S. Slosarčík, J. Banský, J. Urbančík, I. Vehec, S. Kardoš
Technical University of Košice,
Department of Technologies in Electronics, Slovakia

POTENTIAL OF THE LTCC FOR UNCONVENTIONAL THREE-DIMENSIONAL APPLICATIONS

Описано потенційно можливе застосування матеріалів на основі низькотемпературної кераміки. Основну увагу звернуто на тривимірні (3D) електронні модулі, їхні механічні властивості і їхній можливий вплив на якість і надійність кінцевого продукту.

This paper describes one of the utilization possibilities, which is given by the potential of the LTCC materials. The accent was oriented to the three-dimensional (3D) electronic modules, their mechanical properties and their possible influence to the quality and reliability of final product.

Introduction

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

Majority of necessary interconnection attributes for the high powered and sophisticated chips offer Multichip Technologies (MCM), which combine latest assembly and interconnection techniques for universal and for the high frequency application, too. The three basic concepts depend on material and technology base, of which are MCM formed: the MCM-C modules designed on the ceramic substrates and fabricated by thick film technology, the MCM-L modules based on the printed circuits boards and the MCM-D modules constructed via thin film technology and several various substrates. The Low Temperature Cofired Ceramics (LTCC) which offers exclusive properties and enables to create non-standard 3D structures is using in the MCM-C technology. Beside the MCM-C, the LTCC are often used in the sensor's application for its flexibility, its ability to simply create various shapes and multilayer structures. The processing temperature of the LTCC (approx. 850°C) accelerated production, makes it simpler and more economic in confrontation with standard thick film processing. The specific properties and advantages of the LTCC can be profitably included into the MCM production technology, sensorial and three-dimensional applications using multilayer structures [1].

Experimental analysis of the 3D formed modules and their production technology

Electronic modules based on the LTTC are processed by technology that enables to create structures up to 40 ceramics layers.

We have used the particular technology adjustments of ordinary production process for experimental LTCC (GT™ 951) samples production.

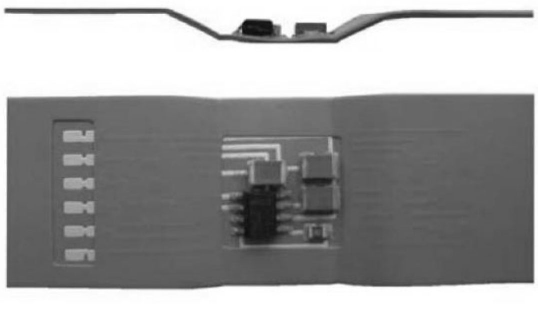


Fig. 1. Samples of the 3D formed LTCC structure – schematic drawing and demonstration of real structures for electronics

Used technology steps are shortly described and listed below:

1. Cutting of the designed strips with orientation and dimensions, which respects the material shrinking during the LTCC processing (i.e. cofiring).
2. For the conductive layers is used LTCC compatible silver paste DuPont 6158.
3. The conductive layers are dried during 5 minutes at 120°C.
4. Planar isostatic pre-lamination at temperature 70°C and pressure 20,7 MPa during 10 minutes.
5. Three-dimensional bending and re-lamination by using of the specific tool (temperature 70°C, pressure 20,7 MPa, 10 minutes).
6. The laminated multilayer ceramic structures are cofired.
7. The fabricated structures are measured, tested and passed trough the diagnostics.
8. Finished 3D samples (Figure 1) were subjected to the following analyses:

– Analysis of the mechanical properties depends on layers number and folding angle,

– Inner conductive layers analyze at the bend location.

3. Mechanical properties analysis of the 3D testing samples

The ceramics based (DuPont GT™ 951) strips with dimensions 10x50 mm were used for the mechanical properties analyze. Used strips were equipped with conductive route across the whole length and with soldering pads placed on the both narrow ends. The specific bending tools were used for the re-lamination process and bending of the raw ceramics strips. This supporting equipment enabled to prepare samples with “inside” and “outside” angles in the range of 20, 40, 60 and 80 degrees (Figures 2, 3) and it is suitable for application up to 10 layers stocking of raw ceramics.

