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Innovation steps towards a novel and cost efficient LTCC packaging technology for high end applications

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Abstract: The emerging of a new MEMS, MOEMS and BioMEMS in the field of Sensors and a new GaN based generation of RF semiconductors in the field of RF Communication create new challenges for the packaging technology. In order to provide adequate packaging solutions for high end applications, manufacturers today are requested for high flexibility, excellent performance and reasonable costs.

Requirements with respect to advanced circuit functionality and enhanced thermal management,   low dielectric losses, low parasitic effects and crosstalk, SiP integration, thermal management, miniaturisation and reliability have to be fulfilled. Today LTCC provides a proven packaging solution for Standard MEMS, GaAs devices and MCMs. increasing frequencies; increasing power and increasing functionality of the systems are the driving forces to investigate into novel packaging solutions.

This paper describes the different steps how LTCC technology can cope with these requirements. Based on a comparison of the different available LTCC systems and a benchmark between them, the packaging performance of several LTCC systems is investigated in detail. Technological features, relevant for miniaturisation, System in package integration and RF performance, like cavities, conductor line resolution, via diameter and flatness are considered. Process capability, relevant for thermal management, SiP integration and hermeticity like brazing of heat sinks, integration of heat pipes, integrated capacitors and resistors are analysed.

The impact of novel and low cost materials for metallization, heat sink and brazing will be evaluated with respect to weight and cost. Compatibility with RoHS and REACH regulations will be discussed. The progress beyond the state of the art will be demonstrated by packaging solutions recently developed for industrial applications and in the frame of research programmes.

Keywords: LTCC, sensors, RF packaging, System in Package, reliability

Inovativni koraki proti novi in ceneni LTCC tehnologiji pakiranja za visokotehnološke aplikacije

Izvleček: Združevanje MEMS, MOEMS in BioMEMS na področju senzorjev z RF polprevodniki na osnovi nove GaN tehnologije predstavlja nove izzive za tehnologijo pakiranja. Visoka fleksibilnost, izjemne lastnosti in sprejemljiva cena so zahteve proizvajalcem za izdelovanje ustreznih rešitev pakiranja visokotehnoloških izdelkov.

Današnje LTCC predstavljajo preizkušene rešitve za pakiranje standardnih MEMS, GaAs elementov in MCMjev. Povečanje moči, funkcionalnosti in frekvenc zahtevajo razvoj novih rešitev.

Članek opisuje različne korake rešitev teh zahtev s pomočjo LTCC tehnologije. Različni LTCC sistemi so medsebojno primerjani in njihove lastnosti natančno raziskane. Opisane so tehnološke značilnosti pomembne za proces miniaturizacije, integracije sistemov v ohišje in RF lastnosti. Analizirane so sposobnosti procesa termičnega upravljanja, SiP integracije in hermetičnosti.

Vpliv novih in cenenih materialov za metalizacijo, hladilnike in spajkanja bodo ocenjene glede na težo in ceno. Opisana bo združljivost z RoHS in REACH regulativami. Predstavljene bodo napredne rešitve novega pakiranja za industrijske aplikacije v okviru raziskovalnih programov.

Ključne besede: LTCC, senzorji, nizke izgube, nizka teža, RF ohišja

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1. Introduction

New microsystems, microsensors and microelectronic devices like MEMS, MOEMS, BIOMEMS and GaN based high power/high frequency semiconductors are emerging. These devices show an outstanding performance with respect to miniaturisation, functionality and power. Adequate packaging solutions, encapsulating heterogeneously the different components have to take into account that some of these devices are sensitive to environmental conditions like thermal cycling, heat dissipation and humidity. In addition good electrical stability and good EMC performance together with excellent high frequency and high power performances have to be obtained and hermetic or quasi hermetic packaging is requested in different cases. These requirements create new challenges to the packaging technology with respect to electrical performance, SiP integration, thermal management and reliability.

2. State of the Art LTCC Packaging solutions

Today LTCC provides an established and proven packaging solution for automotive applications, mobile phone circuits, industrial sensors; GaAs based MMICs and RF MEMS. Passive functional elements like miniaturised antennas, filters, couplers, temperature sensors, heating elements, resistors, capacitors and inductors can be monolithically embedded. Depending on the power dissipation and the reliability requirements those packaging solutions cover the whole range from low power quasi-hermetic packages to high power near hermetic packages and fully hermetic packaged high power MMICs. Glob top and transfer moulding protection, adhesive bonded heat sink and cavity shielded MMICs as well as brazing technology for heat sink and ring frame attachment are used. The type of packaging chosen is related to the lifetime, the reliability and the volumes of the different application.

3. Packaging solutions in the low volume industrial market

The low and medium volume market for LTCC is mainly represented by customized packages in the field of industrial sensors, medical devices and high end rf modules for telecommunication and satellite communication. Driving forces for all of those applications are the technical performance at acceptable cost for the individual customer solution. In the following example (Fig.1) the complete package of an x-ray detector is shown.

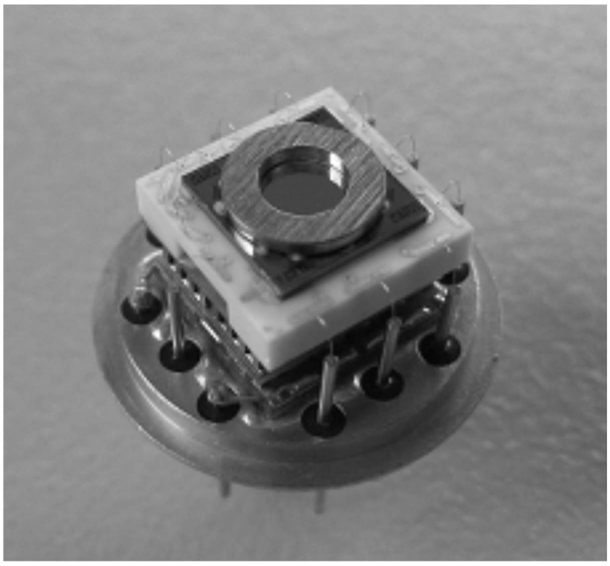


Figure 1: KETEK: x-ray detector

The key benefits with LTCC is the high miniaturisation, the capability of thermal management which includes a channel for heat transfer and thermal vias for power dissipation, the sspectroscopic neutrality and the full Hermeticity with 0 outgassing.

In Fig. 2 different customized packages for X-Ray detectors and pressure sensors demonstrate the benefits of specific shapes; several wire bond levels, integrated fluidic channels and the capability of dedicated material systems.

