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Embedded functional ceramics in LTCC, Opportunities and challenges in packaging

37th Chemnitz Seminar
»Electronic Packaging and Applications«

Qaisar Khushi Muhammad
VIA electronic GmbH

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Partnership for Innovation

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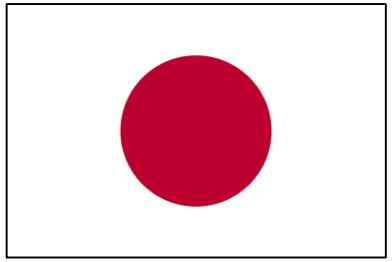
VIA Electronic GmbH

Production start 1997
Since 01.09.2017
KOA Europe GmbH
Main shareholder
Hermsdorf, Thüringen

Focused :

- LTCC technology
- Aerospace, defense, automotive, medical, & telecommunications
- RF modules, interposers, sensors, and detectors

KOA Corporation Japan



Since 10.03.1940
KOA Corporation Japan
4,144 employees world wide
Headquarter:
Ina Valley, Nagano Prefecture

Focused :

- Passive Components
- Resistors, capacitors, Inductors, sensors, & modules
- Environment-friendly products

KOA Corporation Worldwide Network

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LTCC technology: Low temperature co-fired ceramic technology

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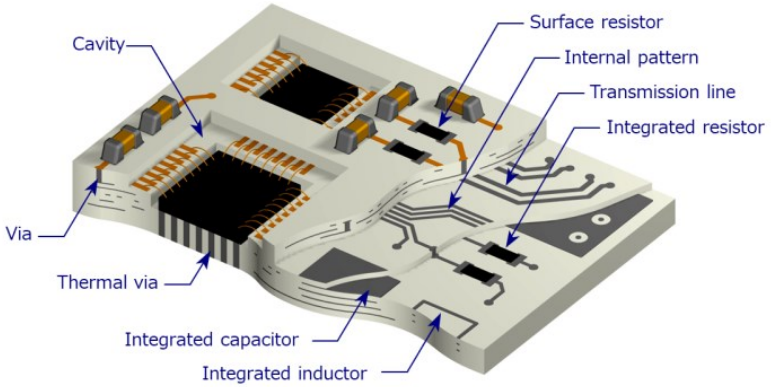
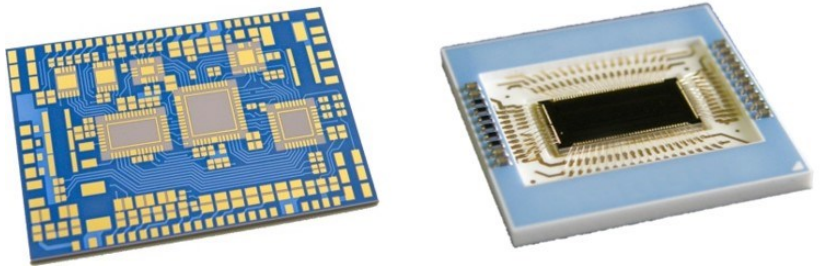
- Multilayer packaging technology with up to 20+ layers
- Moderate firing temperature (below 900 °C)
- Co-firing with highly conductive materials (Ag, Au)
  - Filled via through hole
  - Screen-printed conductor pattern
- Precision cavities and channels
- Thermal vias to enhance heat transport
- Buried components (resistors, capacitors, inductors)





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LTCC technology: Manufacturing process

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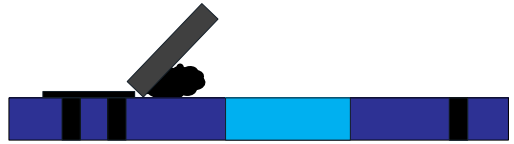
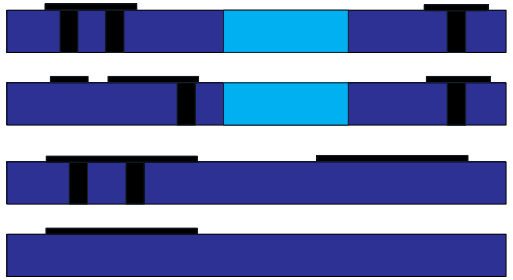
Green tape

