Fraunhofer IKTS

Fraunhofer Institute for Ceramic Technologies and Systems IKTS

Dr. Lars Rebenklau

Funktionalisierte keramische Komponenten – potenzielle Anwendungsfelder

80. Treffen des sächsischen Arbeitskreises Elektroniktechnologie

29.03.2023, IKTS Dresden

Thick-Film Technology

A Way for High Complex Ceramic AM Components

Agenda

- **Introduction of Thick-Film Technology**
- **Thick-Film and Its Ingredients**
- **Functionalization of Ceramics**
- **Summary and Outlook**

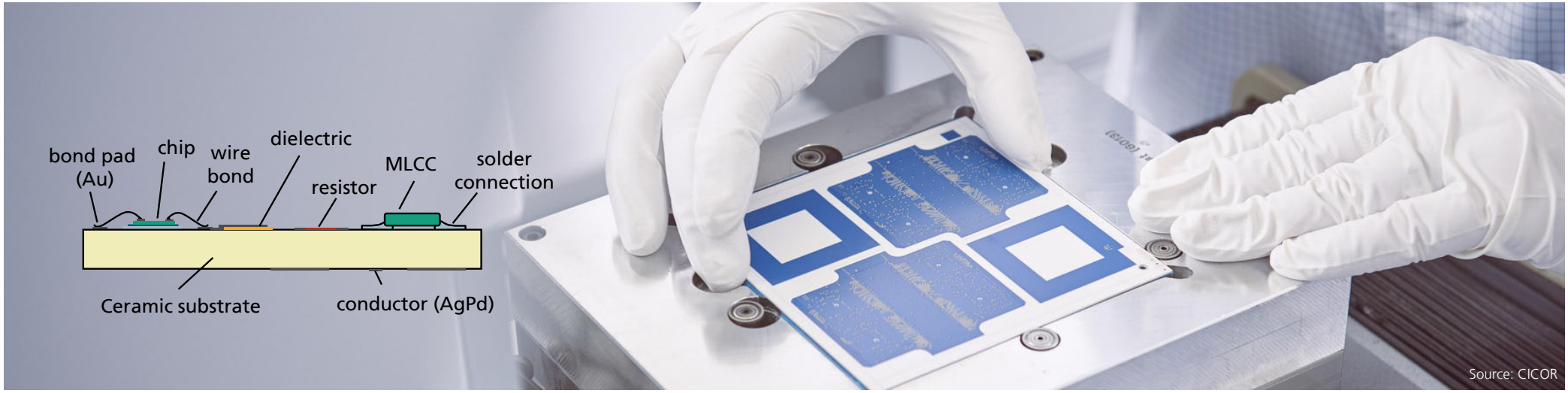
Fraunhofer IKTS

Introduction of Thick-Film Technology

Ceramic Thick-Film and Multilayer Technology

Thick-Film based Hybrid Circuit Boards

Electronic modules consisting of different components, materials and manufacturing technologies, integrated on a sintered ceramic substrate



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

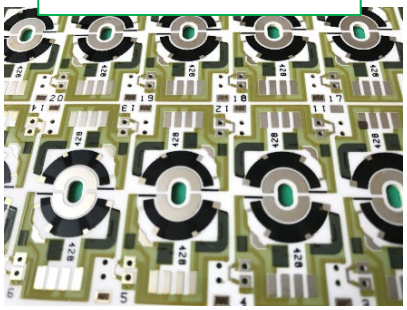
Industries

- Industrial and Power Electronics
- Automotive
- Sensors

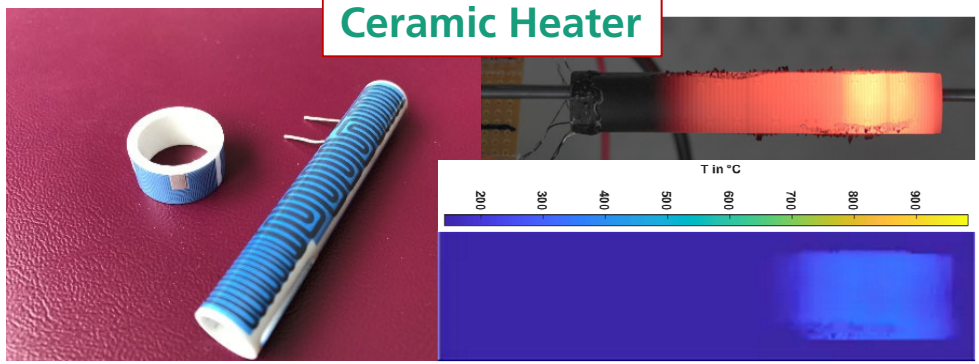
Introduction of Thick-Film Technology

Applications

Potentiometer



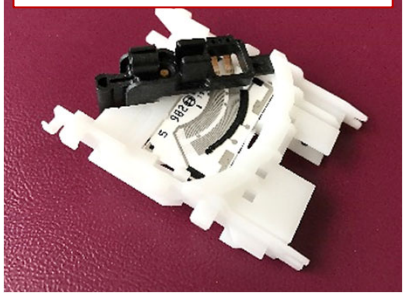
Ceramic Heater



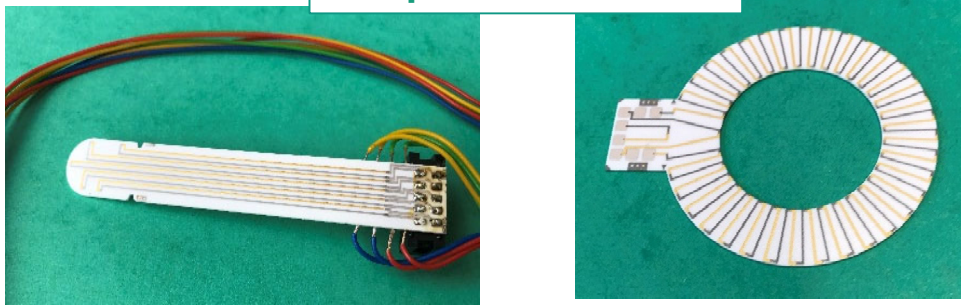
Functionalized Ceramic Structural Component

Quelle: Scheithauer (IKTS)

