Structuring and Fabrication of Sensors Based on LTCC (Low Temperature Co-fired Ceramic) Technology

Hansu Birol, *Thomas Maeder*, *Caroline Jacq*, *Giancarlo Corradini*, *Marc Boers*, *Ingo Nadzeyka*, *Sigfrid Straessler & Peter Ryser*

Swiss Federal Institute of Technology, Lausanne - EPFL

Laboratory for Production of Microtechnologies - LPM

Thick-film Group

lpmwww.epfl.ch

PURPOSE OF THE PRESENTATION

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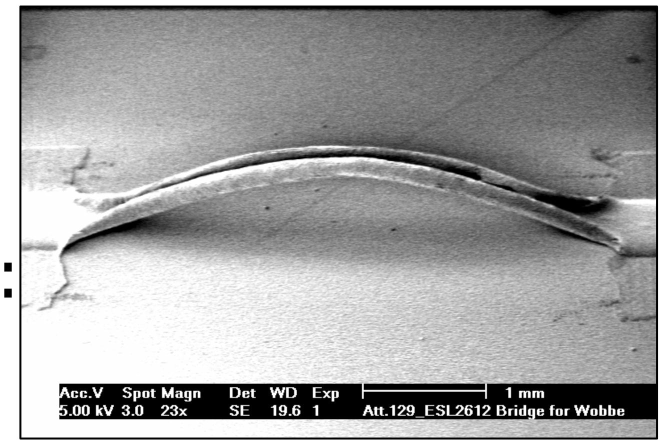
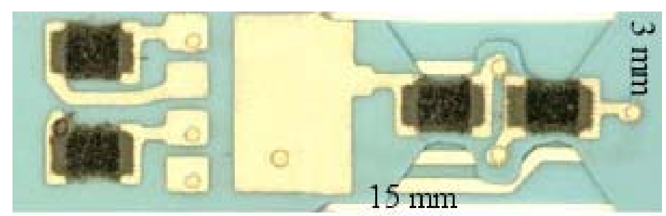
Introduction to LTCC Technology:
General aspects
Sensor applications



Fabrication techniques for sensors:
Major problems encountered
Methods for structuring
Methods for reducing deformation

Fabricated sensors:
Completed devices



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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

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

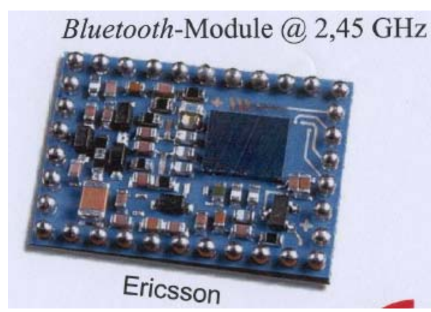
- Transmitters/Receivers
- Phased Array Radar
- Amplifiers
- Filters
- Converters
- Power Drivers
- Sensors

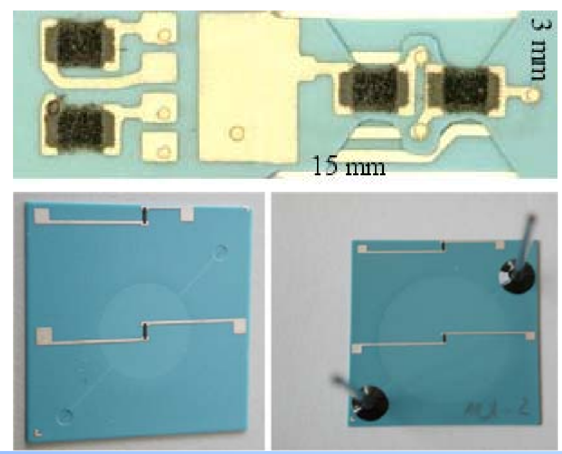
Source: C-MAC Micro-technology

And recently for …

Source: Prismark/Binghamton University

EPCOS FRONT END MODULE
- Key component in new Nokia mobile phone architecture
- Integrates diplexer, switching, LC and SAW filters
- Analysis of LTCC integrates passives and SAW filter packages





