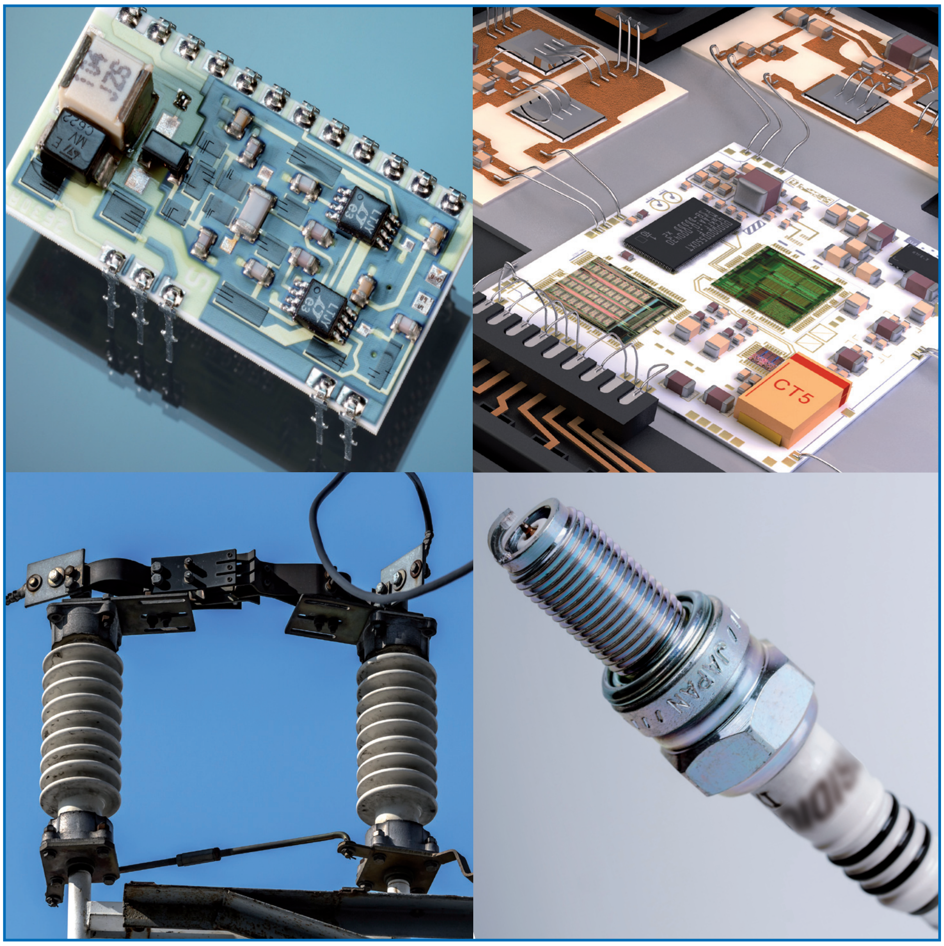
ZVEI:
Die Elektroindustrie

Group Ceramic Microcircuits

Successful Ceramic Solutions

Basic technology for microelectronic systems



PCB and Electronic Systems Division

Die Elektroindustrie

Successful Ceramics Solutions

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ZVEI - Zentralverband Elektrotechnik-
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ZVEI - German Electrical and
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PCB and Electronic Systems Division
Lyoner Strasse 9
60528 Frankfurt am Main, Germany

Responsible:
Dr. Christoph Weiß
Tel: +49 69 6302-437
Fax: +49 69 6302-438
E-mail: pcb-es@zvei.org

Authors:
Franz Bechtold, VIA electronic
Dr. Sebastian Brunner, Epcos OHG - A TDK Group Company
Walter Distler, Siegert electronic
Sebastian Löffler, Cicor Group
Uwe Mirschberger, Murata Europe
Christina Modes, Heraeus Germany
Dirk Schönherr, Lust Hybrid-Technik
Dr. Josef Weber, Robert Bosch

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5 Questions Regarding Ceramics

1. *Do you require reliable systems for use at high temperatures or in harsh environments?*
Robust and thermally resistant ceramic substrates may be the solution.

2. *Are you struggling to handle the thermal management of your power module?*
Why not take advantage of the excellent heat-dissipating properties of ceramics?

3. *Are you looking for a circuit substrate that is ideally suited for use with your semiconductor components?*
Compare the properties of ceramic and alternative materials and you will understand the benefits ceramics provide.

4. *Do your electronics require a long-term stable circuit substrate?*
Thanks to their inert behaviour, ceramic microcircuits are predestined for use in applications where unwanted material release and biocompatibility are an issue.

5. *Is your aim to achieve reliable results from high-frequency signals with extremely short propagation delay?*
Find out more about the excellent HF properties of ceramic circuit substrates.

Introduction

The challenge of providing innovative electronic and microelectronic system solutions that offer maximum user benefit is closely related to the practical application of ceramic microcircuit technology in all its aspects.

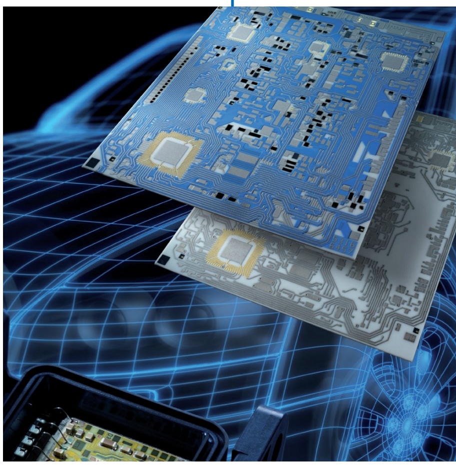
The companies of the ZVEI Group Ceramic Microcircuits have been in constant dialogue with the market for decades to make the use of ceramic microcircuit technology accessible to a wider user group.