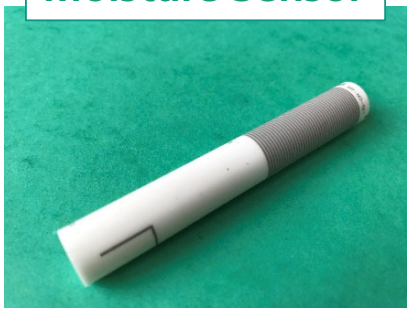
Fuel Level Sensor



Temperature Sensor



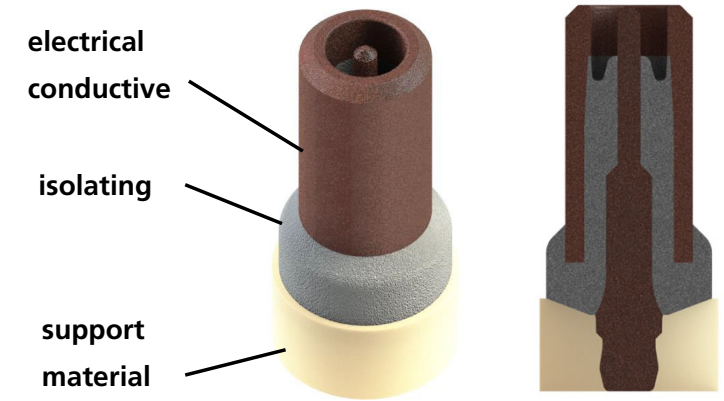
Moisture Sensor

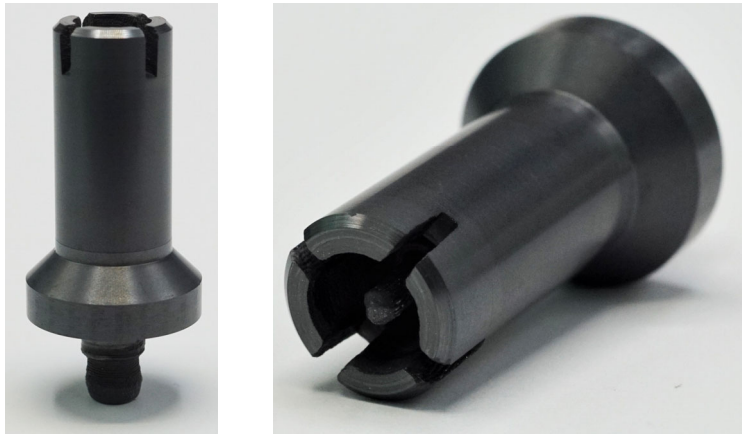


Ceramic Additive Manufacturing

CerAM MMJ of Si_3N_4-$MoSi_2$

- integration of electrical igniter in insulating ceramic component
- simultaneous manufacturing by CerAM MMJ combination of two mixtures of Si3N4 + MoSi2
- higher degree of freedom concerning integration of igniter in ceramic component
- CerAMfacturing + material expertise (thermal co-processing)



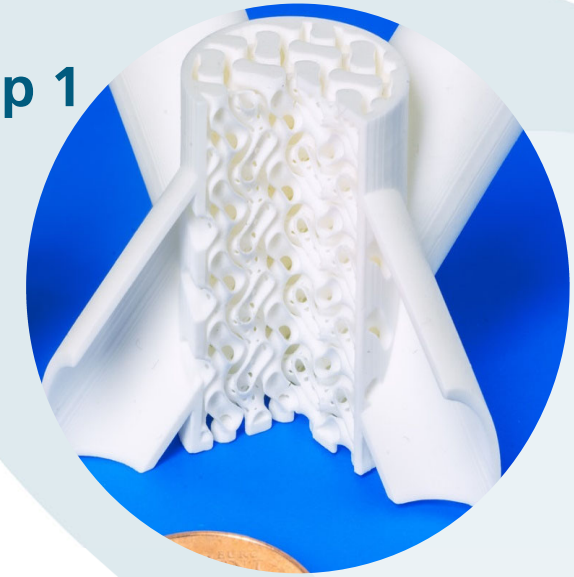


Full-Ceramic Igniter (Student Thesis Justin Ziener)

Thick-Film Technology for Functionalization of Ceramics

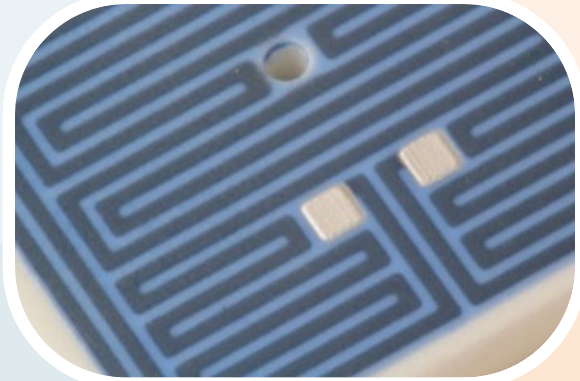
A Way for High Complex Ceramic AM Components

Step 1



CerAMfacturing

Realization of ceramic body using AM



Step 2

Thick-Film

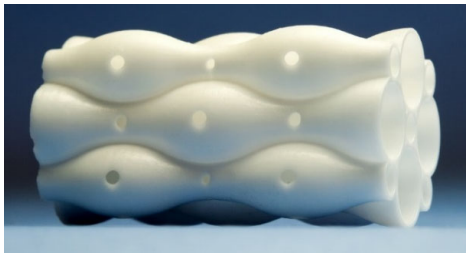
Functionalization using Thick-Film Technology

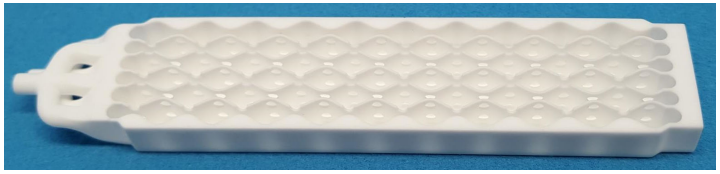
High-dynamic Thermal Cycler for Technical and Medical Application

Step 1 - CerAMfacturing - Additive Manufacturing of ceramic-based components

AM - technologies @ IKTS-DD

- Powder bed-based
  - CerAM BJ (Binder Jetting)
- Suspension-based
  - **CerAM VPP (Vat Photo-Polymerization)**
  - CerAM MMJ (Multi-Material Jetting)
  - CerAM FFF (Fused Filament Fabrication)
- AM of polymeric templates
  - CerAM Replica

