Modification of Thick-film Conductors Used in IP Technology For Reduction of Warpage during Co-firing of LTCC (Low Temperature Co-fired Ceramic) Technology

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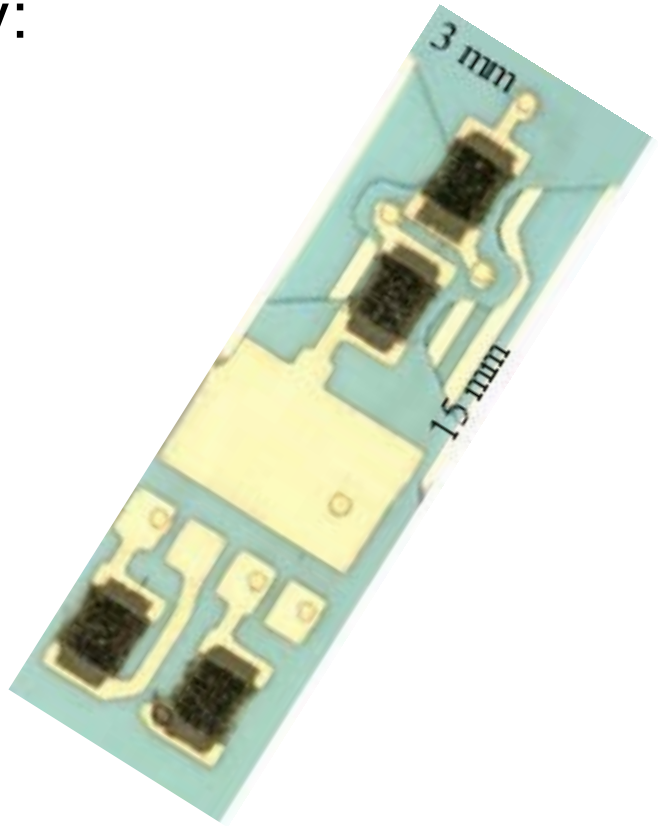
PURPOSE OF THE PRESENTATION

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

- Introduction to LTCC Technology:
  General aspects

- Materials compatibility issues:
  Chemical issues
  *Physical issues**
  Reliability issues for devices

- Ensuring reliability:
  Modification of commercial pastes



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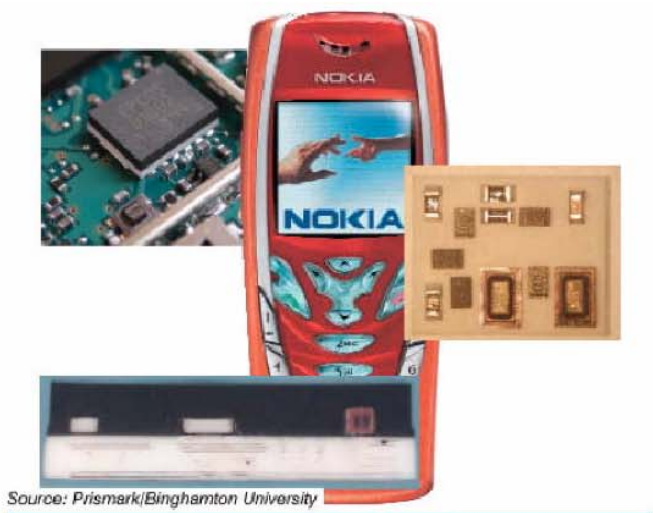
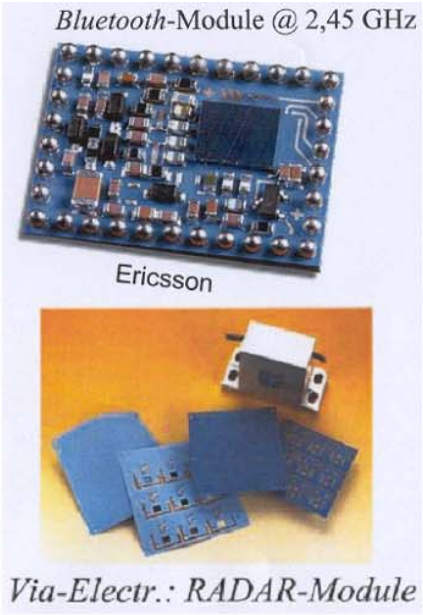
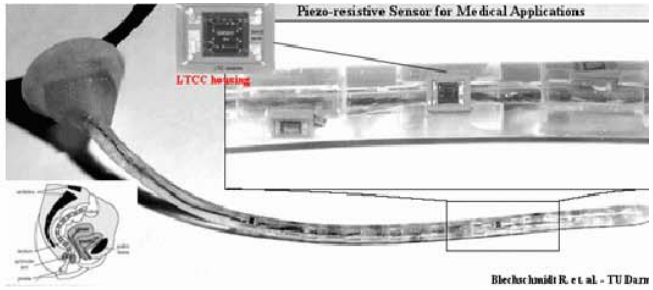
Application areas of LTCC technology have diversified

