

Low Temperature Co-fired Ceramic (LTCC) Technology: General Processing Aspects & Fabrication of 3-D Structures for Micro-fluidic Devices

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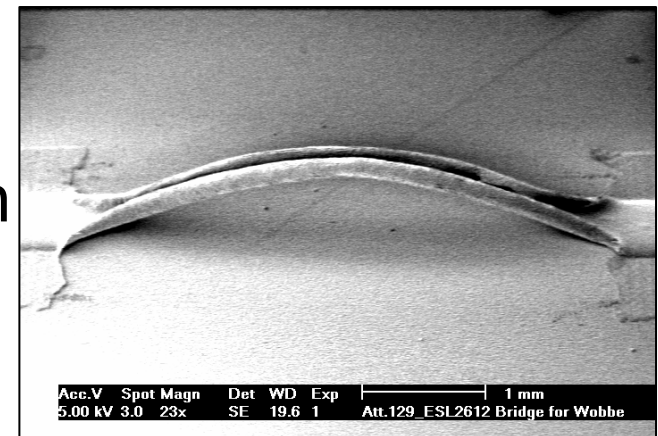
**Swiss Federal Institute of Technology, Lausanne - EPFL
Laboratory for Production of Microtechnologies - LPM
Thick-film Group**

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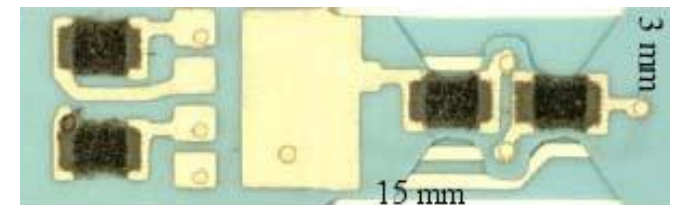
PURPOSE OF THE PRESENTATION

➔ Introduction to LTCC Technology:
General aspects



➔ Major problems encountered with
commercially-available products:
Solutions developed

➔ Fabrication of 3-D structures for
sensor and micro-fluidic applica-
tions: *C-based sacrificial layer*



AN OVERVIEW

LTCC for Wireless Applications

- Base Station Amplifier Modules
- Transmitters and Receivers
- Handset Power Amplifiers
- Low Noise Amplifiers
- Voltage Control Oscillators
- Mixers
- Filters
- Power Splitters and Combiners
- Matching Networks



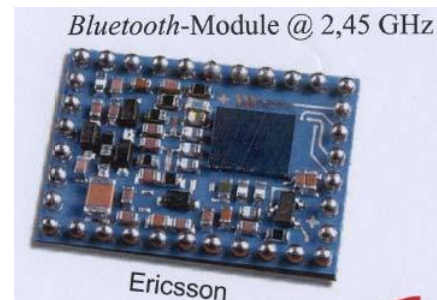
Source: Prisma/Binghamton University

EPCOS FRONT END MODULE

- Key component in new Nokia mobile phone architecture
- Integrates duplexer, switching, LC and SAW filters
- Analysis of LTCC integrates passives and SAW filter packages

LTCC in the Automotive Industry

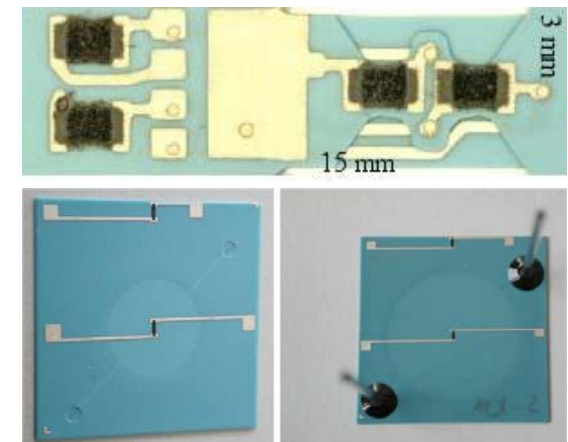
- Engine Management Systems
- Gearbox Management Systems
- Anti-Lock Braking Systems
- Global Positioning Systems
- Gas Discharge Lamp Controllers
- Ignition Modules
- Sensor Modules



LTCC in Military & Space Environments

- Transmitters/Receivers
- Phased Array Radar
- Amplifiers
- Filters
- Converters
- Power Drivers
- Sensors

Source: C-MAC Micro-technology

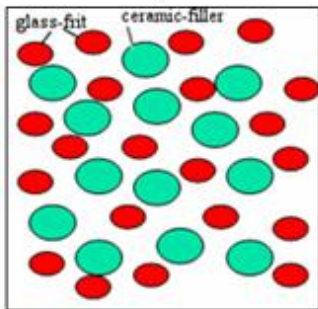
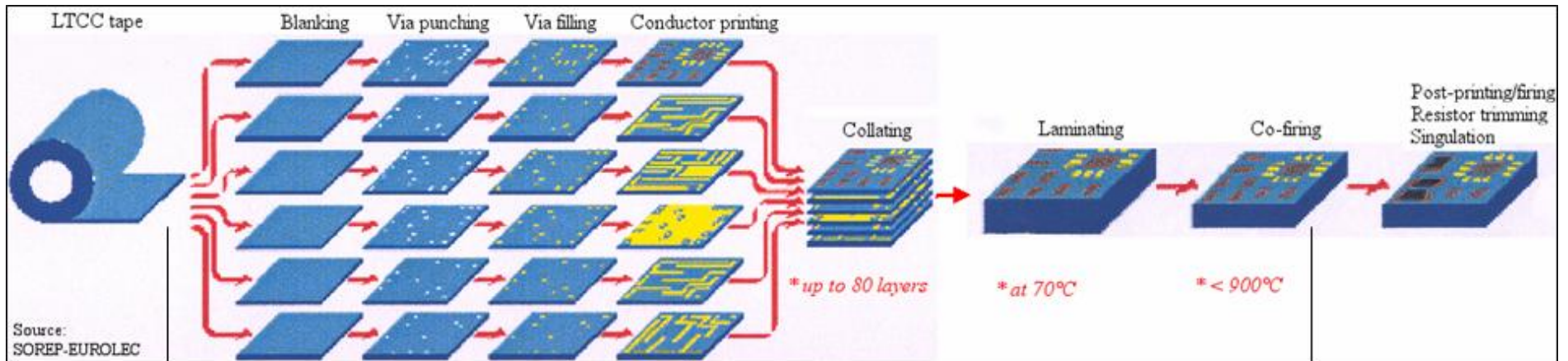