Developed and marketed more than 40 years ago as a cutting edge technology for use in high-quality functional systems, electronic assembly technologies in the field of ceramic microcircuits have since been advanced and are now integral to a wide range of applications, such as power electronics, high-frequency technology, sensor technology, medical engineering, automotive electronics, lighting technology, drive technology, communication technology and renewable energy power plants.

Ceramic microcircuit technology starts where other technologies stop!

From small quantities to high volumes, series applications in industrial and automotive engineering are proof of the profitability and reliability of this technology.

Whenever the question of "how" is raised in connection with optimal circuit integration, we provide the answers by exploiting the technical benefits of ceramic structuring techniques. The nature of the structuring and the ceramic substrate material provide opportunities for functional integration – e.g. by incorporating passive components such as resistors, or inductors into the film structure.



What is the difference between electronic assemblies in ceramic microcircuits and traditional printed board assemblies?

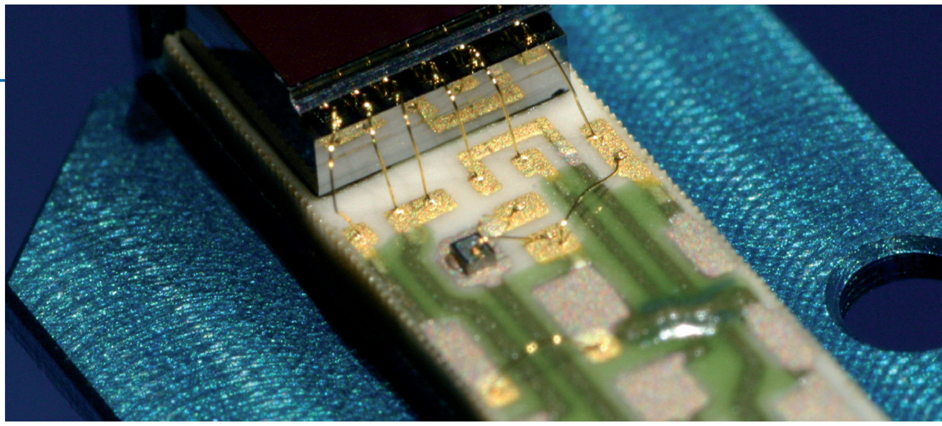
The substrates of ceramic microcircuits are made from inorganic materials, mainly ceramic materials, but also metallic materials. In view of the wide variety of structuring technologies, a distinction is made between thin and thick film, DCB and LTCC/HTCC substrates. The combination of established technologies for the assembly and packaging of components creates endless opportunities for functional integration. The following pages provide an overview of the different technologies.

Discover the performance capabilities of these technologies and contact one of the numerous ceramic microcircuit technology companies to find out more about how they can benefit your applications. Thanks to ceramic microcircuit technology, we open the door to new horizons by developing and manufacturing innovative electronic solutions for you. Welcome to the dialogue.

Development is driven by rising market demands for robust, reliable, compact, complex and integrated system solutions. It is supported by an established research landscape.

Positive market forecasts are an incentive and challenge for the companies within the ZVEI to work closely with their business partners to develop viable integration solutions through innovation and thus help to shape your success.

Thick Film Technology

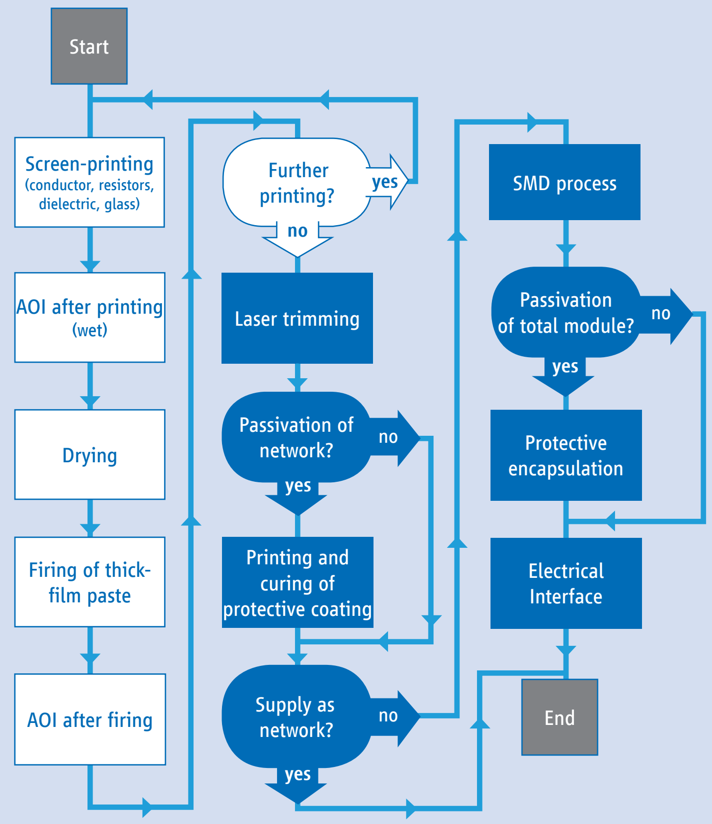


Thick film technology uses screen-printing to form passive circuit structures such as conductor lines and isolative, resistive and protective layers on ceramic substrates (primarily Al_2O_3, but also AlN for increased thermal conductivity). Every printed layer is dried and then fired. The firing process determines the electrical and physical properties of the structures and creates a monolithic ceramic circuit substrate. Conductor materials based on gold, silver, silver-platinum and palladium allow the subsequent use of different assembly methods – from soldering and bonding to gluing – with high reproducibility and reliability. Resistance values from a few milliohm to the three-digit megaohm range can be obtained with high precision using laser trimming. Sensor elements can be integrated in the layer structure.