INTRODUCTION: LTCC MATERIALS SYSTEM

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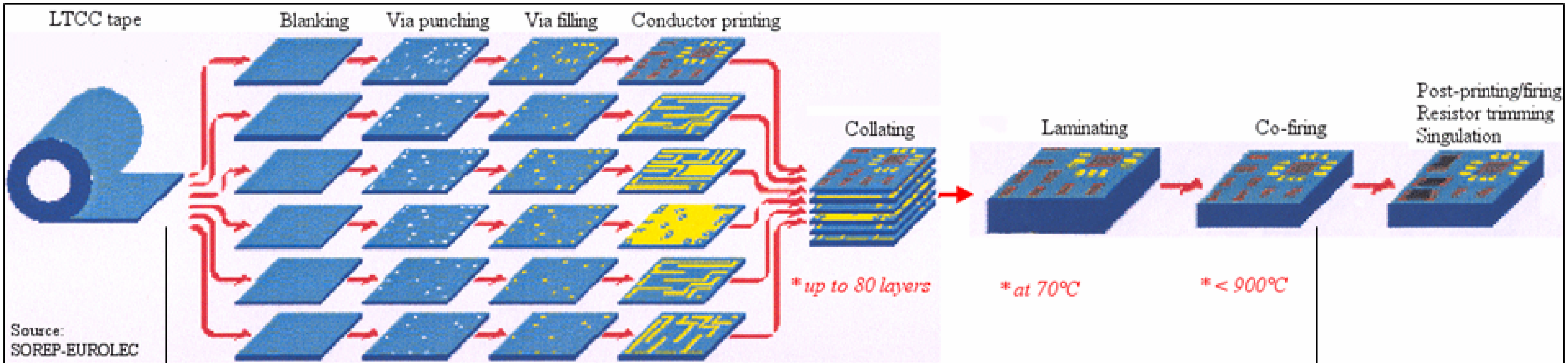
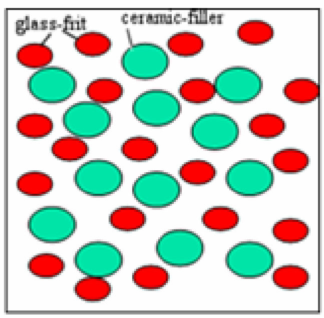
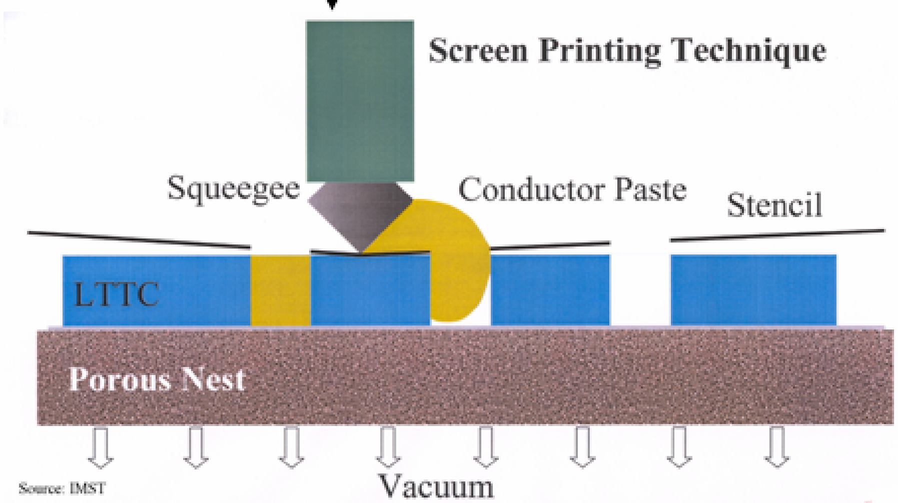
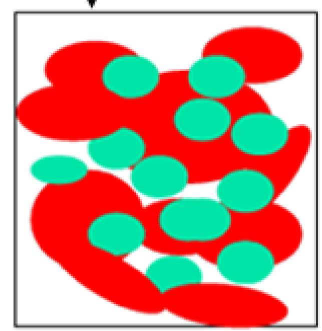




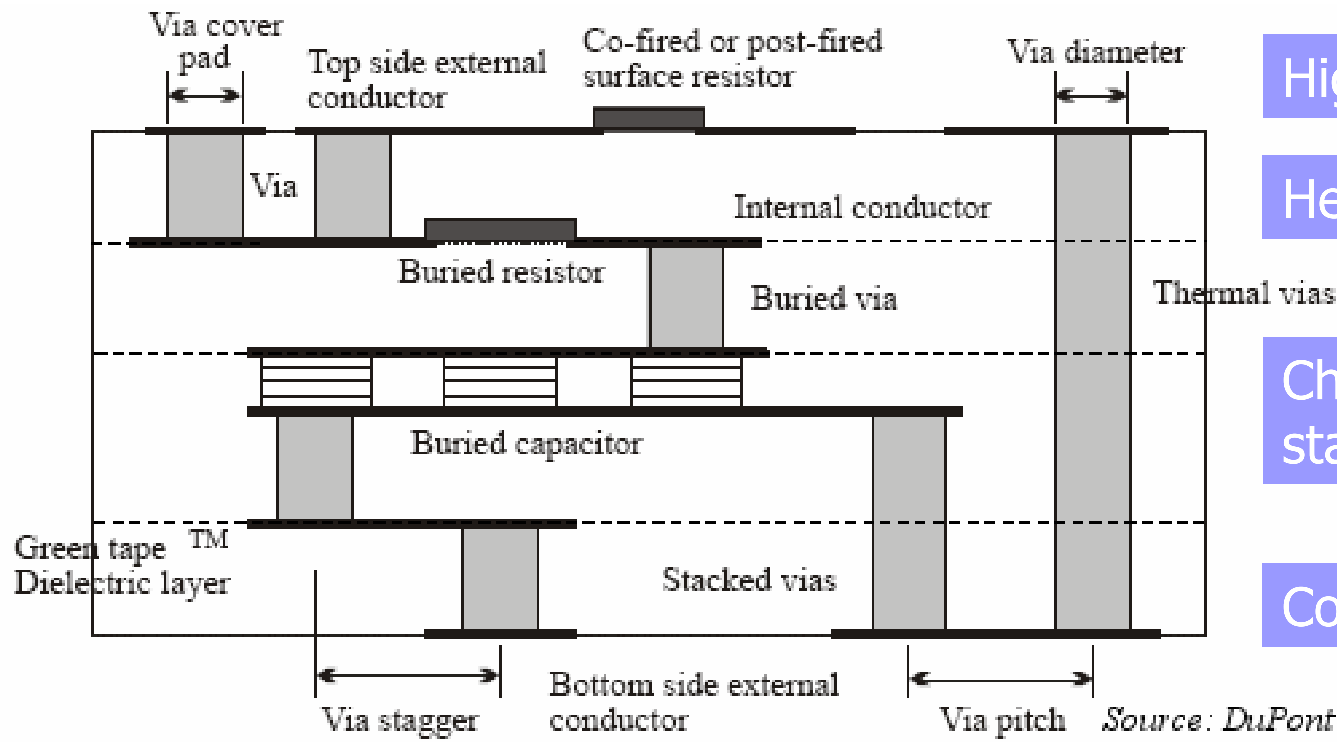
Glass-frit: low firing T
Filler: dimensional stability