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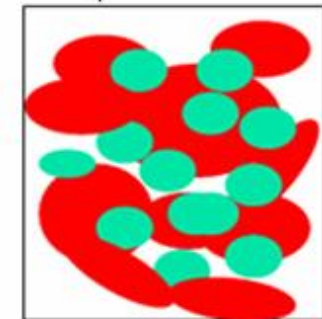
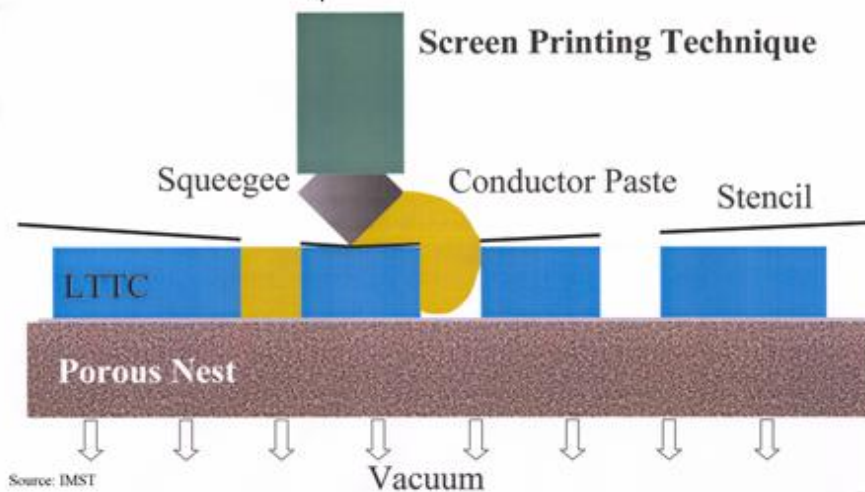