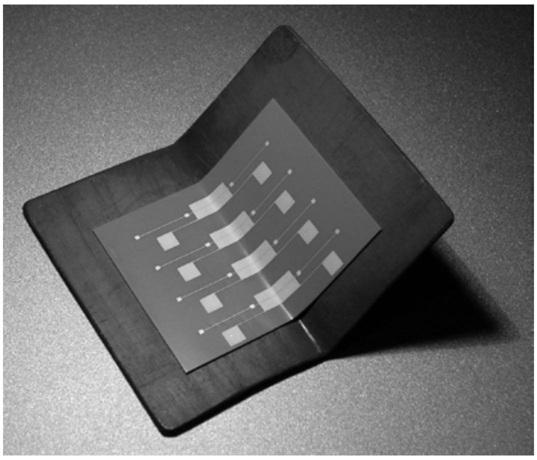


Fig. 2. Samples of the LTCC bended strips with illustrative example of bending angle formation

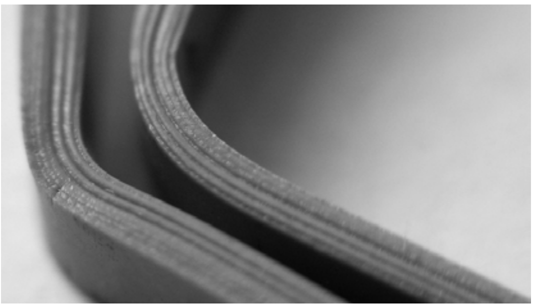
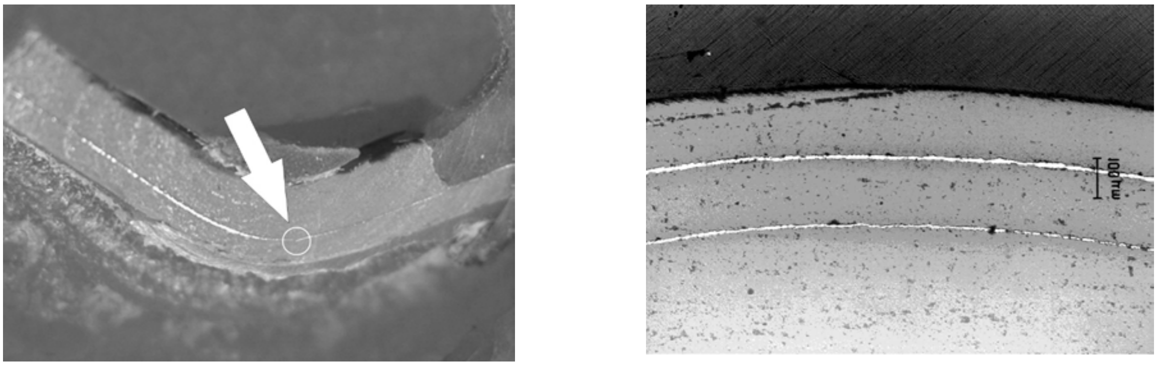


Fig. 3. Detail of the formed multilayer LTCC structure with different bending angles and inner conductive routes

The realized tests followed by the basic analyses show that the inside angle bending brings more significant results and notable influence to possible failure. Consideration of this fact, the results are listed and evaluated in the next passages.

The bending process optimization was realized and evaluated via mechanical tests following the detailed visual inspection. The failure process was activated in the most exposed location (the flexure pint) where were observed micro cracks accompanied by damaging of one or both conductive layers (Figure 4).



(a) (b)

Fig. 4. Sample of the inner conductors at multilayer bended LTCC substrates:
(a) illustration of the micro crack at the flexure point (cross section);
(b) illustration of the result which meets quality requirements (cross section)

Beside the bending angle has number of laminated layers significant influence to the final structure quality and to the mechanical properties. The layer growth brings proportional mechanical properties degradation. Microscope analysis showed to the negative influence of the multilayer lamination, too. The critical layers number seems to be six because the negative affect was observed after this border crossing [2][3].