Via and cavity formation

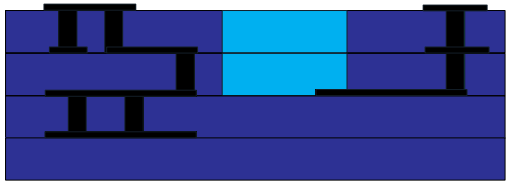
Viafill



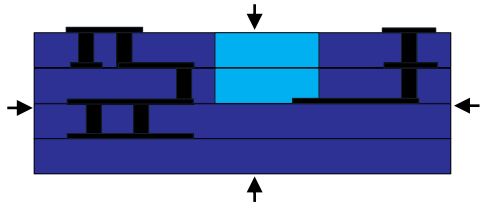
Conductor print



Stacking



Lamination



Firing below 900 °C

Postfire processes
Electrical test
Singulation
Optical inspection

Packaging possibilites and applications

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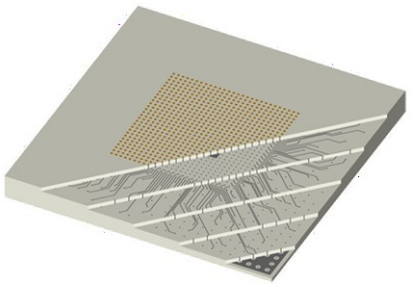
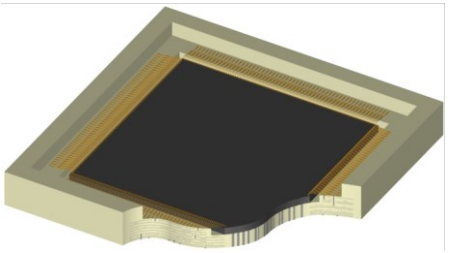
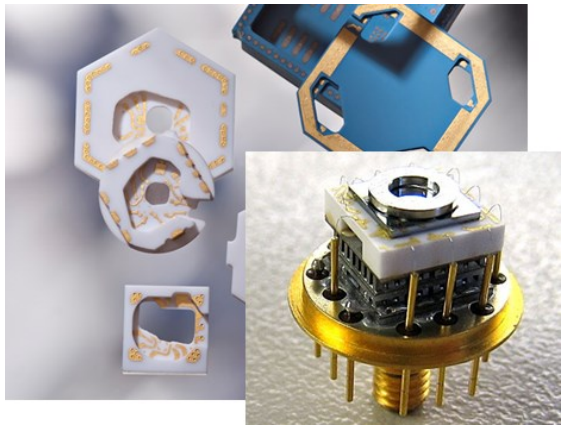
Interposer and packages
- High density through multilayer structure and fine-line print
- CTE close to → Si and GaAs
- Enhanced heat transfer by → thermal vias
- High dimensional accuracy and flatness





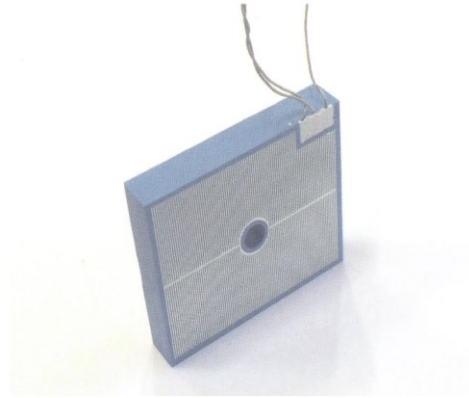
RF modules
- Low-loss ceramic material with a stable dielectric constant
- Low ohm conductors (e.g., Ag)

Harsh environment applications
- Heat and humidity resistance
- Long term stability (no outgassing)



Sensor carrier and fully integrated detector before hermetic sealing

Magnetic filed detector installed at ITER nuclear fusion reactor



One of the Low-Temperature Co-fired Ceramic (LTCC) sensor prototypes manufactured by Via Electronic

➢ Ceramic “PCB” for demanding electronic applications

Embedded functional ceramics in LTCC

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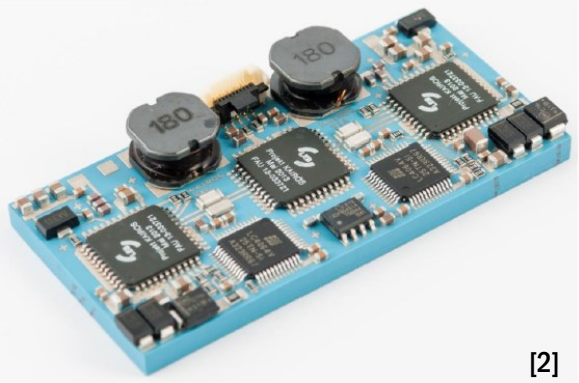
Examples include:

1. High-k dielectrics for buried capacitors[1]
2. Ferrites for transformer or circulator applications [2]
3. NTC materials as temperature sensors [3]
4. ....



[2]

[1] A.H. Feingold, Materials for capacitive and inductive components integrated with commercially available LTCC Systems. Proc. IMAPS 2003
[2] Projekt KAIROS, Keramische Aufbau- und Integrationstechnik für robuste Signal- und Leistungselektronik
[3] M. Hrovat et al. Thick-film NTC thermistors and LTCC materials: The dependency of the electrical and microstructural characteristics on the firing temperature. J. Eur. Ceram. Soc. 29, 15 (2009)
[4] C. Teichmann, J. Töpfer. Sintering and electrical properties of Cu-substituted Zn-Co-Ni-Mn spinel ceramics for NTC thermistors thick films. J Eur. Ceram. Soc. 42, 5 (2022)

Current topic!

- Integration of varistor ceramics into LTCC substrates

  SAPHIR Project: 09/2022 – 08/2025

Embedded functional ceramics in LTCC

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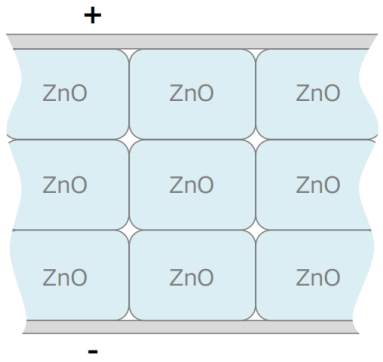
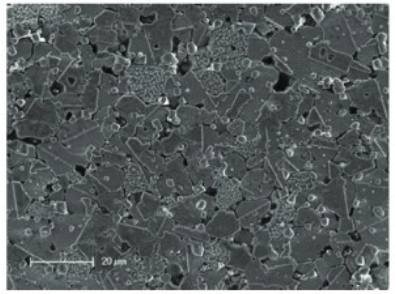
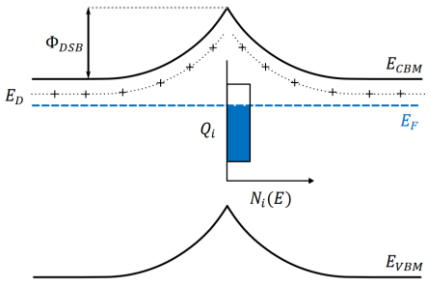
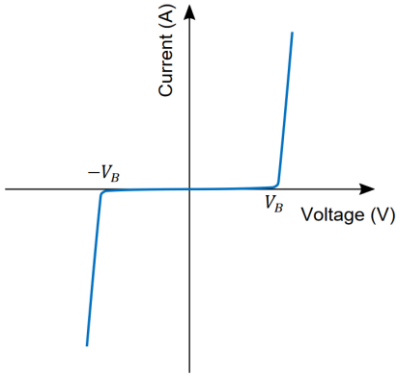
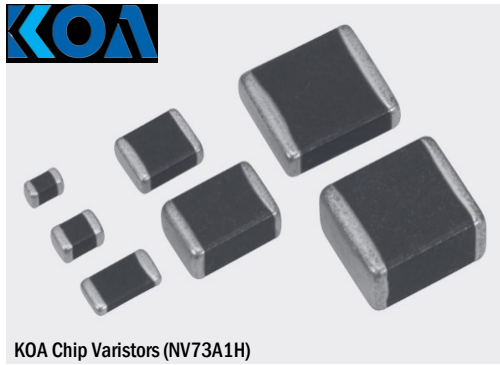
ZnO-based ceramic varistors

