Fraunhofer IKTS

Fraunhofer Institute for Ceramic Technologies and Systems IKTS

Materialentwicklung für keramische Werkstoffe in der Elektroniktechnologie

80. Treffen SAET, Fraunhofer IKTS, Dresden

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Outline

1. Fraunhofer Institute Ceramic Technologies and Systems IKTS
2. Department »Hybrid Microsystems«
3. Materials for thick-film and multilayer technology
4. Summary

01

Fraunhofer Institute Ceramic Technologies and Systems IKTS

Facts & Figures

Fraunhofer Institute Ceramic Technologies and Systems (IKTS)

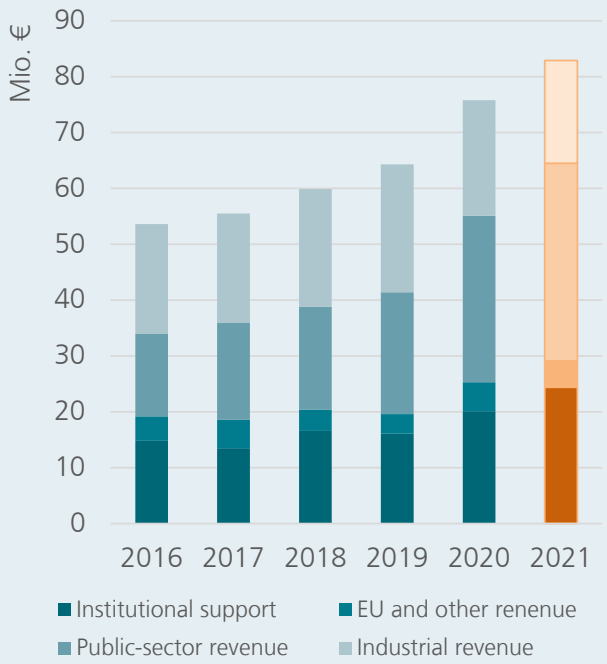
Facts and figures

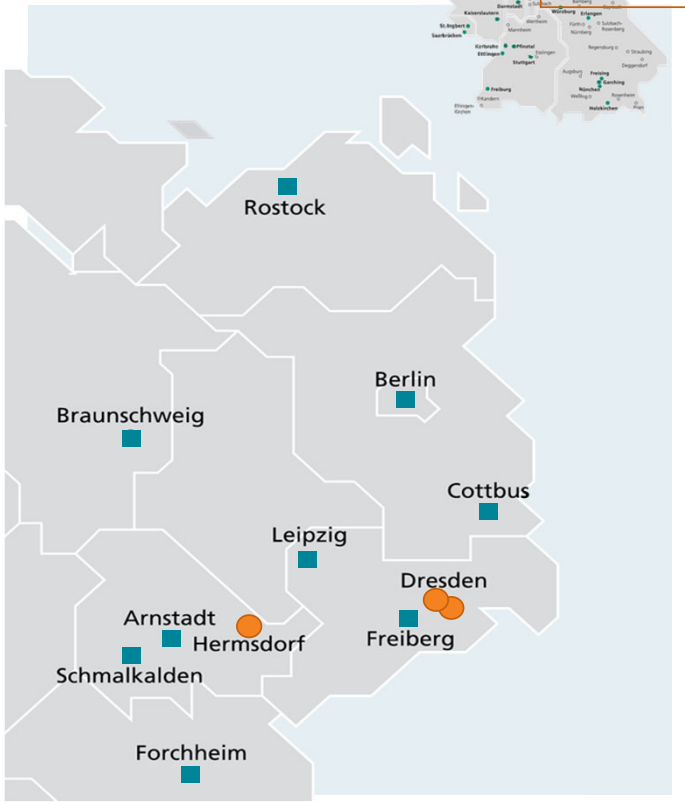
Service provider for applied research on the field of high-performance ceramic materials and technologies

Nearly **800** employees

3 IKTS main sites (●) further external research groups (■)

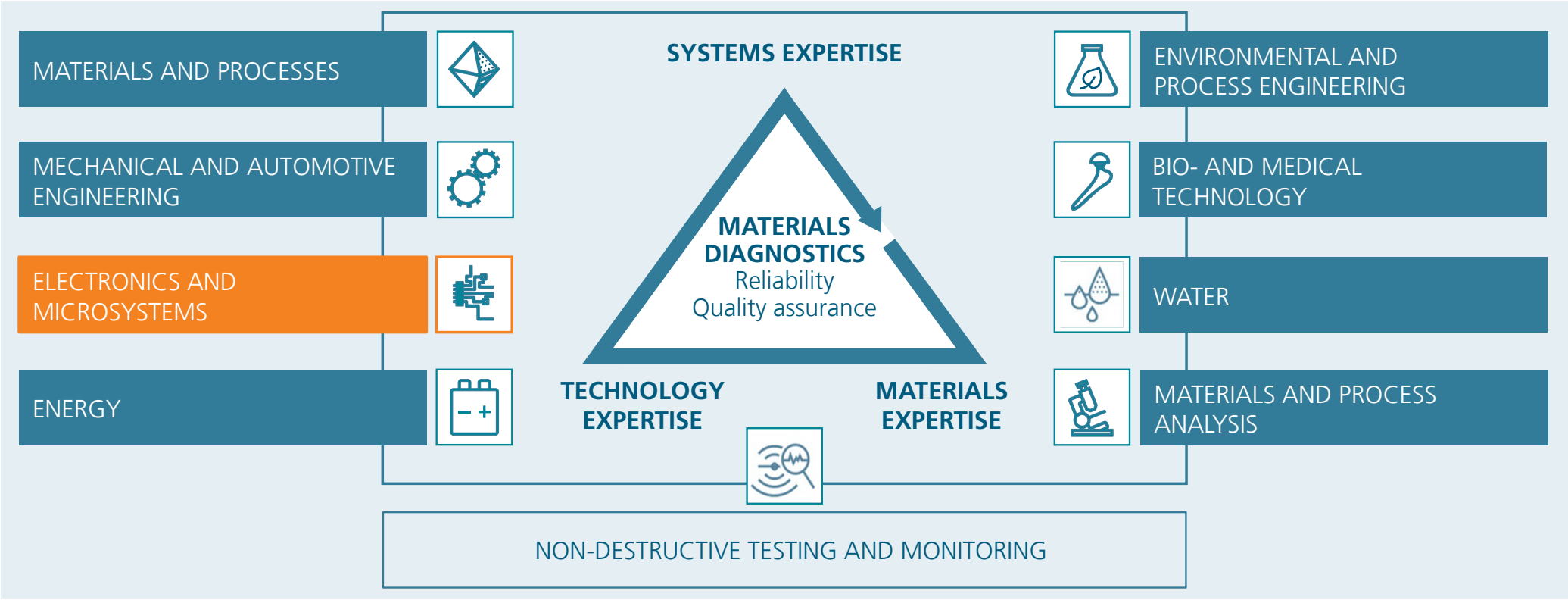
Fraunhofer IKTS overall revenue





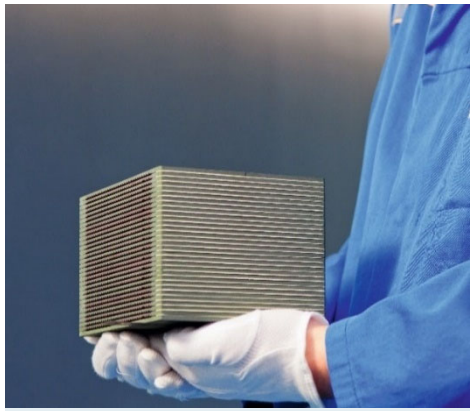
Fraunhofer Institute Ceramic Technologies and Systems (IKTS)

Business divisions



Fraunhofer Institute Ceramic Technologies and Systems (IKTS)

Scientific focus topics - **Energy**



Fuel cell technologies

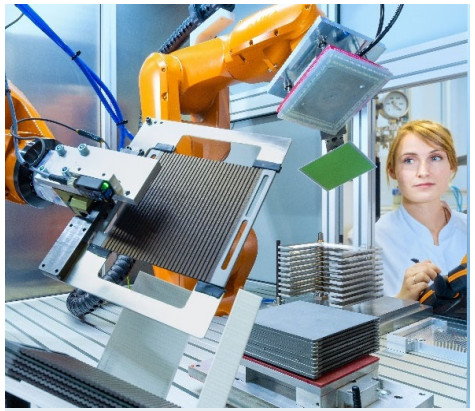
Fuel cells and high-temperature electrolysis cells – development and test from component to system.

Material solutions for Li-ion batteries

Top-down and bottom-up development of new active materials.

High-temperature batteries

Cerenergy® - $Na/NiCl_2$ battery system for stationary storage.

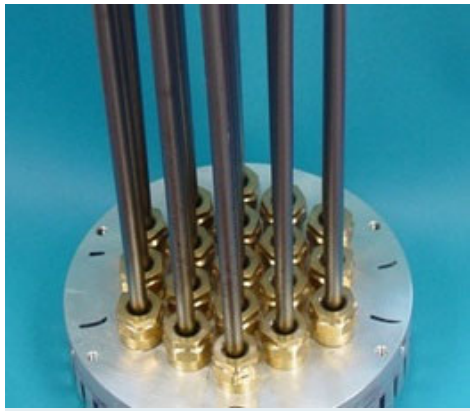


SOEC-Stacks for hydrogen generation

Prototype production of SOFC/SOEC stacks (capacity of 1-10 MW/year) with mPower GmbH.

Fraunhofer Institute Ceramic Technologies and Systems (IKTS)

Scientific focus topics - **Environmental and Process Engineering**

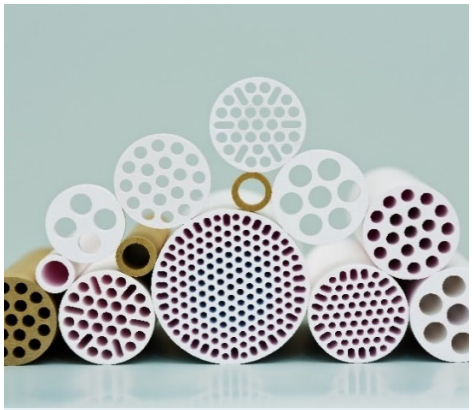


Air separation O_2 generator

High-temperature oxygen separation with mixed-conducting ceramic membranes.

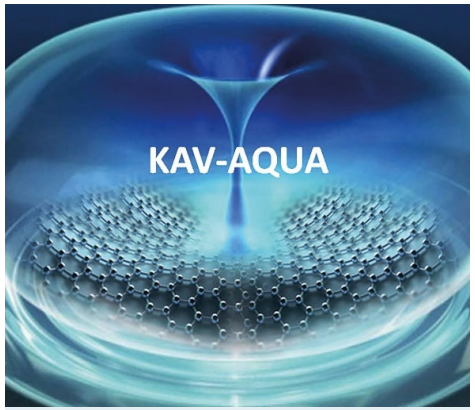
Recycling of valuables from wastewater

Process chain to recycle water, energy, and fertilizer from food industry residues.



Nano filtration

Ceramic nano-filtration membranes with a separation limit of 200 Da.



Cavitation based technologies

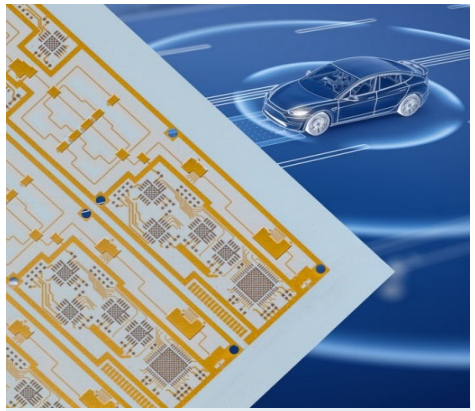
Sono-electrochemistry for the removal of water contaminants (pharmacy, oestrogens, fertilizer)

Fraunhofer Institute Ceramic Technologies and Systems (IKTS)

Scientific focus topics - Electronics/ Microsystem Technology

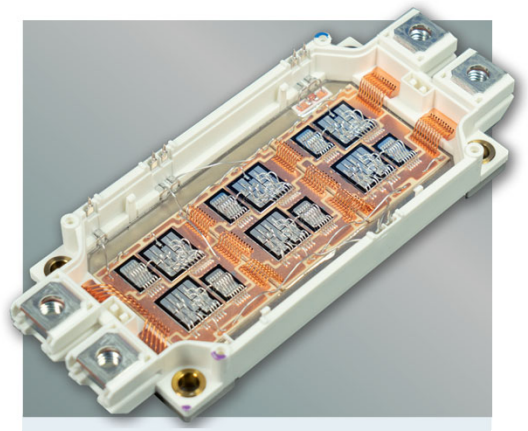
Sensors for extreme harsh environment

Ceramic multilayer-technology based printed sensors for high temperature, aggressive chemical media etc.