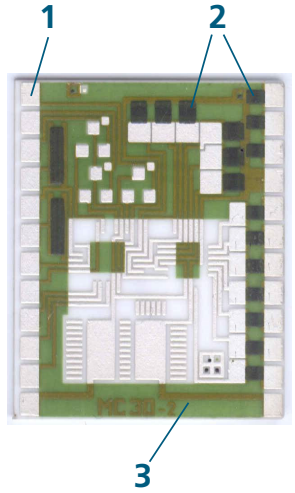




Thick-Film and Its Ingredients

Components of Thick-Film Pastes – Characteristics of Fired Layer

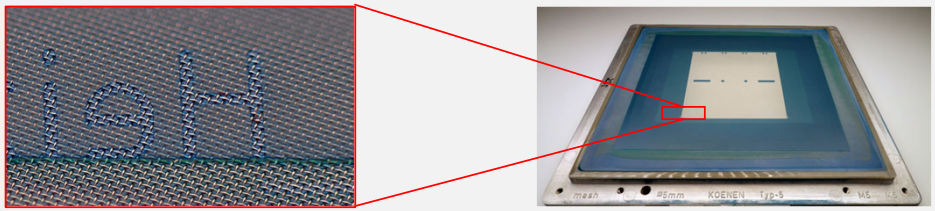
Functional component	Organic binder	Solvent	Glass
Metal, metal oxides, glass, ceramics	Ethyl cellulose, Acetate, …	Terpine oil	Borosilicate glass, Bismuth containing glasses, …
Percentage by weight			
(30 ... 70)%	(12 ... 25)%		(10 ... 20)%
Function / influence			
Determines the electrical properties of the final layer 1. **Conductor** → metal (Ag, Au, Cu, AgPt, AgPd, AuPt, AuPd) 2. **Resistor** → metal oxide 3. **Insulator** → glass, ceramic	■ Rheological paste properties ■ Mechanical stability of the dried paste	Rheological paste properties	Determines the mech. stability and adhesive strength of the fired layer