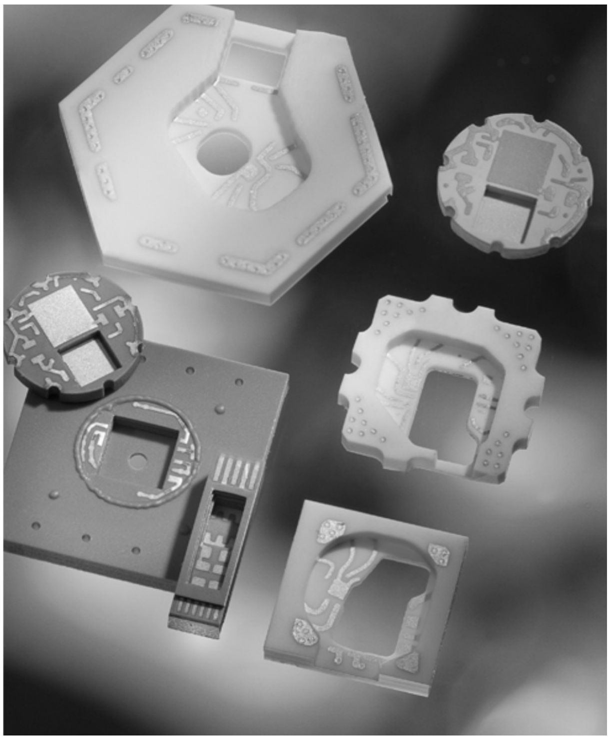


Figure 2: VIA: Customized sensor packages

Key benefits shown are specific shapes, several wire bond levels and Integrated fluidic channels Dedicated material systems

4. Packaging solutions in the high volume automotive market

Cost together with reliability and Miniaturisation are the driving forces in the automotive business. LTCC in Germany's automotive market today is a business of about 250 Mio €. Typical under the hood applications are Antiblocking, Gear control or Steer by wire systems.

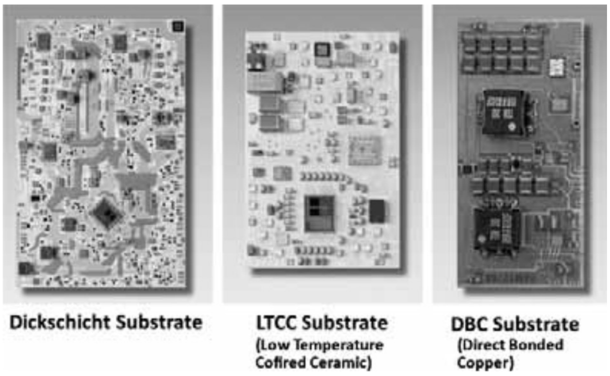


Figure 3: TEMIC: Technology platform

All of them request heterogeneous integration of highly miniaturised signal electronics together with thickfilm and DCB high power substrates into the same package.

Figure 4: TEMIC: Gear control unit

5. Packaging solutions in the high volume mobile phone market

In the high volume market of mobile phones a fast evolution of miniaturisation using LTCC packaging technology can be observed.

Front end (Fig. 5) is realized today in LTCC. The key benefit of LTCC is the possibility to integrate passive RF functions at substrate level. Using a material system which consists of two different dielectric materials, one for signals with K= 8 and the other with K= 20 (the so called electronic ceramic) enables to integrate a number of such functions like filters, baluns, matching networks and others.

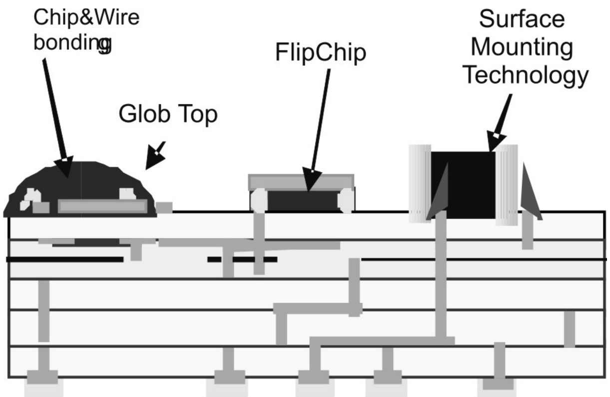


Figure 5: Epcos: Schematic of a LTCC frontend,

Fig. 6 depicts the top view of a dual-band WiMAX LTCC module. Active components like PA, switch and even some power management (PM), functionality are soldered on the top of the module while the RFIC is connected by means of wire bonds.

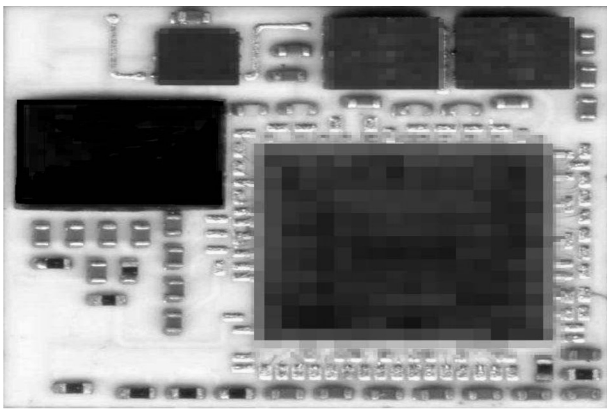


Figure 6: TDK-EPC: WiMAX SiP

The worldwide smallest All-in-one Frontend-Modul for Bluetooth- and WLAN-application has been published by Epcos 2008. With a height of 1,4mm it requests only a small area of 4,5 x 3,2 mm^2 on the PCB. This module integrates the power amplifier, the switch, the receive-balun and the bias network with EMW protection. Furthermore, the integrated coexistence filter allows simultaneous operation of WLAN and Bluetooth having all standards of mobile communication and realises all requested functions between WLAN and Bluetooth.

Figure 7: Epcos D 601: The world smallest All in One Module

The most actual development is an advanced frontend, based on the co-design of Frontend and Antenna by combining flex foil and LTCC. This module combines the advantages of LTCC and Flexible board technology and results in a game-changing 16-band antenna, including Japanese frequency bands in the 1.5 GHz range. It is a single hardware-serving operator worldwide.

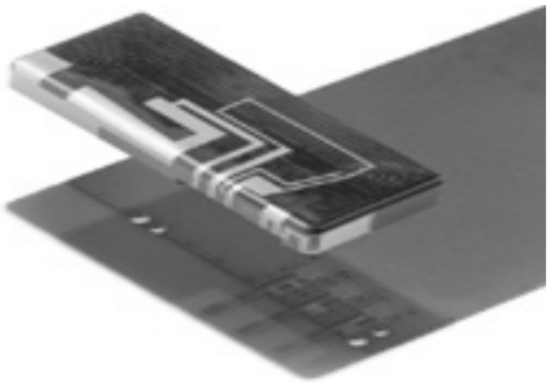


Figure 8: TDK-EPC: Advanced multi-feed RF front-end

6. RF Packaging solutions in other applications

The telecommunication market requests also for high end solutions at medium volumes. High power T/R modules, antenna- and phase shifting modules, RF-MEMs Switches are widely applied in active antennas for satellite communication and radio links. Radar detection systems are used in defence applications. Radar sensors have been successfully introduced in the automotive business and industrial applications are following. The following pictures show a 60GHz-band 500-Mpbs transmitter and receiver multi-chip modules (MCMs), in which MMICs and filters are mounted into a LTCC package using flip-chip technique. A Lid protects the IC's and the MCMs are directly bonded with printed wiring boards using ball grid array technique, achieving connections for signals and biasing.