4. Inner conductive layers – quality inspection in the multilayer and 3D bended structures

Beside the mechanical and electrical analysis the knowledge regarding the electrical characteristics at critical locations from the quality and reliability point of view is important. Necessary experience and basic information can be obtained from testing series which simulate possible and typical applications of the three dimensional bended modules based on the LTCC. One way, which offers basic knowledge and practice, represents measurement of the interconnection resistance at inner conductive net. Multilayer structures, which are bended into several different positions, we have used as a demonstrator for these purposes.

The necessary measurements are represented by interconnection resistance sensing based on the four-point measurement method because the interconnection resistance of thick film conductive layers shows very low values. This measurement way eliminates interferences from surrounding environment, respects the initial quality of measured interconnection. The method is based on the measurement of the potential drop on the interconnection, using direct current flowing through measured vertical connection. Drawings of the basic and slightly simplified layouts for interconnection resistance measurement are showed in the figure below:

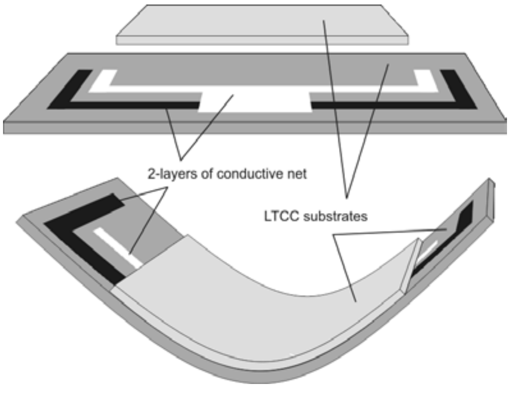


Fig. 5. The inner interconnection layout (the plain – raw structure before processing and final – shrinking; bended testing structure after processing)

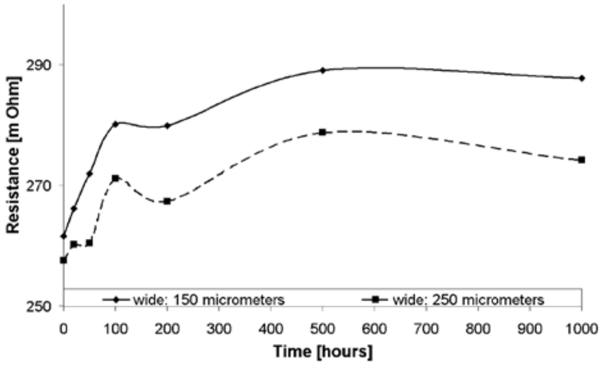
The circuit loops with flowing current are represented by active parts of the first and the second layer. Flowing current causes potential drop at interconnection, this is created by layers overlay. Accurate voltage measurement in the second circuit loop without the current - represented by another part the 1st layer and rest fraction of the second layer – together with known current value bring all necessary information for desired resistance calculation. This value represents interconnection resistance as the parameter suitable for another analysis or as the factor which can be utilized for the reliability testing and finally for quality assurance.

The original equipment based on the computer aided semi automatic measurements we have used for all essential measurements. The necessary tools consist of the precisely controlled current source in the demanded current range, operational amplifier and interface for communication with PC, operating control, data processing and data store. Testing layouts consist of several basic subjects – interconnections, which we prepared by overlap of two layers. The different structures, layers number, shaping and bending angles demand different layout variations for the measurement. However, all of them respect the measurement method and principle by text above. This fact brings several different values of the measured interconnection resistance. On the other hand, the absolute value of acquired resistance is not as important as the value alteration during the reliability test. This alteration brings expected and relevant information from quality and reliability point of view.