LTCC-based RF- and mmWave packaging

High-frequency board for 77 GHz radar for driving assistance systems.



Power electronics

Ceramic solutions for power electronic packages: high performance, high T suited, reliable

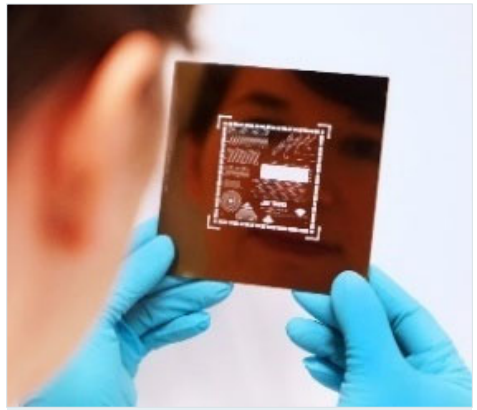


Photo-Image able pastes

High resolution thick-films (conductor lines, resistors, glasses) for HF- and sensor-applications.

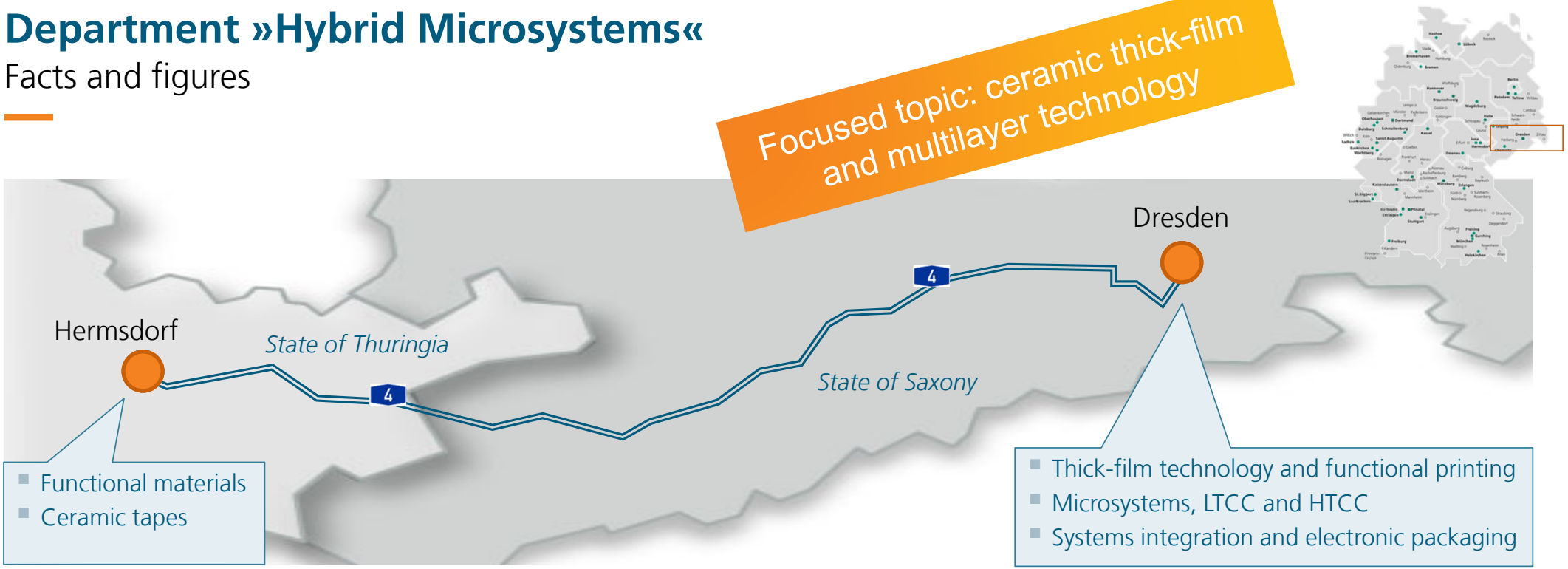
02

Department »Hybrid Microsystems«

Facts & Figures

Department »Hybrid Microsystems«

Facts and figures



- 2 sites, 5 research groups
- 60 employees (scientists, graduates, technicians, PhD-students, student workers)
- Budget 2021 approx. 6.5 Mio. €

Department »Hybrid Microsystems«

Head of department, heads of research groups

Dr.-Ing.
Uwe Partsch
Hybrid Microsystems

Dr. rer. nat.
Arno L. Görne
Functional Materials
for Hybrid Microsystems

Dr.-Ing.
Stefan Körner
Thick-Film Technology
and Functional Printing

Dipl.-Chem.
Beate Capraro
Ceramic Tapes

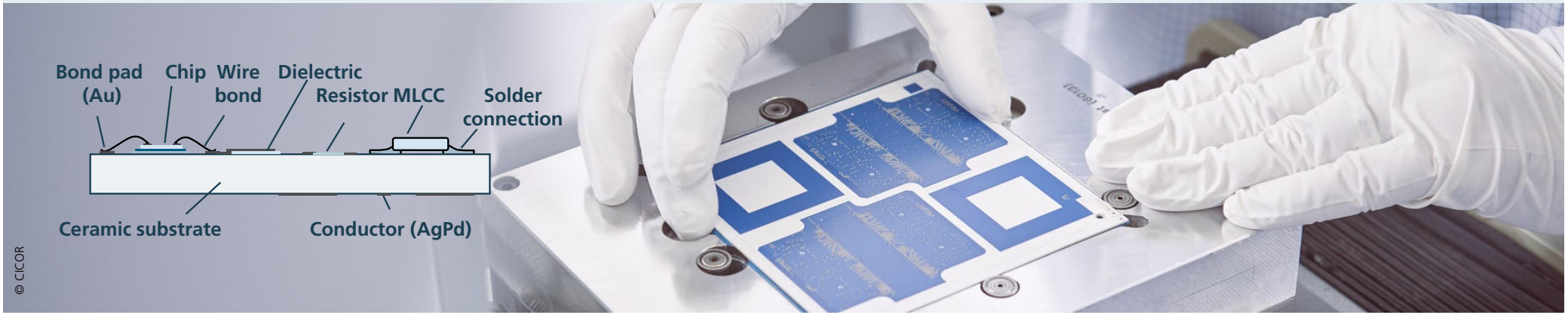
Dr.-Ing.
Steffen Ziesche
Microsystems,
LTCC and HTCC

Dr.-Ing.
Lars Rebenklau
Systems Integration and
Electronic Packaging

Department »Hybrid Microsystems«

Ceramic thick-film and multilayer technology

Thick-film based hybrid circuits: *»Electronic modules consisting of different components, materials and manufacturing technologies, integrated on a sintered ceramic substrate.«*



- **High reliability** (CTE match to Si)
- **Rough environment, high-T** suited
- **High thermal conductivity**

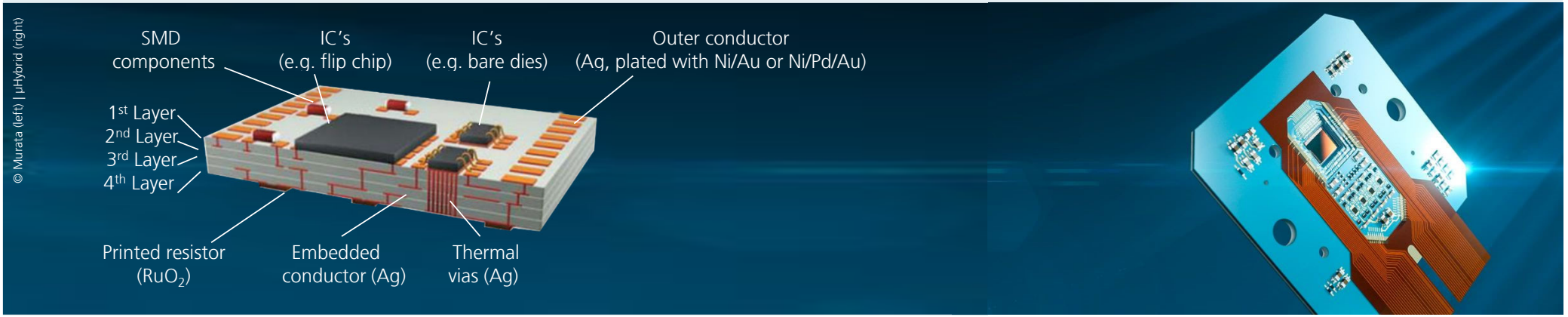
Industries

- Industrial and power electronics
- Green energy, sensors
- Automotive

Department »Hybrid Microsystems«

Ceramic thick-film and multilayer technology

Ceramic Multilayers: *»Succession of (different) **ceramic** or **glass-ceramic layers** which are differently structured, printed with functional layers, subsequently pressed (laminated) and co-sintered below 1000°C.«*



- **High reliability** (harsh environment + high-T suited, CTE match to Si)
- **HF-/mmWave-suited** (low eps, low loss)
- **Functional integration** (embedded passives)

Industries

- Mobility (Automotive, Aerospace)
- Mobile Communication (5G/6G, IoT)
- Advanced Sensors
- Health Care & Life Science

Department »Hybrid Microsystems«

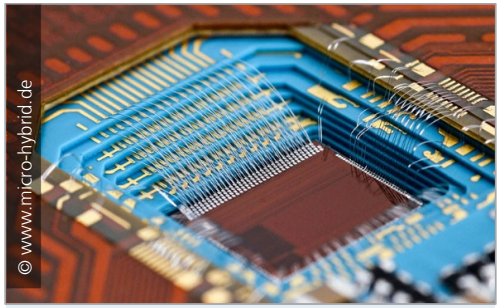
Value chain

from materials to applications…

Functional powder synthesis and processing	Functional semi-finished materials	Component and systems design	Technology development and scale up	Functional characterization and reliability
Functional materials ■ HTCC, LTCC, ULTCC ■ Magneto-ceramics ■ Ferroelectrics ■ PTC, NTC ■ Varistors ■ Luminescent materials **Powder processing** ■ High energy milling ■ Spray-, freeze-drying	**Pastes/inks** ■ Solid/ binder mixing; different dispersion steps ■ Paste/ ink characterization (rheology, PSD, sinter behavior) **Tapes** ■ Slurry development ■ Slurry/ tape characterization **Sputter targets**	**Component design** ■ FE-simulation (multi-physics) ■ Circuit design (3D routing)	**µPrinting** ■ Mask based/digital **µStructuring** ■ Laser, µPunching, µEmbossing **Lamination** **Firing** ■ Air, N2, red., 0-shrink **Surface polishing** **Electronic packaging** ■ Soldering, gluing welding, bonding	**Functional films & components** ■ **Electrical characterization** (R/ |Z|, TCR, tanδ, ε, µ, breakdown voltage/ dielectric strength, STOL, …) ■ **Aging** (thermal and power cycling, humidity aging) ■ **Surface roughness** ■ **Imaging** (thermal, µCT, X-ray imaging)

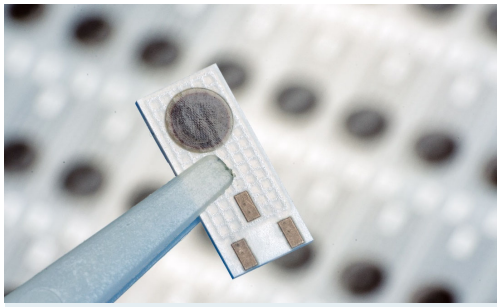
Department »Hybrid Microsystems«

Applications for ceramic thick-film and multilayer based components



Ceramic PCB's

- **Standard thick-film**
- **Multilayer** (ULTCC, LTCC, HTCC)
- **Power electronics** (DCB, AMB)



Sensors

- **Mechanical** (p, F, a, level)
- **Thermal** (resistor type, thermocouples)
- **Chemical** (water)

Components

- **Multilayer integrated passives** (RLC), **Multilayer varistors** (MLV)
- **Chip resistors**
- **Heaters**
- Ceramic **MEMS-packages**
- LED-, laser diodes packages
- LTCC-based actuators

Green energy

- **Solar Cells** (crystalline, HJT)
- **Fuel Cells** (µPEMFC)
- **Li-Batteries** (printed 3D-electrodes, LLZO-separators
- Electrode materials for **Photo-Electro-Catalysis** cells (PEC)