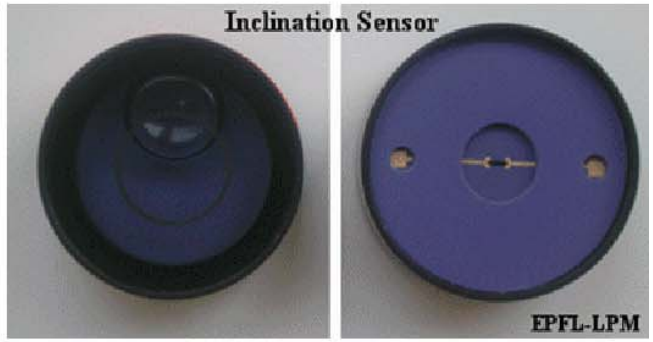


Source: Prismark/Binghamton University

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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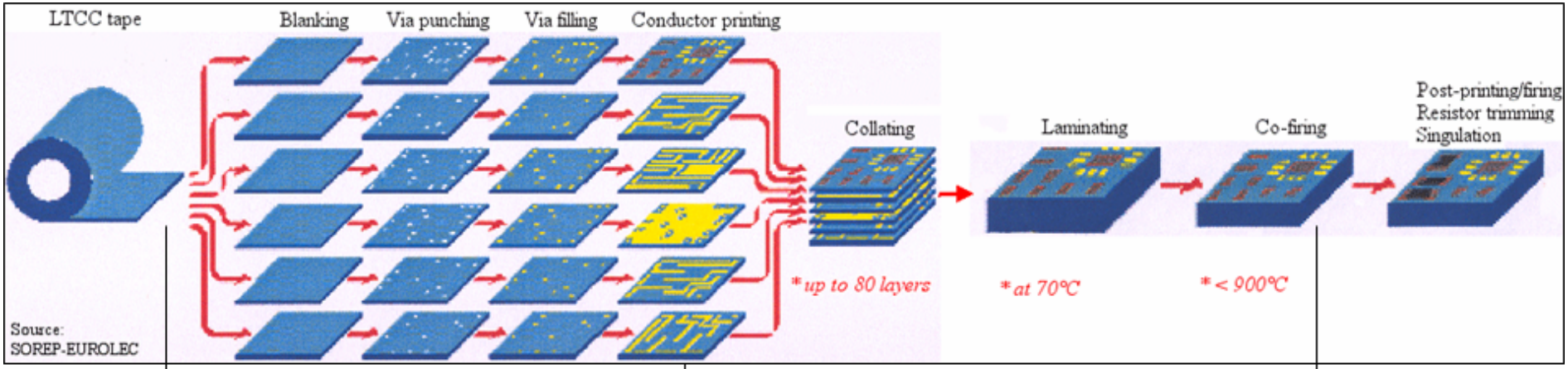
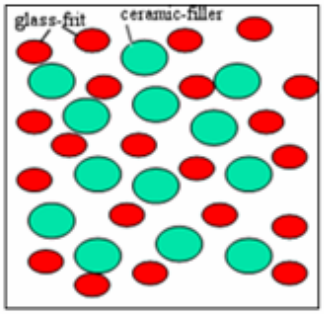
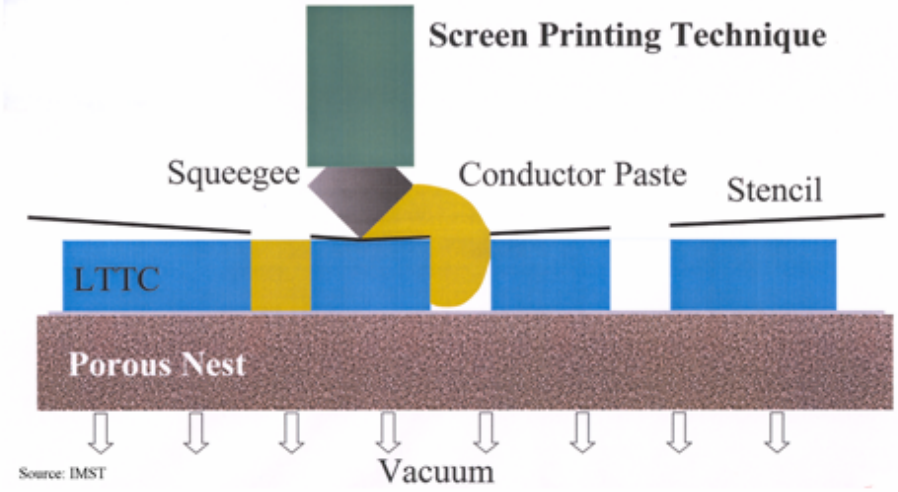
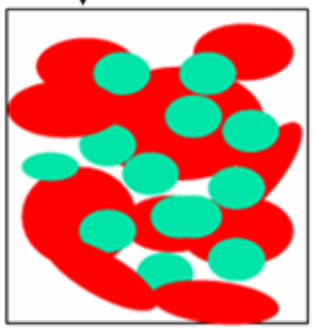