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





Glass wetting and ceramic rearrangement occur

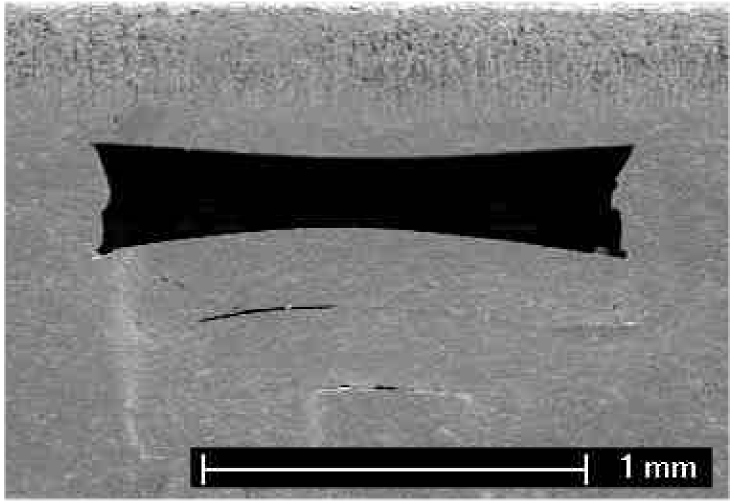


- Machinability of tapes
- High density packaging
- Hermeticity
- Chemical / thermal stability
- Cost effective
- Mechanical and electrical functions in one system

Sagging in cavities

Unsupported cavity is deformed during:

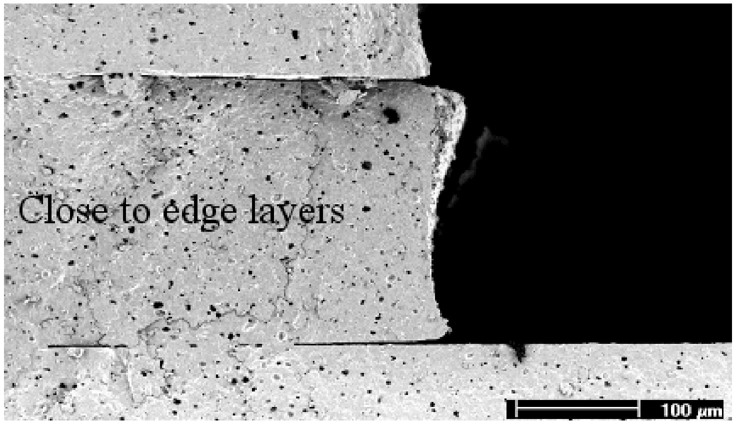
→Lamination (lamination stress)
→Sintering (over Tg)



Delamination / Disintegration

Occurs due to:

→Poor lamination
→Geometrical constraints

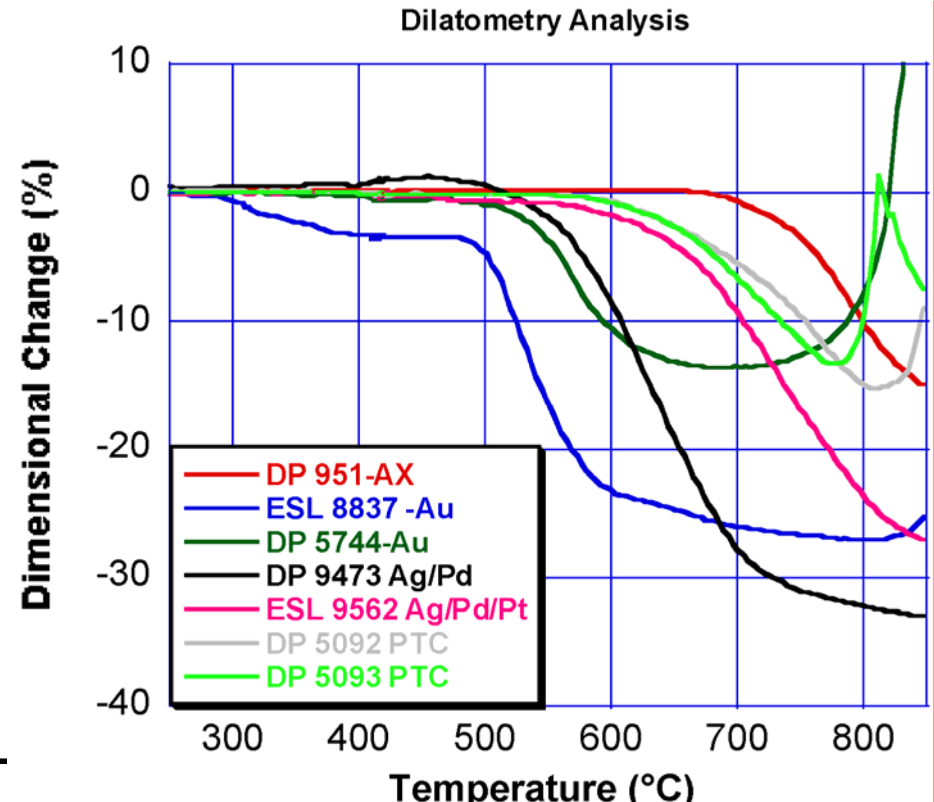


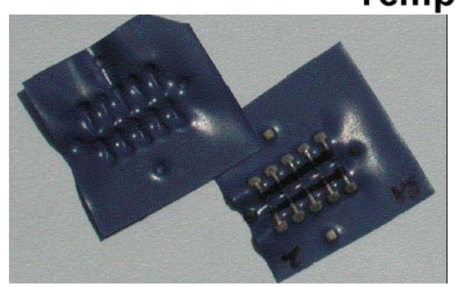
Deformation of co-fired bodies (warpage, etc…) due to <u>differential shrinkage</u>