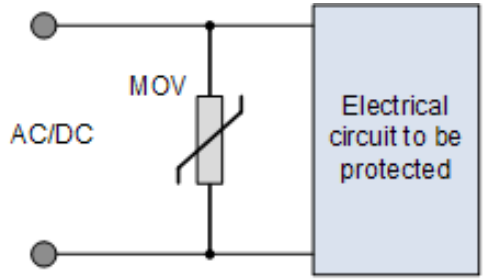









KOA Chip Varistors (NV73A1H)



Voltage surge protection in electronic circuits

- Breakdown Voltage (V_{BR})
- Nonlinear coefficient - Alpha (α)
- Large energy handling capability

Clarke, David R. "Varistor ceramics." Journal of the American Ceramic Society 82.3 (1999): 485-502.

Embedded functional ceramics in LTCC

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Development tasks

1. Reduce the firing temperature of ZnO varistors below 900 °C to allow cofiring with LTCC

2. Development of a screen-printable paste

3. Printing and cofiring of varistor material with LTCC base material and electrode system

Research Project SAPHIR

Fraunhofer IKTS

Embedded functional ceramics in LTCC

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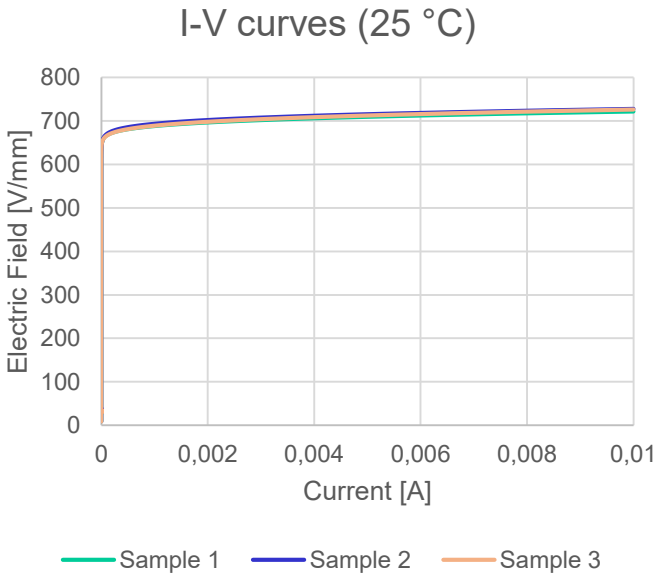
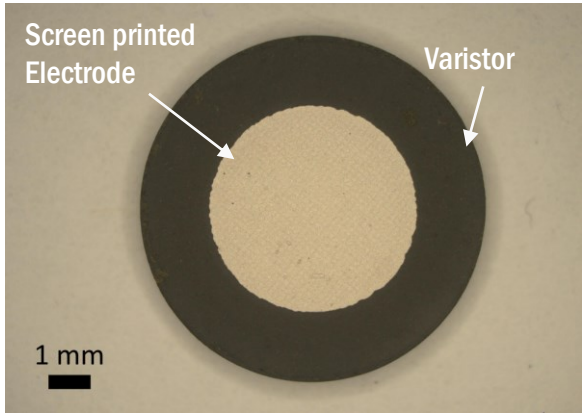
Low-temperature sinterable varistor ceramic

- ZnO+ spinels + BBSZ glass + Additives ⟶ Disc-shaped samples fired at 900 °C





Parameters	Sample 1	Sample 2	Sample 3
V_{BR}	688 V/mm	693 V/mm	689 V/mm
Alpha (α)	72	66	67

- Low sintering temperature (900 °C)
- Retained Varistor behavior
- Clearly defined breakdown voltage (V_{BR})
- Non-linear coefficient: Alpha (α) > 50