INTRODUCTION: LTCC MATERIALS SYSTEM



Glass-frit: low firing T
Filler: dimensional stability

... blended in organic-vehicle
& cast on mylar sheets



ADVANTAGES OF LTCC FOR SENSOR APPLICATIONS

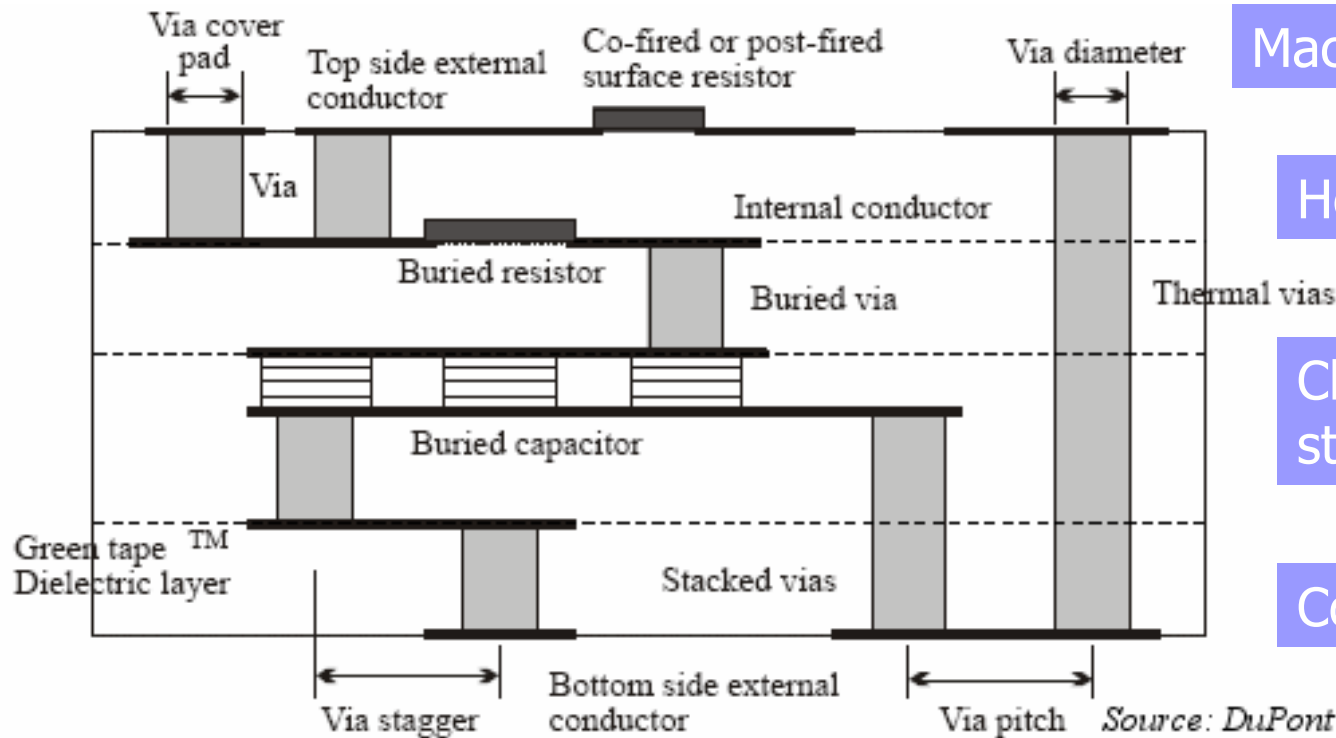
High density packaging

Machinability of tapes

Hermeticity

Chemical / thermal stability

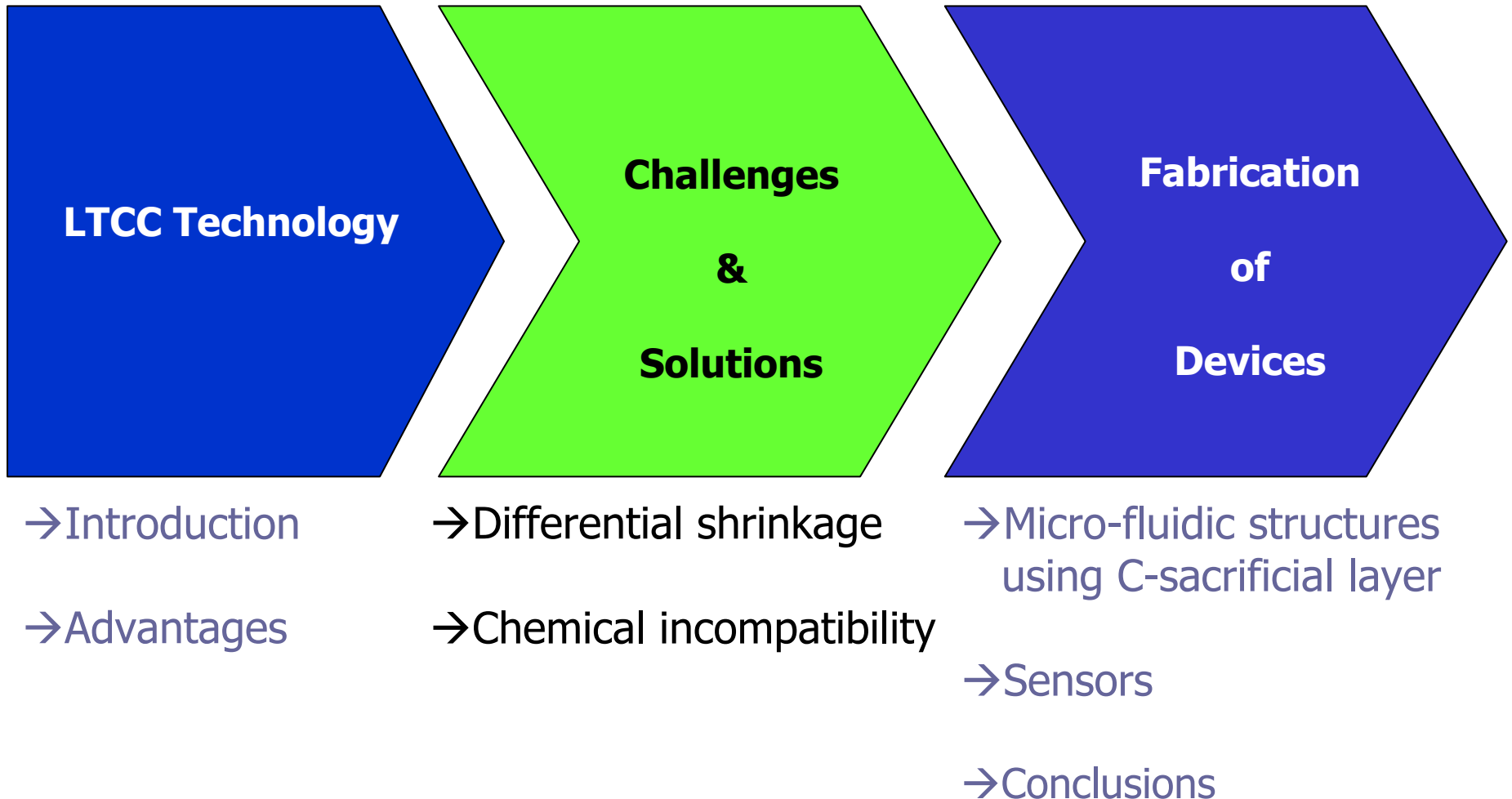
Cost effective



Mechanical and electrical functions in one system

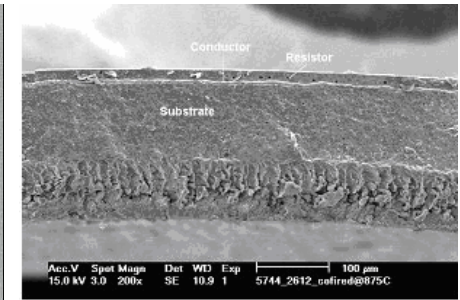
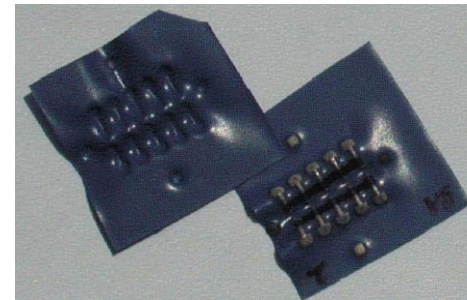
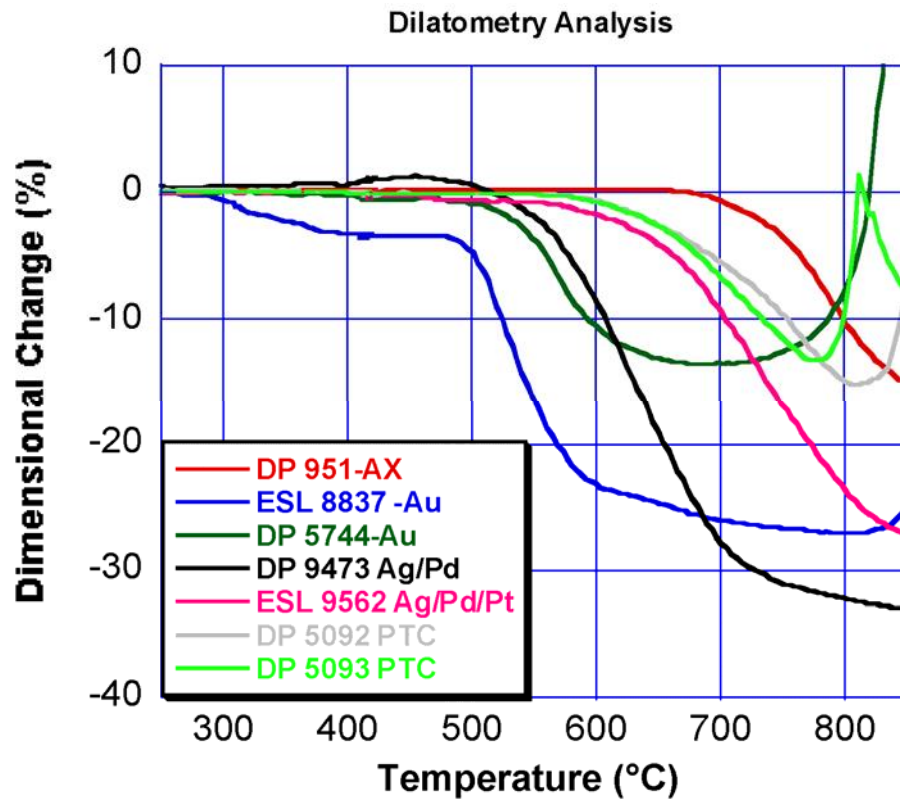


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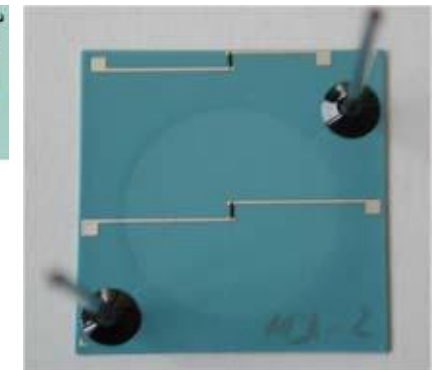
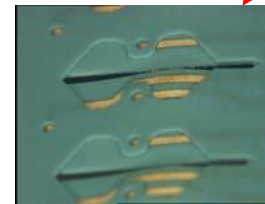
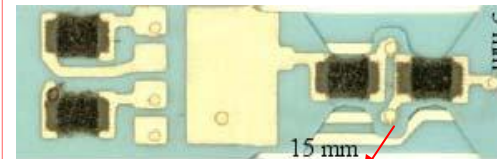


DIFFERENTIAL SHRINKAGE

Not desired for test-patterns



Not desired for devices



No co-firing possible !

Thick-film components starts densifying
→ prior to LTCC (~150-250°C) and
→ at a higher extent than LTCC



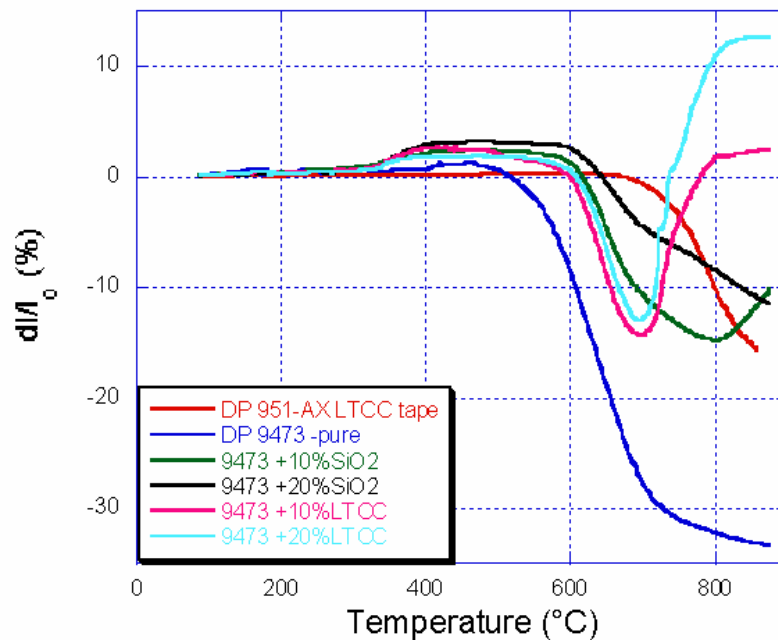
MODIFYING COMMERCIAL PASTES-I

Paste	Specification	Additive	
		SiO ₂ *	LTCC
DP 9473	Ag/Pd	10%	10%
		20%	20%
ESL 9562**	Ag/Pd/Pt	10%	10%
		20%	20%