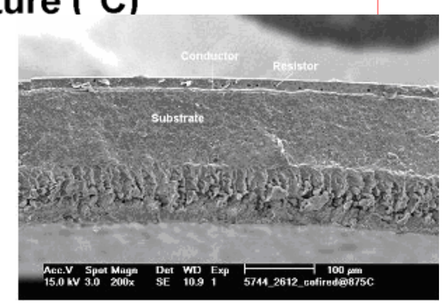
As a result of:

1. rapid sintering
2. higher extent of shrinkage

of thick-film components compared to LTCC





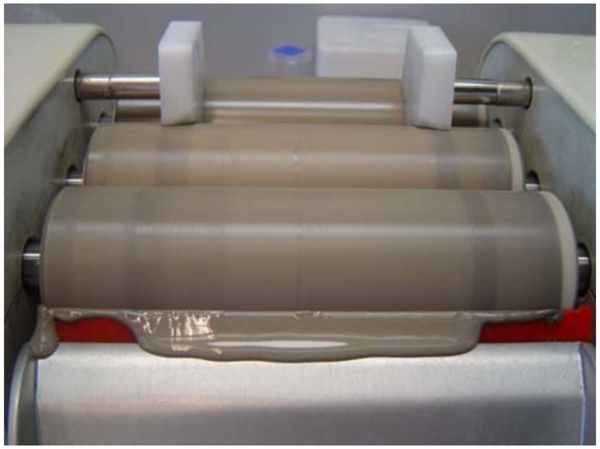


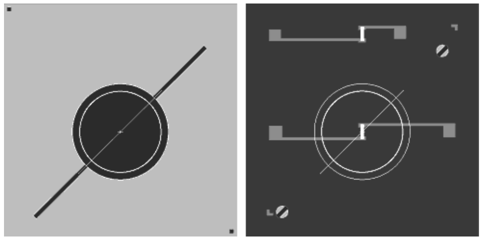
METHODS FOR STRUCTURING

Utilization of temporary sacrificial layers, which are screen-printed & laminated with LTCC to fabricate « sag-free & well-integrated »

- micro-fluidic channels,
- cavities such as membranes,

Product	Function	Specification	Supplier
Graphite	Sacrificial	d_{50} : 1-2µ (used lot)	Aldrich, 28,286-3
		d_{50} : 11µ	KS25
		d_{50} : 15. 3µ	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