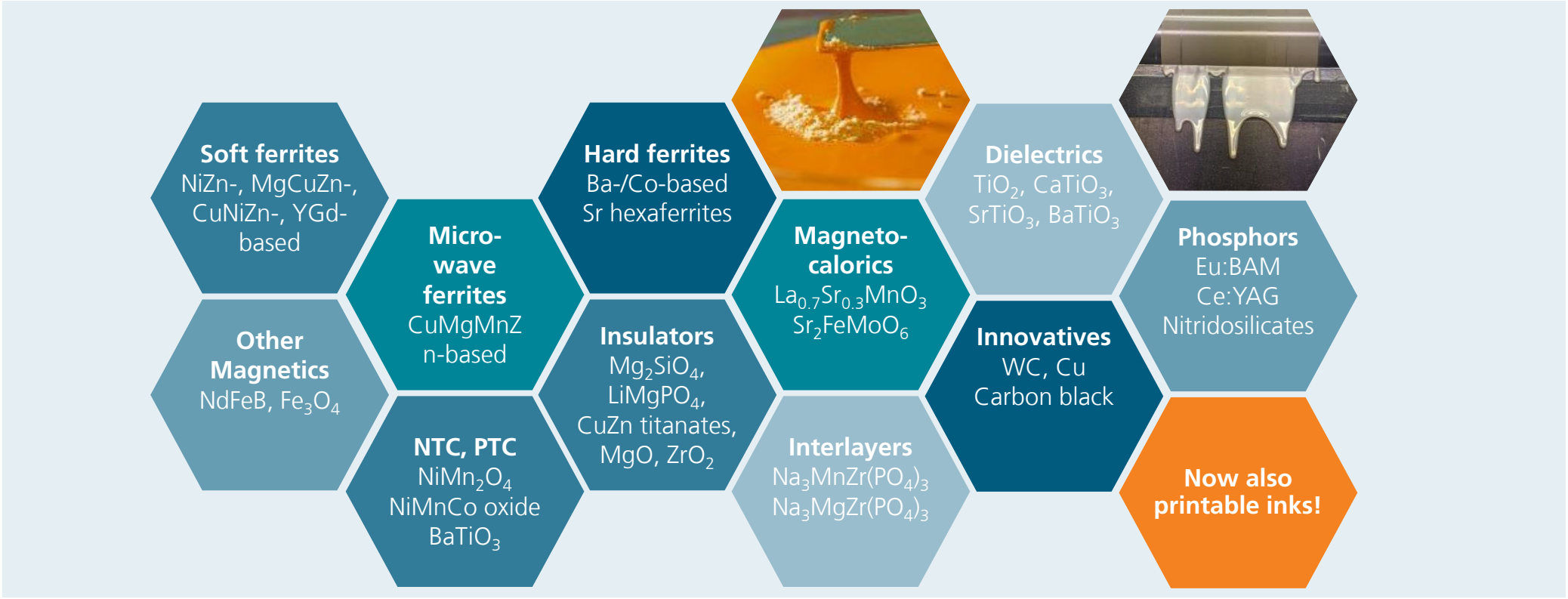
Triple-Slot-Die casting machine (backend) @ IKTS tape casting center

03

Materials for TF- and ML-Technology

Materials for thick-film and multilayer technology

Synthesis of functional materials

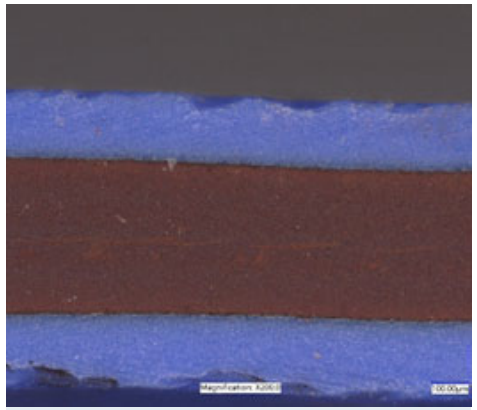


Materials for thick-film and multilayer technology

Passives integration in LTCC for satellite communication

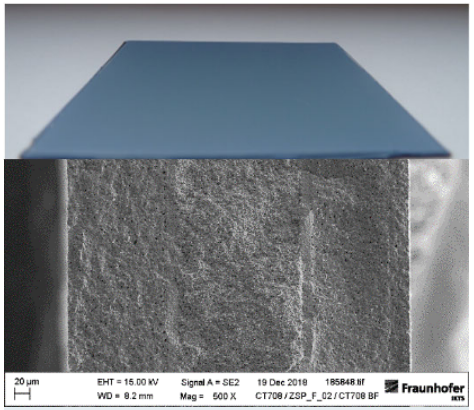
Material adaptation

Substitution and addition of sintering aids lowers the sintering temperature of our ferrites (here pressed magnets shown) into the LTCC range of about 900°C.



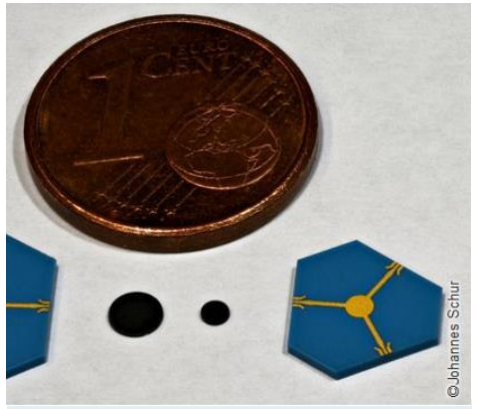
Screen printing

We process our own powder into our pastes, so we adapt and control. This allows to preserve function after filling cavities of a LTCC tape and cofiring.



Tape integration

We also offer ferrite tapes that can be laminated with LTCC tapes and co-sintered. Interface reactivity and thermal behavior were closely controlled for these results.

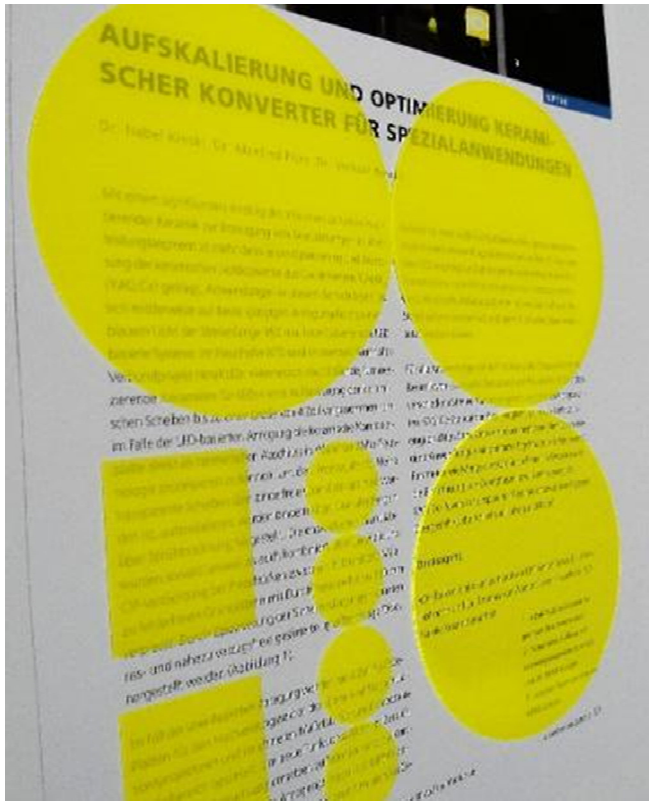


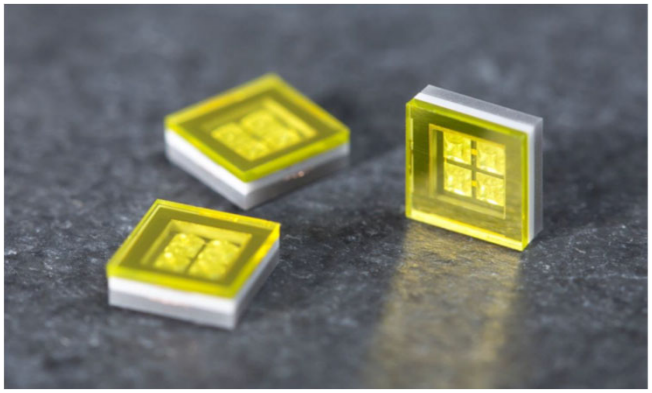
Circulator in LTCC

Together with TU Ilmenau, we prepared ferrite circulators with excellent high-frequency properties in LTCC.

Materials for thick-film and multilayer technology

YAG phosphores: Hermeticly tight, luminescent ceramics for LEDs

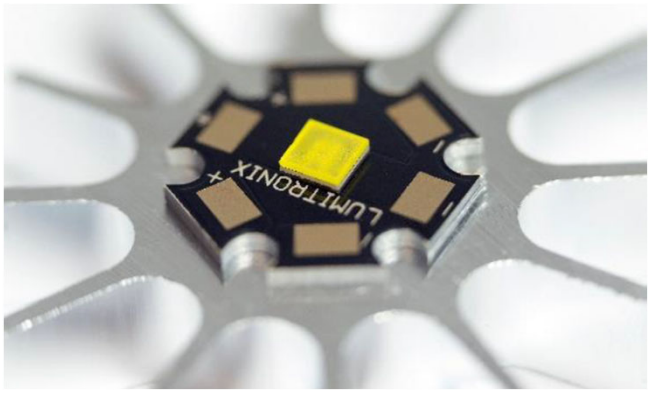


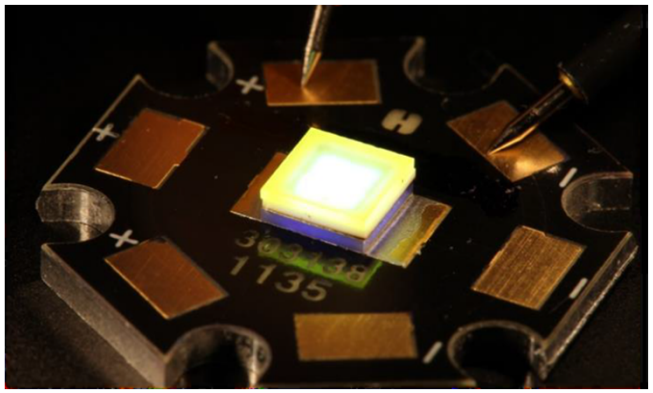


HeraKLED

Fraunhofer project “HeraKLED”: IKTS, IAF and IZM.

(I. Kinski, M. Fries, M. Arnold, Scale-up and optimization of ceramic phosphors for special applications, Fraunhofer IKTS Annual Report 2016/17, p. 57.)



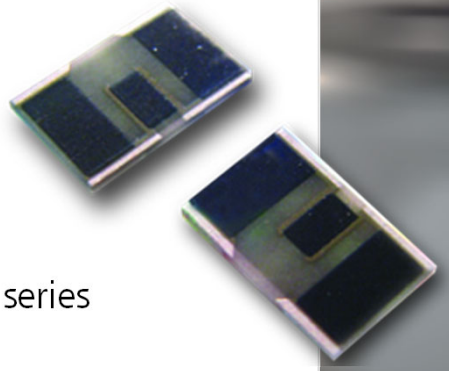


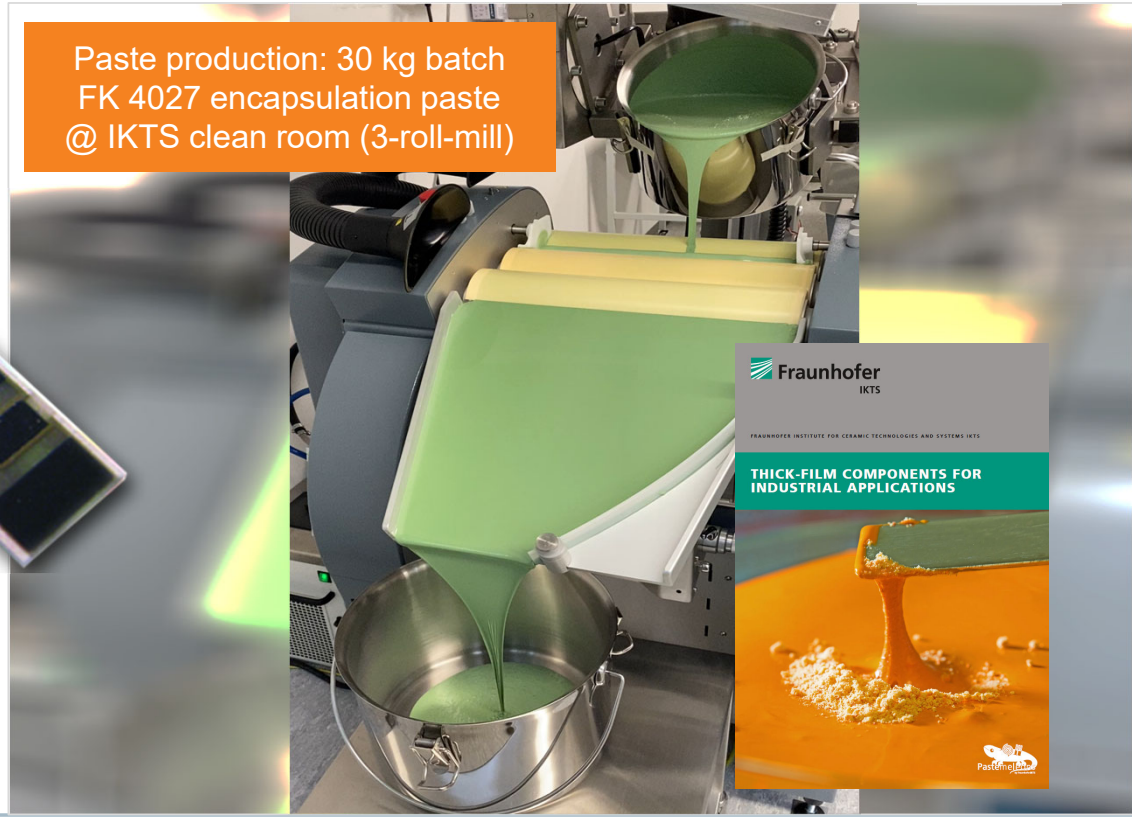
Materials for thick-film and multilayer technology