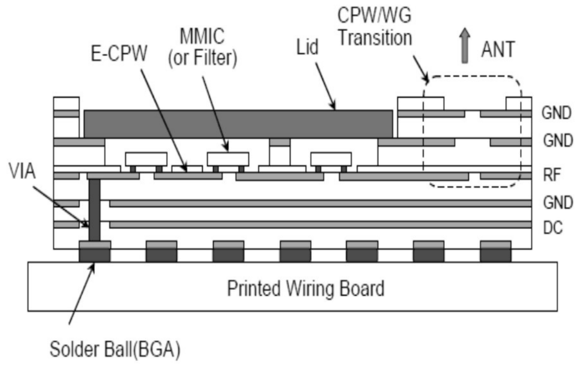


Figure 9: NEC: Schematic of the NEC 60 TR module

The transceiver is applied to the IEEE1394 wireless adapter, which demonstrates 17-mcommunication distance in line of sight.

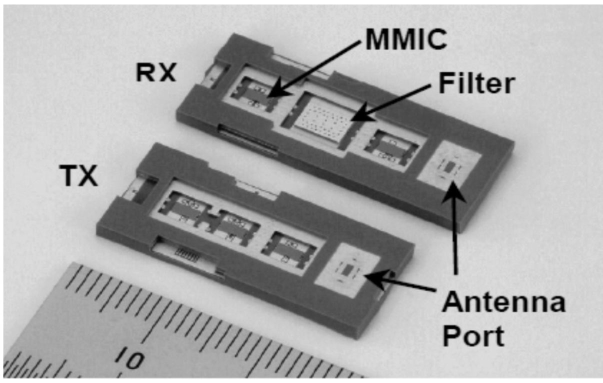


Figure 10: NEC 60 TX and RX Module

LTCC is offering again numerous advantages like the rf performance and the capability of passive integration. Another one is the design flexibility combined with the approach of modularity. Ericsson has demonstrated how to develop a number of T/R modules working at different frequencies from 15 to 39, using the same or similar RF building blocks for the realisation of the circuit. Filters, waveguide transition and other RF functions were successfully integrated at substrate level together with buried resistors. The other advantage is the high reliability performance.

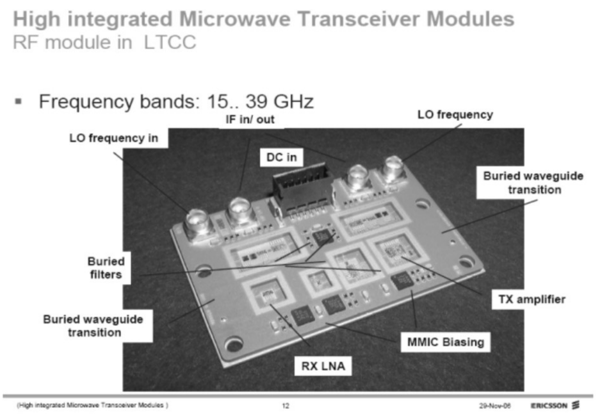


Figure 11: Ericsson: Modular kit of LTCC T/R modules, 15 to 39 GHz

LTCC circuits perform a lifetime of more the 20 years, they are stable under harsh environment and they are capable for full hermeticity according to Mil Std. Those substrates can be sourced from foundries like VIA on the free market in Europe.

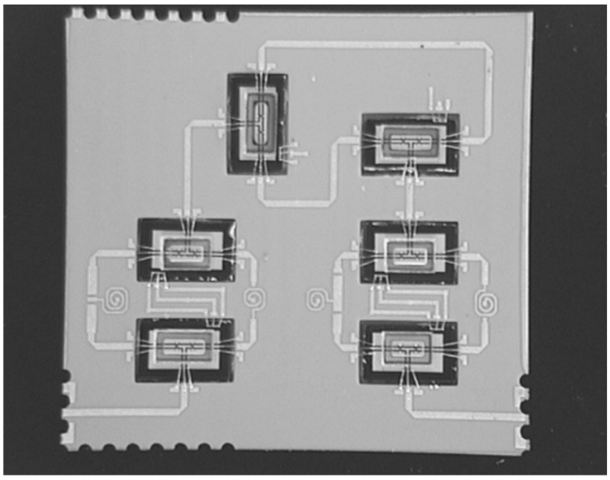


Figure 12: Thales: 3-bit phase shifters for phased array antenna

For space and military applications hermeticity is a must. Weight plays an important role and also cost is a key issue for success. Efficiency in packaging and miniaturisation in order to reduce cost, weight and size are key benefits of the LTCC technology.

According to the high energy requested for transmission, power dissipation and thermal management are integral part of the packaging requirements and components like heat sinks and ring frames as well as the attachment of those elements to LTCC are in the focus of this paper.

The following picture shows the TNO design of a state of the art packaging solution for a TR module working at K- band for nautical application.

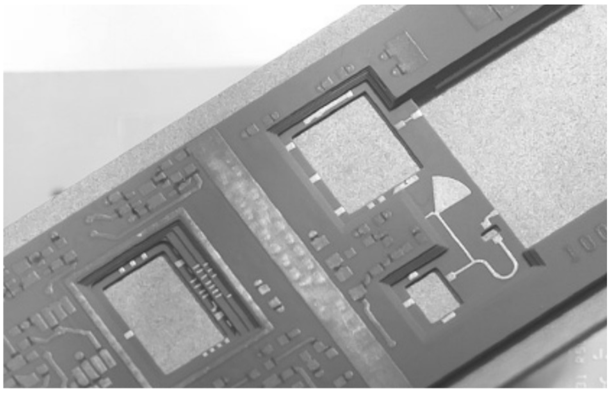


Figure 13: TNO: Design of a LTCC Transmit Receive Module

The package contains a rather complex stepped cavity structure for MMIC, Circulator and IC integration. The LTCC is adhesive bonded to the Molybdenum heat sink and then populated with SMT and chip and wire technology.