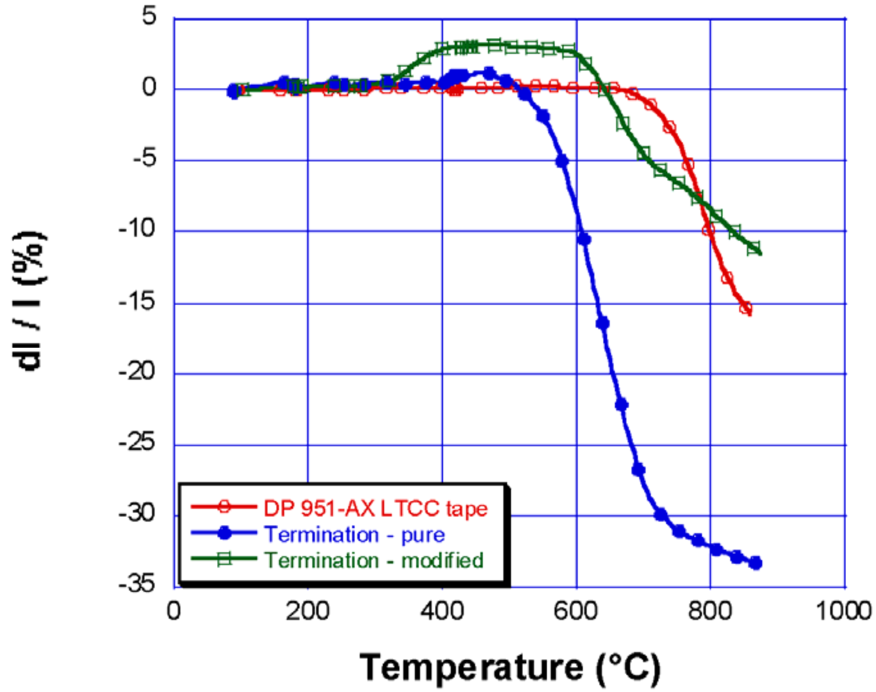


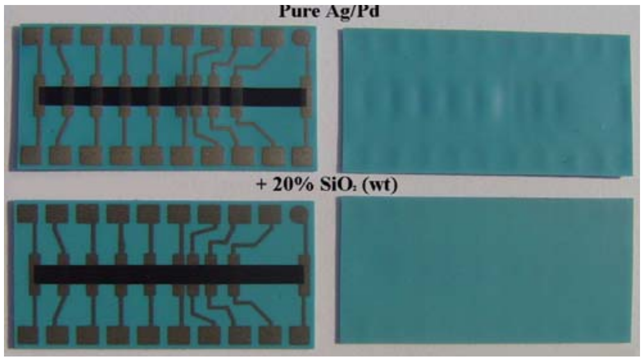


METHODS FOR REDUCING « DIFFERENTIAL SHRINKAGE-RELATED » DEFORMATION

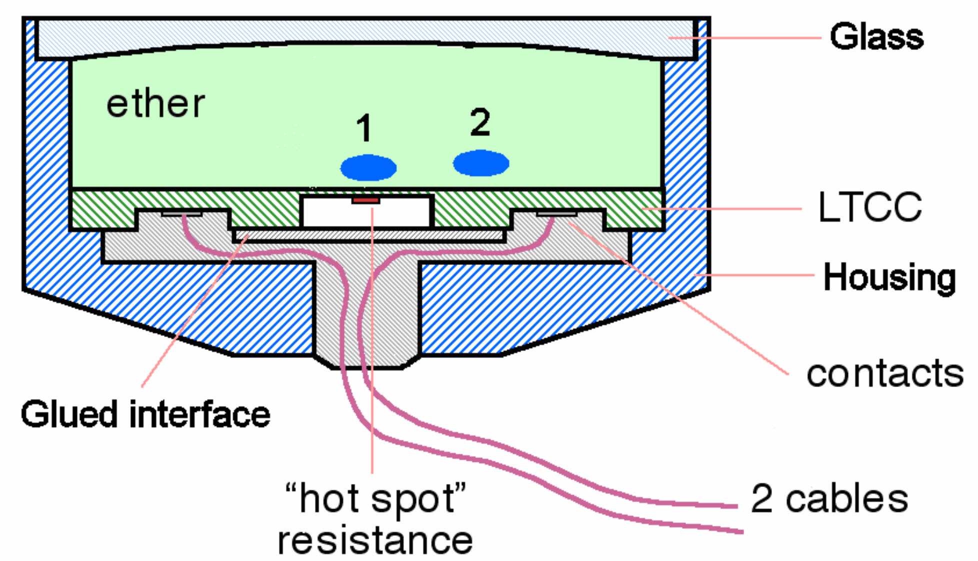
Modifying commercial thick-film components by selected additives to

- shrinkage match paste with LTCC,
- reduce the overall shrinkage of the paste,



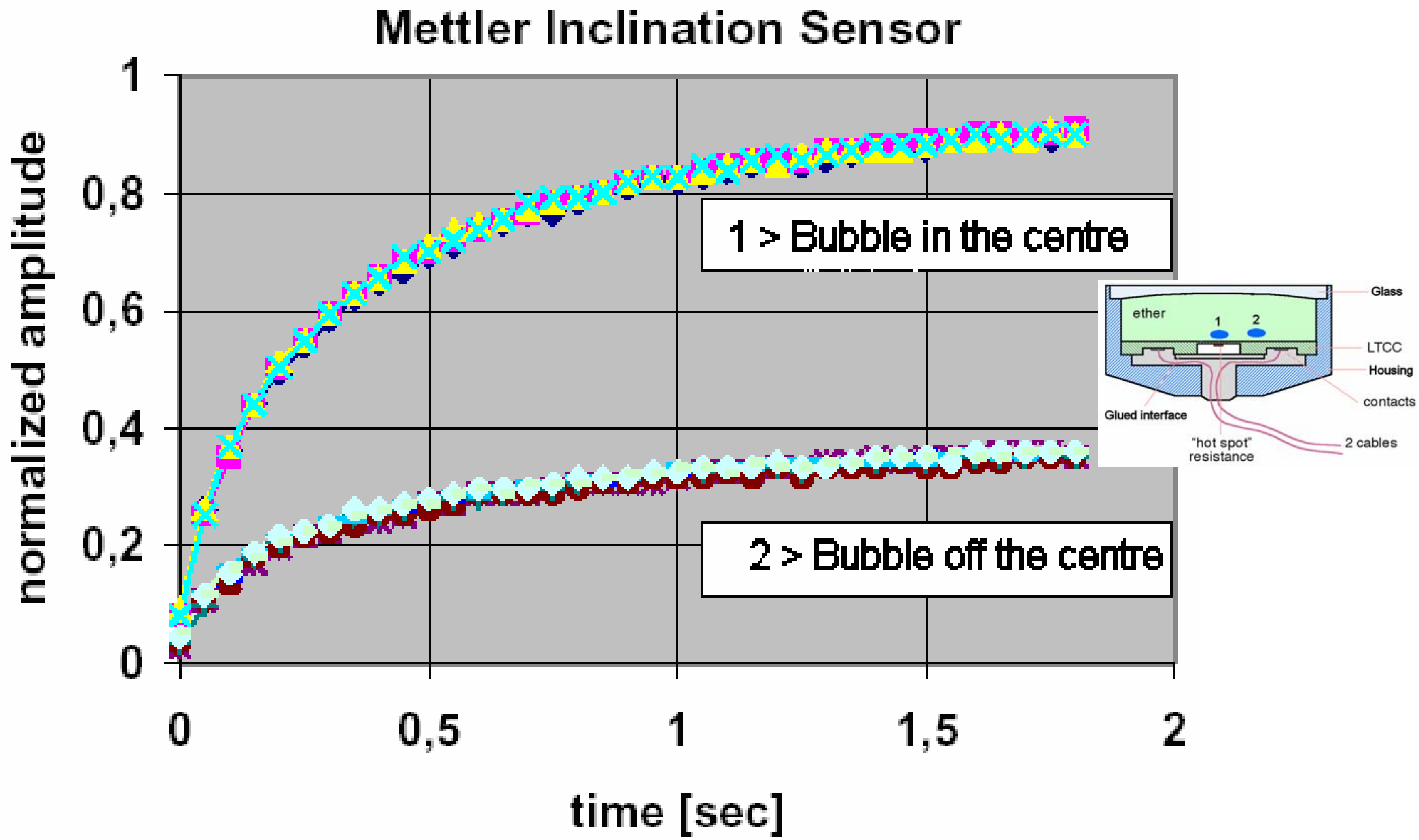


LTCC: an excellent substrate for hot-spot application (λ~2-3 W/m.K)



PRINCIPLE

Detection of heat loss from the PTC resistor to the surroundings (bubble surface / liquid)


Mettler Inclination Sensor
normalized amplitude
time [sec]
1
0,8
0,6
0,4
0,2
0
0
0,5
1
1,5
2
1 > Bubble in the centre
2 > Bubble off the centre
Glass
ether
1
2
LTCC
Housing
contacts
Glued interface
"hot spot" resistance
2 cables