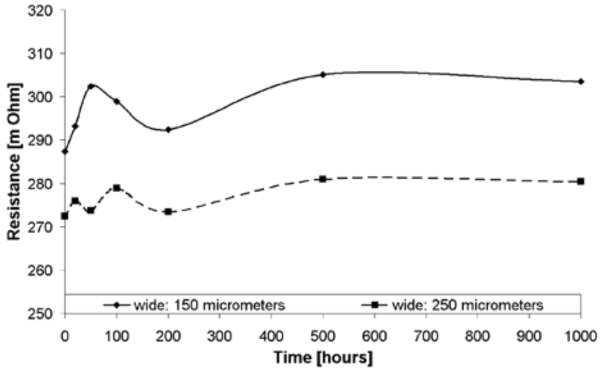
For initial property analysis of inner conductive net was used ageing process based exclusively on temperature acceleration. There were prepared several different structures with testing layout. All of tested modules were subjecting to the measurement of the potential drop for 45 different values by steady current in the range from 50 to 500 mA. The consequential resistance determination poses the average value from 45 measurements and its graphical behavior enables monitoring of linearity or contingence errors during measurement process in real time. Finally, all of the tested substrates were subjected to the optical control (for prevention of the potential mechanical damaging by the shaping, bending or handling) before testing. The damaged interconnections were removed from further measurement. In compliance with ageing methodology, the substrates were exposed to effect of temperature 150°C at 1000 hours and the electrical measurements were carrying out in intervals 0, 20, 50, 100, 200, 500 and finally 1000 hours.

For results demonstration were chosen two modules: planar one and another with bending angle of 60°. Conductive net of both samples was based on the 150 and 250 μm widths prepared by the principle drawing on the Figure 5. Results of the inside conductive net inspections are showed on the Graphs 1 and 2. Both figures show to the fact that shaping has only minimal or insignificant influence to the interconnection resistance and secondary to the interconnection reliability, too. Routes based on 250 μm widths bring slightly better results and this fact refers to the expected reality that the wider routes are less sensitive to the bending or shaping. Of course, the shaping or bending process supposes the exact and very strict processing, which eliminates micro cracks, and respect all thresholds.

As follows inside conductive net inspection and analyze represents the non-destructive measurement of the transitional resistance between two conductive layers at critical location. The transitional resistance represents value of the vertical connection between two conductive layers spread on the substrate surface or inside the laminated ceramic structure. Very low resistances represent the resultant measured values and this is the reason why it is necessary to eliminate all surrounding influences. Sample of the tested demonstrator with layers overlap and contact pads is showed on the Figure 6.



Graph 1. The resistance behavior at planar demonstrator sample during accelerated test



*Graph 2. The resistance behaviour at flexure point during accelerated test –
multilayer sample, outside 60° bending angle*

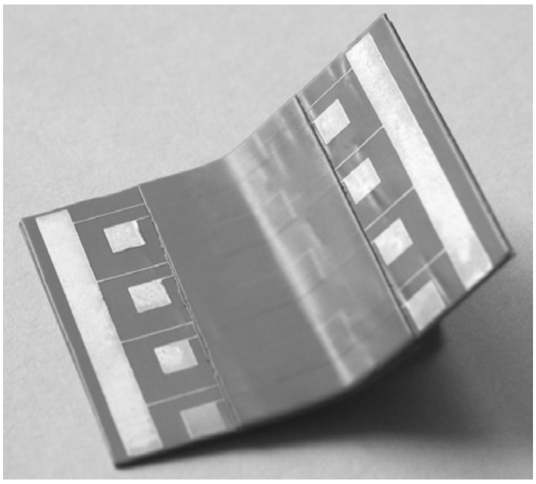


*Fig. 6. Representative sample of the multilayer bended structure
for inside conductive net analysis*

5. Conclusion

The high-level flexibility of raw LTCC material enables production of the multilayer 3D formed electronic modules with thick film inbuilt layers and production technology modification brings other possibilities for design engineers. The LTCC plasticity allows comparatively large-scale bending. This reality could bring some troubles in the flexure points which are represented by increased and irregular mechanical stress, micro cracks and finally by the inner layers damaging. Increased layers number at final structure highlights this potential hazard. Our observations show to the fact that the modules up to six layers with bending angle up to the 60° do not cause above listed problems. The modification of the standard technique base 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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3. Z. Hotra, W. Kalita, A. Pietriková, S. Slosarčík, "Best Laminated Modules Based on LTCC", Technične listi, 2002/1,2, Ľvov, Ukraine, pp.51-55