Thick-film paste system for AlN-ceramics

Klick for further information

- **Topic**: **Unique paste composition for AlN-Substrates** (high thermal conductivity (180-200 W/m·K, CTE matches Si) **provided by IKTS** (DIN/ISO 9000 certified)
- **Resistor** paste series
  - **FK 96XX** (RuO_2)**, FK 99XX** (AgPd)
- **Metallization** paste series
  - **FK 11XX/ 12XX** (AgPd)
  - **FK 10XX** (AgPt)
- **Glass encapsulation and marker** paste series
  - **FK 40XX**



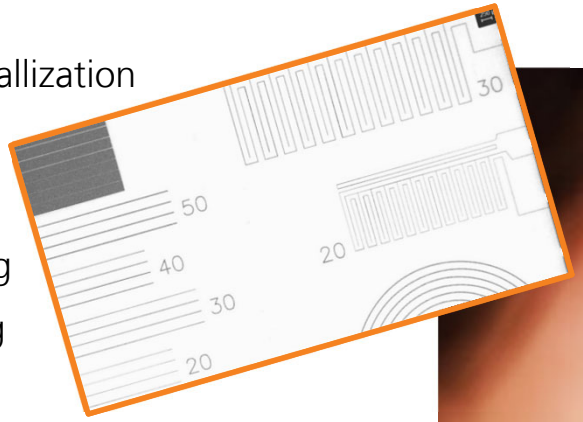


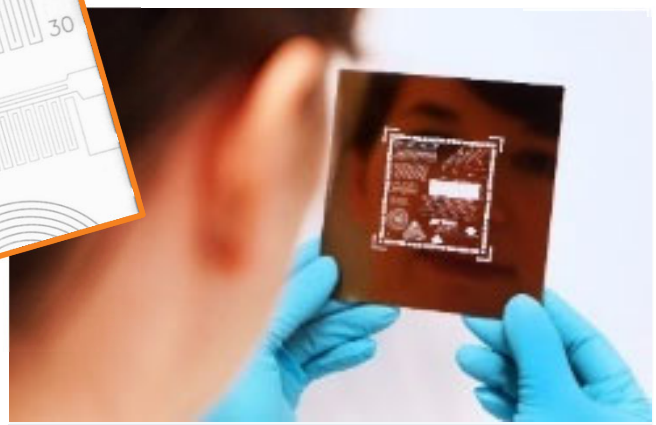
Materials for thick-film and multilayer technology

Photo-image able (PI) thick-film pastes

- **Topic**: new lithography-based technology for fine-line metallization
- **Objectives**:
  - **Improved printing resolution** (<10µm),
  - **Improved surface quality, new features:** e.g. fencing
- **Process**: Screen printing – exposure – development – firing
- **Materials**: **Ag**, Au, Cu, glasses, **LTCC**

Klick for further information

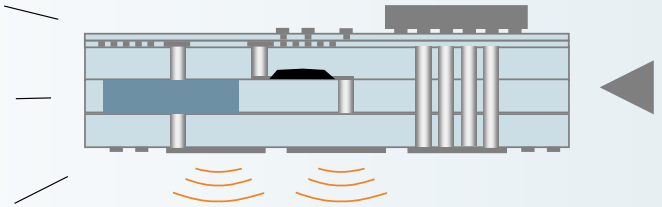




LTCC-PI
20µm l/s, 30 µm vias

LTCC-Standard core
75µm l/s, 75 µm vias

LTCC-PI
20µm l/s, 30 µm vias



Embedded RLC
Embedded PI films
Thermal vias

Photo-imaging of thick-films

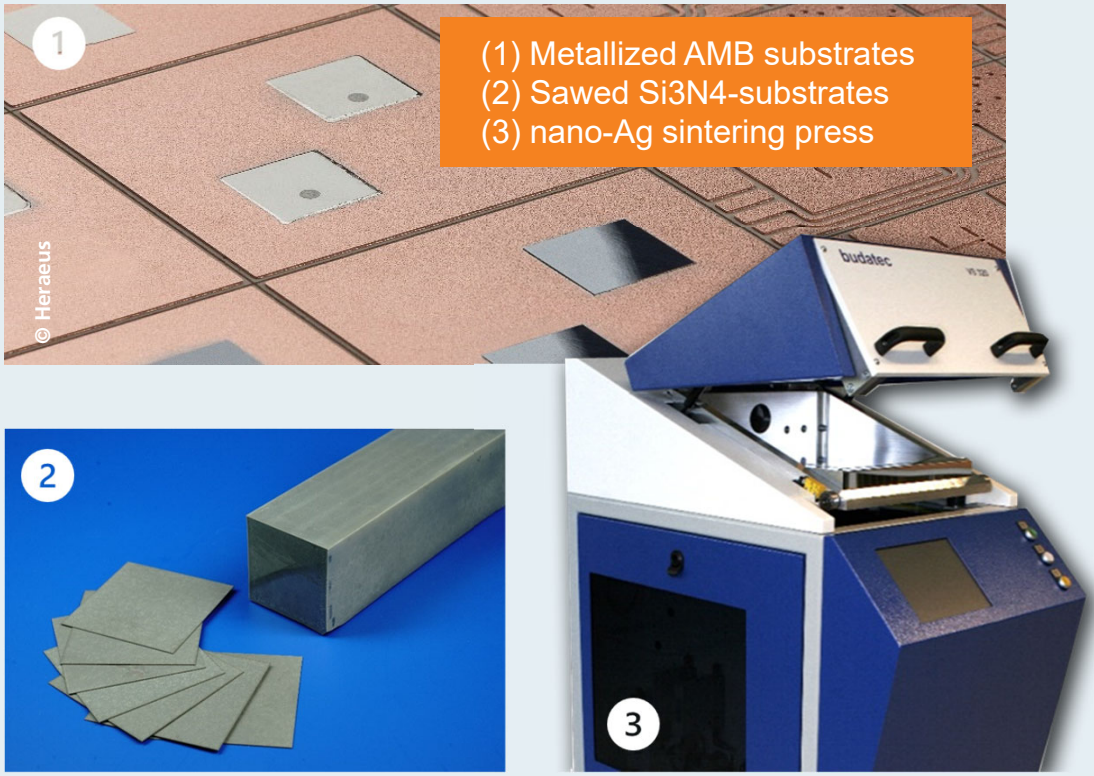
- Printing mask-based
- Exposure LDI, spray developing
- Max. resolution <10 µm

Materials for thick-film and multilayer technology

Copper-Si_3N_4 joining technology for power electronics substrates

* BMWK = German Federal Ministry for Economic Affairs and Climate Protection

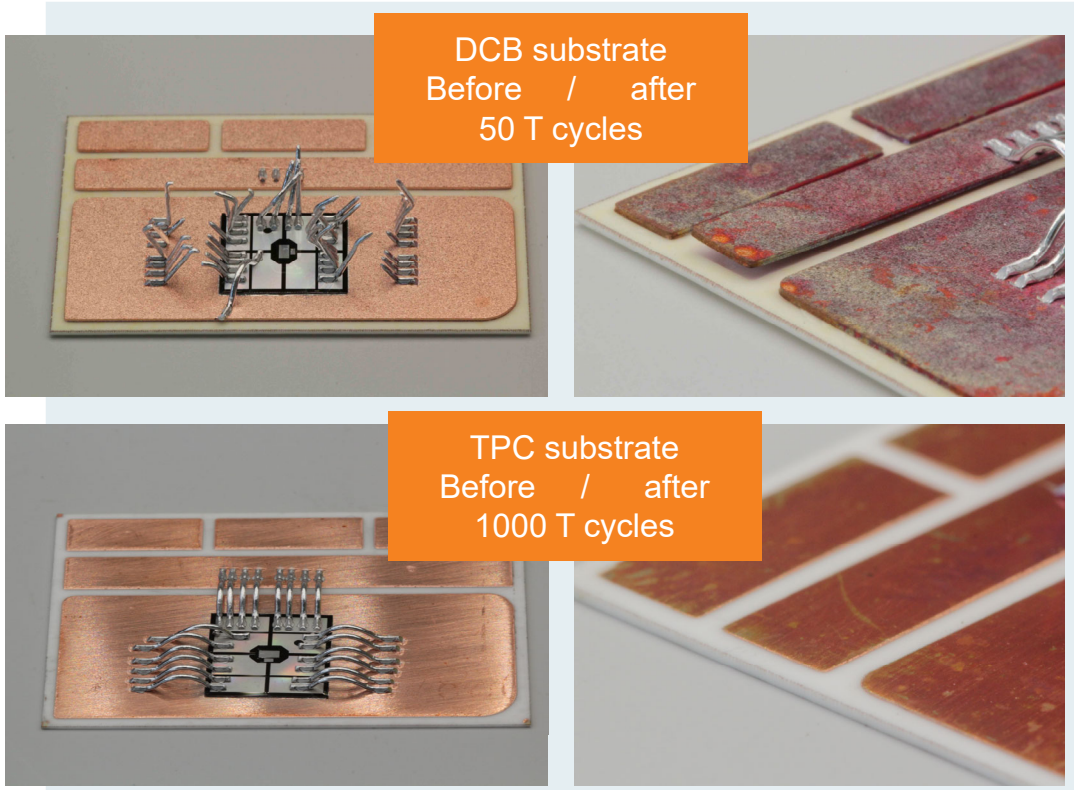
- **Topic**: **Reliable and cost-effective AMB Si_3N_4**-substrates for power electronics
- **Project partners**: Infineon, PV-Crystalox, IKTS
- **Objectives**:
  - Wafer sawed Si_3N_4 -substrates from ingot
  - Robust AMB-process
  - Nano-Ag-sintering for IGBT assembling
- **IKTS Department »Hybrid Microsystems«**:
  - **Mechanical characterization** of Cu-Si_3N_4 joining
  - **Electrical characterization** of Si_3N_4 ceramics (PD measurement)
  - **Assembly demonstrator circuit**



Materials for thick-film and multilayer technology

TPC LE - Reliability of thick-printed copper on alumina substrates

- **Topic**: Reliability of thick-printed copper metallisation vs. DCB (thermal/ power cycling)
- **Project partners**: Fraunhofer IISB, IKTS
- **Objectives**: Reliability comparison between DCB-, AMB- and TPC-metallized ceramic circuits for power applications
- **IKTS Department » Hybrid Microsystems« Thermal cycling**
  - Temperatures: -40 … +125 °C
  - Cycle time < 30 s
  - Dwell time > 15 min



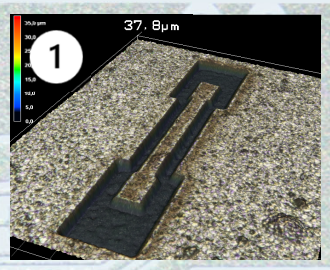
Materials for thick-film and multilayer technology