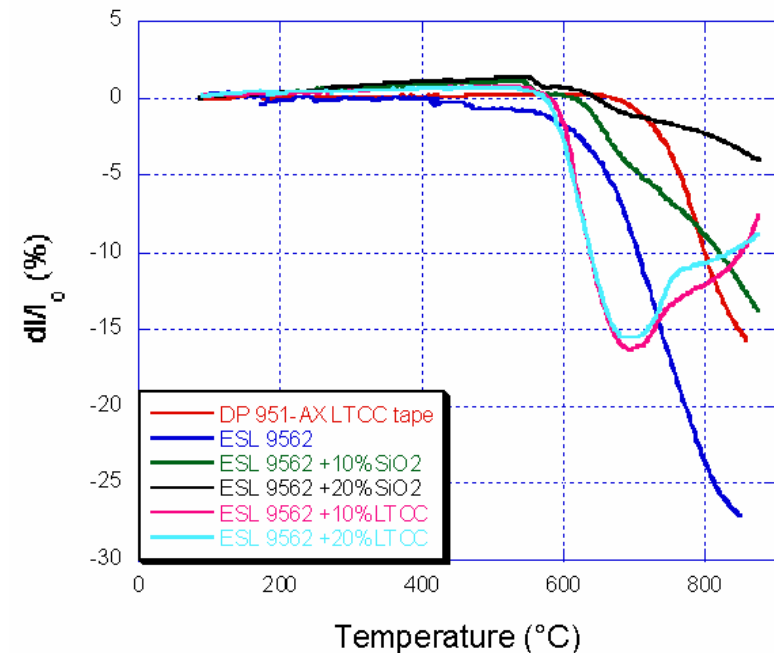
*SiO₂: Sihelco, Sikron B 600

** Fritless conductor with Cu additions (Ag/Pd~16)

Shrinkage Match Analysis with DP 9473



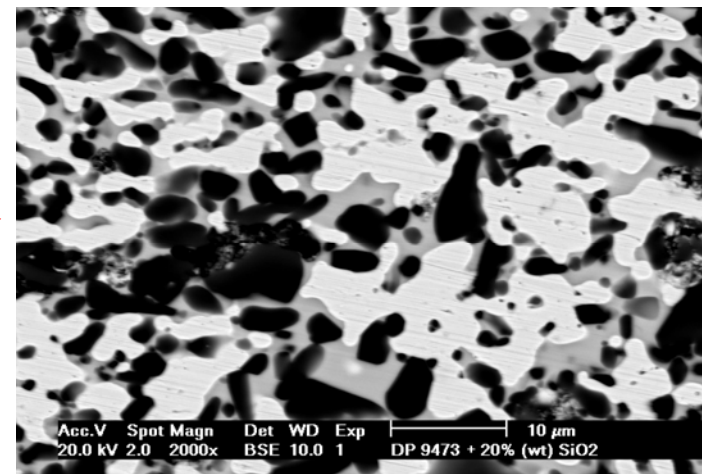
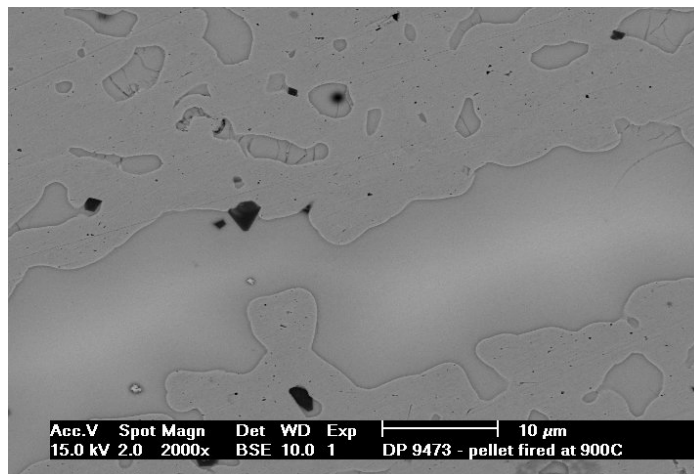
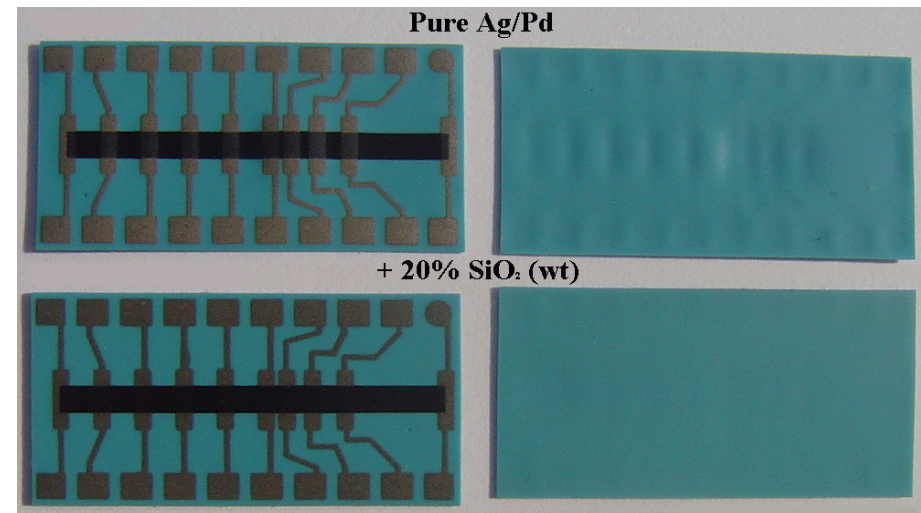
Shrinkage Match Analysis with DP 9562



MODIFYING COMMERCIAL PASTES-II

Paste (ratio of doping)	$T_{shr.}^+$ (°C)	%Shrinkage ⁺⁺ (-)
DP 9473	516	23
DP 9473 + 10%	618	7.7
DP 9473 + 20%	644	2.3
ESL 9562	430	5.5
ESL 9562 + 10%	615	3
ESL 9562 + 20%	646	0.7

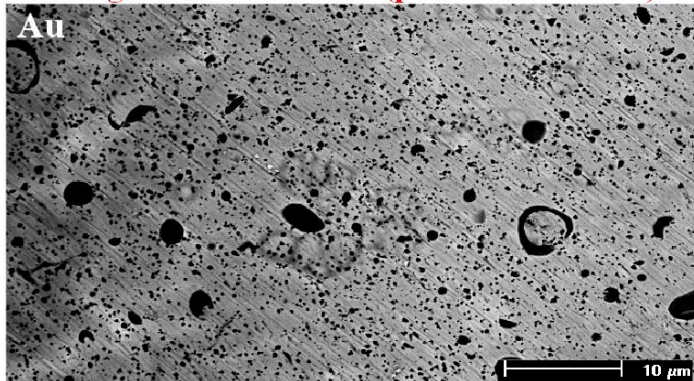
$T_{shr.}^+$: Onset temperature of shrinkage of the paste ($\Delta l/l < 0$)
 %Shrinkage⁺⁺: Amount of paste shrinkage at the onset temperature of the tape shrinkage (670°C).