Glass-frit: low firing T
Filler: dimensional stability

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





Glass wetting and ceramic rearrangement occur

ADVANTAGES OF LTCC TECHNOLOGY

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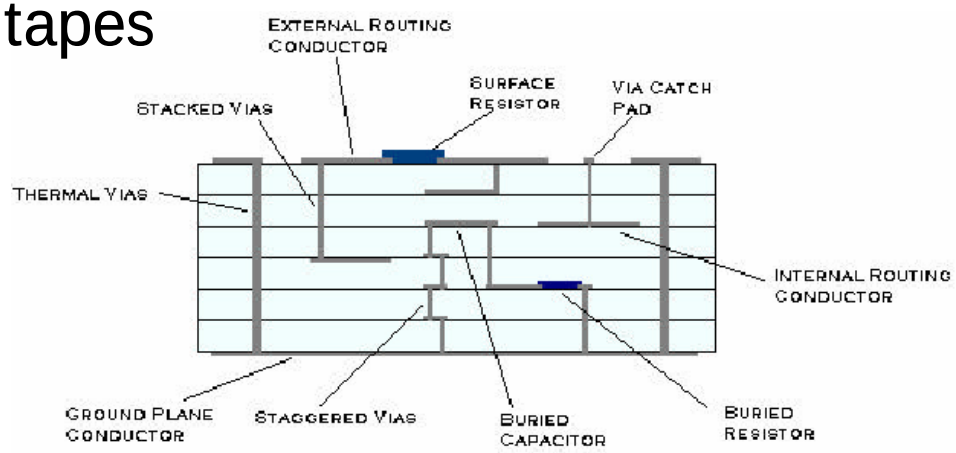
- Excellent dielectric properties for high frequencies
- Ease of machinability of tapes
- Cost effective
- High density packaging
- Excellent chemical / thermal stability
- Hermeticity of the structures
- Mechanical and electrical functions in one system

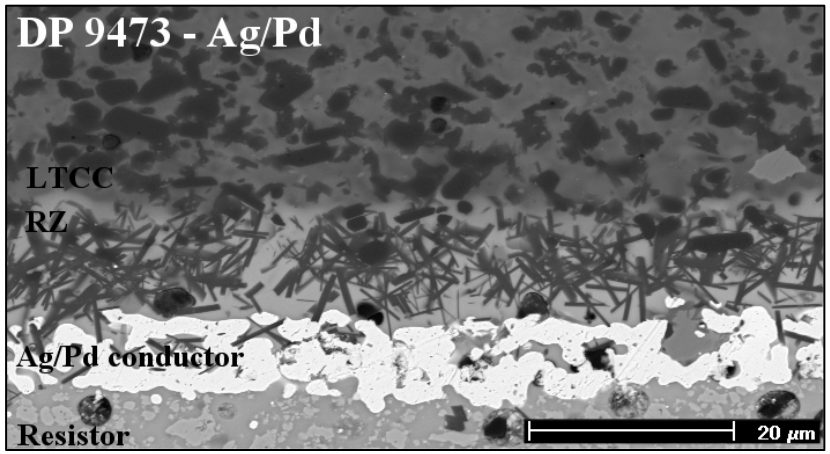


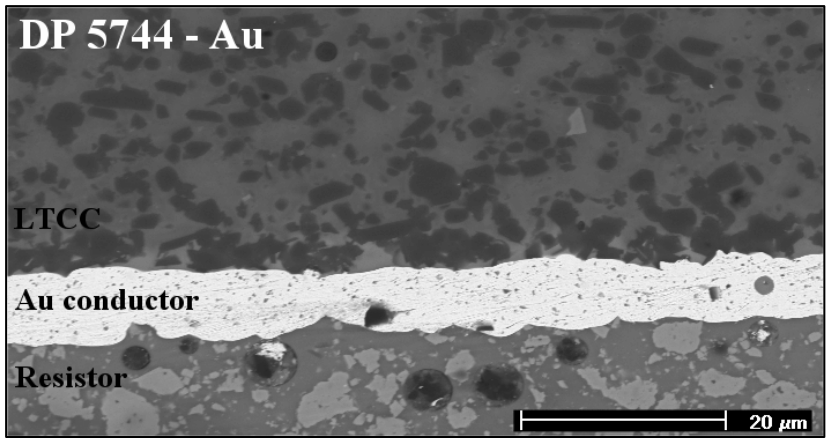
CHEMICAL ISSUES

Related to materials interaction during co-firing:

→Pronounced over Tg*
→Enhanced by concentration gradient of certain species in different components

** Glass in LTCC softens over Tg, wets the ceramic fillers, fills the interparticle-regions & rearranges them*





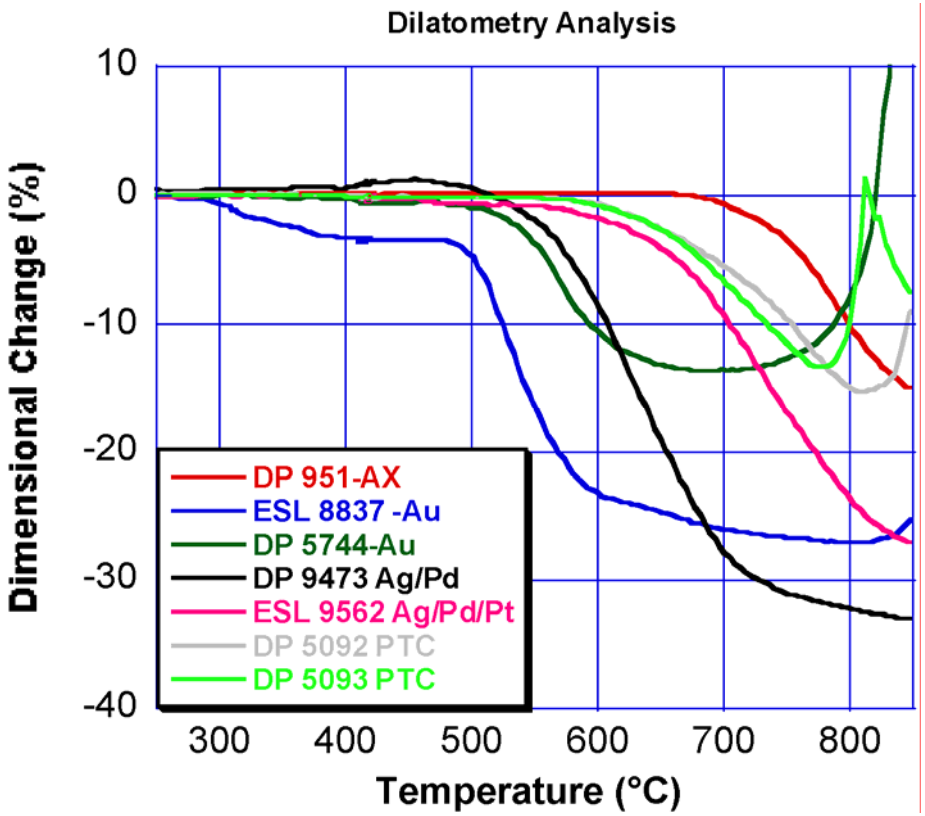
PHYSICAL ISSUES

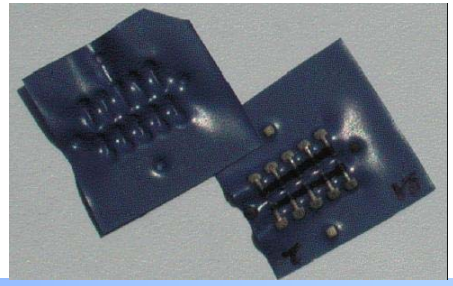
Arises from the difference in thermo-mechanical properties of co-fired components & de-gassing.