By using several conductor layers or conductor crossovers, it is possible to construct ceramic circuit boards with higher wiring densities. The individual conductor layers are insulated from each other by a dielectric layer. Furthermore, the wiring structure is possible on both sides of the ceramic circuit substrate. The front and back sides are electrically connected by vias, which go through the ceramic board.

A thick film circuit is usually protected by a layer of glass or dielectric paste. Other passivation or protective mechanisms can also be used such as coating, dipping or overmoulding with various materials (silicones, dipping varnish, epoxy resins, etc.).

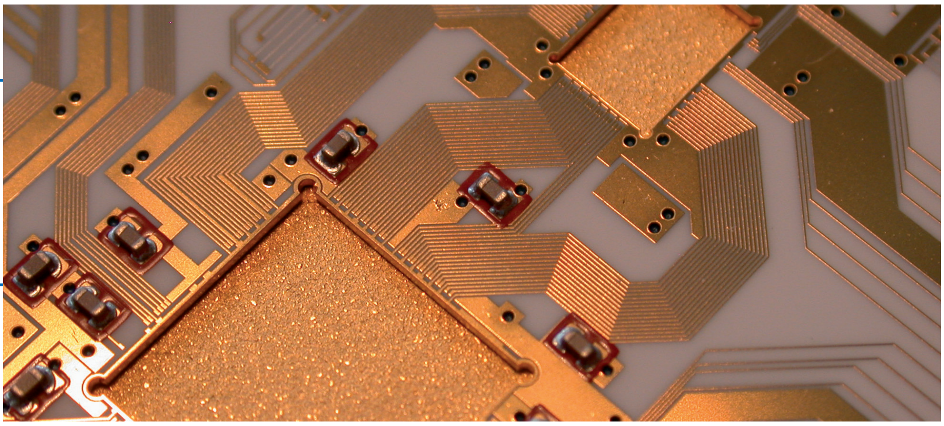
Process flow diagram



Main application areas:

Control technology,
power electronics and sensors
for industrial, automotive and aeronautical applications.

Thin Film Technology

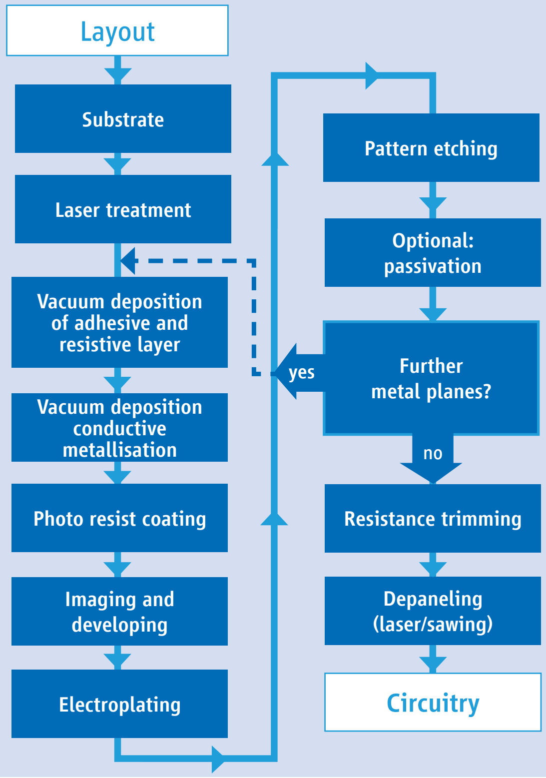


Thin film substrates allow the implementation of a high connection density and extremely precise structures combined with ceramic and/or organic insulation materials. Thin film technology makes it possible to optimise the thermal, mechanical and electrical properties of the materials used in substrates, or components, as well as their biocompatibility. Ceramics (Al_2O_3 or AlN) are mainly used as substrate materials (carrier material) for rigid circuits, as well as ferrite materials or glass. Flexible circuits are produced using different types of polymer materials.

Similar to semiconductor or microelectronic system technology, thin film technology uses photolithography to form the structures, which provides a line width and spacing as fine as 10 µm, or even better. In addition, PCB technology processes are often combined with thin film technology to increase the number of possible applications. Thin metal layers, e.g. for integrated resistors (typically NiCr or TaN), are applied by direct vacuum deposition and usually structured by subtractive etching. Electroplating is often used to create thicker conductive layers (e.g. Au or Cu), achieving layer thicknesses ranging from a few micrometres up to several 100 µm.

Thin film technology is mainly used on ceramic substrates for high frequency circuits where tight structural tolerances, reliability and low weight play a major role. Rigid and flexible thin film circuits are also increasingly used in applications where smaller form factors and the use of noble metals instead of copper provide additional benefits.