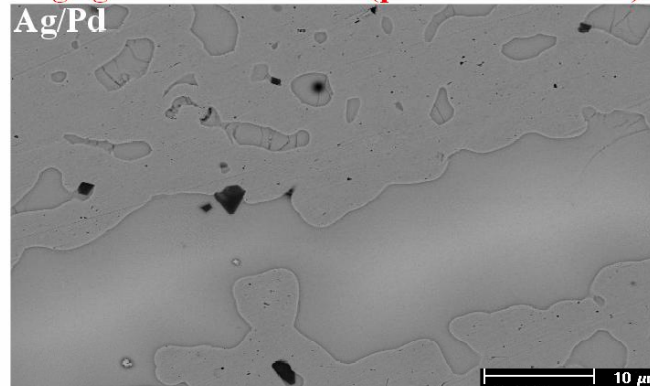
→ Mobility of glass phase is suppressed by SiO₂ addition

CHEMICAL INCOMPATIBILITY: GLASS LOAD

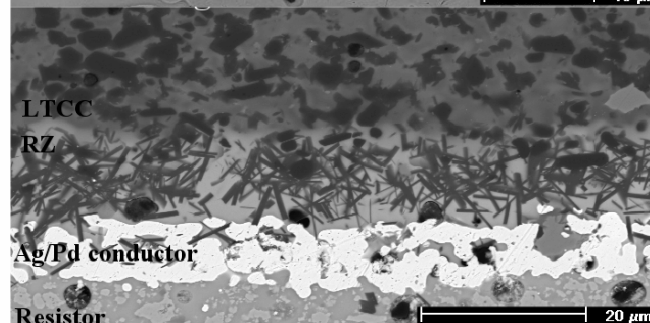
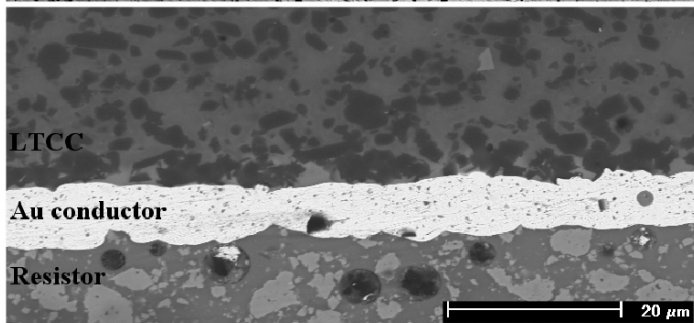
Low glass load conductor (pellet and interface)



High glass load conductor (pellet and interface)

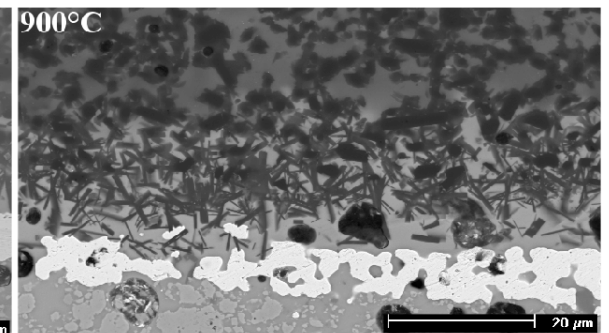
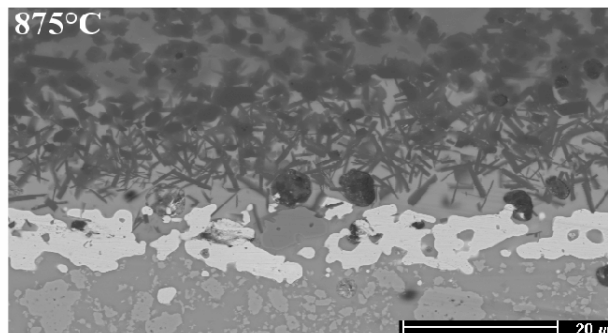
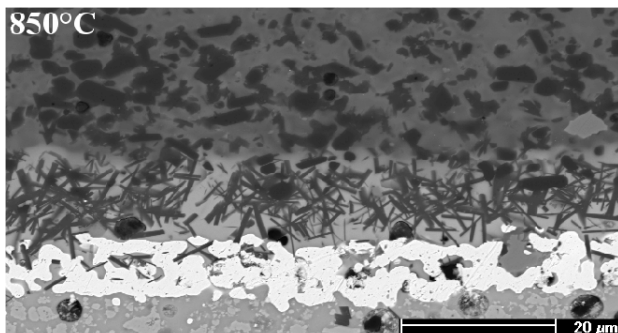


- The type and amount of glass load,
- The chemistry of the material,
- Processing conditions

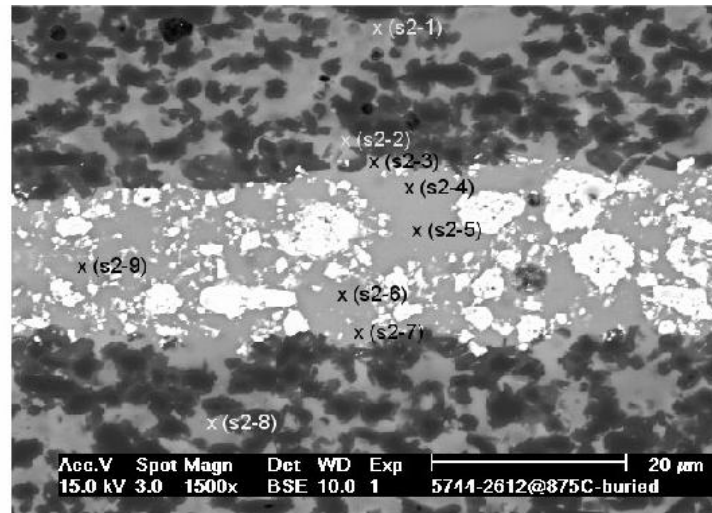
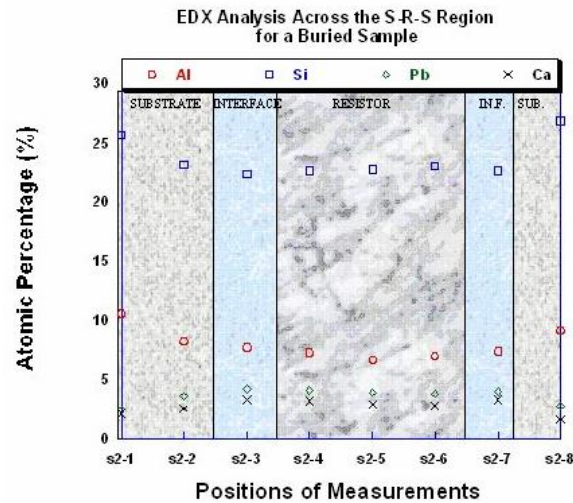