A further step towards reliability has to be made if full hermeticity of the packaged dies is required. This is the case in space and defence radar applications. An example is given in the following package of a TR module for phased radar antennas. Molybdenum heat sink and Kovar ring frame are AuSn brazed to the LTCC substrate. This package type shows extremely good thermal and reliability behaviour and it fulfils the MIL specification for hermeticity (>5x10^{-8}atmcm3/s)

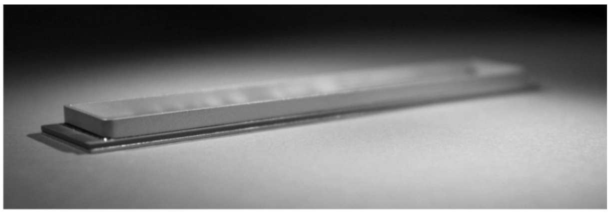


Figure 14: EADS: LTCC T/R Package

Another approach to achieve full hermeticity and good heat dissipation is shown in the following example, in which a Kovar frame is AuSn brazed to achieve hermeticity and a BGA is used on the backside for PCB assembly.

Figure 15: SELEX: RF package Kovar ring and BGA

7. Future system requirements

Increasing frequencies, power and functionality of systems are the driving forces to investigate novel packaging solutions. In the following pictures typical T/R modules for x-band and wide band are shown.

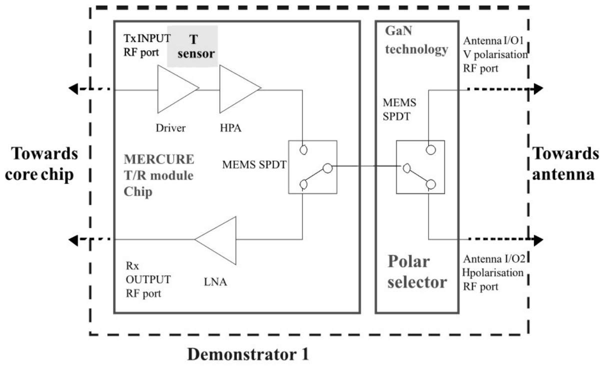


Figure 16: Thales: Block Diagram Wide Band T/R module

Typical functions and sizes to be integrated are:

- HPA: 20 mm²
- Driver: 5 to 10 mm²
- LNA: 5 mm²
- MEMS: 2 mm²
- Decoupling capacitors and others about 30 mm² in total
- Temperature sensor

In order to have a smart package, the internal room for components is thus typically estimated from 100 to 250 mm² for wideband and 150 to 400mm² for x-band. The developed package must be compatible with a cold plate cooled by fluid.

Power to be dissipated is up to 80 watts peak dissipated power, pulsed with a pulse time from 1 to 20µs associated to a duty cycle of up to 20%.

Materials with excellent thermal conductivity are required. These materials must be compatible with high temperature gold tin brazing. Return loss of one microwave transition must be better than – 25 dB and the isolation between the antenna access and the LNA access must be better than -80 dB. The isolation between biasing and /or control ports must be typically 50 dB, which is typically realised by a metallic wall.

As sensitive devices are encapsulated a good hermeticity must be by enclosure obtained. Typically a 5x10-8 Atmcm3/s (air) is required. The package must withstand –55 +125°C 500 cycles without lack of hermeticity or electrical performances degradations.

8. Steps to cope with these requirements

The expertise in the technology together with the relevant application know how of the customer is the backbone of the small and medium sized European LTCC Foundries like VIA in order to service the free market with high flexibility and medium to low volumes.

9. Understand materials and their properties

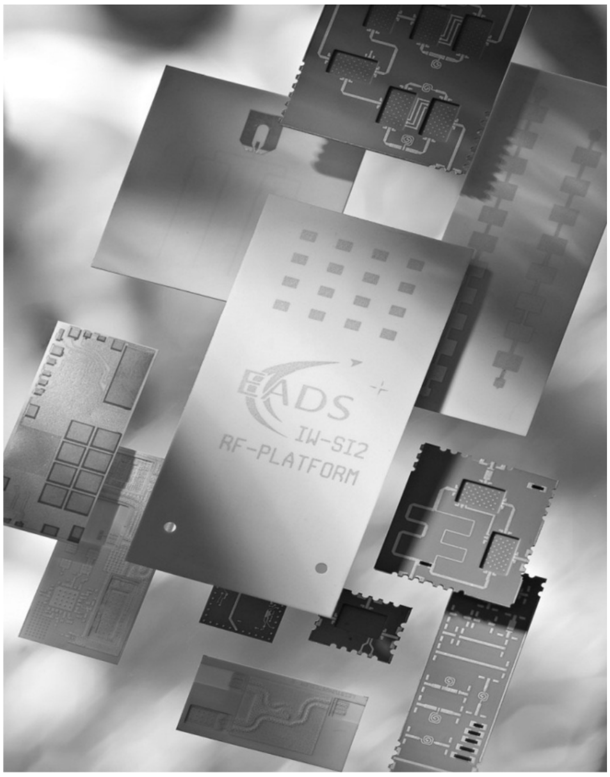


Figure 17: VIA: LTCC RF packages transition from DuPont 951 towards DuPont 9K7.

10. Overview

One of the most mature systems used is DuPont 951. The RF capability of this system is limited to about 10 GHz, dependent from design and application. For RF applications above 10 GHz specific low loss materials are available from different suppliers. RF Properties and characteristics are listed in table 1, in comparison with DuPont 951:

Table 1:

	Commercial LTCC materials for High Frequency				
	951 DuPont	943 DuPont	9K7 DuPont	9K5 DuPont*	A6M-E Ferro
Permittivity ε					
≤ 1 GHz	7,8	7,5	7,1	5,8	5.9+/-0.20
1-20 GHz	7,4	7,4	7,1	5,8	5.9+/-0.20
20-40 GHz	-	7,4			5.9+/-0.20
Dielectric losses tan δ [10-3]					
≤ 1 GHz	< 2	< 1	< 1	≤ 1	≤ 1
1-20 GHz	5	1	<1	≤ 1	≤ 2
20-40 GHz	<15	< 2			≤ 2
Insertion loss [dB inch-1]					
Conductor	Ag	Ag	Ag		
1- 20 GHz	≤ 1,4	≤ 0,3	≤ 0,3		

* Published October 2011, available in Europe end of 2012

And in table 2 physical properties and available tape thicknesses, relevant for RF designs, are as given and compared to DuPont 951

Table 2:

Physical Property	DuPont 951	DuPont 943	DuPont 9k7	DuPont 9K5	Ferro A6ME
	Value	Value	Value	Value	Value
Unfired thickness [µm]	50 ±3 114 ±8 165 ±11 254 ±13	51 ± 4 127 ± 9 254 ±13	127 ±9 254 ±14	127* 254*	127 254
X,Y, shrink-age, [%]	12.7 ±0.3	9.5 ±0.3	9.1 ±0.3	9.1*	15.4 ±0.3
Z shrinkage, [%]	15.0 ±0.5	10.3 ±0.5	11.8 ±0.5	11,8*	24.0 ±0.3
Dielectric constant, (40GHz)	7.4	7.4	7.1 ±0.2		5.9±0.2
TCE α [ppm K-1] (25-300°C)	5,8	4,5	4,4	4,4*	5,6
Environ-mental		Lead-free	Lead-free	Lead-free	

Large entities like the big Japanese and Bosch are dealing only with high volume markets. Bosch is focussing on automotive and Epcos on the telecom business. They all have their proprietary material systems either provided by external partners or made by themselves. Constrained sintering and plating are key process for cost and performance reasons. All these processes are dedicated to automate high volume production. A summary is given in table 3:

Table 3:

Murata	TDK-EPC	Kyocera
K8.8/K15.1 for telecom K7.7 for automotive Plating Pressure assisted sintering (0-Shrinkage	K8/K20 for telecom Plating Pressure assisted sintering (0-Shrinkage) DuPont 943 for automotive	K9,4/K18,7 for telecom K7,7 Cu K5,7 Cu K5,7 Cu K5,2 Cu Plating

It is obvious, that a deep understanding of materials and processes as well as a good knowledge about the application requirements have to meet together in order to provide proper cost efficient LTCC packaging solutions.