Embedded functional ceramics in LTCC

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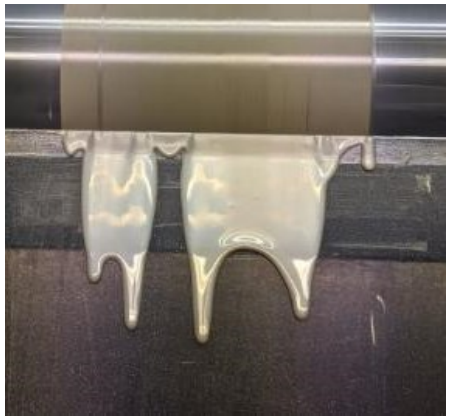
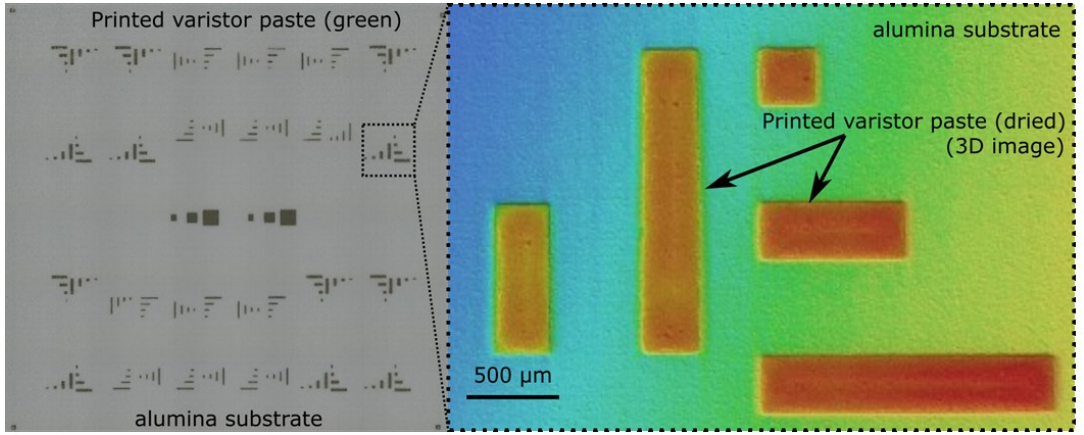
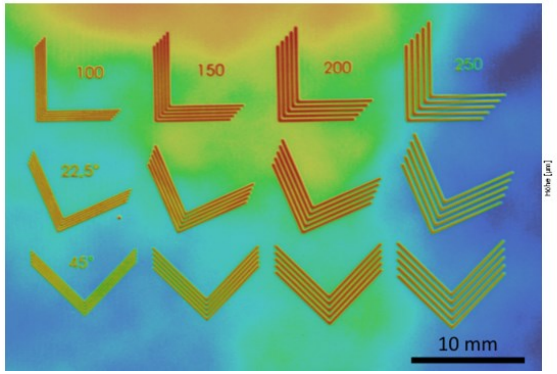
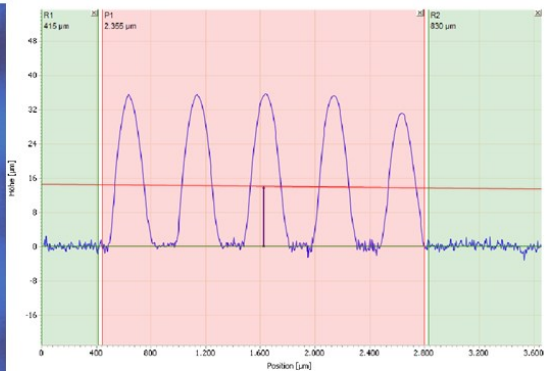
Screen printable Varistor paste and its electrical behavior