DETERMINES

- The extent of reaction
- The type of the interface:
abrupt - broad - diffuse



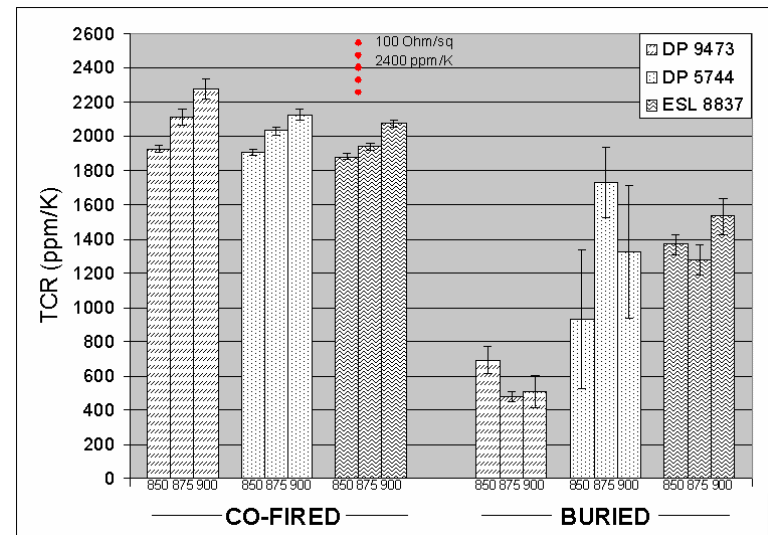
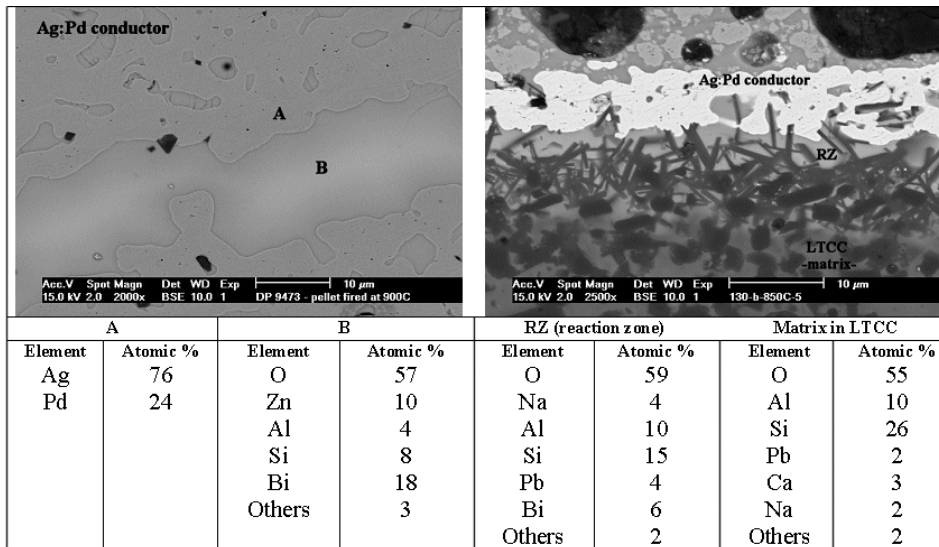
CHEMICAL INCOMPATIBILITY: DIFFUSION



Diffusion of elements at the interface

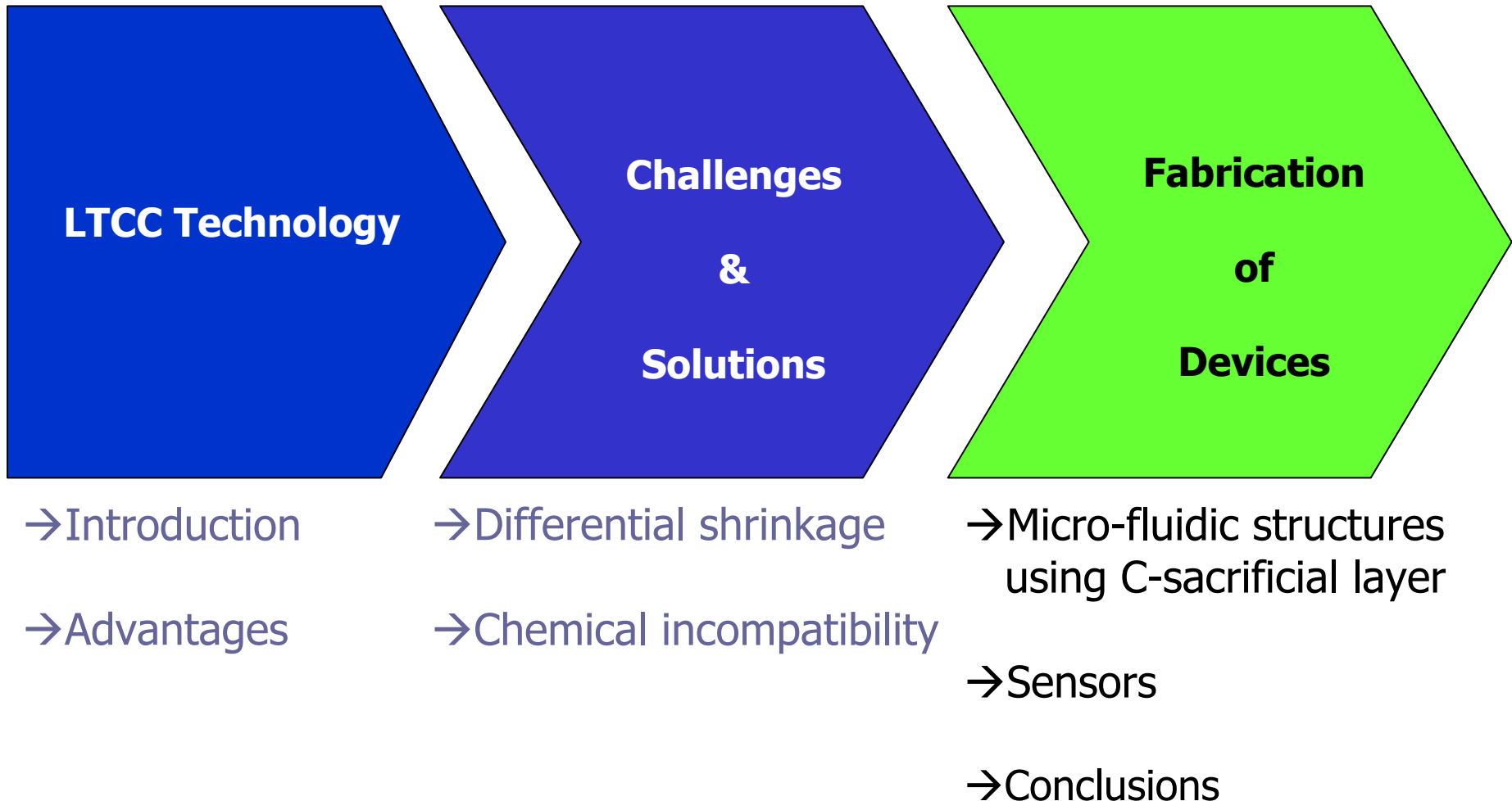
LEADS TO

Deviation in functional properties of the components (resistance, ..)