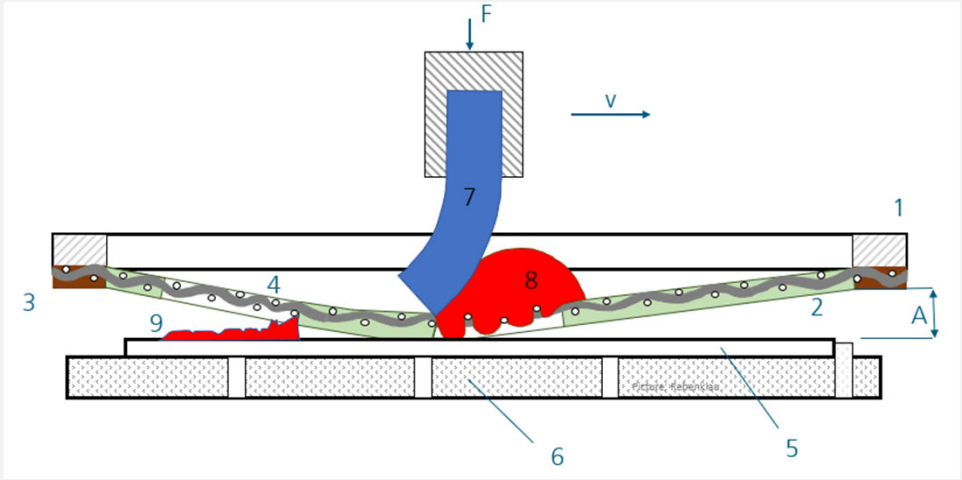


Thick-Film Production Process

1. Printing Technologies – Applying the Paste

Form based printing technology



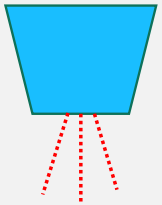


Digital printing technology

Inkjet-printing

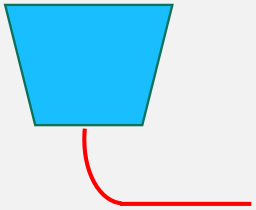
inks

Aerosol-printing



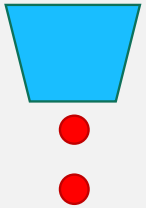
inks, low viscosity pastes

Micro-dispensing



pastes

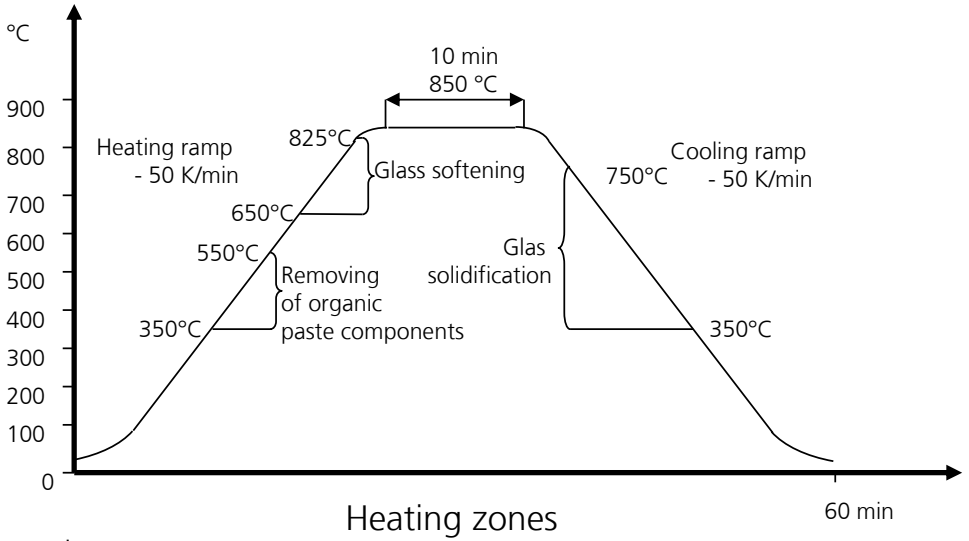
Jet-printing

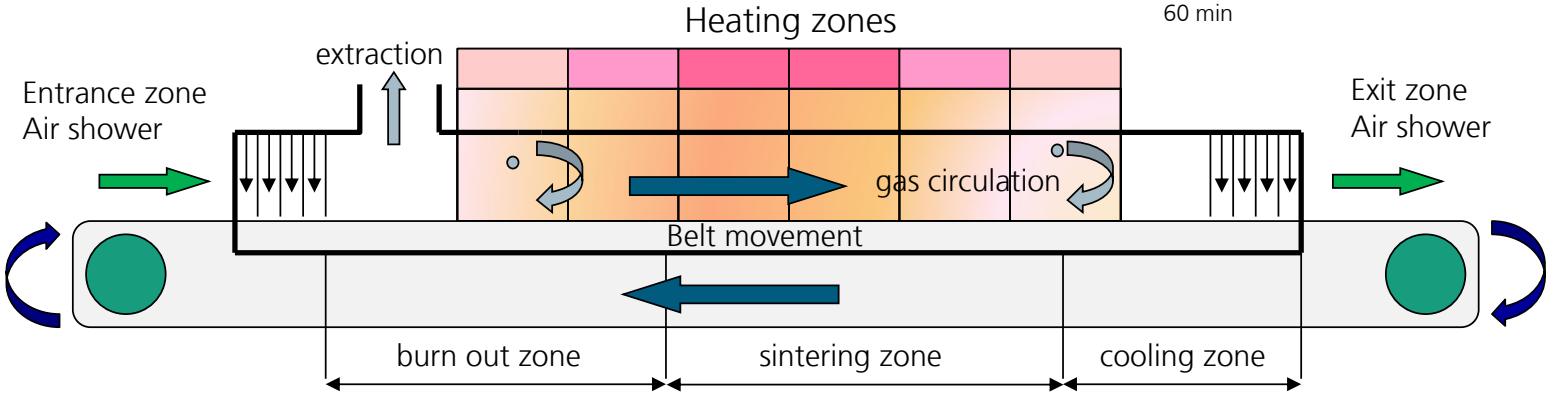


pastes

Thick-Film Production Process

2. Heat Treatment - Drying and Firing the Paste

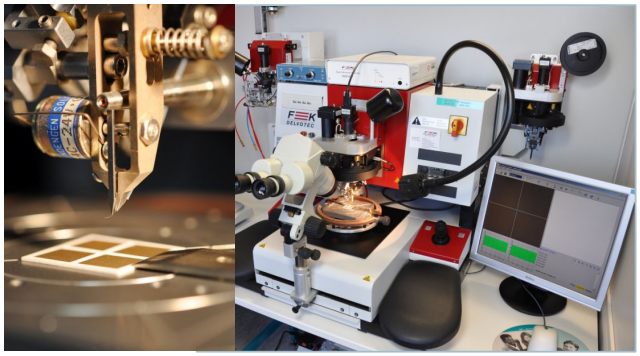




Thick-Film Production Process

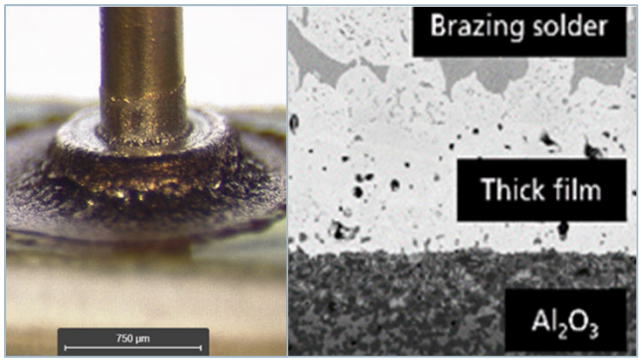
3. Applying Electrical Contacts – Wire Bonding, Brazing and Resistance Welding

Wire bonding



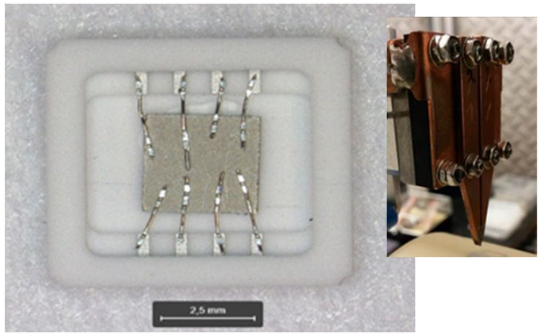
- Max. 300 °C
- Ball-wedge and wedge-wedge bonding
- Al, Ag, Au wires
- Thin-/heavy wire

Brazing



- Max. 600 °C
- Ag-based brazing of Kovar lead frames on thick-films
- Mechanical characterization at application related temperatures