LTCC: an excellent substrate for force sensing

Maximum signal, $(\Delta R/R)$ ⟷ $\text{Signal} = \varepsilon_{max} G_f$

Maximum strain, ε $(\Delta l/l)$ ⟷ $E = \sigma / \varepsilon$

Maximum stress, σ_{max} ⟷ $\sigma_{max} = (6FL) / (bh^2)$

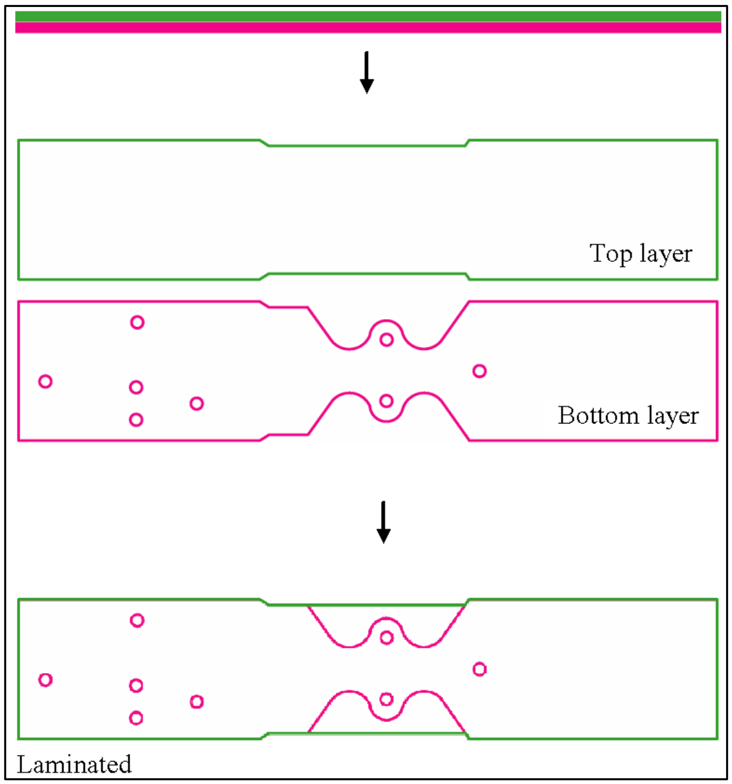
$$\varepsilon = (6FL) / (bh^2)E$$

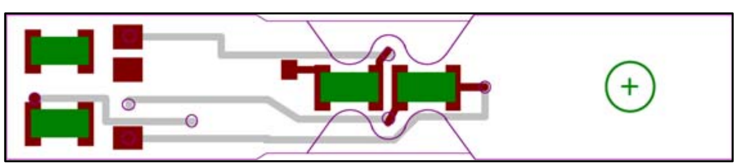
Properties	Kyocera A-476 Al_2O_3 (96%)	DuPont LTCC 951 (fired)
Elastic modulus (GPa)	330	152
Flexural strength (MPa)	310	320
Available thickness (mm)	0.25-1.00	0.04-0.21

$$\varepsilon_{LTCC} / \varepsilon_{Al2O3} = (h^2_{Al2O3} E_{Al2O3}) / (h^2_{LTCC} E_{LTCC})$$

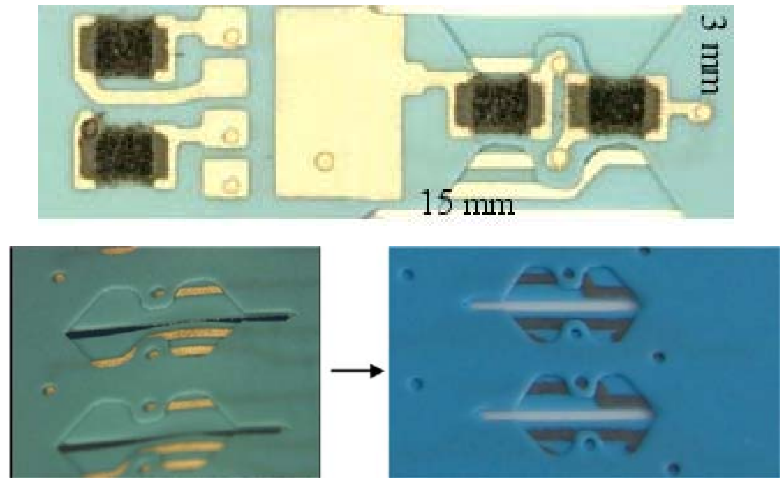
$\varepsilon_{LTCC} / \varepsilon_{Al2O3}$ → up to ~70 times theoretically