OUTLINE OF THIS PRESENTATION

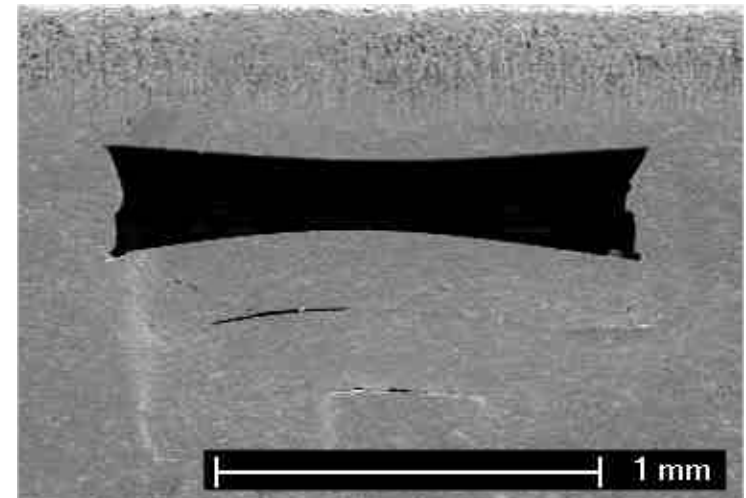


CHALLENGES IN FABRICATION OF MICRO-FLUIDIC STRUCTURES

Sagging

Unsupported cavity is deformed during:

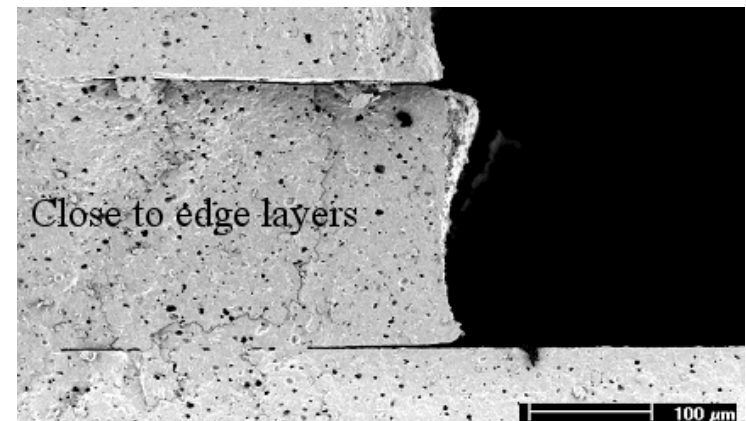
- Lamination (lamination stress)
- Sintering (over T_g)



Delamination / Disintegration

Occurs due to:

- Poor lamination
- Geometrical constraints

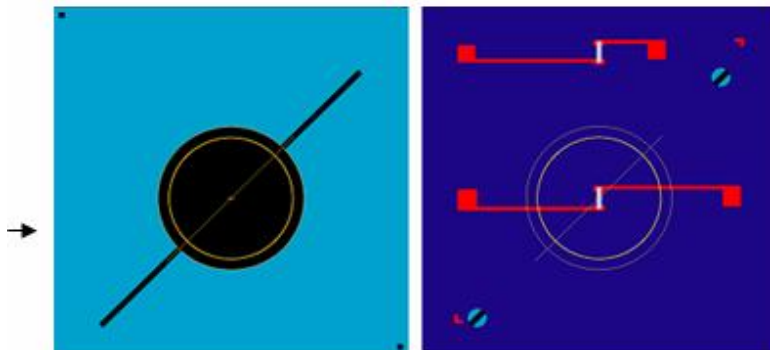
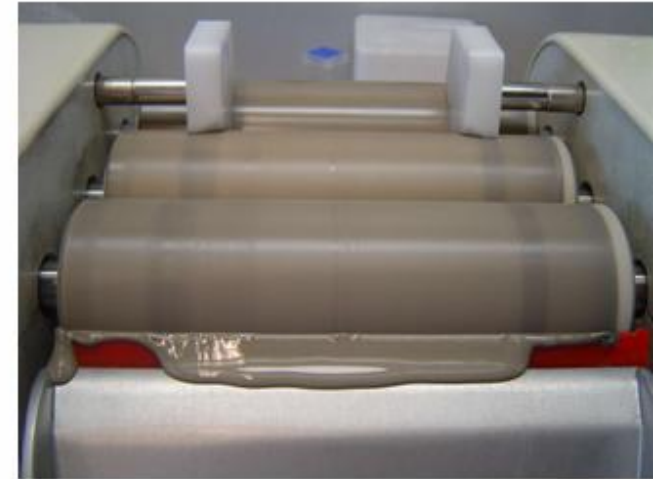


CARBON SACRIFICIAL PASTE PREPARATION

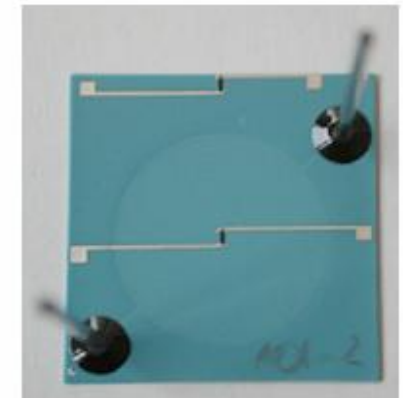
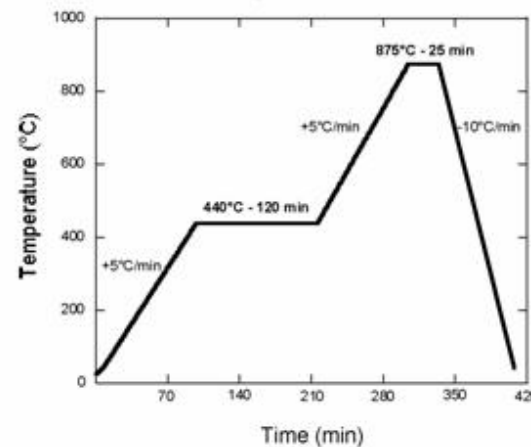
Product	Function	Specification	Supplier
Graphite	Sacrificial	$d_{50} : 1-2\mu\text{m}$ ★ (used lot)	Aldrich, 28,286-3
		$d_{50} : 11\mu\text{m}$	TIMCAL, Timrex-KS25
		$d_{50} : 15.3\mu\text{m}$ ★	TIMCAL, Timrex-KS5-25
Ethyl cellulose	Binder	control of rheology	Aldrich, 43,383-7
Terpineol	Solvent	slurry viscosity	Fluka, 86480
Acetyl acetone	Dispersant	dispersing additive	Sigma-Aldrich, P775-4