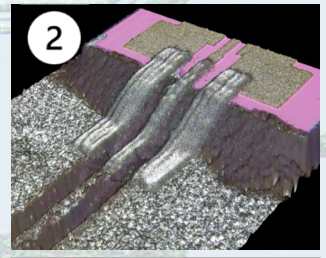
Terahertz ceramic circuits

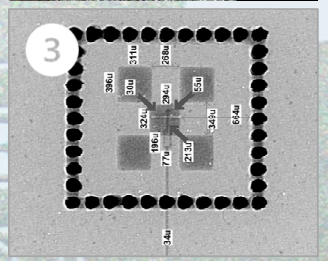
Klick for further information

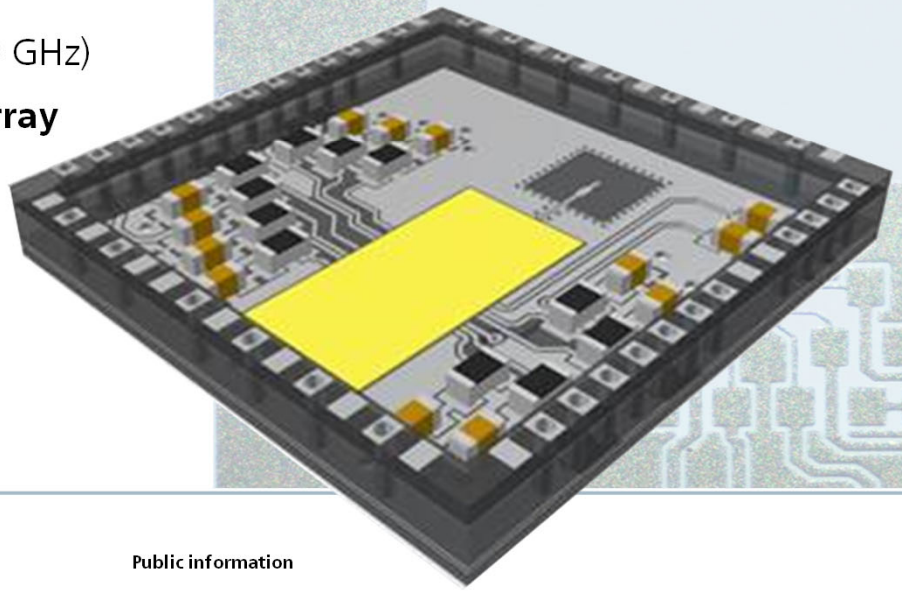
- **Topic**: Terahertz ceramic circuits for ultra-wideband 240 GHz sensing and communications
- **Project partners**: Fraunhofer IAF, IKTS
- **Objectives**:
  - **Ultra fine line metallization technologies** for 220/ 320 GHz
  - **Printed MMIC interconnections** (up to 320 GHz)
  - 140 GHz aperture-coupled **stacked-patch array antenna** in package
  - **LTCC-package** with
    - MMIC
    - Stacked patch antenna
    - BGA connection to next packaging level

(1) Ultra fine line metallization
(2) Printed MMIC interconnections
(3) Stacked-patch array antenna





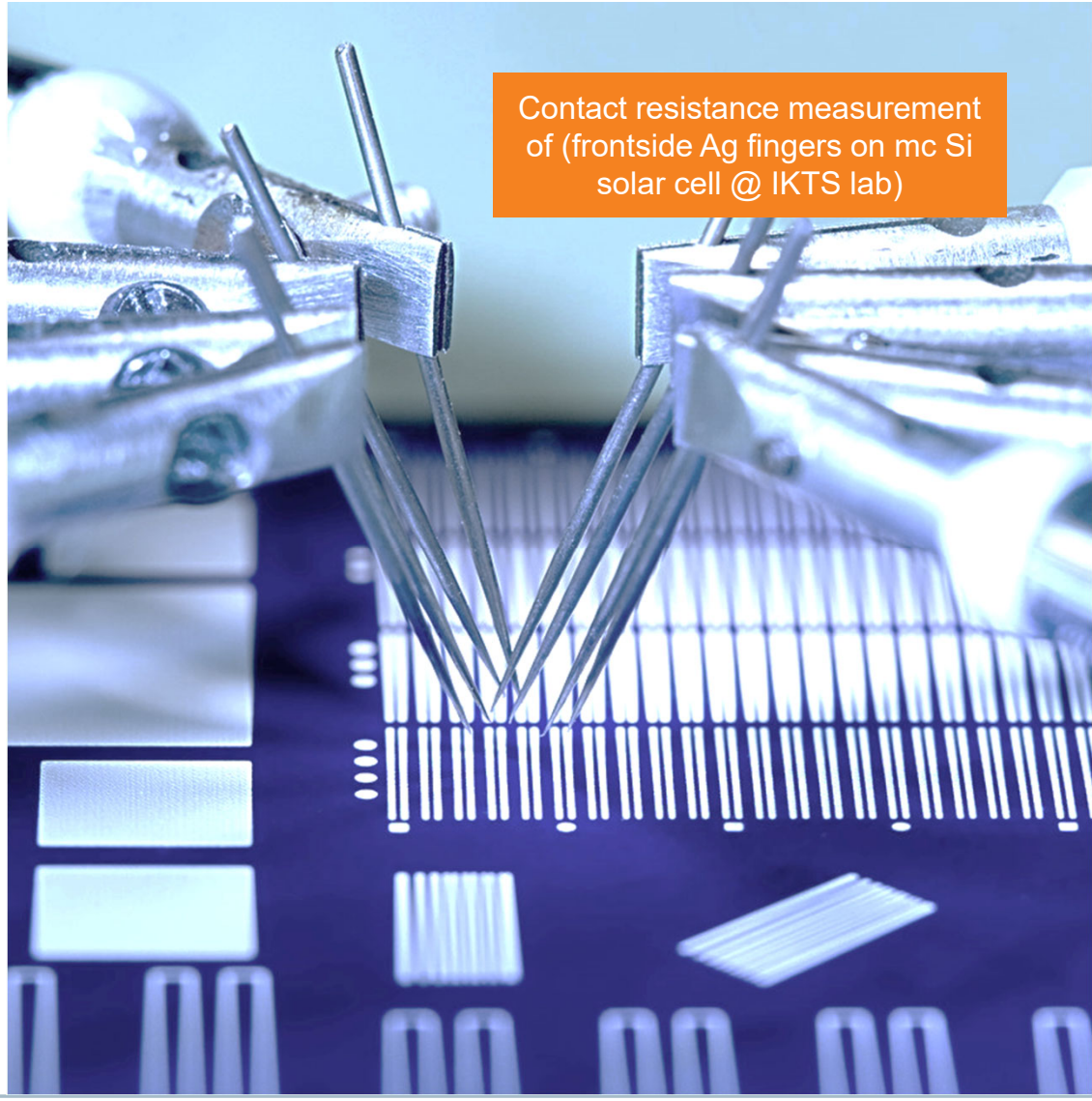


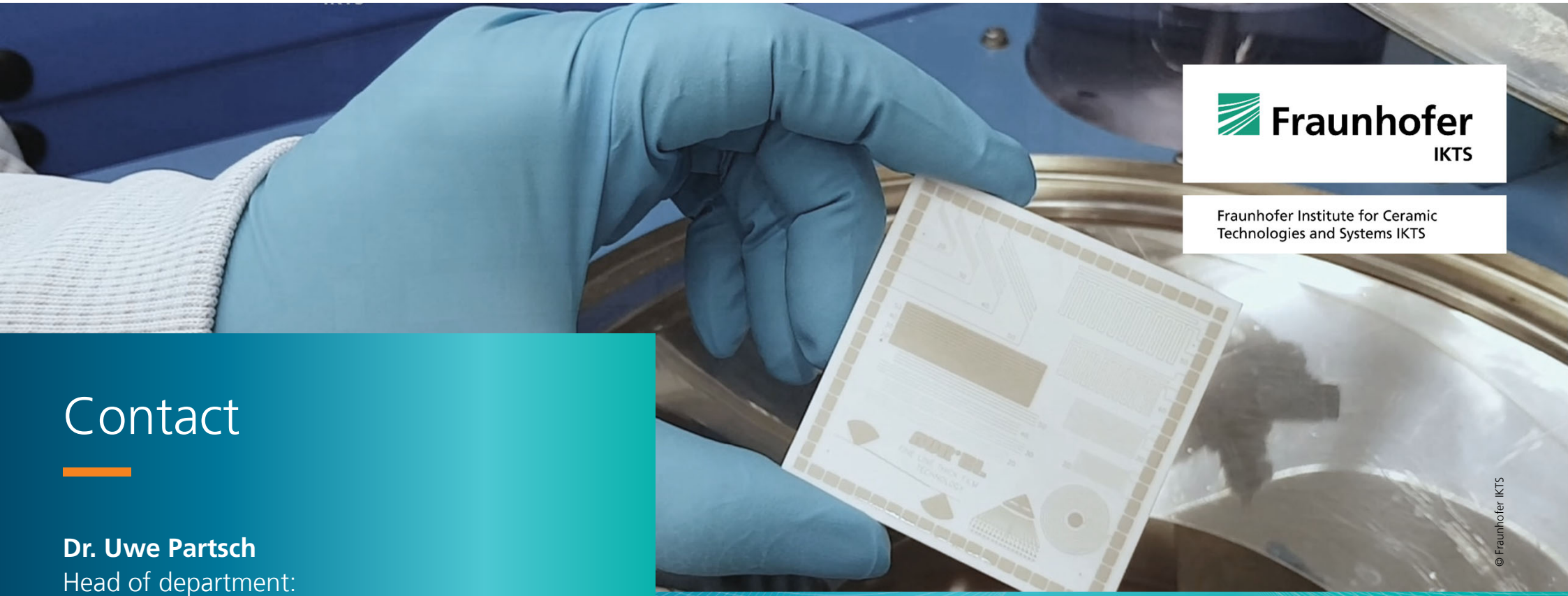


Summary

- **IKTS-Department “Hybrid Microsystems“**
  - Covers the whole value chain of ceramic thick-film and multilayer technology

- **Customer-specific solutions @ different topics**
  - **Functional materials**
  - Functional semi-finished products
  - Component and systems design
  - Technology development for components and subsystems
  - Scale up and functional characterization/ reliability





Contact

Dr. Uwe Partsch
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www.ikts.fraunhofer.de

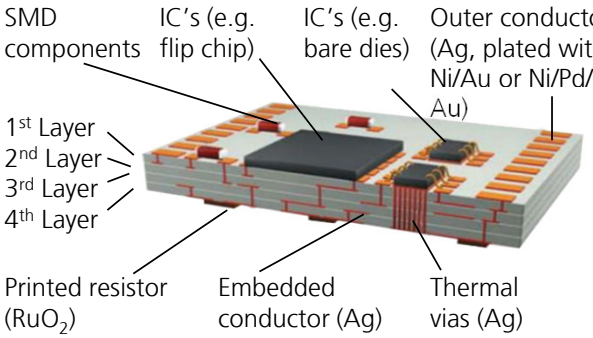
Thank you for your attention!

Ceramic thick-film and multilayer technology

Co-firing

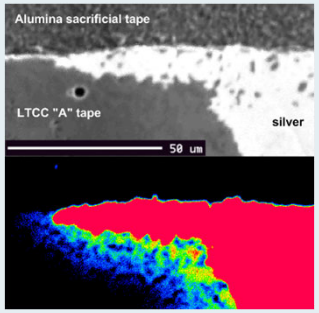
Ceramic multilayer technology = co-firing!