11. Benchmark DP 943/9K7

In order to understand deeply the different materials, VIA made a detailed manufacturability benchmark between DP 943 and DP 9K7. The impact of thermal co- and post processes parameters on RF characteristics and geometrical properties of LTCC was investigated. Radar front ends also including calibration structures and test vehicles were fabricated using Du Pont Green Tape® 943 and 9k7 material systems. The following parameters have been investigated:

- The x- and y- dimensions both after co-firing and re-firing
- Warping of the whole substrate
- Warping of cavities
- Characterization of electrical properties up to 110 GHz
- Influence of re-firing on the dielectric constant.

The LTCC wafer has been a multi-project wafer, having a particularly complicated package combining several features with unfavourable impact on even and homogeneous shrinkage. Uniformity of the shrinkage is constricted by perforations, clusters with more metal content, cavities or cut-outs. The following Figure shows the test vehicle MPW1 to visualize the local differences of metallization.

The left part of the substrate contains 80% of the vias and 70% of the co-fired conductors, while the right side has larger metallization of inner layers and cavities as chip pockets or decoupling features. Both parts of the substrates were measured separately in x- and y-axis in order to quantify possible differences in the local and overall shrinkage. The results are shown in table 4. Shrinkage values are given in % deviation from the mean value. Warping is given in µm of maximum to

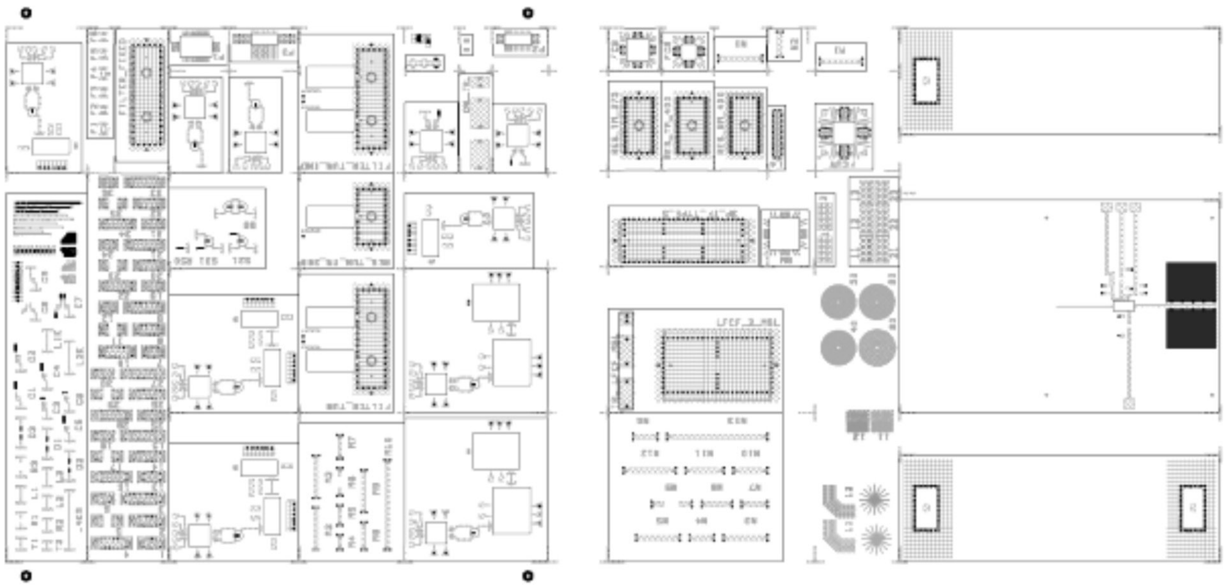


Figure 18: VIA: Multiwafer design

minimum value using a 40mm long scanning line. Refiring stability in % expansion after re-firing.

Table 4:

Investigation	measurement	DuPont 943	DuPont 9K7
Shrinkage sensitivity	Shrinkage around cavity areas	-0,175%	-0,19%
	Shrinkage in dense metallisation area	-0,02 to -0,040%	-0,02 to -0,03%
	Shrinkage in low metallisation area	0,02 to 0,035	0,02 to 0,035%
Shrinkage accuracy	Overall substrate area	+/- 0,16%	+/- 0,13%
Planarity sensitivity	Warping around cavity	-3 to 17µm	-3 to 17µm
	Warping in dense metallisation area	9-15µm	10 – 14µm
	Warping in low metallisation area	15-22µm	16 – 17µm
Dimensional Stability vs. refiring	Expansion after 3 refirings	0,07-0,11%	0,07-0,11%
	Expansion after 5 refirings	0,14-0,17%	0,13-0,15%
	Expansion after 8 refirings	0,17-0,21%	0,16-0,18%
Dielectric Constant vs. refiring (20-60GHz)	Deviation of the Dielectric constant after 5 refirings	-0,10 to -0,12	-0,02 – 0,02

The 9K7 LTCC material shows excellent RF performance up to 100 GHz and above. Comparing to the previous generation 943, process stability, higher accuracy in its shrinkage behaviour and RF stability have been improved. Due to these benefits it allows SiP solutions with complex structures and a high accuracy of co-fired features.

12. Understand the requirements

Table 5 gives an overview of the different systems available concerning the aspects of miniaturisation and process capability, which impact cost and performance. Datas are based on the experience of VIA..