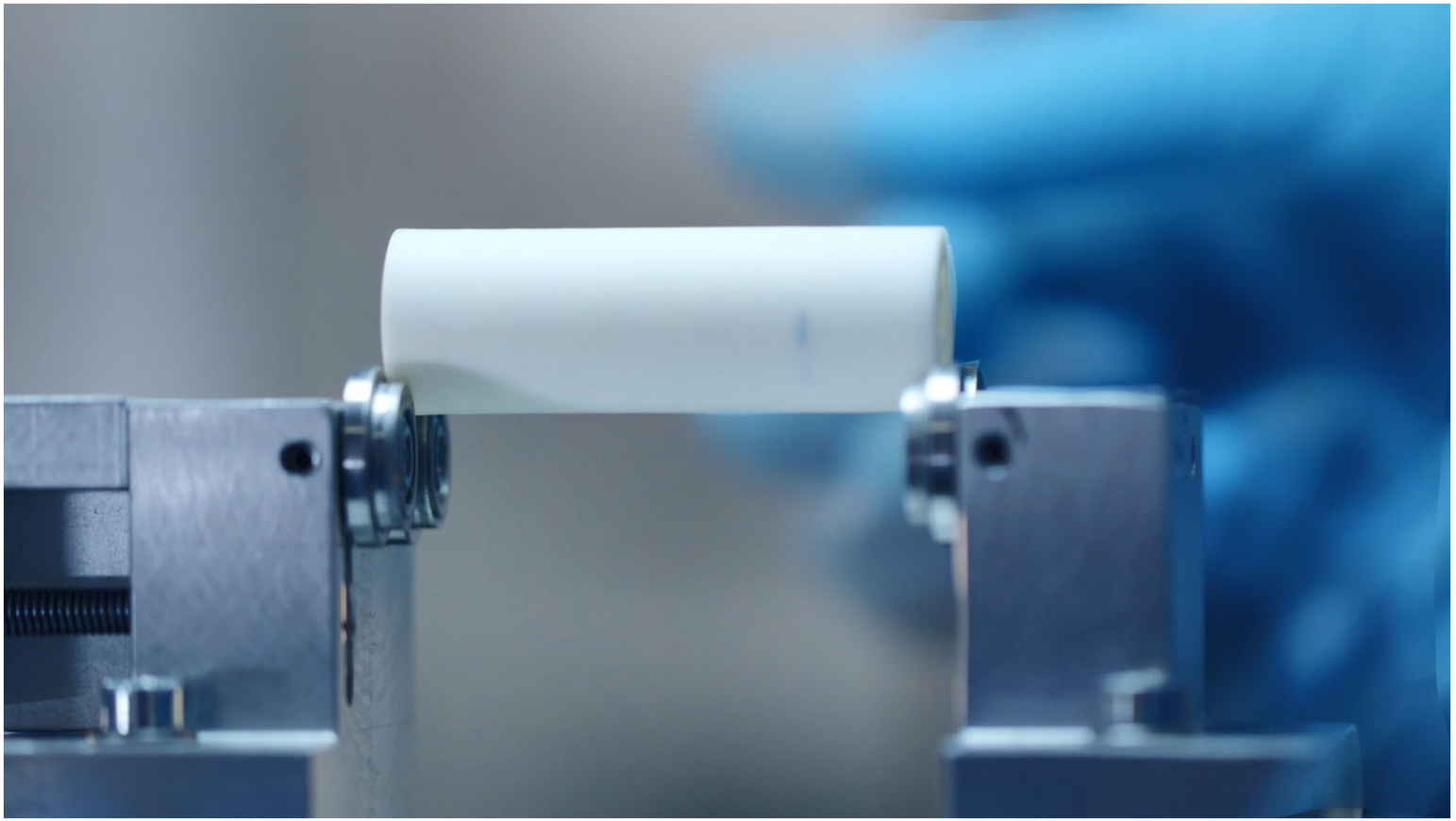
Gap Welding



- 600 … 800 °C
- Gap welding on thick-films
- Pt, Au, Ni – wires
- Mechanical characterization at application related temperatures

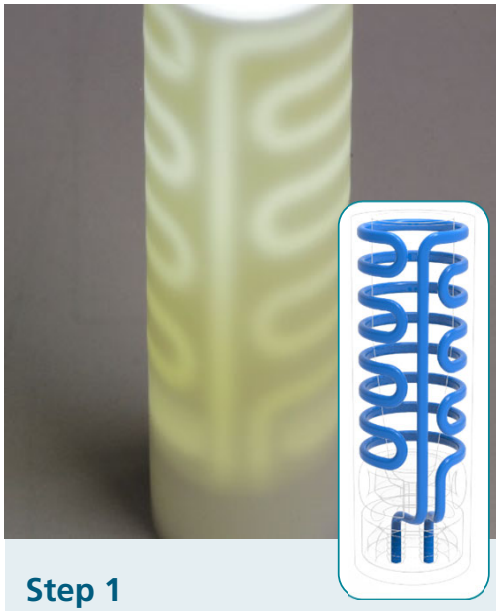
Thick-Film Production Process

Tubular Substrates

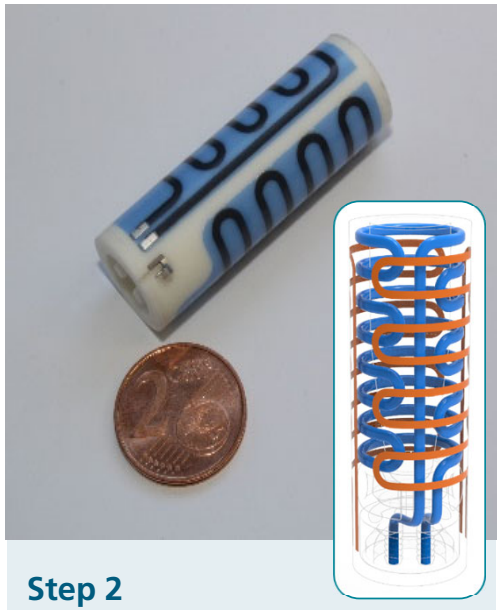


Research Project: High-dynamic Thermal Cycler for Medical Application (1)

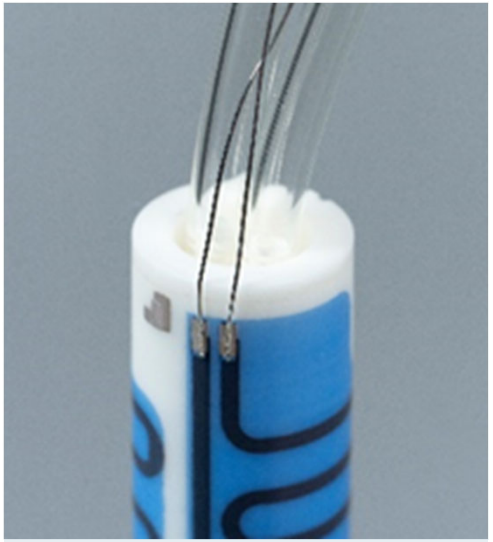
Thermal Cycler for Technical and Medical Application on tubular substrates → Example µPCR



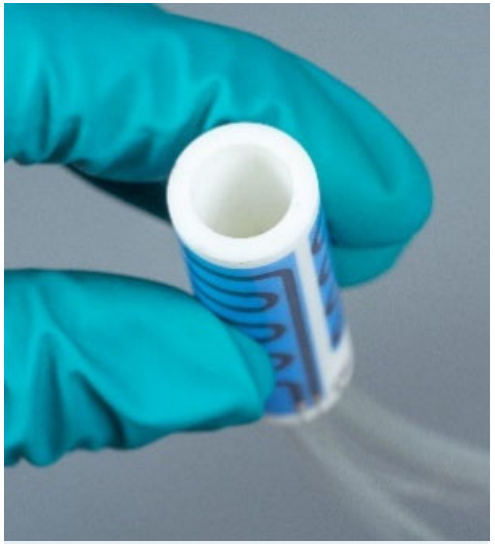
Step 1
CerAMfacturing of Components



Step 2
Functionalization of ceramic components with thick-film technology



Step 2 + 1
Hybridization (assembling of additional components and electrical connections)