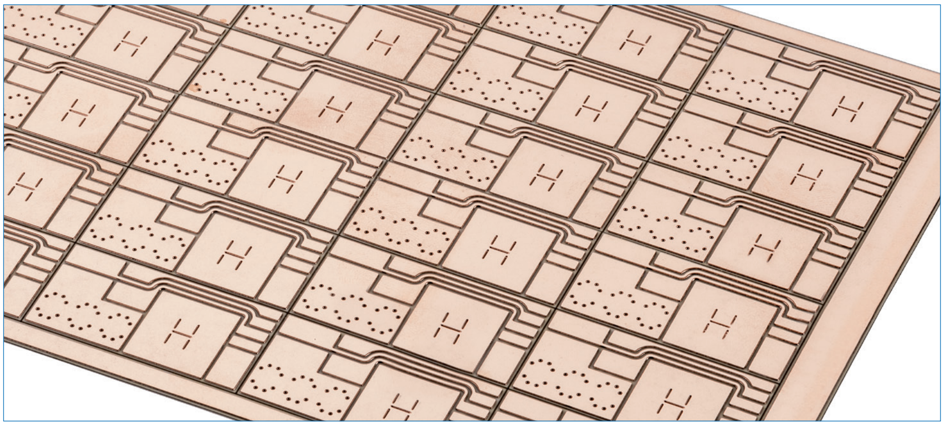
Process flow diagram



Main application areas:

Radar systems
Aerospace
Sensors
Medical technology
Telecommunications

Direct Copper Bonded Ceramics (DCB)



In power electronics, direct copper bonded ceramic substrates, i.e. DCB substrates, are the “backbone” of the modules. They combine the tasks of a circuit carrier for semiconductors with that of an electrical insulator for the heat sink and inverter housing.

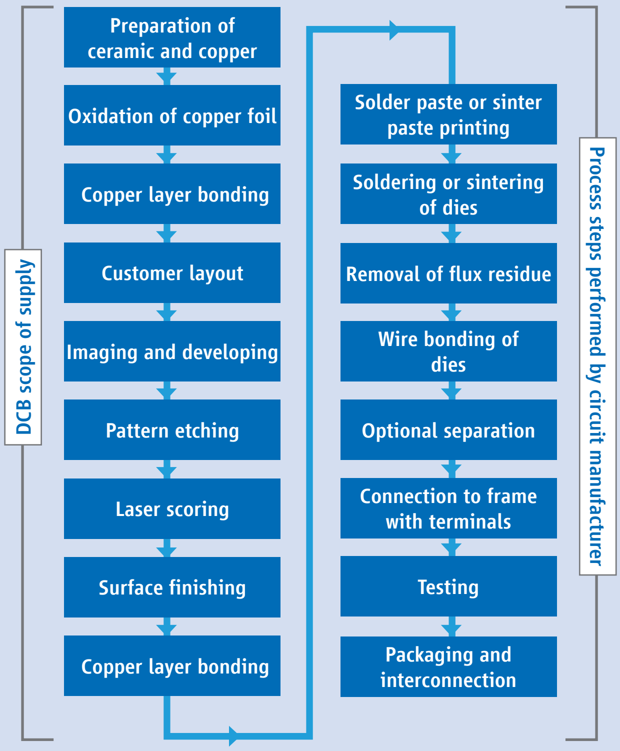
DCB substrates are composed of a 0.4-1 mm thick ceramic carrier with an approx. 0.3 mm thick sheet of copper bonded to both sides at very high temperatures using an eutectic melting process. Patterns in the copper layer on the front side of the substrate are achieved by chemical etching to form a customer-specific circuit layout.

Power semiconductors such as IGBTs, MOSFETs or diodes based on Si, GaN and SiC are sintered or soldered to the DCB substrate to provide the electrical and mechanical contact. The chips are electrically interconnected and attached (e.g. to the package) by means of bonding to thick Al and Cu wire or Al and Cu ribbons.

The thick copper layers enable the application of high currents and ensure good dissipation of the heat produced by the power semiconductor components (e.g. IGBTs) when operated with high power density.

The interior ceramic (Al_2O_3, Zr-doped Al_2O_3, AlN for improved thermal conductivity, Si_3N_4 for increased mechanical robustness) provides excellent voltage insulation up to several 1,000 volts. Compared to metal core boards, the thermal expansion coefficient of DCB substrates is similar to that of semiconductor materials and ensures good thermal shock resistance.

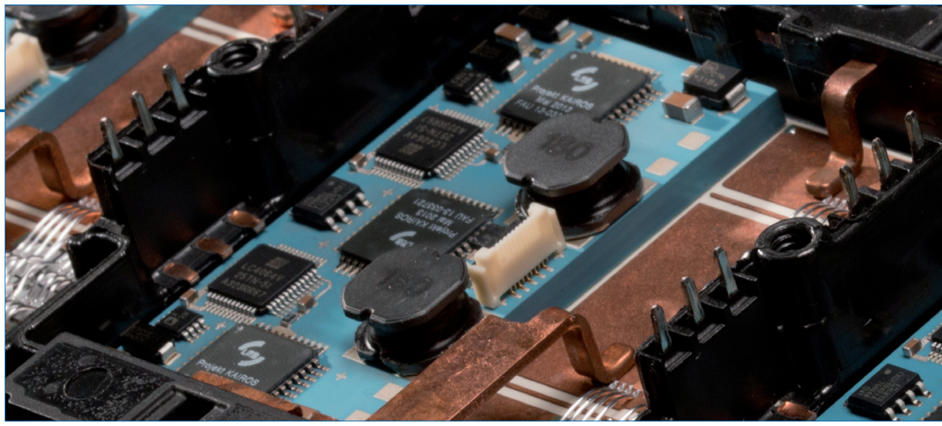
Process flow diagram



Main application areas:

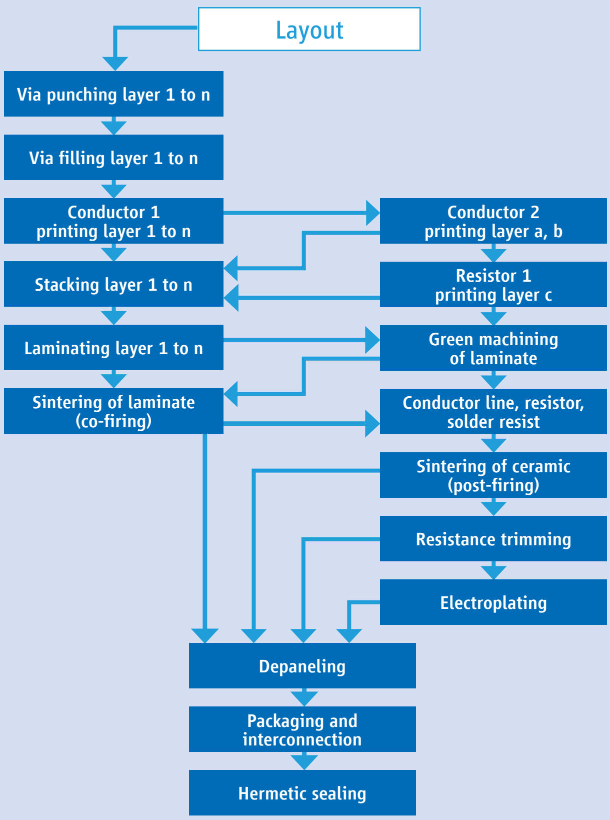
Power electronics for industrial applications (frequency converters)
Electric vehicles
Wind power
Traction
Solar

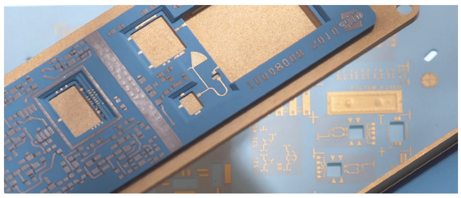
Multilayer Ceramics (LTCC/HTCC)



Ceramic microcircuits based on multilayer technology (LTCC = Low Temperature Co-fired Ceramics, HTCC = High Temperature Co-fired Ceramics) are ideally used to achieve maximum functional integration with smallest size. The circuit design is formed by structuring the individual unfired ceramic layers with conductor lines and other passive components using screen-printing. The layers are then stacked, laminated and co-fired at a temperature of approximately 850 °C. After the co-firing, the modules are singulated. Then the semiconductor components are attached to the ceramic substrate as bare dies using chip-and-wire technology, while SMD technology is used to solder or glue the passive components. High-frequency applications particularly benefit from the possibility of embedding passive components such as resistors, capacitors, filters, coils, couplers and the waveguide between the individual layers and integrating them into the substrate. High-frequency semiconductors can be buried in cavities, with the shortest route connection by vias and hermetically sealed if necessary. This achieves a high level of miniaturization.

Process flow diagram





LTCC in combination with the excellent electrical conductivity of Ag, Cu or Au make this technology the ideal choice for high and maximum frequency applications.

Due to its high mechanical strength, good thermal conductivity and hermeticity, HTCC (High Temperature Co-fired Ceramic, approx. 1600 °C) is used as multilayer substrate in packaging technology.

Main application areas:

Communication systems
Automotive
Control technology
Packaging technology
Radar modules

Packaging and Interconnection Technology

Established assembly technologies used for ceramic microcircuits!

Electronic components are assembled on ceramic substrates using the same process technologies as for components on printed circuit boards. SMD components ranging from 01005 miniature chips to high-pin components are populated in fine interconnection pitches – such as chip scale packages (CSP) and BGA packages. The electrical connection is made using standard soldering and adhesive bonding processes by applying solder mask material or inkjet printing of the structure and subsequent reflow soldering. In addition to standard solder materials such as SnAgCu, SnAg or SnCu, special solders or conductive adhesives are used.

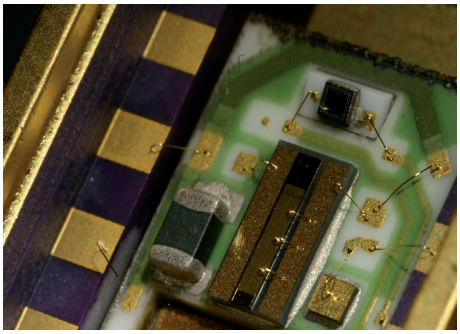
The result is an assembled ceramic substrate, also known as a hybrid microelectronic circuit.

The evaluation of the manufacturing quality is based on recognised MIL and IPC standards (MIL883, IPC610). The excellent thermal conductivity properties of the substrate also create new opportunities for optimising thermal management from semiconductors to heat sinks, e.g. by low-void soldering of power components in an inert atmosphere or direct connection of the entire circuit substrate to the heat sink.