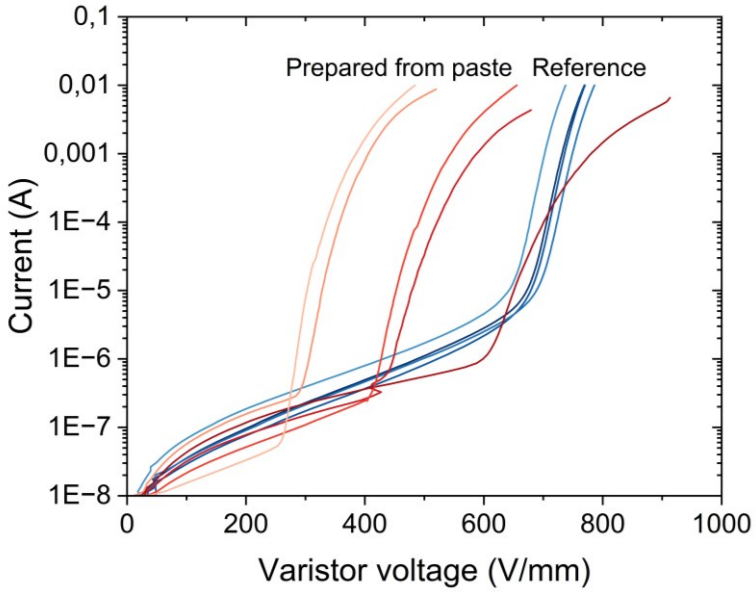








Printing behavior on Alumina



Varistor behavior degraded, but clearly demonstrated

Fraunhofer IKTS

Embedded functional ceramics in LTCC

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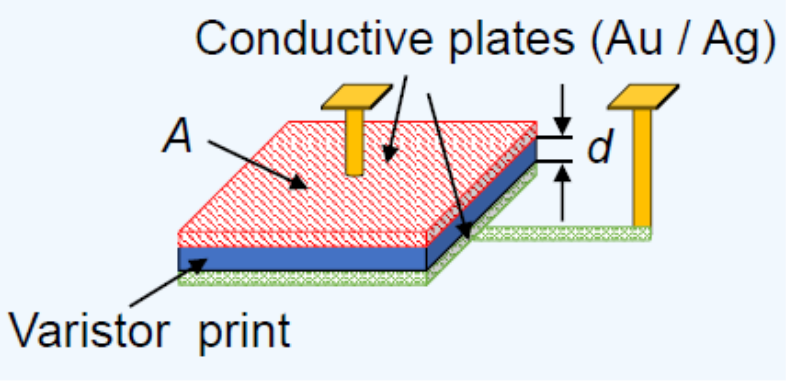
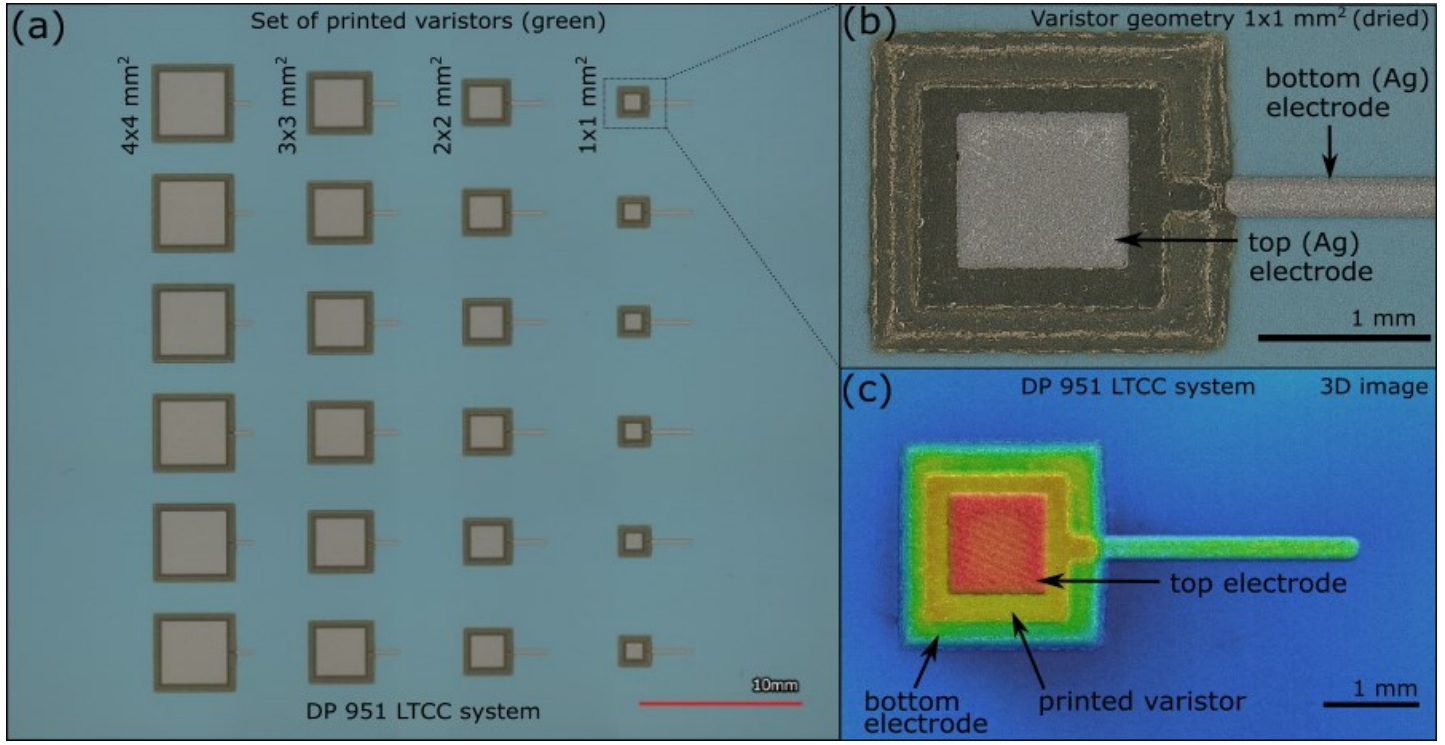
Design and screen printing





Tested metallization: Ag, Ag/Pd, Au

Printed varistor elements after drying, before lamination

Embedded functional ceramics in LTCC

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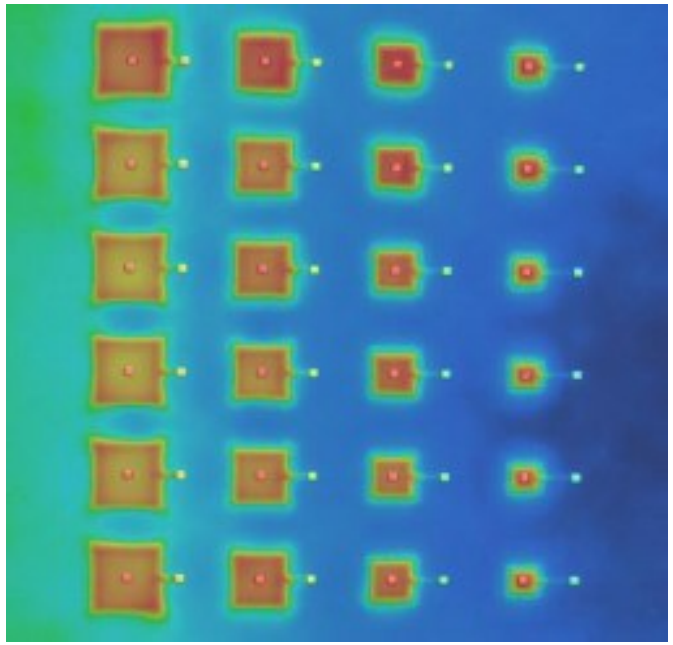