Table 5:

Investigation	DuPont 951	DuPont 9K7	Ceram tape	Heraeus CT 700
Available sheet thickness µm	50 114 165 254	127 254	320	100 320
Shrinkage tolerance % Standard Minimum Cavities	0,6 0.3 1,0	0,6 0.3 1,0	0,6 0.3 1,0	0,8 0.5 1,2
0-Shrinkage Capability	++	+	++	++
Line width µm Line spaces µm	100 100	100 100	100 100	100 100
Dimension Stability Green, µm Refiring, in %	30-70 0,1-0,15	30-50 0,1-0,15	<20 <0,1	<30 0,1
Embedding capability lines >30µm resistors high k capacitors	+ ++ +-	- - -	+ - - - - - -	+++ - - - - - -

Process sensitivity Warpage Waviness Metallisation impact	 ++ + +-	 + + -	 ++ ++ +-	 - +- +-
Maximum density of metallisation %	75	75	75	75
Line density Width Spaces	 100 100	 100 100	 100 100	 100 100
VIA density Diameter µm Distance µm	 100 250	 100 250	 150 250	 150 250
Postfired resistors	+++	+	-	-
Embedded Fluidic Channels Chambers	 +++ +++	 ++ ++	 ++ ++	 ++ ++
Bonding Al Au Al heavy wire	 ++ ++ ++	 ++ ++ -	 ++ +- -	 + ++ ++
Cavity bonding Al Au	 ++ ++	 -- ++	 -- +	 -- ++
Soldering PbSn 95-5 SnAg	 ++ ++	 ++ ++	 - - - -	 ++ ++
Brazing AuSn GeSn	 ++ ++	 + 	 - - - -	 - - - -
Laser processing Green Fired	 +++ +-	 +++ +	 +++ ++	 +++ +++
RoHS/REACH compatibility	In process	Yes	Yes	In process
Lead-free	no	yes	yes	yes

In order to provide adequate packaging solutions for high end applications, manufacturers today are requested for high flexibility and excellent performance at acceptable costs. Also RoHS and REACH compatibility have to be considered.

13. Introduction and impact of novel and low cost materials

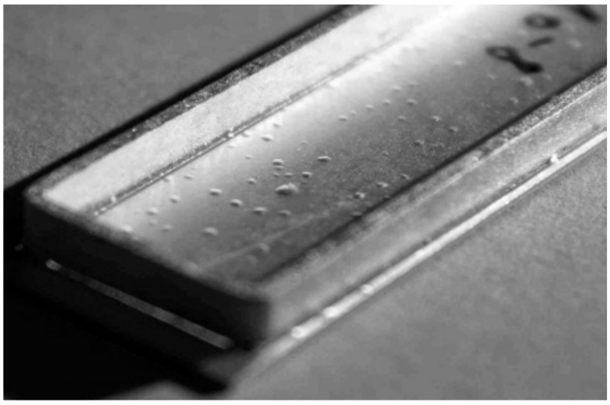
To improve weight and cost, VIA did investigations in alternative materials for heat sinks, brazing and mixed metal wiring. This work is initially focused on the mature DuPont 951 material system and then expanded to the new 9K7 system. The criterions for materials investigated were availability, thermo mechanical properties, weight and cost. All materials and components investigated were introduced on an existing functional RF design. Hermeticity was tested and compared with standard package performance.

14. Carbon-fibre Aluminum Composite (CarfAl)

This material is very promising concerning weight, machinability and costs. The following pictures are demonstrating that customer designed heat sink and ring frame elements can be easily realized. Solder experiments have been carried out using the same AuSn performs as they are used with conventional Kovar and Molybdenum Components. The solderabilty was excellent and no difference to conventional components could be observed. Hermeticity tested was according to MIL Standard at $5x10^{-9}$, comparable to conventional components.

After Hermeticity tests some defects were identified: small blisters occurred on the plated surface, which could be eliminated at the supplier side by improvements in the plating process.

Figure 19: CarfAl heat sink and ring frame after hermeticity tests



15. Solder performs

AuSn brazing using solder performs is well established for high hermetic packages required in space and defence industry. It is obvious that Au is a cost-driving element in these packages. Promising alternatives are high lead containing solder materials, which are widely used for soldering of power devices or sealing of ceramic sensor packages. Additionally SnAg alloyed performs have been investigated..

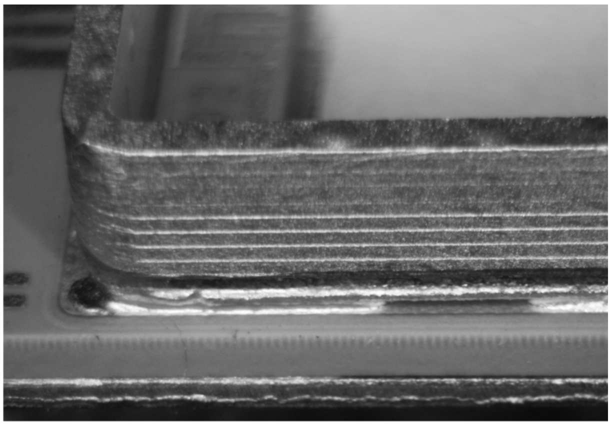


Figure 20: Preform Pb92.5Sn5Ag2.5 on AgPt, CarfAl ring frame

Table 6 shows some promising results:

Pre form	Liquid. temp. °C	Pad	Ring	Herm. atm	Result
Au80Sn20	278	AgPt	Kovar	3x10-9	Excellent
		AgPd	Kovar	3x10-9	Good
		AgPd	Kovar	3x10-9	Good
		Au/AuPd	Kovar	3x10-9	Good
		AgPt	Kovar	3x10-9	Good
Pb92.5Sn5Ag2.5	287	AgPt	CarFAL	6x10-9	Bad
		AgPd	Kovar	leaky	bad
		Au/AuPd	Kovar	5x10-9	acceptable
		AgPd	Kovar	2x10-9	acceptable
		AgPd	Kovar	leaky	bad
Sn96.5Ag3.5	221	AgPt	CarFAL	leaky	bad
		AgPd	CarFAL	leaky	bad
		Au/AuPd	CarFAL	leaky	bad
		AgPt	Kovar	leaky	bad
Sn99.1Ag0.4Cu0.5	228	AgPt	CarFAL	6x10-9	acceptable
		AgPd	CarFAL	leaky	bad
		AgPd	Kovar	5x10-9	good
		Au/AuPd	CarFAL	5x10-9	acceptable
		AgPt	CarFAL	4x10-9	acceptable

16. Mixed metal LTCC

With respect to LTCC, changing from AuSn to high lead and tin/silver alloys require a change in the thickfilm metallisation beneath. Expensive Au/AuPd metallisation systems shall be replaced by more economic Ag/AgPd systems or even simple AgPt solder pads. Consequently, Ag shall replace external and internal Au wiring, and AgPd and only pads for wire bonding have to be fabricated with gold. Unfortunately Ag has very low activation energy and tends to migration. Therefore a proper diffusion barrier system has to be introduced in order to avoid silver migration problems.

In the past, diffusion barriers made of AgPd inks were used between Au and Ag conductors. As far as vias are concerned connecting a silver conductor with an Au pad, AgPd transition vias are used. These transition vias show the disadvantage to expand during firing and to create a non-negligible posting of via, which arrives up to 30µm. Those postings are a problem of accurate die attach and should be avoided as far as possible. DuPont recently published a new recipe for transition vias for the mixed metal system, which is under investigation. Measurements show a significant reduction of the posting from around 20 to about 10µm using the new ink.