- **Compatibility of all embedded materials** (organic, functional)
  - Shrinkage (T-range/ -rates, relative shrinkage)
  - Chemical interactions
  - Atmosphere/ micro-atmosphere
  - CTE
- **Know-How**
  - Materials adaption
  - Optimized processing
  - Component design



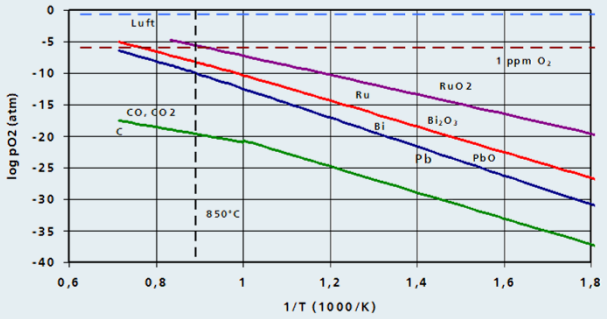
Tape	Conduct or lines, vias	R	L	C
LTCC	Ag, Cu, AgPd, Au	Metal-oxide/ glass	MnZn, NiZn, NiCuZn/ glass	$BaTiO_3$/ glass
HTCC	Pt, W, Mo	-	-	-

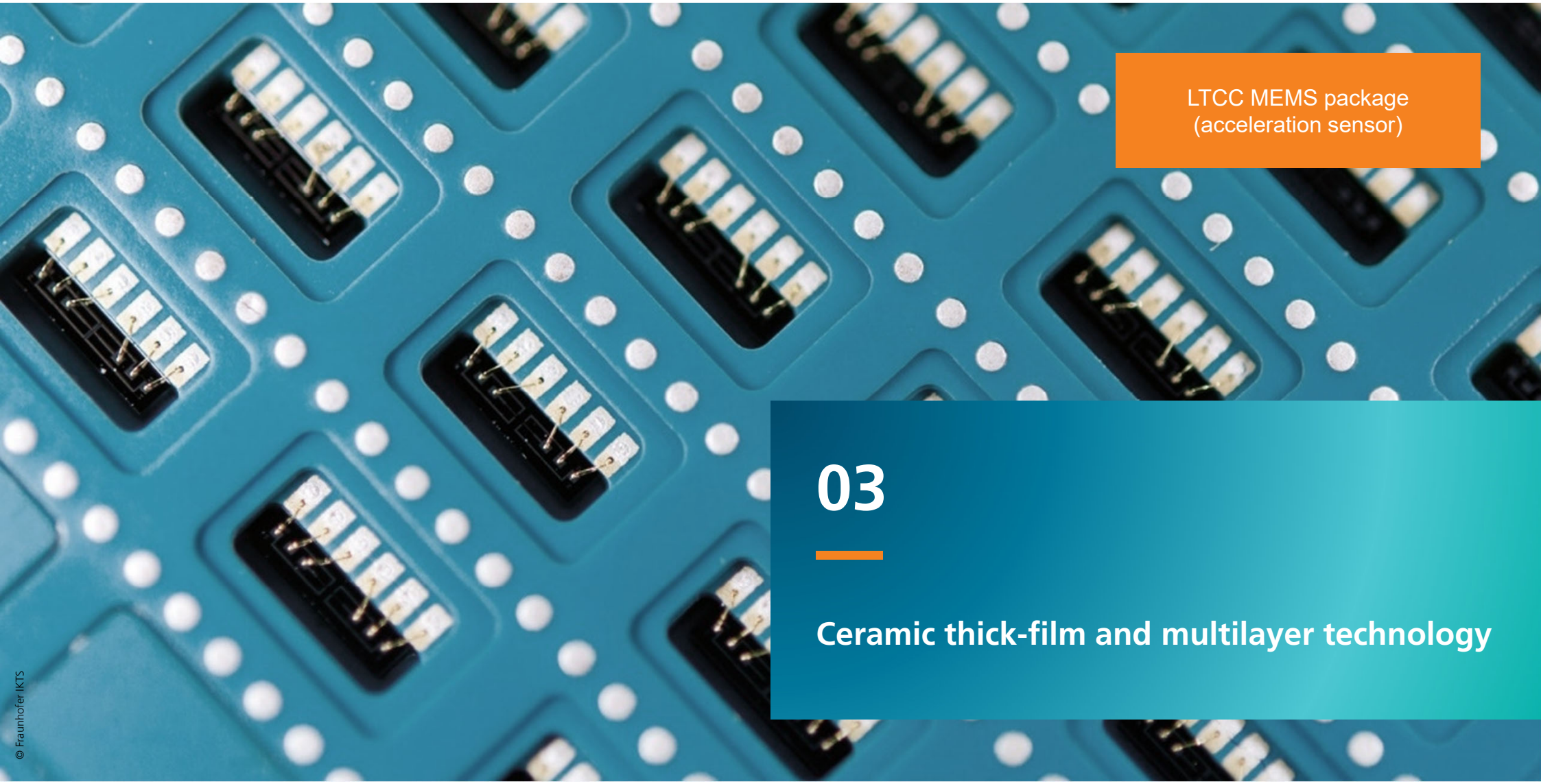
Chemical interactions



Rabe, T. et al: "Silver in LTCC – Interfacial Reactions, Transport Processes and Influence on Properties of Ceramics", CICMT 2009, Denver.

Micro- atmosphere





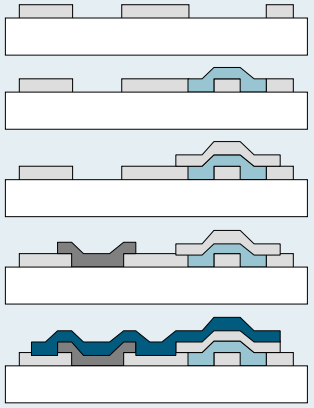
03

Ceramic thick-film and multilayer technology

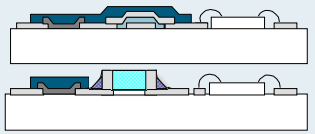
Ceramic thick-film and multilayer technology

Process flow thick-film technology

- **Sequential film** printing, drying, firing (on fired substrate)
- **Different functional pastes/inks**
  - Metallization – Ag, AgPd, AgPt, Au, Pt, Cu (contact pads, conductor lines; solder able, plate able, bond able)
  - Resistors – different decades (1 Ohm .. 1 MOhm/sq)
  - Glass layers
    - Type 1 – 850 °C isolation, overcrossing
    - Type 2 – 600 °C encapsulation

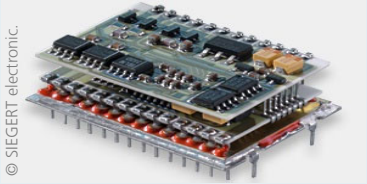


Volume shrinkage (multilayer) 35–50 %



Laser trimming, assembling

conductor lines printing/drying
firing 850 °C
isolation printing/drying
firing 850 °C
conductor lines printing/drying
firing 850 °C
resistors printing/drying
firing 850 °C
encapsulation printing/drying
firing 600 °C



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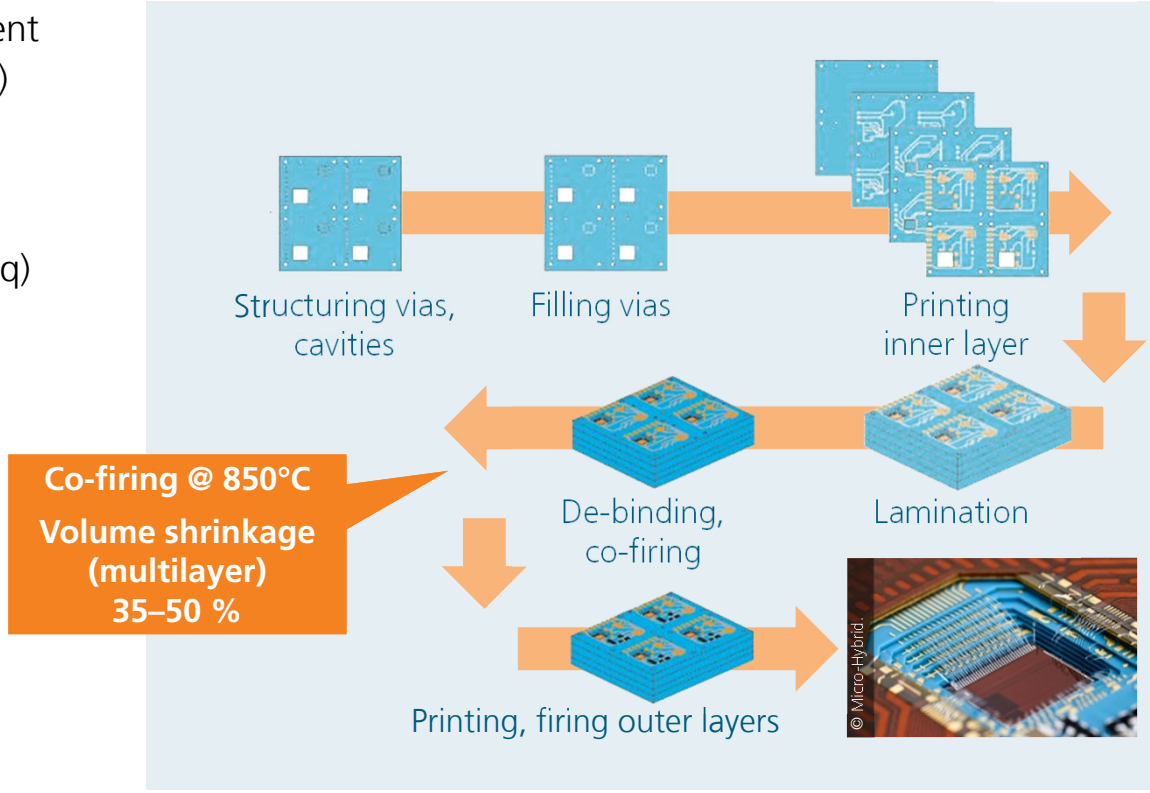
Introduction

LTCC-process flow

Klick for further information

- **Parallel structuring**, **film printing**, drying … , different layers (on unfired tapes – thicknesses 50 µm – 250 µm)
- **Various embedded materials** (printable pastes, inks)
  - Conductors – Ag, AgPd, AgPt, Au, Cu
  - Resistors – different decades (1 Ohm .. 100 kOhm/sq)
  - Magneto-ceramics + capacitors for MLCC/ MLIP
- **LTCC-materials properties**

Dielectric constant	ε_r @ 3 GHz	3-7
Loss tangent	tanδ @ 3 GHz	<0.001
Thermal expansion	CTE/ ppm/K	4-7
Hermetic, no water absorption, high isolation resistance		

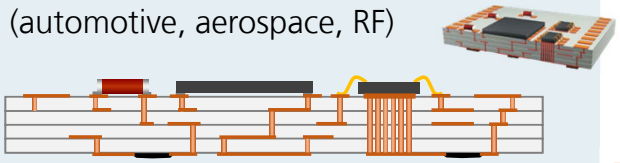


Ceramic thick-film and multilayer technology

LTCC 3D-functional integration

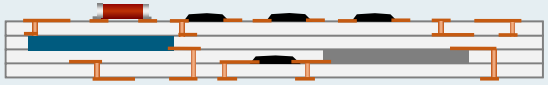
Electronic packages, ceramic PCB's

- High density electronic packages (automotive, aerospace, RF)



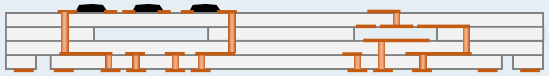
Embedded passives

- Filters (RC, RLC), R-networks, heaters



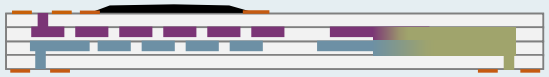
Diaphragms, cantilever

- Sensors, actuators, hot plates

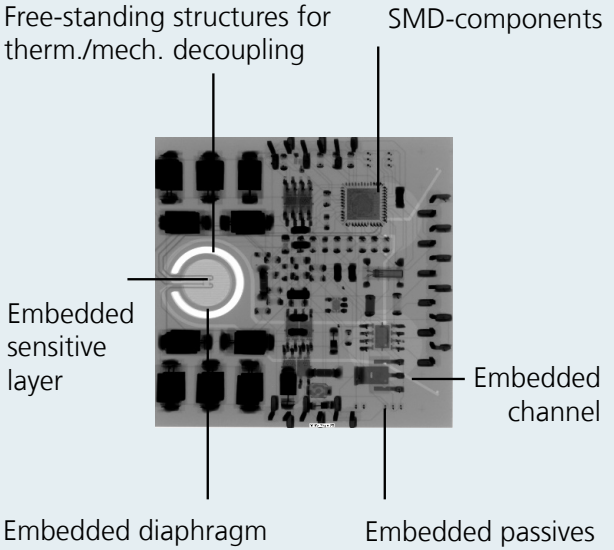


Channels, chambers

- Sensors, micro-reactors, mixers, heat exchanger



Ceramic PCB + nonelectric functions



Ceramic thick-film and multilayer technology

Materials for ceramic 2- and 3D-substrates

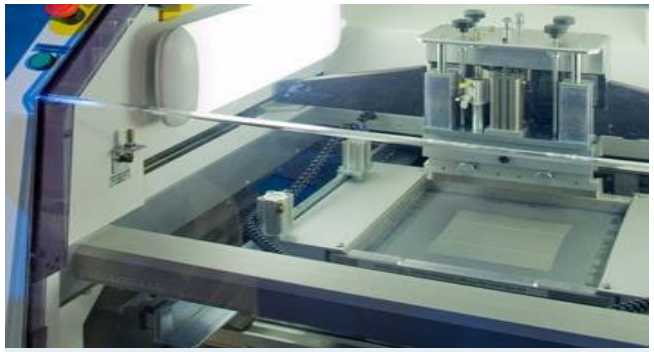
.. wide material range of thick-film suited substrates