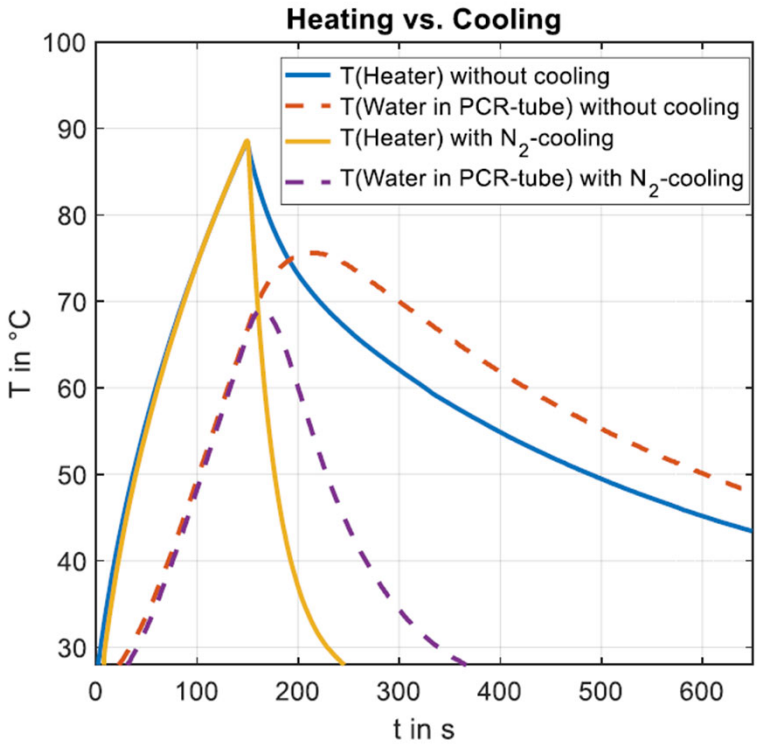
Step 2 + 2
Characterization and use of the components

Research Project: High-dynamic Thermal Cycler for Medical Application (2)

Design study µPCR Module

Heating: 14 V (max. temperatures: 100°C)
Cooling:
without active cooling: 5 minutes
with nitrogen-cooling: < 40 seconds

Source Images for visualization: L. Opeskin, TU Dresden

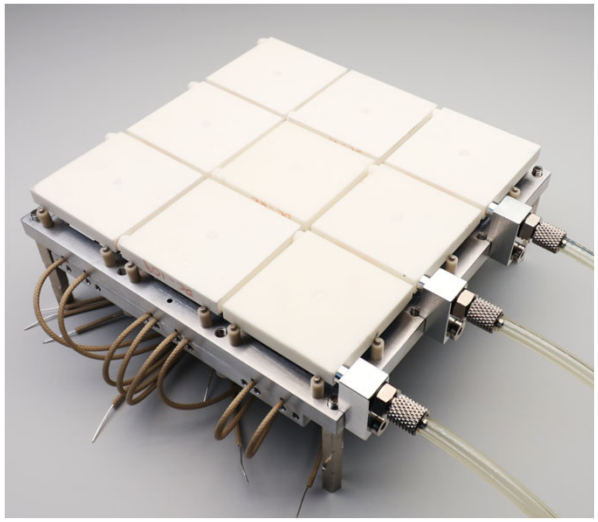


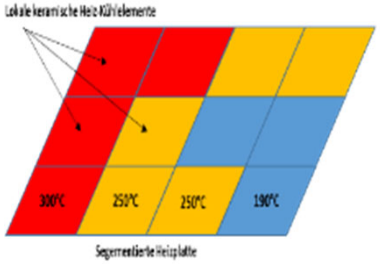
Research Project: Thick-Film Functionalization of AM Ceramics (1)

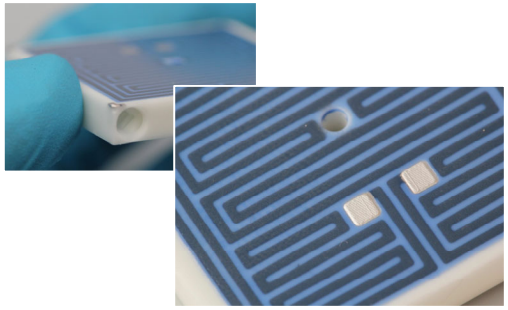
DynaCool – Advanced Ceramic Temperature Cycling System (ZIM funding: 16KN054345)

Research Objective:

- Matrix of controlled heaters for soldering process of printed circuit boards with metal inlay
- High heating and especially cooling rates
- Ceramic container with heating and cooling features , i.e. integrated cooling channels
- Targeted Material: Alumina (Al_2O_3)







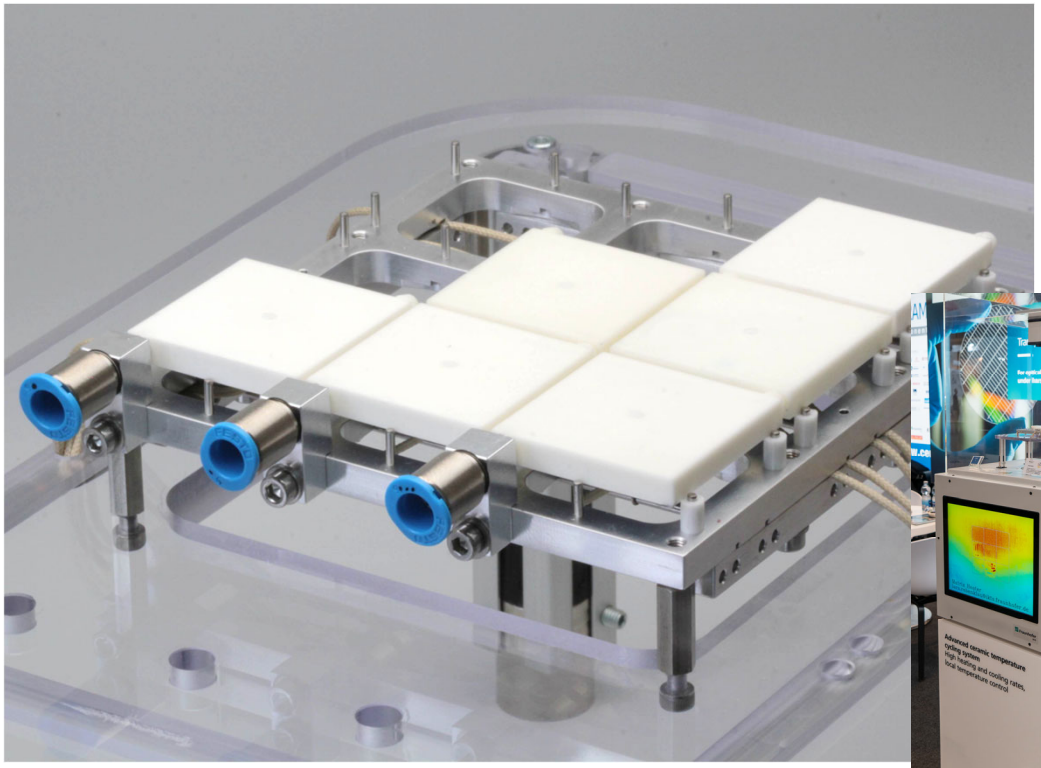
Funding:

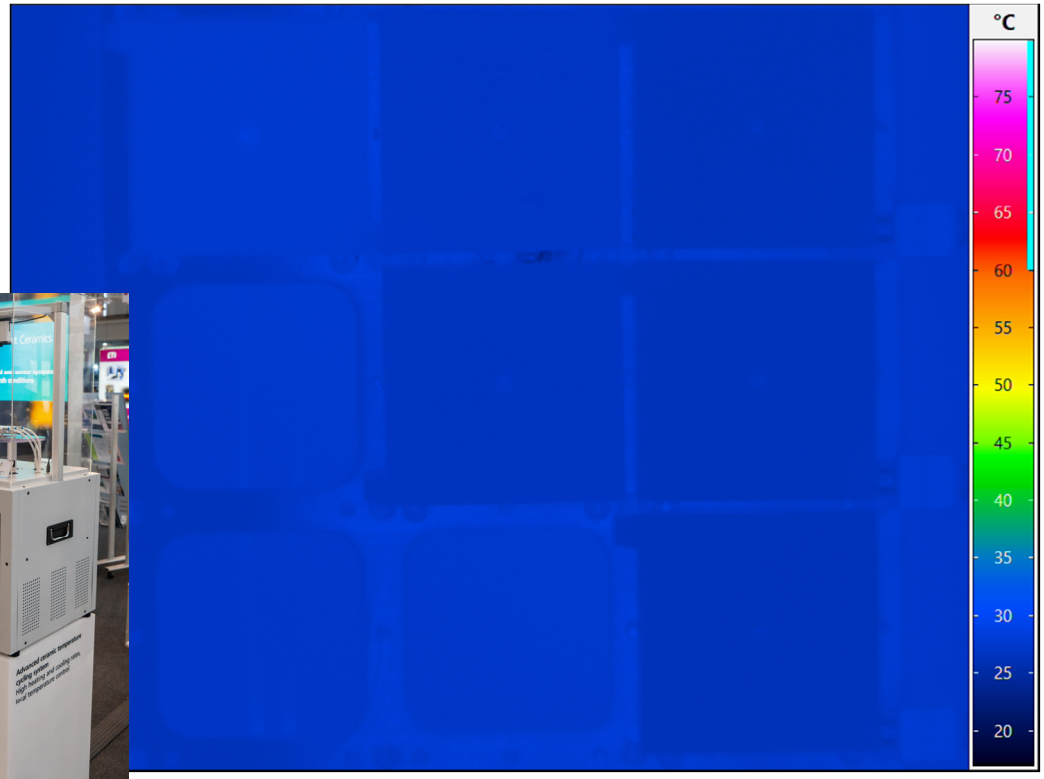
Bundesministerium für Wirtschaft und Klimaschutz

ZIM Zentrales Innovationsprogramm Mittelstand

Research Project: Thick-Film Functionalization of AM Ceramics (2)

DynaCool – Advanced Ceramic Temperature Cycling System (ZIM funding: 16KN054345)





Thick-Film Technology

Advantages vs. Disadvantages of Sequential Build Up in Comparison to “Real” Multi Material Printing

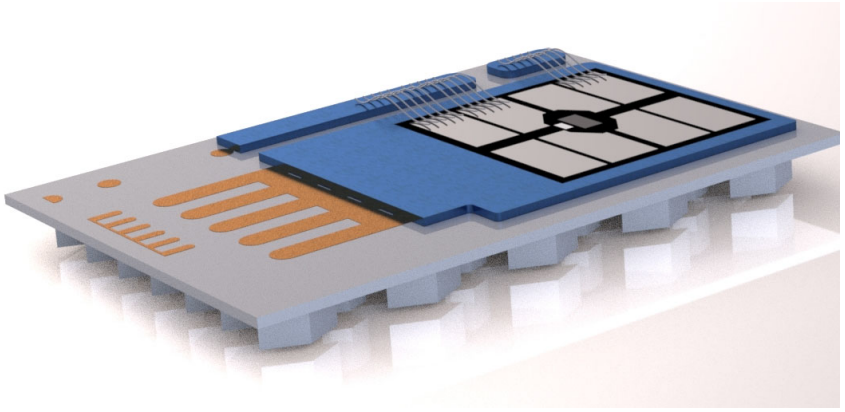
Advantages	Disadvantages
Thick-Film technology is a well-known technology and established in industry	Two-step process flow
Commercial paste systems are available	Not all geometries are possible
Thick-Film layers can be assembled	Functionalization is only possible on the surface
Different functionalities can be realized	Thermal processes are required
The results are in principle transferable to other materials (plastics, metals)	

→ Due to the advantages, a short-term implementation is possible for selected applications

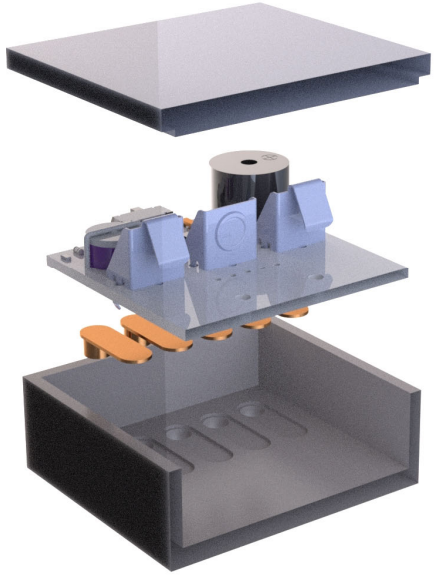
Future of Thick-Film Technology

Possible Development Directions ….