Graphite
26 wt%

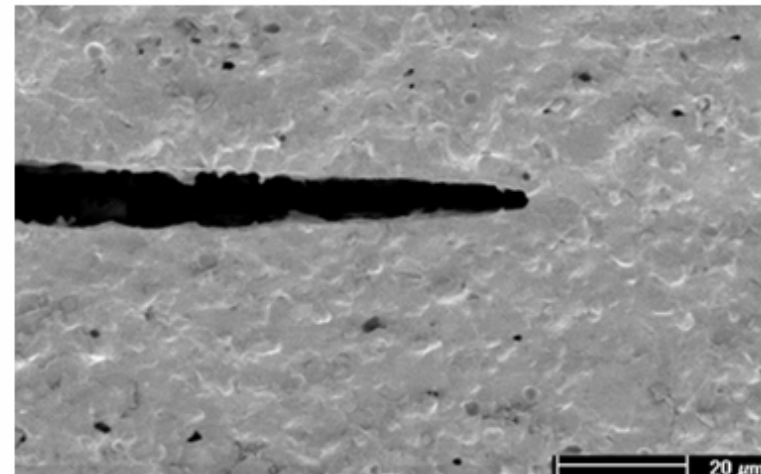
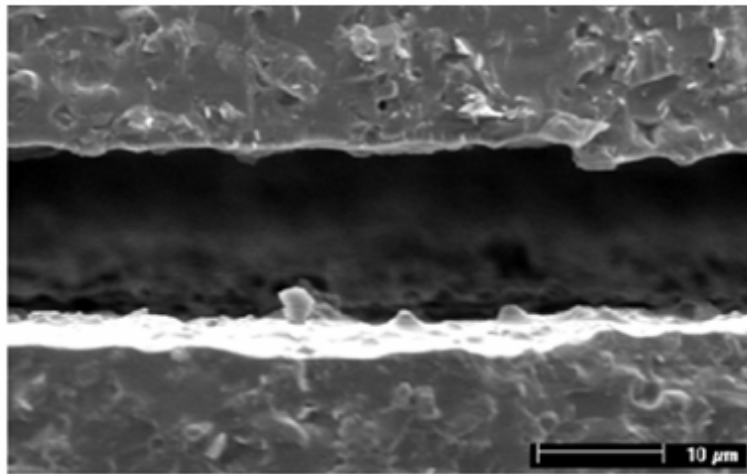
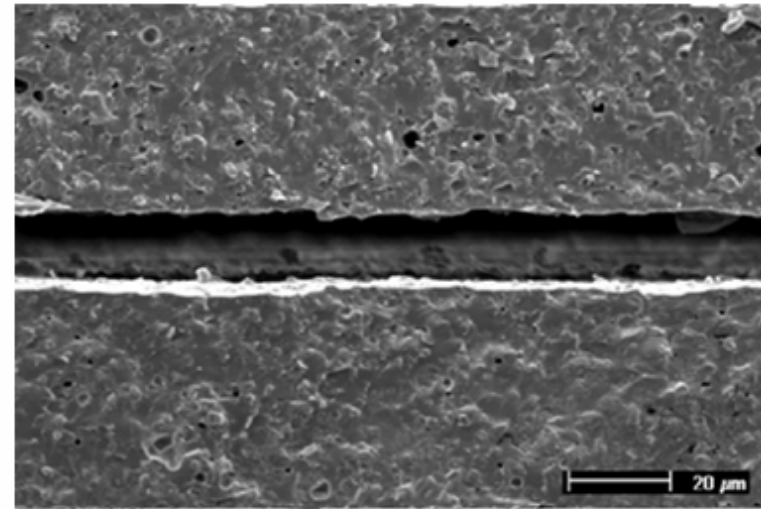
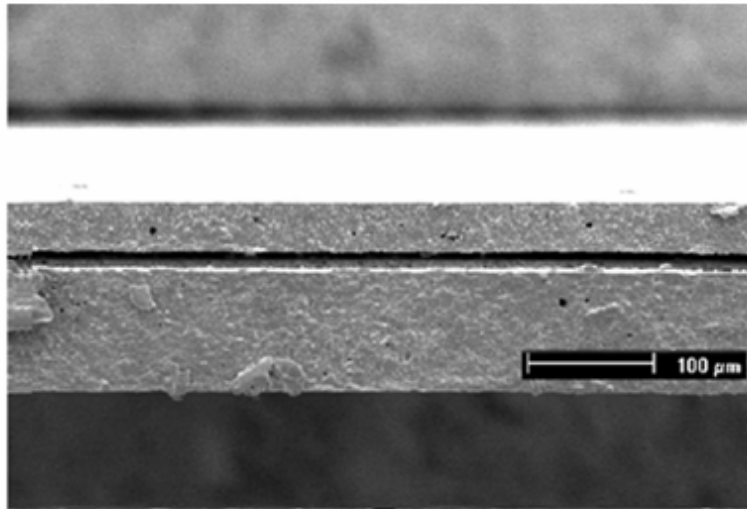
Organics
74 wt%



Firing Profile of LTCC



FABRICATED STRUCTURES

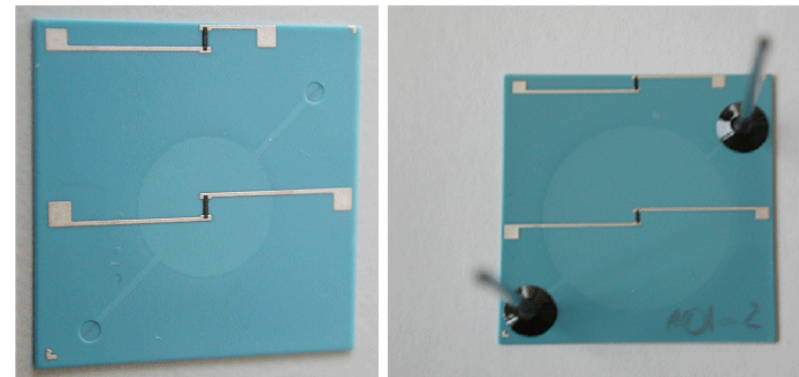


Membranes produced: 40 μm thickness / diameters (7,10, 15, 18mm) / spacing (10-100 μm)

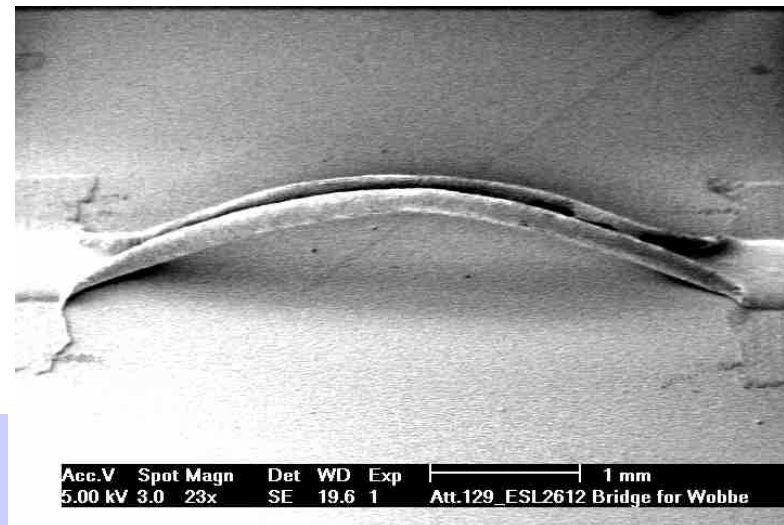


CONCLUSIONS

- Compatibility of the LTCC materials system is extremely important:
 - thermomechanical properties,
 - selected material (glass),
 - processing conditionsmust be well-known and optimized
- Shrinkage-match of commercial conductors possible by modifying the pastes
- Carbon sacrificial pastes effectively used for fabrication of membranes/channels
- Final membrane features dependent on **graphite powder** and **LTCC properties**



14mm-diameter-membrane with PTC resistors



PTC free-hanging bridge on LTCC