They are mostly observed as warpage, curling due to:

1. early sintering
2. higher extent of shrinkage

of thick-film components compared to LTCC

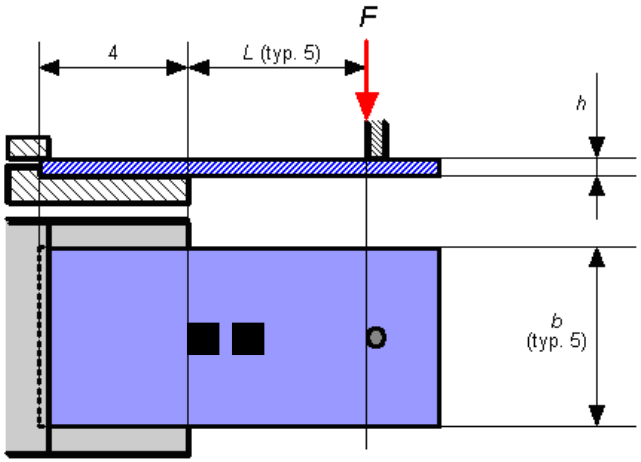




RELIABILITY OF DEVICES

Motivation of the study is driven by fabrication of millinewton force sensor* (MFS).

** The beam of the MFS, where the piezoresistors pastes are screen-printed and the force is applied must be be flat & warpage-free following co-firing*



$$\text{Signal} = \varepsilon_{max}\, G_f$$

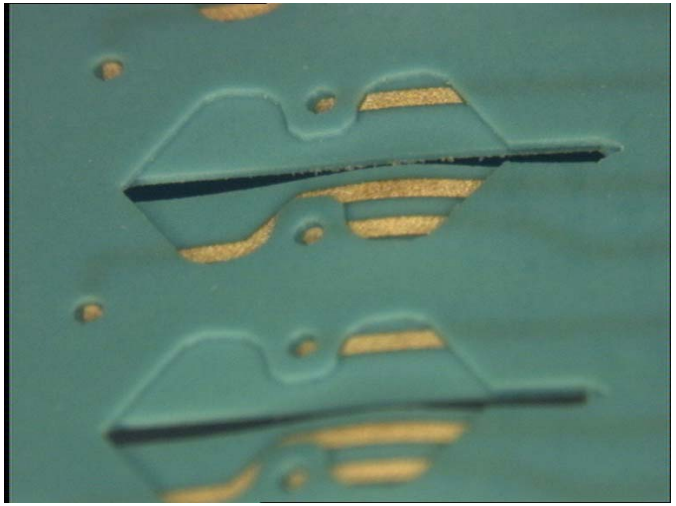
$$\varepsilon = (6FL) / (bh^2)E$$

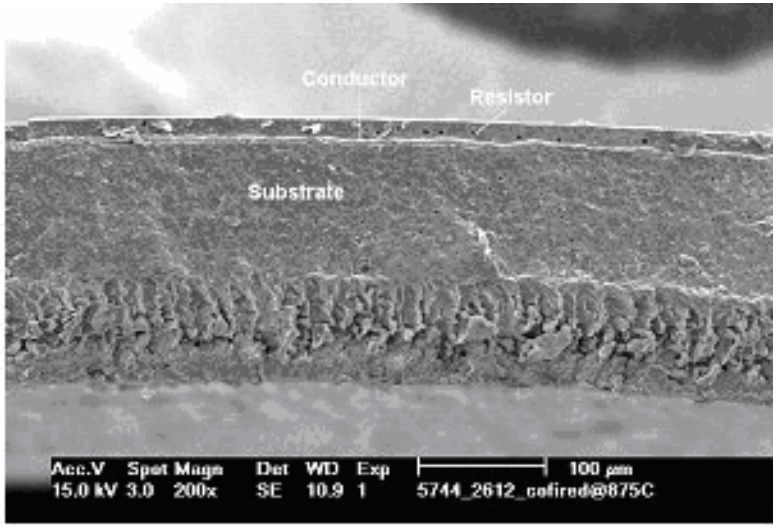
Figure of merit: *h*
Limitation: *warpage*

MODIFICATION OF PASTES

With the objective of reducing warpage in the co-fired module of LTCC+thick-film components by:

Matching the shrinkage rate & extent of commercial conductors with LTCC





MODIFYING PASTES USING ADDITIVES

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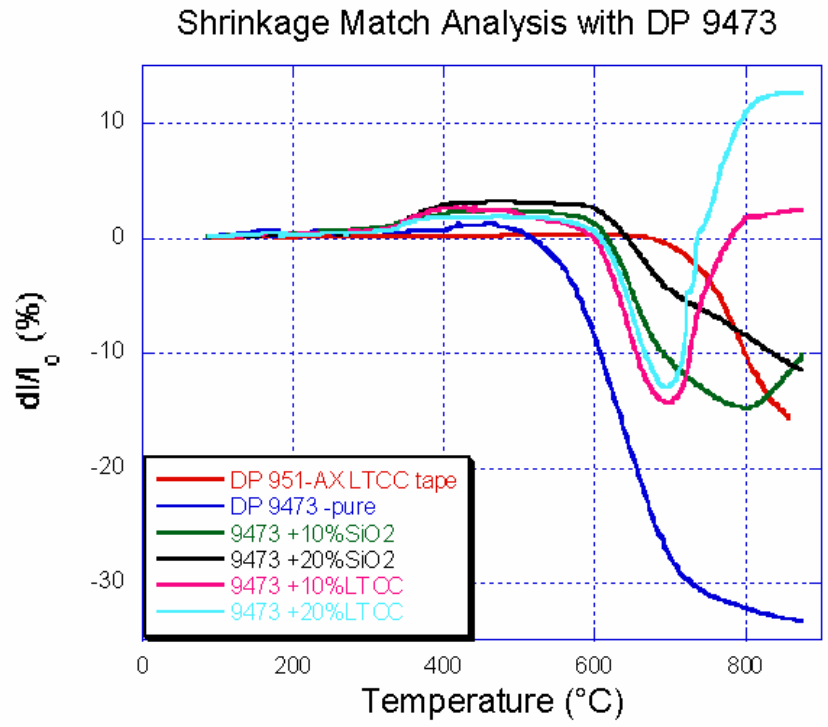
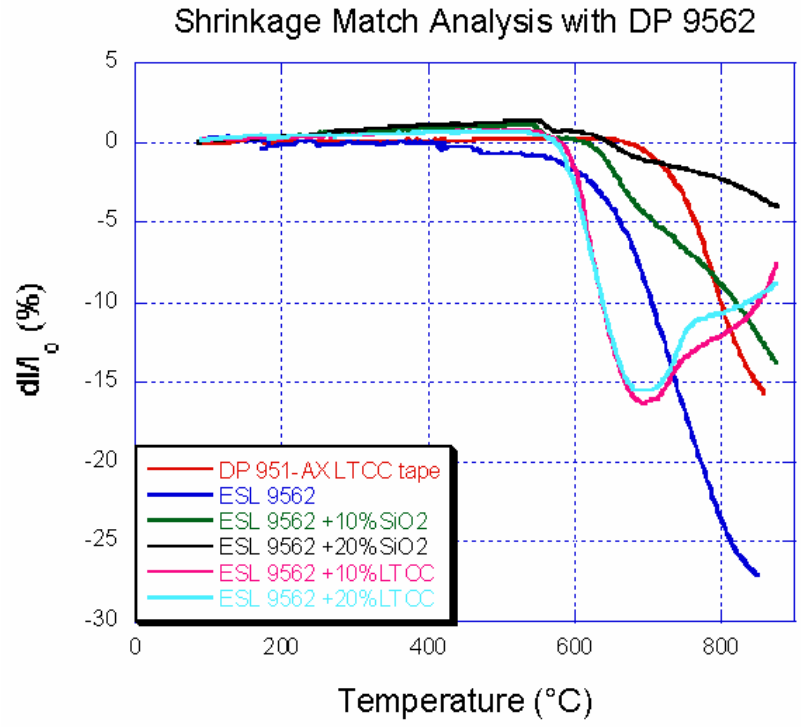
Paste	Specification	Additive	
		SiO_2*	LTCC
DP 9473	Ag/Pd	10%	10%
		20%	20%
ESL 9562**	Ag/Pd/Pt	10%	10%
		20%	20%