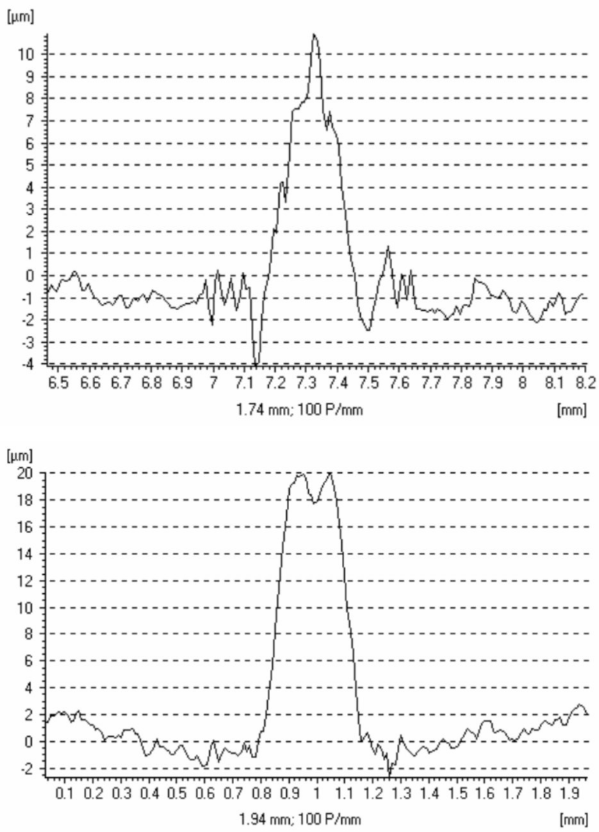


Figure 21: Posting effect: 10µm, new transition via compared to 20µm Conventional AgPd transition via

The progress beyond the state of the art is demonstrated by new packaging solutions recently developed at VIA for RF and non RF industrial applications and in the frame of research programmes.

17. 77 GHz Radar Front end

To introduce the new 9K7 LTCC material system into the manufacturing line to qualify the processes and to validate the system, it was decided to use the new system for the development of a very challenging 77 GHz Radar Front-end. This development was carried out in the frame of a joint cooperation research project, funded by the German BMWI/AiF.

The sensor developed aims at applications where the sensor is mounted very close - but contactless - to the target. The target can be measured by using the continuous wave (CW) mode of operation. Since the phase is ambiguous the measurement range is limited to half the wavelength. For example, in the case of a frequency of 77 GHz, these measurements range of ë/2 = 1.95 mm might be located at 1cm distance to the sensor with measurement accuracy in the µm range. The sensor's centre frequency is therefore a trade off between the measurement range, which decreases with frequency, and the precision, which increases. A very important point for the design is the available space for the sensor. The LTCC frontend takes only 1.4mm x 30mm x 12mm including a broadband Vivaldi antenna. The 9K7 LTCC process has been chosen for its RF capability, miniaturization capabilities and robustness in harsh environments. The key features of the Frontend, designed by IMST, are as the following:

Frequency	77 GHz (72 ... 77 GHz)
Operation	CW and FMCW
Output Power	5 dBm
Antenna	Vivaldi
Module Size	30 x 12 x 1.4 mm3
Material	DuPont 9k7

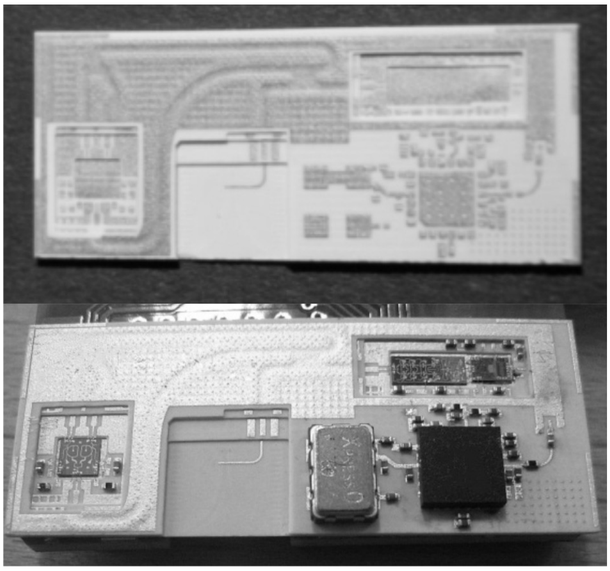


Figure 22: VIA/IMST: 77 GHz Radar Front end, Substrate and assembled package

The following pictures are showing the radar module in different stages of the development:

18. Light weighted TR Module using CarfAl heat sinks

In the first run (compare Fig. 13) a conventional Molybdenum heat sink was bonded to the LTCC substrate, assembled and qualified.

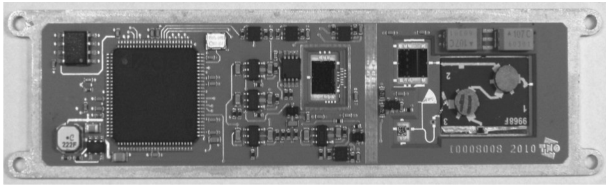


Figure 23: TNO: TR-Module using CarfAl heat sink

Introducing the CarfAl material has lead to a weight saving of 80 % of the complete module!

19. High Speed Optical Router

A LTCC substrate has been used as an optical bench to integrate and optically interconnect a high speed data transmission chip. The accuracy challenges were extreme:

cavity with ± 50µm, blind holes ± 25µm, Vias 90µm diameter, Via position over the whole substrate ± 50µm, thickness 1,5mm 5± µm, Signal speed 10 Gbit/s, Flip chip pitch 100µm, BGA Pitch 500µm.

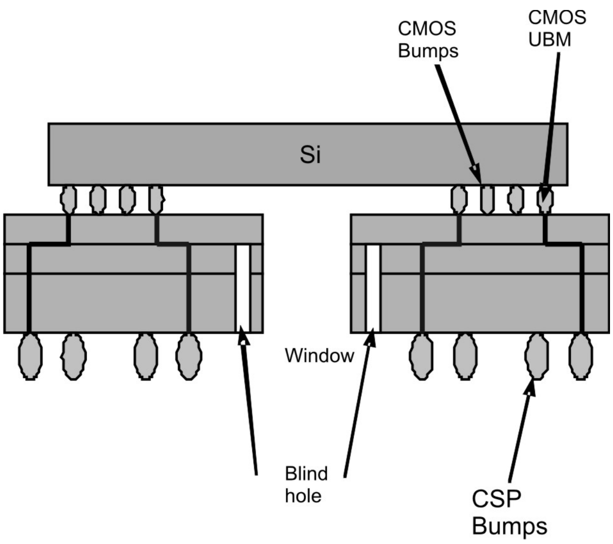


Figure 24: CEA: Optical Router, Schematic

A solution could be found by applying the 0-Shrinkage process, picosecond laser drilling, grinding and lapping the substrate and interconnecting with thinfilm on top and thickfilm on bottom to provide a full high accuracy solution.