Properties	Ceramics/ glass-ceramics composites substrates				Isolated metal substrates		Polymer substrates	
Material	**Al_2O_3**	**Si_3N_4**	**AlN**	**LTCC**	**Steel**	**Al**	**PI**	**FR4**
Post (TF)/co-firing (ML)	+/+	+/-	+/-	+/+	+/-	+/-	-/-	-/-
$T_{sinter\ max}$ [°C]	1600	1500	1400	900	900	600	260	120
CTE [10^{-7}/K]	75	31	34	30–70	125	231	270	300
Thermal conductivity [W/m·K]	20	110	200	4-6	25	235	1.2	0.2
Dielectric constant ε_{rel}	9.5	5.0	10.0	3–7	–	–	3.5	5.0
Loss factor ($\cdot 10^{-3}$) @10 MHz	0.3	4.5	2.0	0.1	–	–	3.0	5.0
Cost factor approx.	1	< 40	< 40	10	4	1	0.5	0.25

Ceramic thick-film and multilayer technology

2D/ 3D-printing technologies for functional film deposition

Wide range of possible printing technologies



Screen-/stencil printing

- Mask- based (pastes)
- 2D/3D (tubular)
- Max. resolution 25 µm

Ink-jet/ aerosol-jet printing

- Digital, multi-material (5 inks)
- 2D/ 3D, NovaCentrix Pulse Forge
- Max. resolution 10 µm

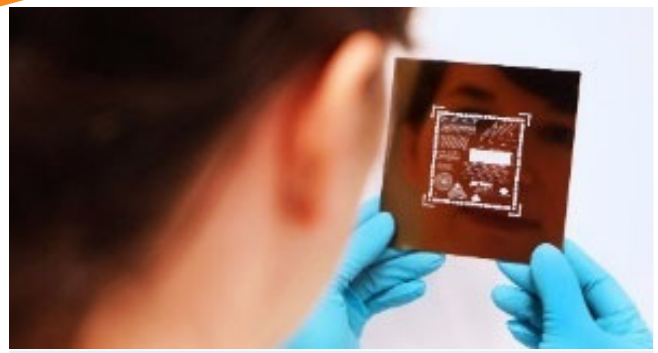


Photo-imaging of thick-films

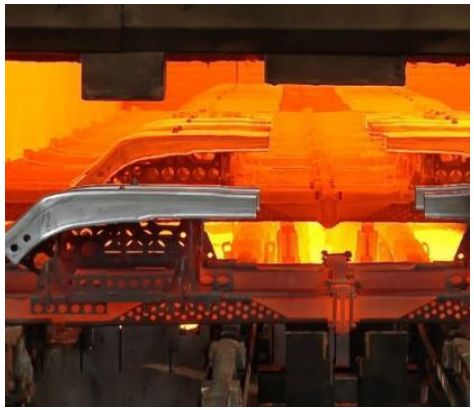
- Printing mask-based
- Exposure LDI, spray developing
- Max. resolution <10 µm

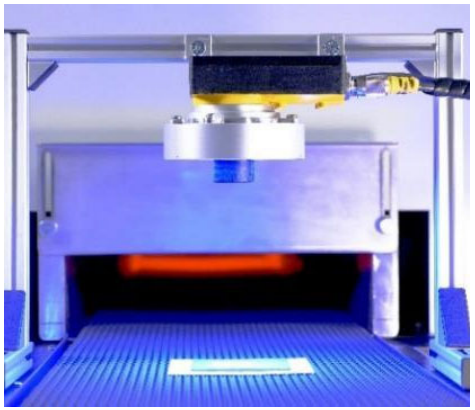
Customized paste/ink formulations for different printing technologies available @ IKTS

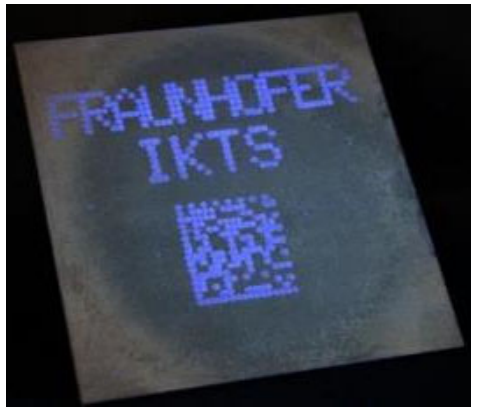
- Adaption of solids (functionality, sintering behavior – PSD, specific surface)
- Adaption binder system (type, viscous behavior, wetting, printing and burn out behavior)

Materials for thick-film and multilayer technology

Printing ceramic phosphors matrixes before hot forming







- Increasing use of press hardening of steel parts in automotives
- Individual marking of parts tricky due to high temperatures, oiliness of steel sheets
- Startup Senodis offers full service and integration
- Upcoming developments: detection of heat treatment for 100 % monitoring

- Developed traceability solution for continuous, individual, and cheap marking
  - Ceramic phosphor ink
  - Commercial inkjet printer inline, UV light for reading
  - Inert in process, no residues, can be painted over

SENODiS Industry. Information. Insights. ceracode Fraunhofer IKTS

05

Further information material

Department “Hybrid Microsystems”

Further research group information

Dr. rer. nat. Arno L. Görne

Functional Materials for Hybrid Microsystems

- Synthesis of functional ceramic materials (LTCC, ULTCC; magneto-ceramics, ferroelectrics, non-linear resistors (PTC, NTC), luminescent materials)
- Powder processing (high energy milling, spray tower, freeze drying)

Dr.-Ing. Stefan Körner

Thick-Film Technology and Functional Printing

- Functional pastes and inks, customized (conductors, TFR’s, glasses, heaters, sensors, LTCC …) adapted to different ceramics, LTCC, steel, different alloys, low T … high T firing, photo image-able; printing technologies
- Advanced rheometry of printable suspensions

Dipl.-Chem. Beate Capraro

Ceramic Tapes

- Functional tapes (HTCC, LTCC, ULTCC, metal, piezo, magnetic, glass, Li-battery electrodes, transparent)
- Application adapted solvent/ binder/ plasticizer systems
- 7 casting machines, doctor blade (DB), DB on roll, slot-die and triple slot-die casting

Dr.-Ing. Steffen Ziesche

Microsystems, LTCC and HTCC

- LTCC and HTCC based components and systems (ceramic PCB, sensors, mixing and micro-reactor devices, packages, actuators)
- Technology and process development
- Component and multilayer circuit design/ layout

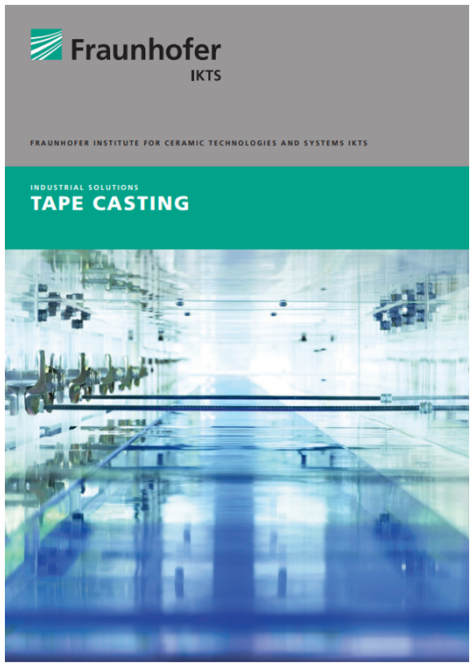
Dr.-Ing. Lars Rebenklau

Systems Integration and Electronic Packaging

- Packaging technologies – wire bonding (thin, heavy, ribbon), welding, reflow/ selective soldering, Ag nano sintering
- Functional characterization and reliability (pull/shear force, IR, power cycling, ESD, isolation resistance, STOL, R_{sqr}/TCR, T shock, humidity, salt fog, mechanical shock)

Further information material

[Catalogue]



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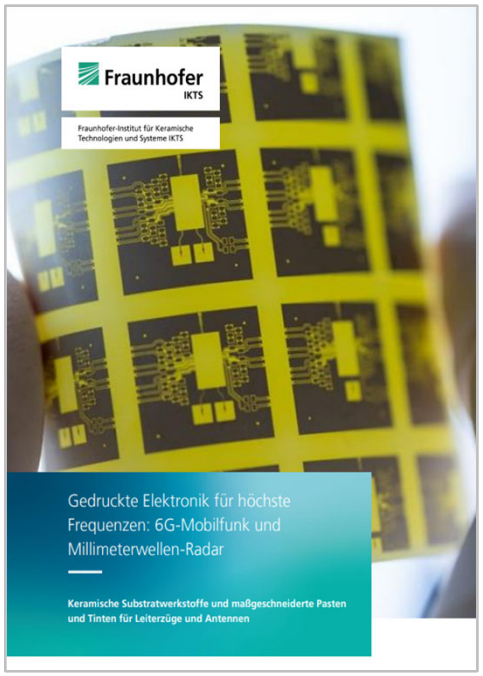

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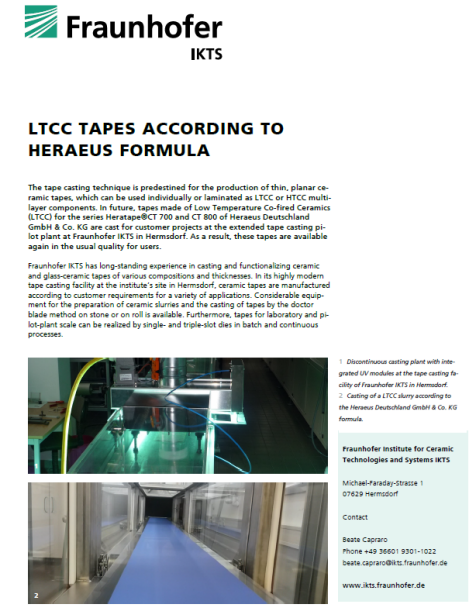

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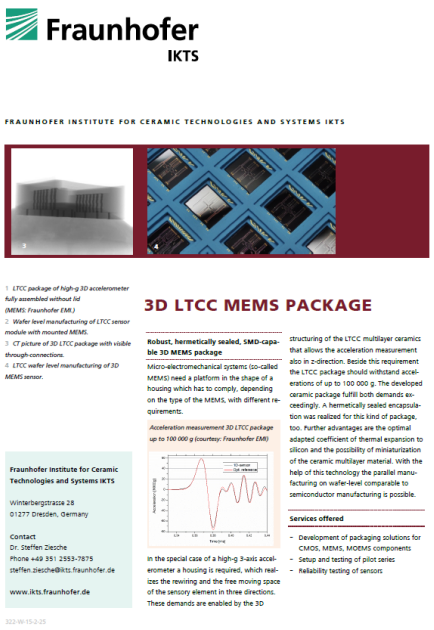
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3D LTTC MEMS PACKAGE

Robust, hermetically sealed, SMD-capable 3D MEMS package

Micro-electromechanical systems (so-called MEMS) need a platform in the shape of a housing which has to comply, depending on the type of the MEMS, with different requirements.

Acceleration measurement 3D LTCC package up to 100 000 g (courtesy: Fraunhofer EMI)

in the special case of a high-g 3-axis accelerometer a housing is required, which realizes the rewiring and the free moving space of the sensory element in three directions. These demands are enabled by the 3D structuring of the LTCC multilayer ceramics that allows the acceleration measurement also in z-direction. Beside this requirement the LTCC package should withstand accelerations of up to 100 000 g. The developed ceramic package fulfill both demands exceedingly. A hermetically sealed encapsulation was realized for this kind of package, too. Further advantages are the optimal adapted coefficient of thermal expansion to silicon and the possibility of miniaturization of the ceramic multilayer material. With the help of this technology the parallel manufacturing on wafer-level comparable to semiconductor manufacturing is possible.