Chip assembly

Traditional chip bonding / chip-and-wire technology

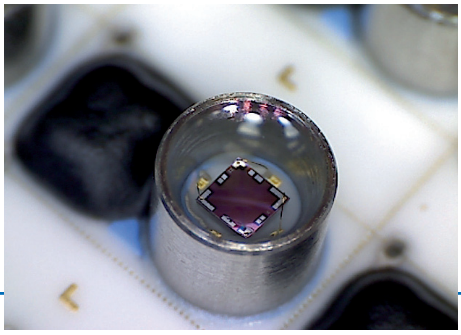
The use of unpackaged chips, also known as bare dies, is the key for miniaturisation and ensures maximum reliability.



Electrically conductive or non-conductive adhesives are typically used for traditional chip assembly (chip bonding); in the event of high power dissipation, the back side of the chip is attached to the basic substrate or a heat sink by soldering or Ag sintering. The chips are usually electrically connected using wire bonding with 17-35 µm Au wire or 20-35 µm Al wire, and 150-500 µm Al or Cu wire for power applications.

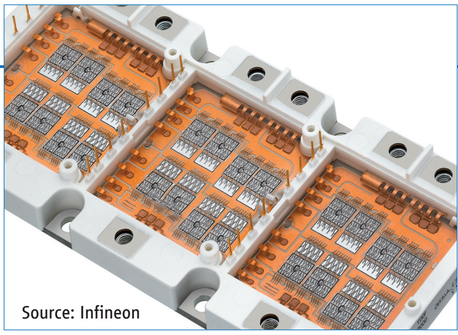
Flip chip bonding

Flip chip bonding is a special type of chip bonding particularly effective for high volumes. Several electrical connections are simultaneously created by mounting the chips with the top side facing down (flipping). The processes used include soldering, adhesive bonding, thermocompression bonding or thermosonic bonding.



Vacuum soldering of power semiconductors

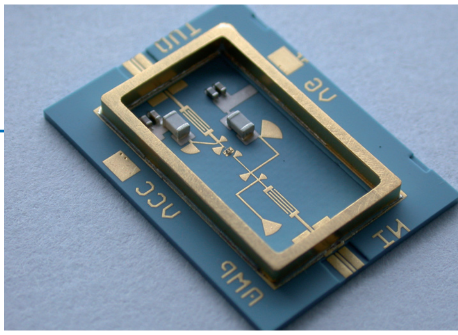
Vacuum soldering is used to achieve excellent thermal coupling of unpackaged power semiconductor assemblies, e.g. IGBTs and diodes, on ceramic substrates with good thermal conductivity (e.g. DCB). Solders with a high lead content are primarily used for this purpose, but sometimes also eutectic AuSn. The high liquidus temperature (>280°C) of these solders permits the use of high operating temperatures and a process sequence that allows further thermal processes below 280 °C.



Source: Infineon

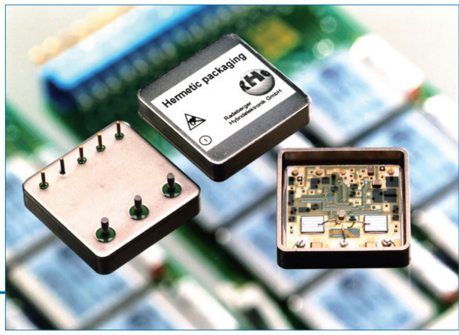
Vacuum soldering of electronic assemblies

Powerful, reliable and long-lasting assemblies as used in aerospace applications must be hermetically sealed. Ceramic microcircuits are particularly suitable since their thermal expansion behaviour perfectly matches that of standard weldable frames and heat sinks that can be soldered or adhesive-bonded. Vacuum soldering using formic acid for flux-less activation of high temperature solders ensure residue free, low void contact of components to the ceramic circuit. Components such as ceramic microcircuit lids, heat sinks and lead frames are attached with AuSn or high lead content solders creating a hermetically sealed assembly.



Encapsulation (circuit protection) / packaging

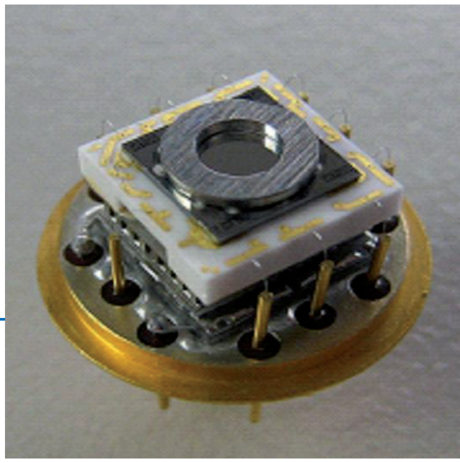
Several packaging/encapsulation methods are used in hybrid technology to ensure maximum reliability and permanent circuit protection, depending on the environmental conditions of the specific application.



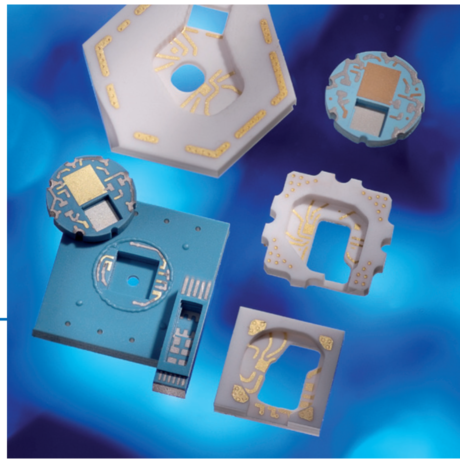
1. Varnishing or conformal coating for basic moisture protection and electrical insulation
2. Glob-topping for covering a targeted area and for mechanical protection of wire-bonded chips
3. Overmoulding of components or sub-assemblies with plastic for high volume/ mass applications
4. Polymer potting (e.g. PU/silicone) of circuits, especially for chemical protection of semiconductors in harsh environments
5. Welded or soldered hermetic packages, e.g. ceramic, Kovar or titanium, for maximum reliability and protection against harsh environments

Thanks to the external robustness and inert behaviour of ceramic materials, ceramic circuit substrates, especially LTCC and HTCC, can be used as part of the hermetic package.