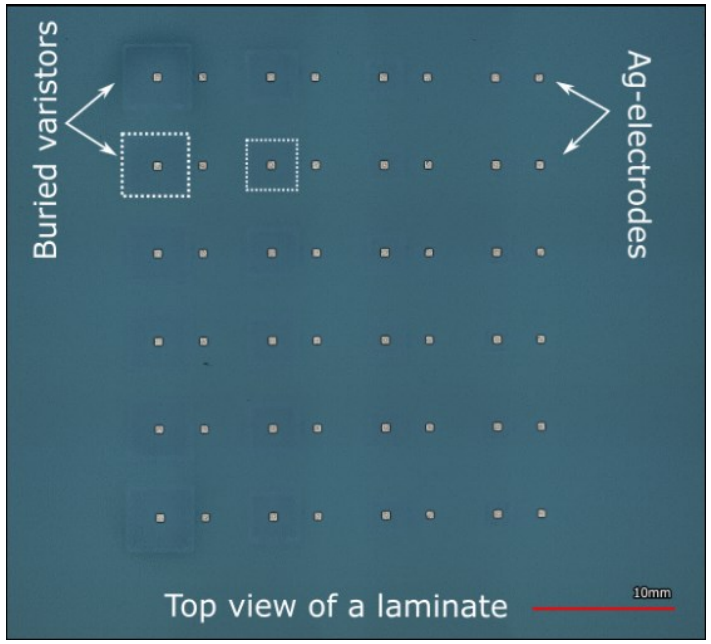

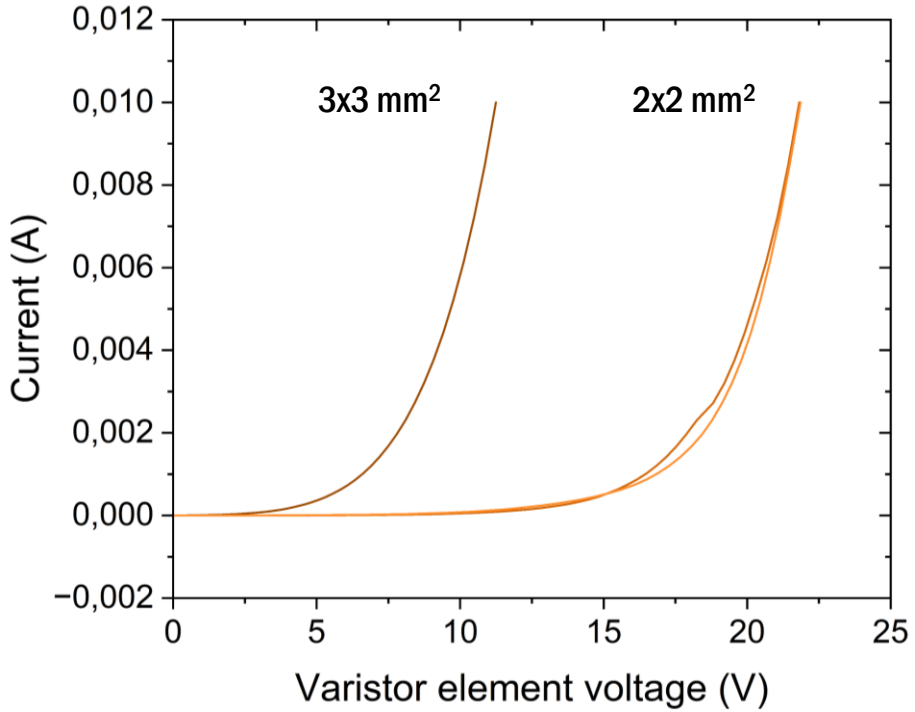

Parameter	Au - 2x2 mm²	Au - 3x3 mm²	Ag - 2x2 mm²	Ag - 3x3 mm²
$\alpha_{0.1/1mA}$	25.7	24.5	5.0	3.5
I_L [A]	4.7E-06	6.6E-06	4.5E-04	3.3E-04

LTCC technology have more to offer..

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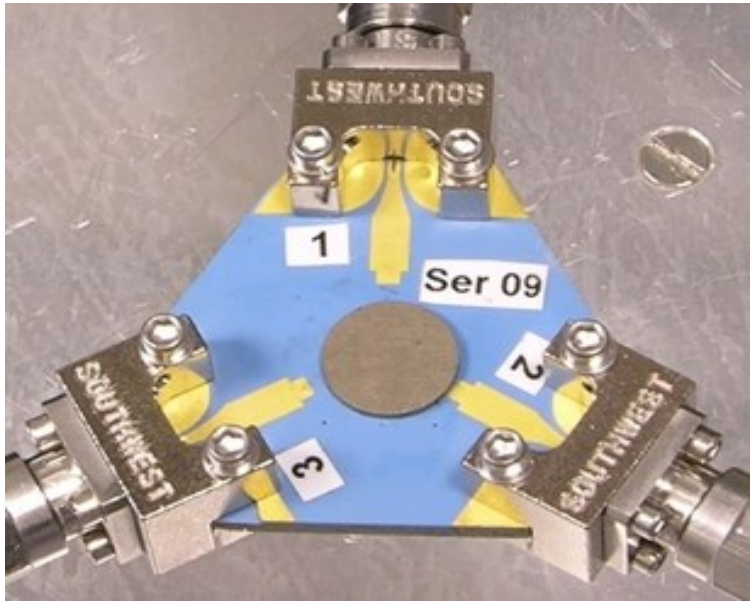
LTCC integrated circulator

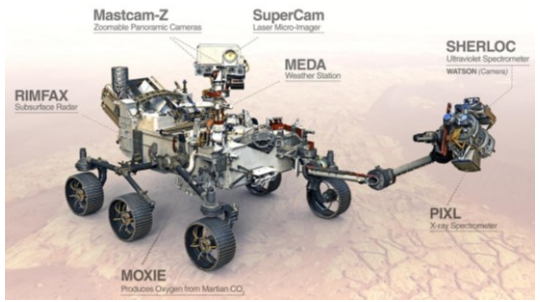


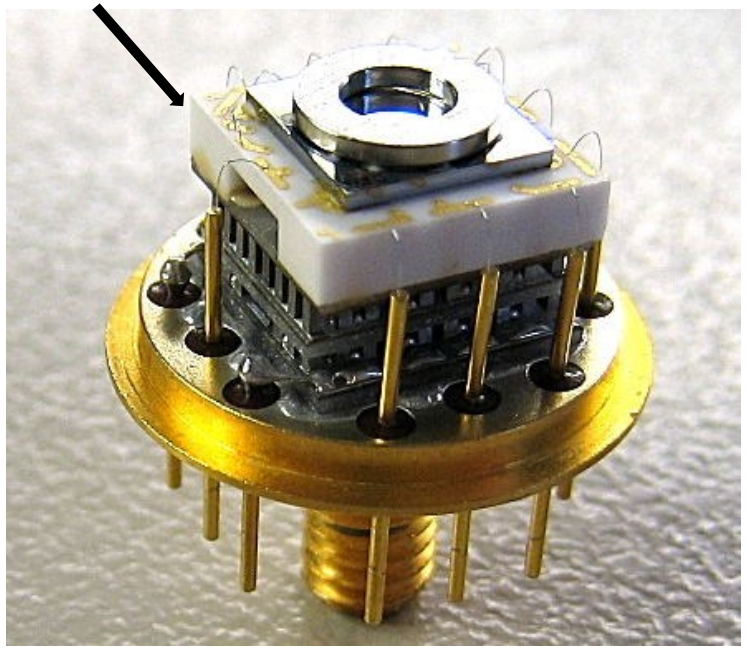
Projekt INFERSAT

- 3D integration technology
- Satellite communication
- Suitable for radar systems

EDX - detector

Mars mission „Curiosity“ and „Perseverance“





EDX – Sensor carrier for KETEK

LTCC technology have more to offer..