Services offered

- Development of packaging solutions for CMOS, MEMS, MOEMS components
- Setup and testing of pilot series
- Reliability testing of sensors

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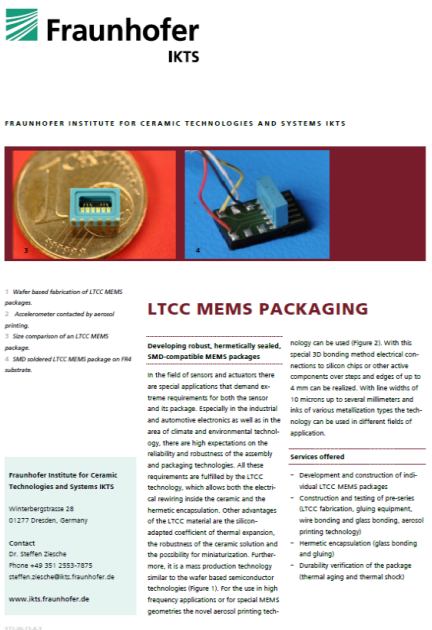
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LTCC MEMS PACKAGING

Developing robust, hermetically sealed, SMD-compatible MEMS packages

In the field of sensors and actuators there are special applications that demand extreme requirements for both the sensor and its package. Especially in the industrial and automotive electronics as well as in the area of climate and environmental technology, there are high expectations on the reliability and robustness of the assembly and packaging technologies. All these requirements are fulfilled by the LTCC technology, which allows both the electrical rewiring inside the ceramic and the hermetic encapsulation. Other advantages of the LTCC material are the silicon-adapted coefficient of thermal expansion, the robustness of the ceramic solution and the possibility for miniaturization. Furthermore, it is a mass production technology similar to the wafer based semiconductor technologies (Figure 1). For the use in high frequency applications or for special MEMS geometries the novel aerosol printing technology can be used (Figure 2). With this special 3D bonding method electrical connections to silicon chips or other active components over steps and edges of up to 4 mm can be realized. With fine widths of 10 microns up to several millimeters and inks of various metallization types the technology can be used in different fields of application.

Services offered

- Development and construction of individual LTCC MEMS packages
- Construction and testing of pre-series (LTCC fabrication, gluing equipment, wire bonding and glass bonding, aerosol printing technology)
- Hermetic encapsulation (glass bonding and gluing)
- Durability verification of the package (thermal aging and thermal shock)

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LAYER DEPOSITION TECHNOLOGIES

The deposition of functional films is very important in many sectors of industry, such as microelectronics, microsystems technology and sensor technology.

Equipment

The department of Hybrid Microsystems can provide the entire technology line for the manufacturing and characterization of screen printing pastes.
Furthermore, complete technology lines for the manufacturing of micro-structured films are available, such as:
1. Aerosol printing and
2. Inkjet printing as digital printing technologies,
3. Screen printing (planar, tubular) and
4. Gravure printing as mask-based technologies

These processes are used for the manufacturing of films with thicknesses between 25 nm and 100 µm. Structure widthnesses are between few micrometers and some millimeters.

	Line resolution	Line thickness
1	< 10 µm...5 mm	25 nm...10 µm
2	50...100 µm	> 0.5 µm
3	> 10 µm...area	1...100 µm
4	> 30 µm...area	Depending on printing pad

	Viscosity inks/pastes
1	7–2500 mPas
2	6–15 mPas
3	> 10.000 mPas
4	> 100.000 mPas

Services offered

- Development and characterization of pastes/inks
- Development and manufacturing of components for microelectronics, microsystems technology and sensor technology using several deposition technologies

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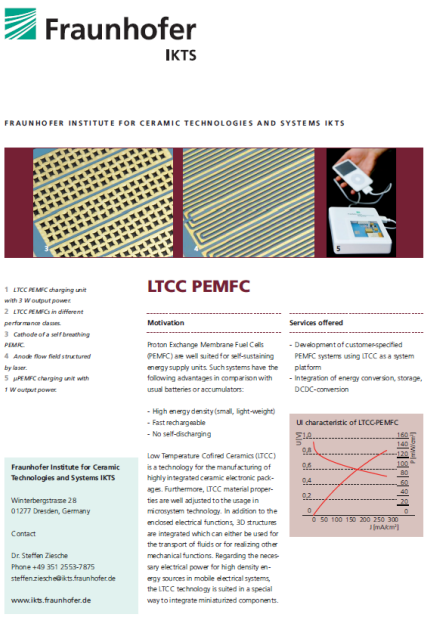
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LTCC PEMFC

Motivation

Proton Exchange Membrane Fuel Cells (PEMFC) are well suited for self-sustaining energy supply units. Such systems have the following advantages in comparison with usual batteries or accumulators:

- High energy density (small, light-weight)
- Fast rechargeable
- No self-discharging

Low Temperature Cofired Ceramics (LTCC) is a technology for the manufacturing of highly integrated ceramic electronic packages. Furthermore, LTCC material properties are well adjusted to the usage in microsystem technology. In addition to the enclosed electrical functions, 3D structures are integrated which can either be used for the transport of fluids or for realizing other mechanical functions. Regarding the necessary electrical power for high density energy sources in mobile electrical systems, the LTCC technology is suited in a special way to integrate miniaturized components.

Services offered

- Development of customer-specified PEMFC systems using LTCC as a system platform
- Integration of energy conversion, storage, DCDC-conversion

UI characteristic of LTCC-PEMFC

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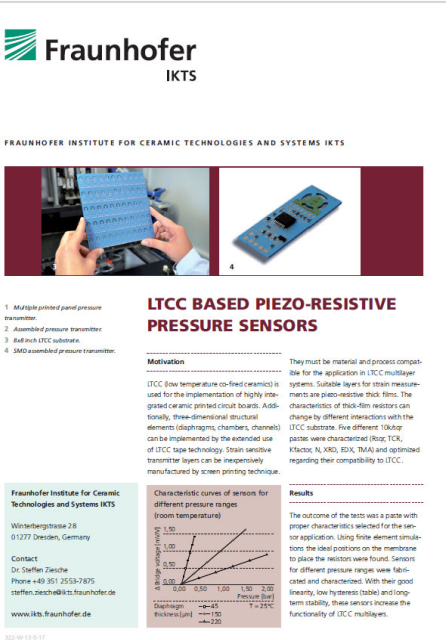
Further information material



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1 Multiple printed panel pressure transmitter.
2 Assembled pressure transmitter.
3 8x8 inch LTCC substrate.
4 SMD assembled pressure transmitter.

LTCC BASED PIEZO-RESISTIVE PRESSURE SENSORS

Motivation

LTCC (low temperature co-fired ceramic) is used for the implementation of highly integrated ceramic printed circuit boards. Additionally, three-dimensional structural elements (diaphragms, chambers, channels) can be implemented by the extended use of LTCC tape technology. Strain sensitive transmitter layers can be inexpensively manufactured by screen printing technique.

They must be material and process compatible for the application in LTCC multilayer systems. Suitable layers for strain measurements are piezo-resistive thick films. The characteristics of thick-film resistors can change by different interactions with the LTCC substrate. Five different 10kΩsp pastes were characterized (Rsqr, TCR, Kfactor, N, XRD, EDX, TMA) and optimized regarding their compatibility to LTCC.

Results

The outcome of the tests was a paste with proper characteristics selected for the sensor application. Using finite element simulations the ideal positions on the membrane to place the resistors were found. Sensors for different pressure ranges were fabricated and characterized. With their good linearity, low hysteresis (table) and long-term stability, these sensors increase the functionality of LTCC multilayers.

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Characteristic curves of sensors for different pressure ranges (room temperature)

322-W-13-5-17

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1 Double-D LTCC miniature coil (Ø 4mm) for the integration onto a turbocharger speed sensor component.
2 Detail of a polished cross-section trough silver coil embedded in LTCC with high aspect ratio (> 1 possible).
3 Printed spiral coil on LTCC with lateral wounding distance of the printed coil of min. 25 µm.
4 Turbocharger speed sensor with LTCC coil on the front (Source: Jaquet Technology Group).

LTCC-BASED INDUCTORS FOR EDDY CURRENT SENSORS

Eddy current sensors are sensitive to electrical conductive materials and completely contactless. When this principle is implemented as sensors, they can detect path, distance, position as well as velocity. Measurements in highly contaminated environment or of covered objects are easily possible.
The multilayer ceramic technology offers an optimal platform for the flexible integration of eddy current measuring inductors with very small designs. LTCC multilayer printed and embedded inductors can be used in very rough environments and under operation temperatures up to 350 °C. The coil is typically located in the head of the sensor. A crucial element for its performance is the quality factor of the embedded coil. Due to the use of novel LTCC manufacturing processes (developed at Fraunhofer IKTS) the lateral wounding distance of the printed coils can be reduced to 25 µm. The metallization thickness can be simultaneously enhanced which reduces the internal resistance as well. Thus, the inductivity and the ohmic resistance achieve an obvious optimization that results in significant improvements of the inductors' quality factor compared to standard technologies. Embedded microinductors have a sintered metallization aspect ratio of more than one and thus an optimal performance differing clearly from prior art.
The developed LTCC-based inductors are inserted e.g. in turbocharger speed sensors for measuring of turbochargers speed for passenger cars and trucks. The measurement and control of turbochargers speed provides the key enabling technology for the optimal regulation of airflow into the engine and therefore to improve the fuel economy and reduction of engine emissions. Due to the compact construction of the inductors, the high quality factor and reliability as well as the innovative design the solution is optimally suited for speed sensor systems.

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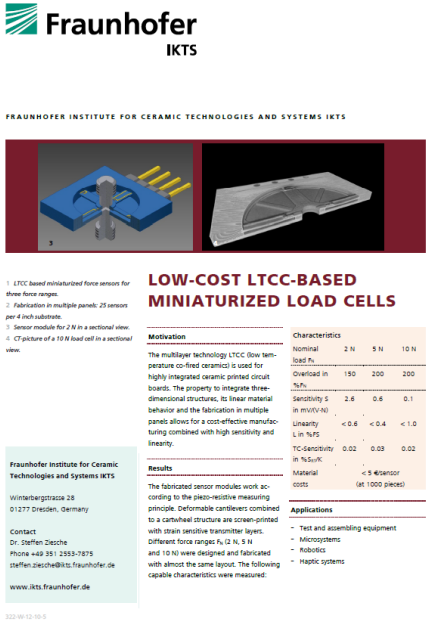

FRAUNHOFER INSTITUTE FOR CERAMIC TECHNOLOGIES AND SYSTEMS IKTS

1 LTCC based miniaturized force sensors for three force ranges.
2 Fabrication in multiple panels: 25 sensors per 4 inch substrate.
3 Sensor module for 2 N in a sectional view.
4 CT-picture of a 10 N load cell in a sectional view.

LOW-COST LTCC-BASED MINIATURIZED LOAD CELLS

Motivation

The multilayer technology LTCC (low temperature co-fired ceramics) is used for highly integrated ceramic printed circuit boards. The property to integrate three-dimensional structures, its linear material behavior and the fabrication in multiple panels allows for a cost-effective manufacturing combined with high sensitivity and linearity.

Results

The fabricated sensor modules work according to the piezo-resistive measuring principle. Deformable cantilevers combined to a cartwheel structure are screen-printed with strain sensitive transmitter layers. Different force ranges F_N (2 N, 5 N and 10 N) were designed and fabricated with almost the same layout. The following capable characteristics were measured:

Characteristics			
Nominal load F_N	2 N	5 N	10 N
Overload in F_N	150	200	200
Sensitivity S in mV/(V·N)	2.6	0.6	0.1
Linearity L in %FS	< 0.6	< 0.4	< 1.0
TC-Sensitivity in %S/K	0.02	0.03	0.02
Material costs	< 5 €/sensor (at 1000 pieces)		

Applications

- Test and assembling equipment
- Microsystems
- Robotics
- Haptic systems

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[Information sheet]

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1 CAD design a of temperature sensor in HTCC multilayer technology.
2 HTCC multilayer temperature sensor.
3 PTCR on LTCC.
4 PTCR on isolated steel and PTCR chip resistor.

T-SENSORS IN THICK-FILM AND MULTILAYER TECHNOLOGY

Motivation

One main information concerning to the actual state of numerous systems is their temperature. Often it is necessary to measure at different positions. Because of this reason compact and integratable solutions are essential. One possibility of temperature measurement are PTCR (positive temperature coefficient resistor).

Thick-film and multilayer technology are well suited for the manufacturing of these films with thicknesses between 2 and 100 µm and lateral dimensions of some 1/10 mm.

With the help of such technologies homogeneous, hermetic and very compact temperature sensors can be developed. The possible measurement range is up to 900°C.

Services offered

- Development of pastes with high temperature coefficients of resistance (TCR) for temperature measurements on customer-specific substrates
- Development and manufacturing of temperature sensors on different substrates (Al_2O_3, AlN, Si_3N_4, YSZ) and in LTCC and HTCC multilayer technology
- Characterization and calibration of temperature sensors (T = -20...1200°C)

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