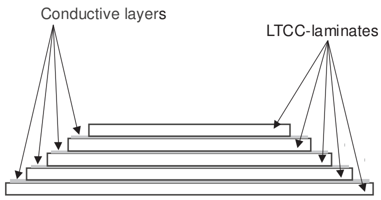

Fig. 5. The LTCC testing structure for electrical measurements

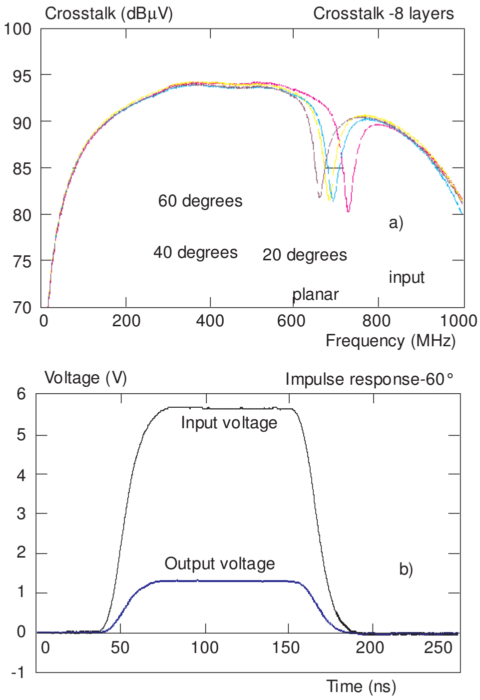

Fig. 6. a) The signal cross-talks depending on the frequency for 8-layers testing structure, b) Time dependence of the impulse response for 6-layers structure with 60° bending.

exposed location (the bending vertex) where micro cracks were observed (Fig. 4.a) accompanied by damaging of one or both conductive layers (Fig. 4.b).

The results of mechanical tests via three-point bending method confirm LTCC base substrates eligibility for bending up to 60 degrees. Applications after overstepping this threshold are not recommended because the cracks growth is evident and critical.

Besides the bending angle, the number of laminated layers has a significant influence on the final structure quality and on the mechanical properties. The layer growth brings about mechanical properties degradation. Microscope analysis showed a negative influence of the multilayer lamination, too. The critical number of layers seems to be 6 because the negative effect was observed after crossing this border [2].

4 ELECTRICAL PROPERTIES MEASUREMENT

The electrical properties of the multilayer LTCC structures (GT 951) were tested by signal cross-talk and impulse response measurements in the laboratory of the electro-magnetic compatibility at Polytechnica Rzesowska in Poland.

Figure 5 shows the principal design of the multilayer planar structure version. Analogical bend structures, at 20, 40, and 60 degrees bending angles, were used for electrical measurement besides planar compositions, too.

The spectrum analyzer Advantest R3132 in the frequency range from 1 kHz up to 1 GHz was used for signal cross-talk measurements. The adjusted results showed inconsiderable or zero influence of the bending and layers laminating upon the signal cross-talk in the whole frequency range. From this point of view, the structure bending and layers stratifying do not represent any reduction demands or limits for the high frequency applications. The acquired results are shown in Fig. 6.

The impulse response measurements were performed via oscilloscope Tektronix TDS 220 in compatible combination with functional pulse generator HP Agilent 33120 A with output impedance 50 mΩ. All acquired results showed insignificant or no influence of structure bending or layers stratifying on the impulse response measurement during the whole testing [3].

5 INSIDE CONDUCTIVE LAYERS INSPECTION AT BENDING VERTEX LOCATION

The LTCC based 2 and 4-layer structures were realized for inside conductive routes inspection. A series of the created testing samples exploited inner and outer angles 20 and 60 degrees and the conductive routes were designed with 250 and 150 μm width. The design of the routes, conductive pads and structures shaping respects the demands of the Kelvin method for low resistance measurement — Fig. 7.

Inside the conductive net, inspection and analysis consisted of non-destructive measurement of the transitional resistance between two conductive layers at the bending vertex location. The transitional resistance represents the value of the vertical connection between two conductive layers spread on the substrate surface. Very low resistances represent the resultant measured values and this is the reason why it is necessary to eliminate all surrounding influences. The best way how to solve this measurement task is using the Kelvin method based on the voltage decrease measurement at interconnection, see Fig. 8.

The computer aided semiautomatic measuring equipment at the Technical University of Košice was used for all essential measurements. The necessary tools consist of the precisely controlled current source in the range from 50 to 500 mA, operational amplifier and interface for communication with PC for operating control, data processing and store. Testing samples were situated into accelerated test surroundings with stable temperature 150 °C and during the prescribed intervals electrical measurements were made. The basic inside conductive net inspection results are shown in Fig. 9 and they reveal the fact that shaping

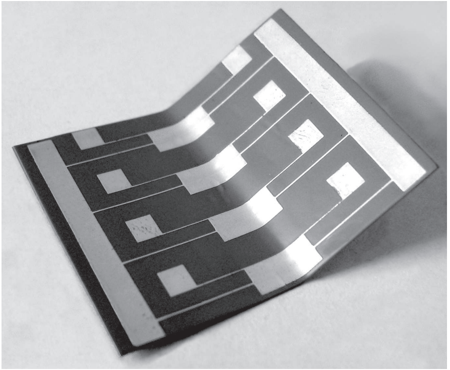

Fig. 7. Sample of the multilayer bend structure for inside conductive net analysis.

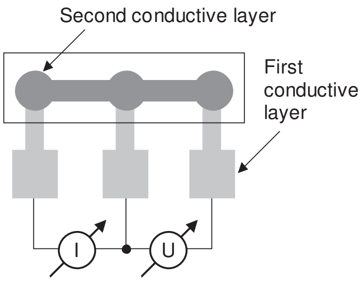

Fig. 8. Measurement principle of the law values interconnection resistance.

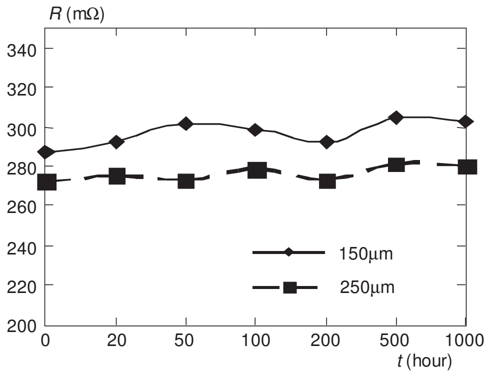

Fig. 9. The resistance behaviour at bending vertex during accelerated test (multilayer sample, outside angle 60°).

has only minimal or insignificant influence on the interconnection resistance and secondary on the interconnection reliability.

5 CONCLUSION

The high level flexibility of raw LTCC material enables production of 3D formed electronic modules and production technology modification brings other possibilities for design engineers. The modification of the standard technique is based on the gradational bending steps at multilayer ceramic modules. The achieved and observed results give good assumption for their reliable application into hybrid sensors and interconnection technology.

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Reinhard Bauer (Prof) received his professorship at the Faculty of Electrical Engineering, University of Applied Sciences, Dresden. He graduated with a doctor thesis in the field of precision engineering development of thick film hybrid technology and it application for electronic circuits and sensors. His experiences are at the field of LTCC multilayer technology in which he published more than 50 papers, especially on new results of three-dimensional shaped LTCC multilayer structures for different applications obtained an international allowance. He co-authored a German schoolbook for electronics technology and is coordinator of the Saxony Work Group of Electronics Technology (VDE/ VDI), Germany since 1994.