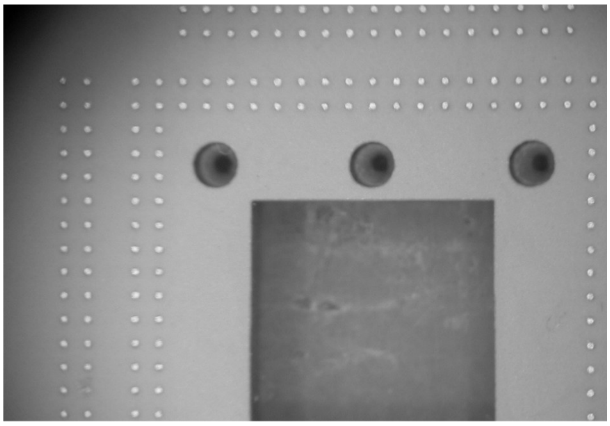


Figure 25: Optical Router Package

20. One way DSC-Chip

A complete differential scanning calorimetric system was developed and integrated into a LTCC substrate. The key features have been:

- Integrated Temperature sensors
- Integrated heater elements
- Pinout in chip card format
- Total mass of the chip: 1,43g
- Measuring head: 400mg

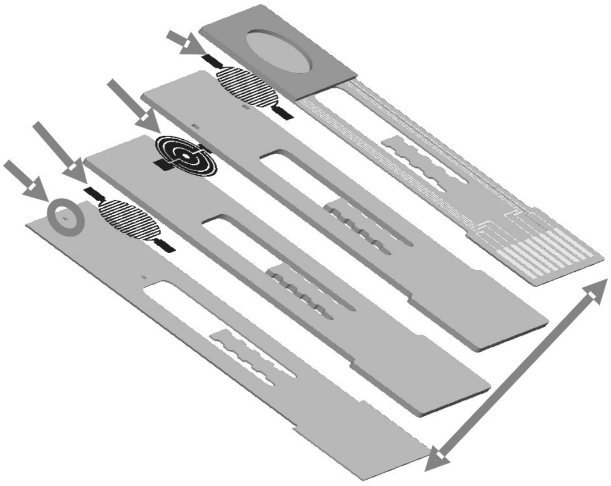


Figure 26: One way DSC Chip

The system has been realised at VIA in Heraeus CT 700 and HL 800 material system.

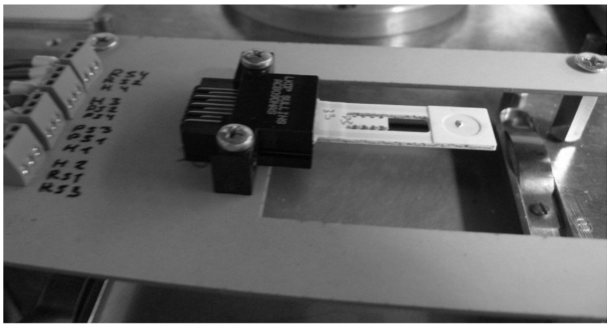


Figure 27: DSC Chip in test fixture (University of Bayreuth)

21. Ceramic Microreaktor

BioMEMS and biosensors, Lab on chip systems and similar devices are in development and under investigation since a couple of years. One of the elements which VIA has developed is a highly integrated micro reactor, shown in the following figures.

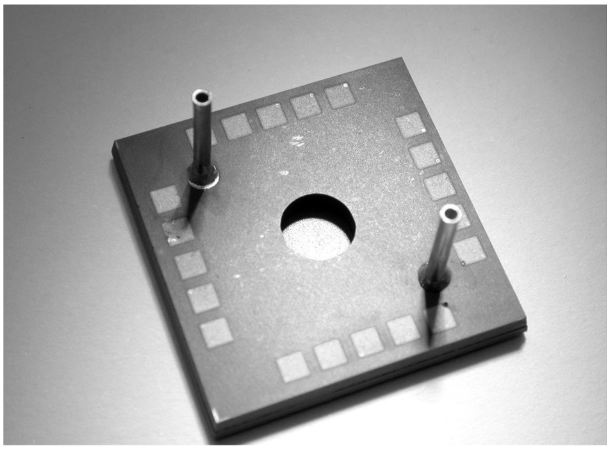


Figure 28: LTCC Micro reactor

The micro reactor contains fully integrated fluidics and soldered fluidic interfaces. The key features are the 50µl reactor with a fluidic system allowing a flow rate of 1µl per minute.

Enzymes were immobilised onto a 0,1x0,4mm 3d channel.The cell growth in the reactor has been verified.

Conclusions

LTCC is providing manifold advantages for packaging tasks in the field of high-end applications. Applying new materials like 9K7, new light weighted materials for packaging components like CarfAl, low cost materials for brazing like SnAg together with a proper man-

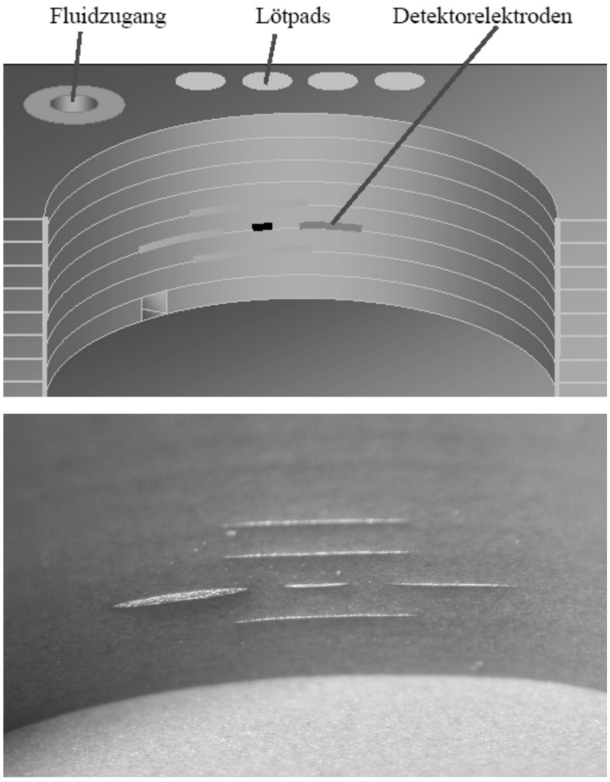


Figure 29: Micro reactor, schematic of the sensor and detail

agement of mixed metal processing; the LTCC technology will make a significant step ahead towards a cost efficient packaging technology. In addition with the well-known integration capabilities and its superior reliability performance it provides innovative and novel RF packaging solutions.

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