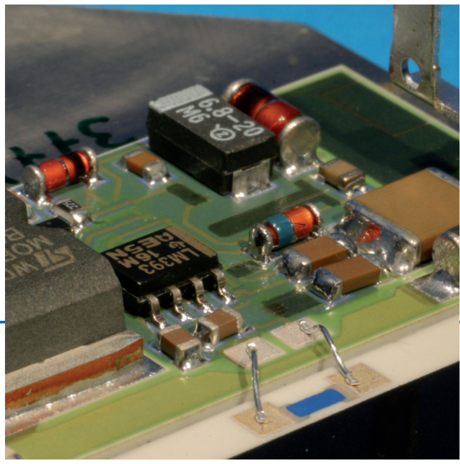
Industrial Applications and Examples



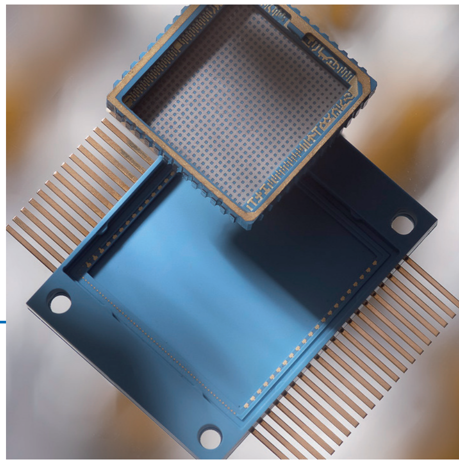
Hybrid assembly using LTCC as circuit substrate in transistor package.
Use: x-ray detector



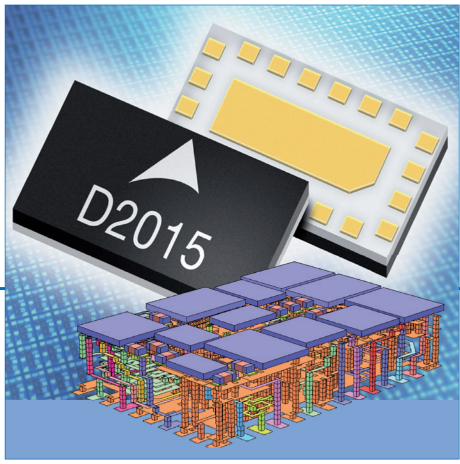
Packages for different sensors based on LTCC technology
Use: printing, x-ray



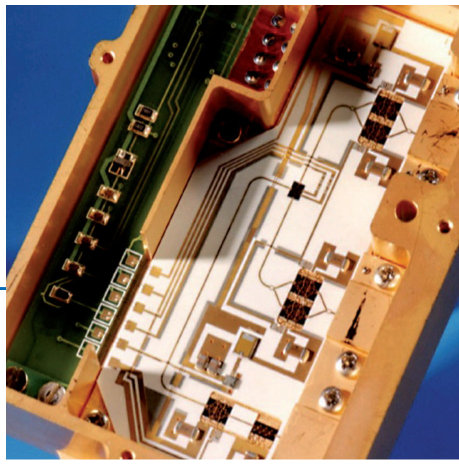
Vacuum-soldered power assembly on heat sink. Connection by thick-wire bonding. Use: drive technology applications



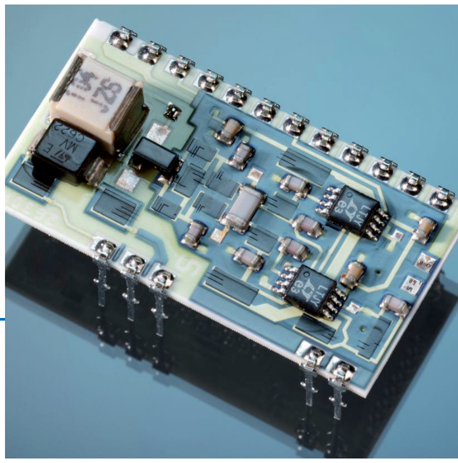
LTCC empty package for component packaging.
Use: optoelectronics



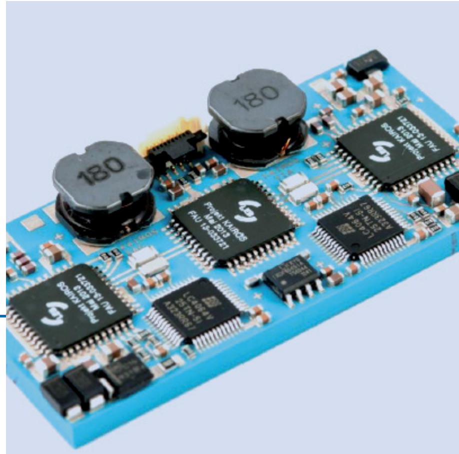
Highly integrated multi-mode and multi-band, LTCC front-end module with 3D layout data.
Use: mobile communications applications