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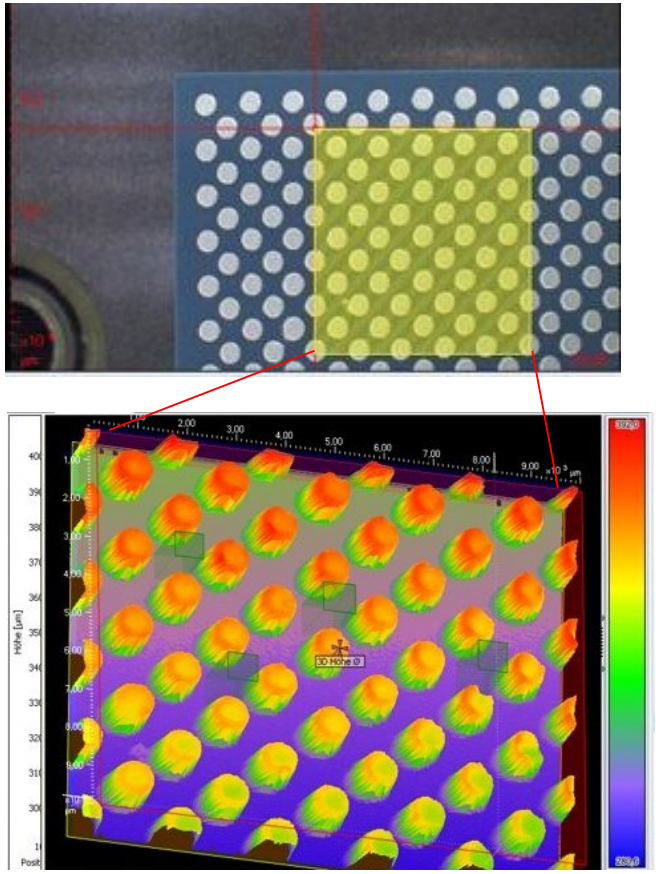
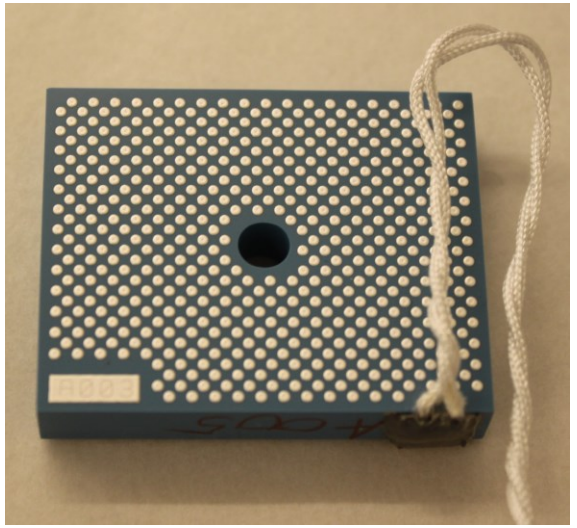
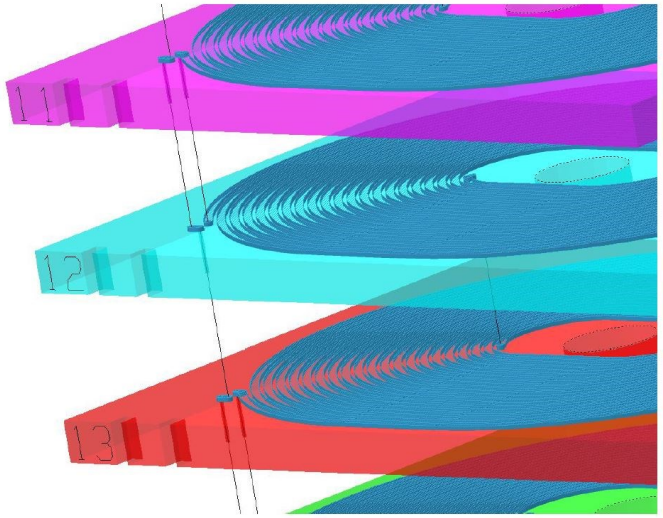
Application: Nuclear Fusion Reactor / magnetic field sensor (ITER project)



Laser scan measurement: avg. (printed) dot height of *ca.* 120 µm



- Sensor module with Ag-wire interconnection
- Printed metal dots on top
- Operating temperature 300 – 400 °C



- 38 layers each layer with
- 20 high precision windings
- Connected with electrical vias

https://fusionforenergy.europa.eu/news/europe-delivers-magnetic-sensors-for-iter-vacuum-vessel/