CUTTING & LAYOUT

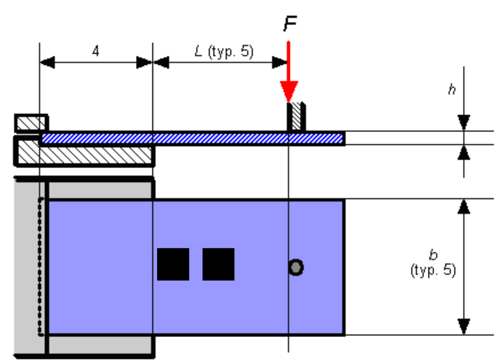


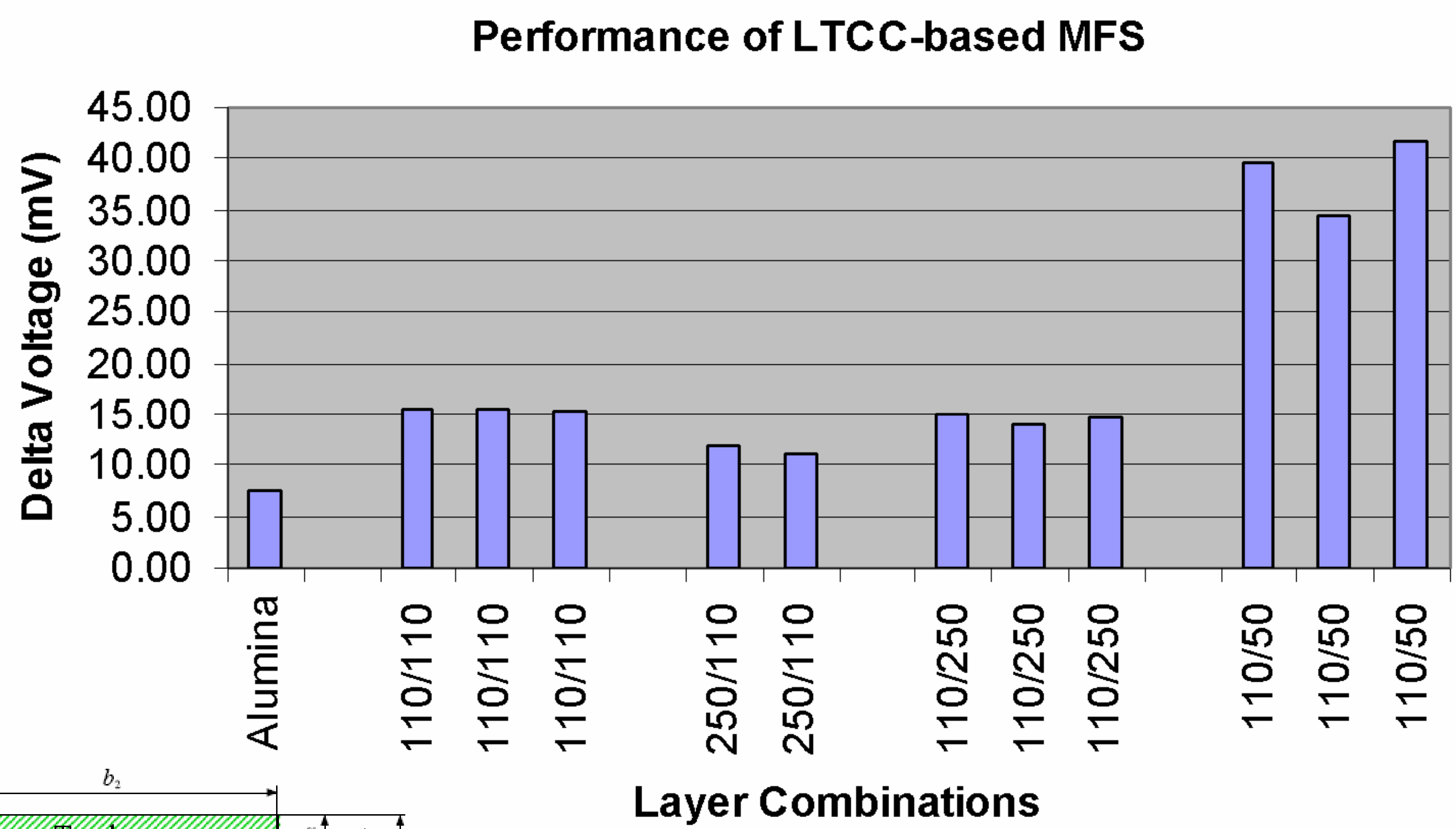


CO-FIRING

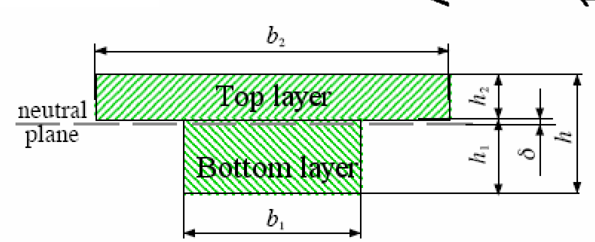


MEASUREMENT SET-UP



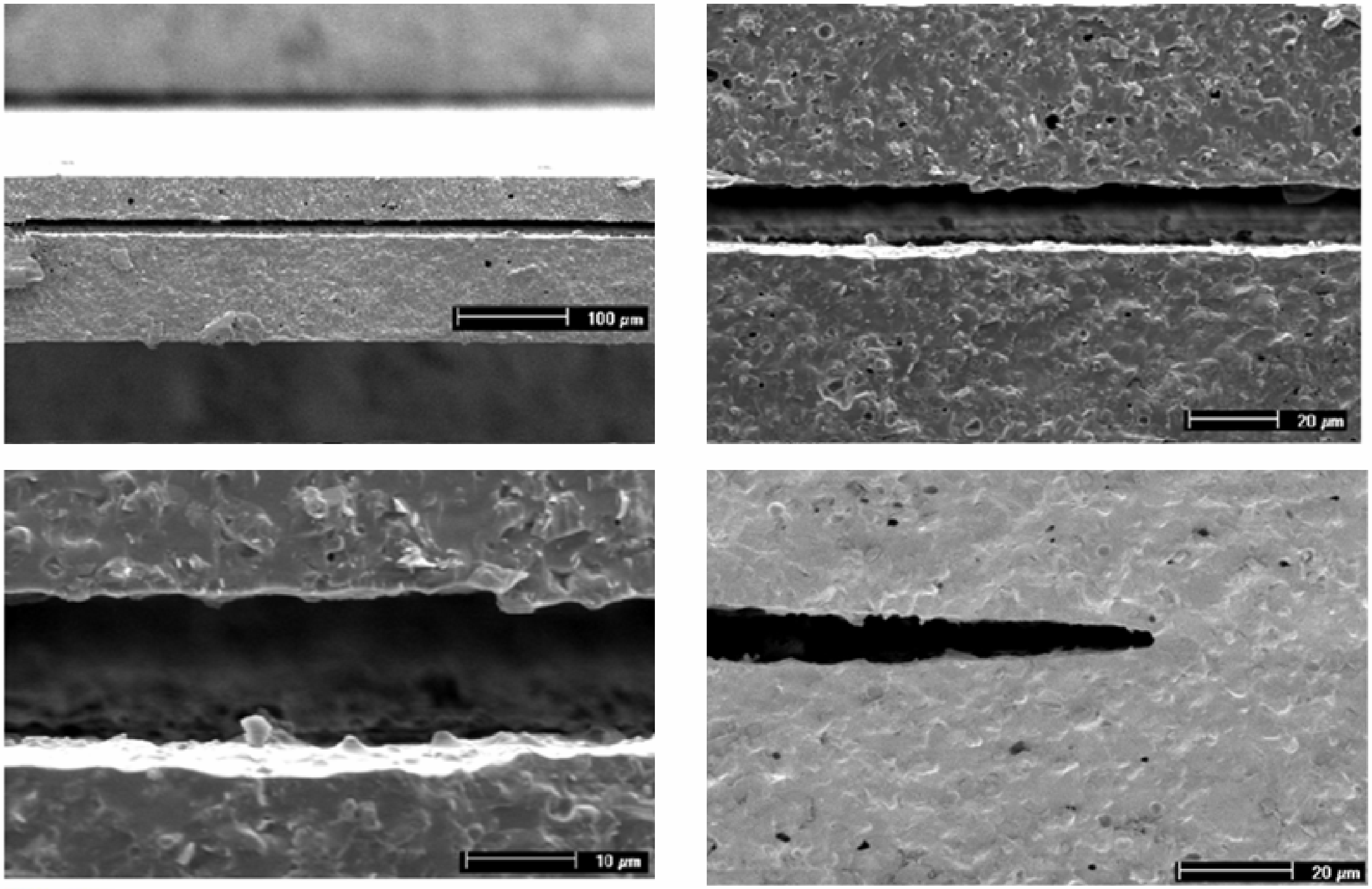


Performance of LTCC-based MFS
Delta Voltage (mV)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Alumina
110/110
110/110
110/110
250/110
250/110
110/250
110/250
110/250
110/50
110/50
110/50
Layer Combinations



b_2
Top layer
neutral plane
Bottom layer
b_1
h_2
h_1
δ
h

LTCC + sacrificial layers: an effective & smart packaging approach



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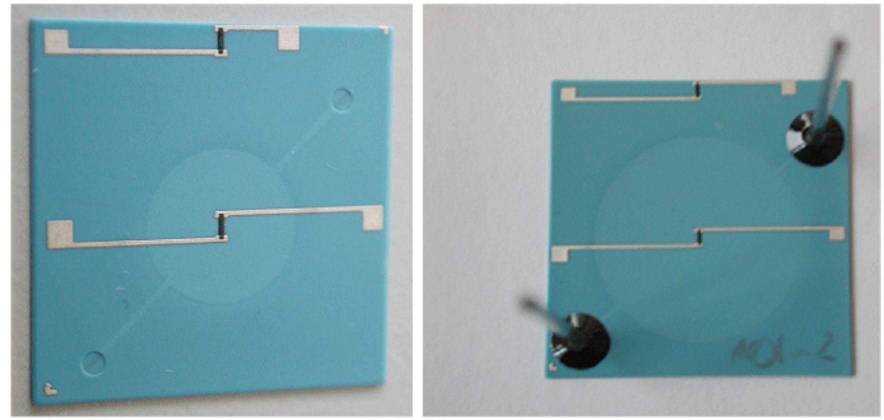
MICRO-FLUIDIC SENSOR: STRUCTURES

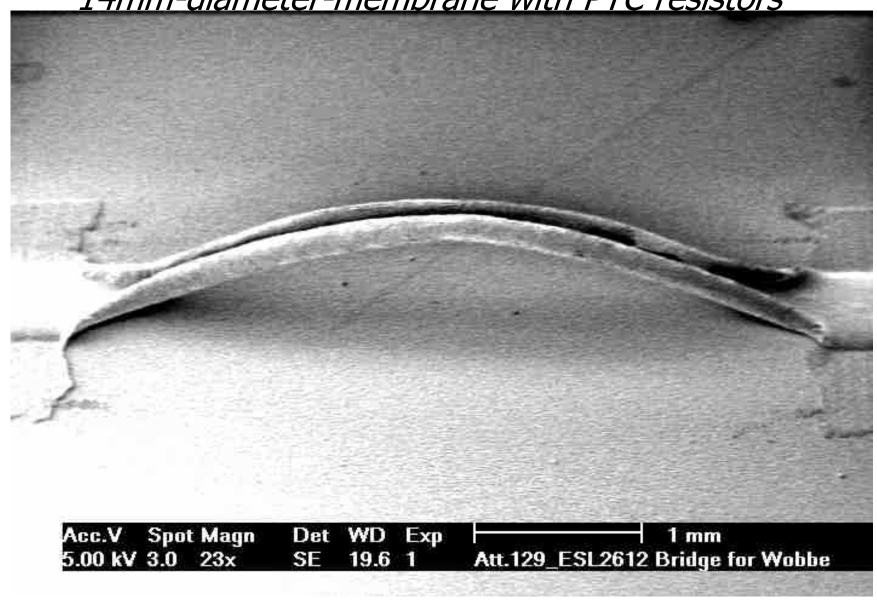
Using the graphite-based sacrificial paste, membranes produced with

→ thickness: of 40µm
→ diameter: 7,10, 15, 18mm
→ spacing: (10-100µm)

Final membrane features dependent on graphite powder and LTCC properties



14mm-diameter-membrane with PTC resistors



PTC free-hanging bridge on LTCC

CONCLUSIONS

→LTCC Technology has been efficiently used for fabrication of sensor & micro-fluidic devices such as: *inclination, millinewton force, pressure sensors & micro-fluidics*

→Structuration & fabrication is basically limited by: *the methods used for structuring and the materials compatibility issues*

→Low sintering temperature, High packaging density, Thermal & chemical stability Integrability with thick-films *favors the application of the technology in multi-disciplinary areas very soon*