Specially adapted ceramic chip carriers for power electronics



Functionalized ceramic housings for high temperature sensor technology applications

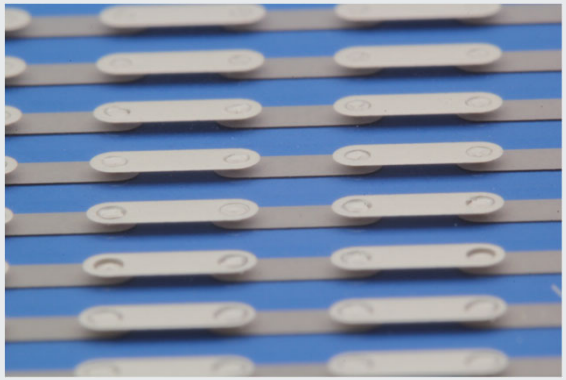
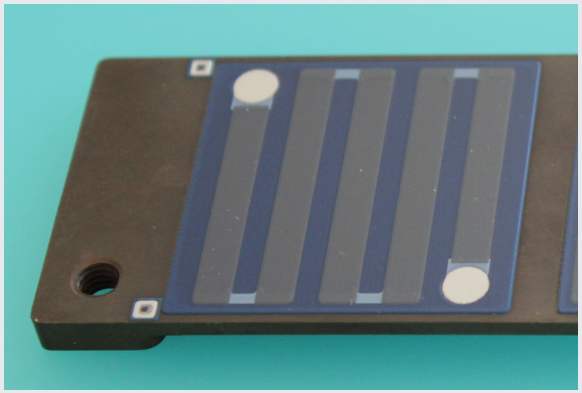


Images: M. Kirchhoff

Thick-Film Technology – A Way for High Complex Ceramic AM Components

Outlook - Is the Technology Transferable to other Material Systems (Plastics, Metals)?

In general: YES … BUT: it depends → on the used paste!

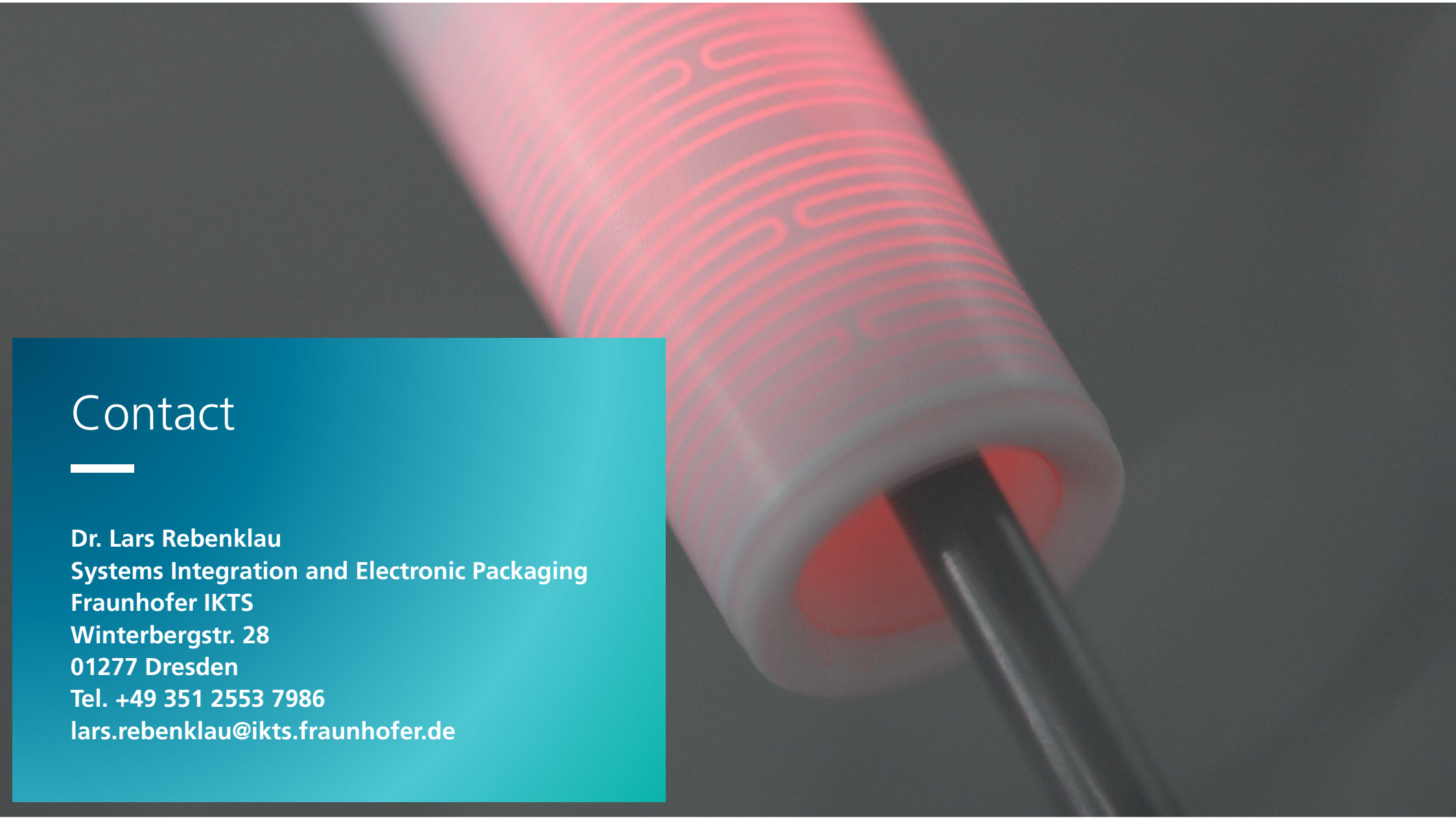
Polymer	Glass	Steel
		
Polymer Thick-Film pastes with process temperatures of < 300 °C	Modified Thick-Film pastes with firing temperatures of 500 °C	Thick-Film pastes with an insulating start layer

Summary

- An overview of the Thick-Film technology was presented in the contribution
- Thick-Film technology can be used to functionalize additively manufactured ceramic Al_2O_3 structural components
- The advantages of the respective technologies can be combined symbiotically and the combination of the two processes opens up various possibilities for the production of functionalized ceramic components
- Different application examples were discussed
- The results of the two-step processing can be principally transferred to other material groups such as plastic, glass or metal

For further information on the functionalization of ceramic components (PDF document, German)

For further information on electrical characterization (website, English and German)



Contact

Dr. Lars Rebenklau
Systems Integration and Electronic Packaging
Fraunhofer IKTS
Winterbergstr. 28
01277 Dresden
Tel. +49 351 2553 7986
lars.rebenklau@ikts.fraunhofer.de