… and there are ways for electronic packaging

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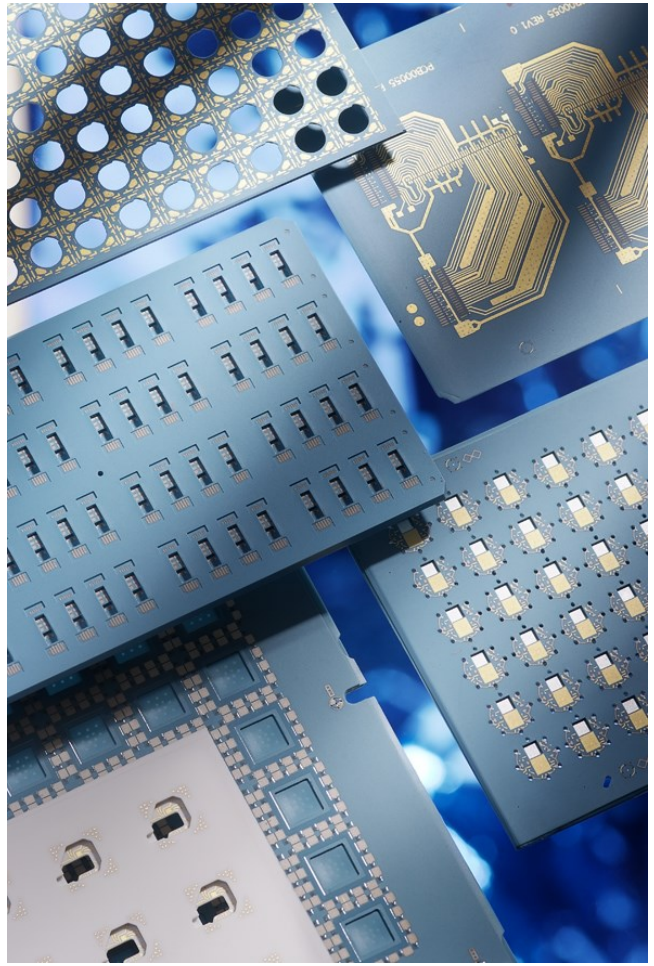
LTCC technology

- Low permittivity tolerance
- Good thermal conductivity
- Low coefficient of thermal expansion or TCE (adapted to silicon and GaAs)
- Highly suited for multilayer modules
- Integration of cavities and passives such as R-, L-, and C-components



https://via-electronic.de/

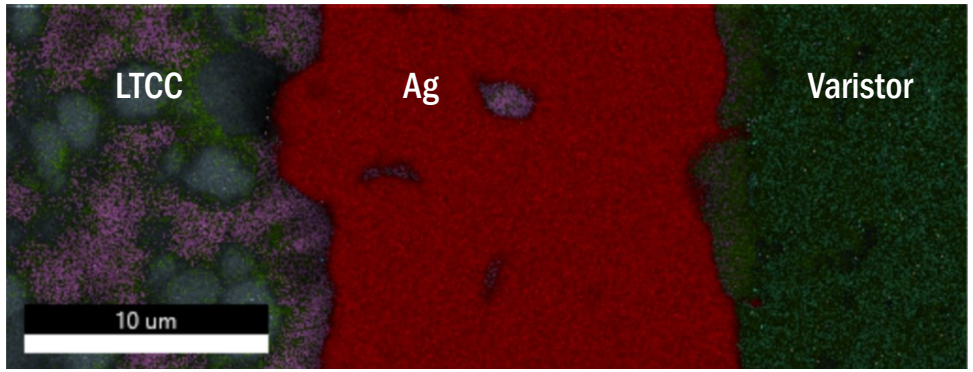
Thank you for your attention!

Challenging to realize our 2030 vision

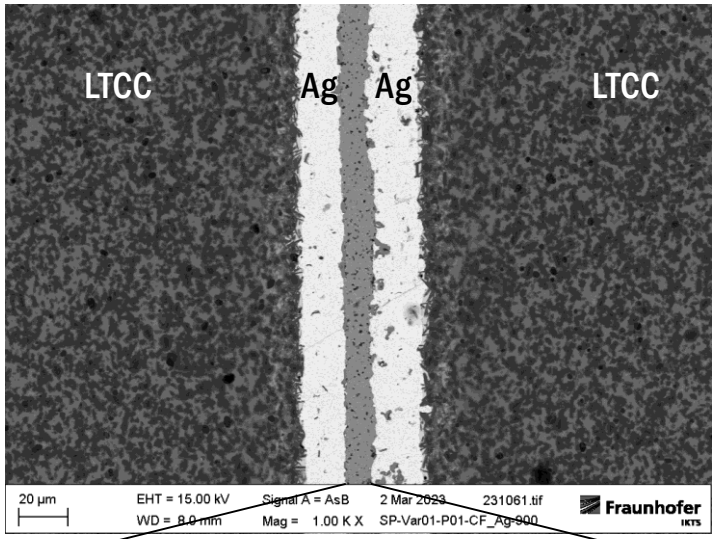
Contact: q.muhammad@via-electronic.de

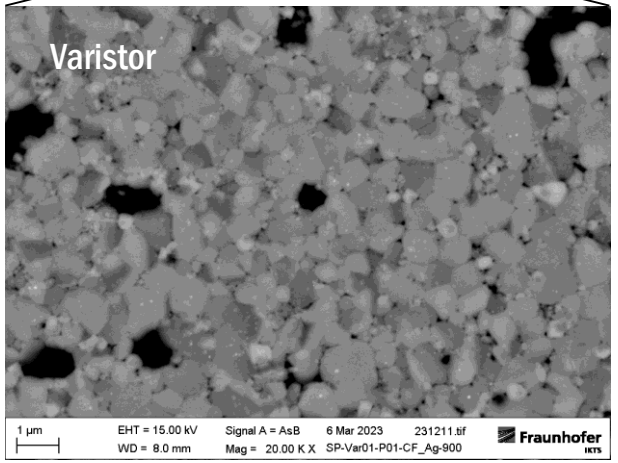
- **http://www.koaglobal.com(JAPAN)**
- **http://www.koaspeer.com(USA)**
- **http://www.koaeurope.de (EUROPE)**
- **http://www.via-electronic.de(HERMSDORF, Germany)**

Microstructure



EDX superposition
of different elements





SEM of varistor shows ZnO grains and most likely the Sb spinel,
but no Bi-rich phase