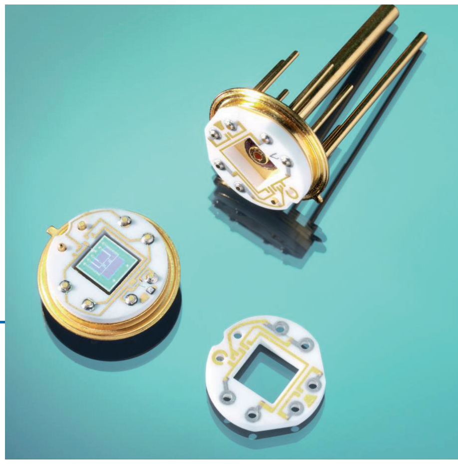
Thin film substrate (Al_2O_3), package assembled with SMT components and bonded chips. Use: high frequency data transmission and telecommunications testing technology



Double-sided, soldered hybrid with printed and laser-trimmed resistors on dielectric.
Use: analogue power supply unit used in energy technology

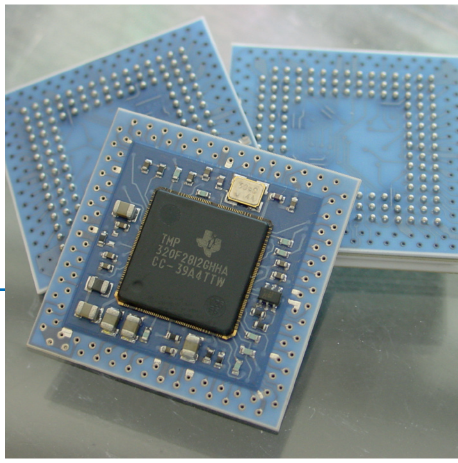


Driver circuit for power converter with integrated transformer made by LTCC technology.
Use: electric vehicles

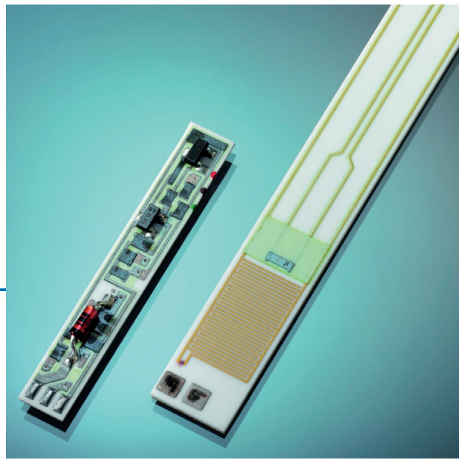


Thick film printed customised ceramic shape to accept a gold wire bonded sensor chip and assembly on connector housing.
Use: sensors

Vacuum-soldered thick film circuit, thermally conductive bonded to aluminium sheet. Thick wire bond contact to connector housing.
Use: electronic ignition systems for internal combustion engines



Customer-specific package as ceramic BGA thick film with SMD and chip assembly
Use: ultrasonic sensor systems



Thick film hybrid circuit and thick film network with integrated sensor function.
Use: mechanical engineering (left) and food industry (right)

Design Rules

Comparison of ceramic microcircuit technologies

	LTCC	HTCC	DCB	Thick film	Thin film
General					
Reliability	●	●	●	●	●
Recyclability	●	●	●	●	●
Availability	●	●	●	●	●
RoHS compliance	●	●	●	●	●
Mechanical properties					
Robustness	●	●	●	●	●
Temperature resistance	●	●	●	●	●
Coefficient of thermal expansion vs. Si	●	●	●	●	●
Dimensional stability	●	●	●	●	●
Thermal conductivity	◐	◐	●	◐	◐
Chemical resistance	●	●	○	●	◐
Hermetically sealed	●	●	○	◐	◐
Electrical properties					
Insulation resistance	●	●	●	●	●
Embedding passive functions	●	○	○	●	◐
Capacitors	●	○	○	◐	●
Inductors	●	◐	○	◐	●
Resistors	●	○	○	●	●
HF applications	●	○	○	◐	●
Dielectric losses	◐	◐	○	◐	●
Ampacity	◐	◐	●	◐	◐
Design rules					
Fine-line technology	◐	◐	○	◐	●
Via	●	●	○	◐	◐
2.5D/3D integrability	●	◐	○	◐	◐
Cavities	●	●	○	◐	◐
Processing/IC packaging, chip technology					
Soldering	●	●	●	●	●
Adhesive bonding	●	●	●	●	●
Sintering	◐	◐	●	◐	●
Au thin wire bonding	●	●	◐	●	●
Al thick wire bonding	●	●	●	●	○
Al thin wire bonding	○	●	●	●	◐
Cu thick wire bonding	○	○	●	○	○
Typical application areas	Automotive, telecommunications, medical engineering, sensor systems	Automotive, packages	Power electronics for: automotive, industry, traction	Automotive, sensors, industry, LED technology, aerospace	High frequency, microwave applications, optoelectronics, medical engineering, aerospace

● Excellent ◐ Suitable ○ Possible

Benefit from our Professional Expertise.

ZVEI - German Electrical and Electronic
Manufacturers' Association e.V.
Lyoner Strasse 9
60528 Frankfurt am Main, Germany

Tel: +49 69 6302-0
Fax: +49 69 6302-317
E-mail:zvei@zvei.org
www.zvei.org

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