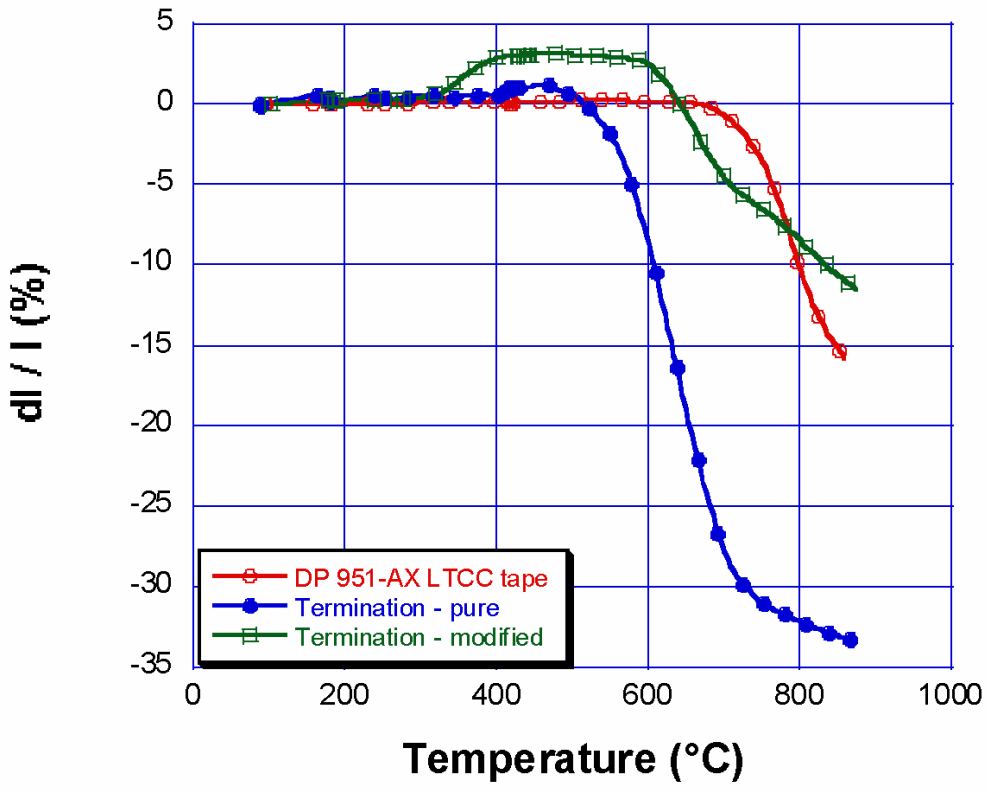
SiO_2: Sihelco, Sikron B 600

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



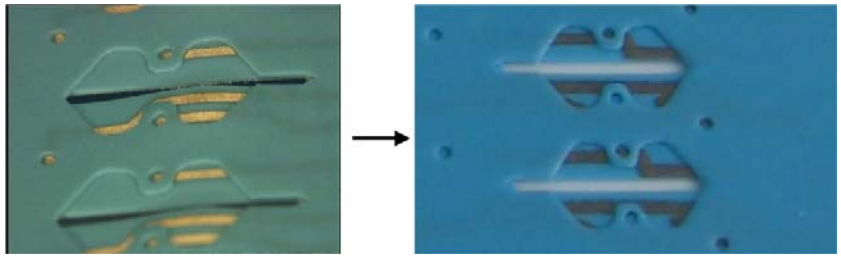


RESULTS I
SHRINKAGE MATCH



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).



The (onset) sintering temperature of the conductor has been shifted up to that of LTCC

RESULTS II
MICROSTRUCTURE

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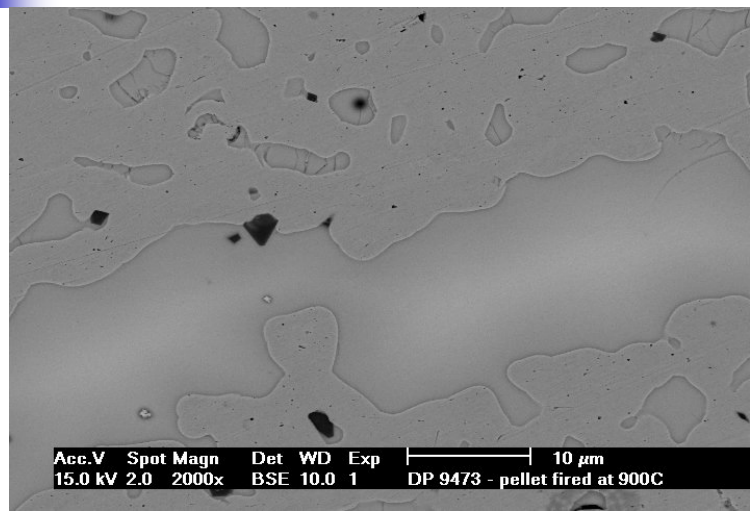
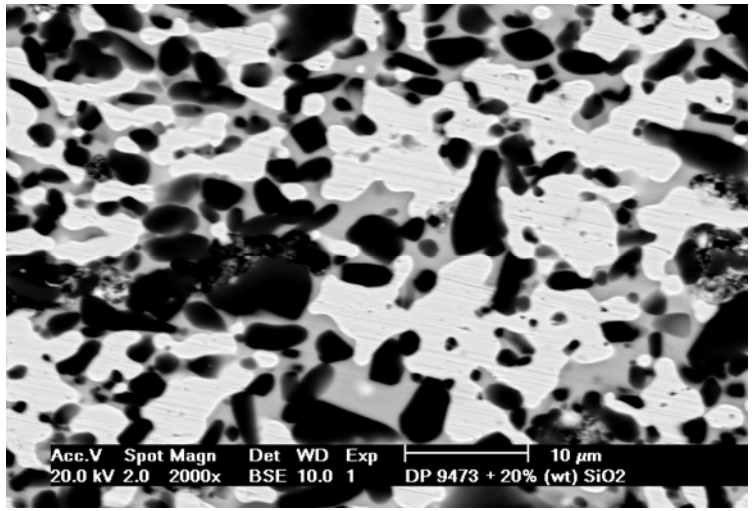
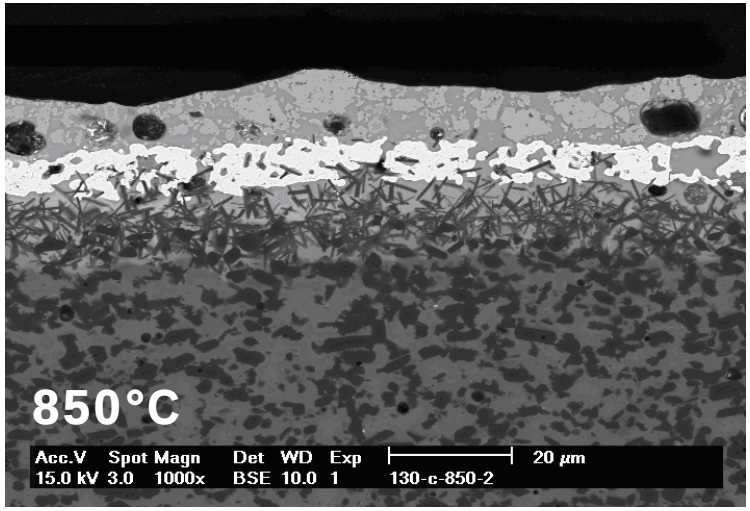
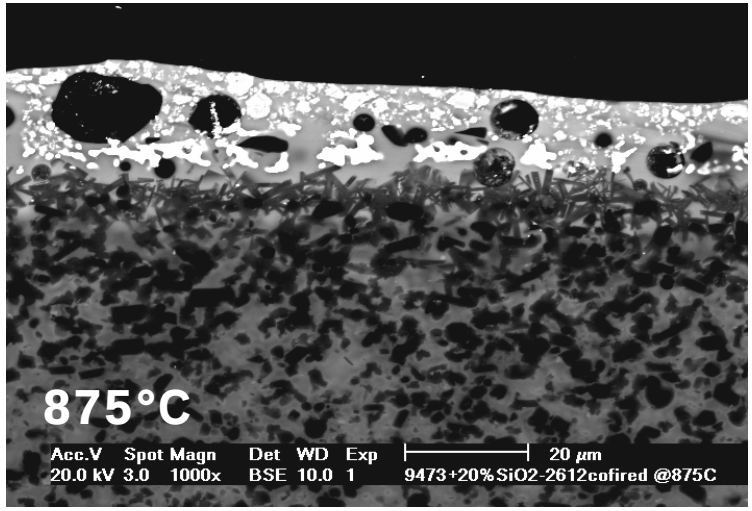
PELLET





TRANSVERSE





RESULTS III
ELECTRICAL PROP. & DEVICE

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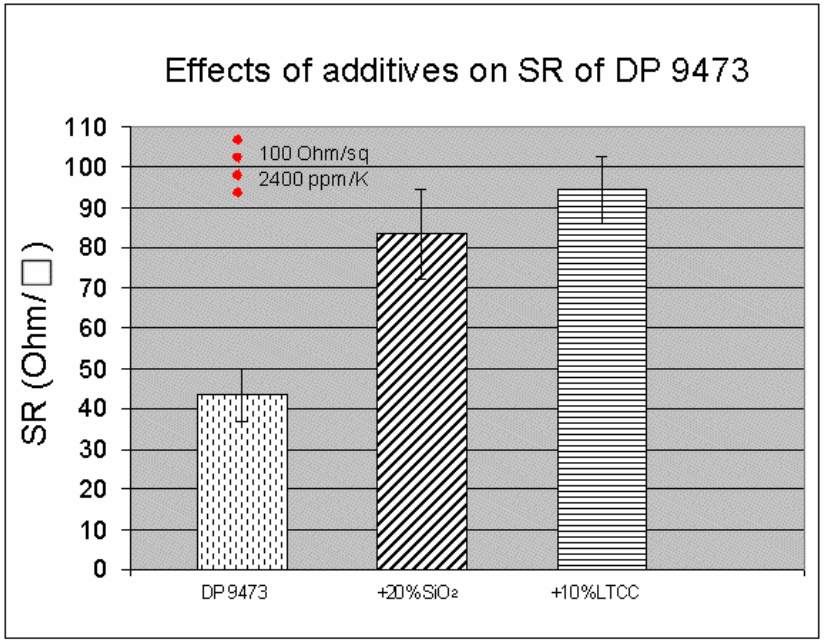
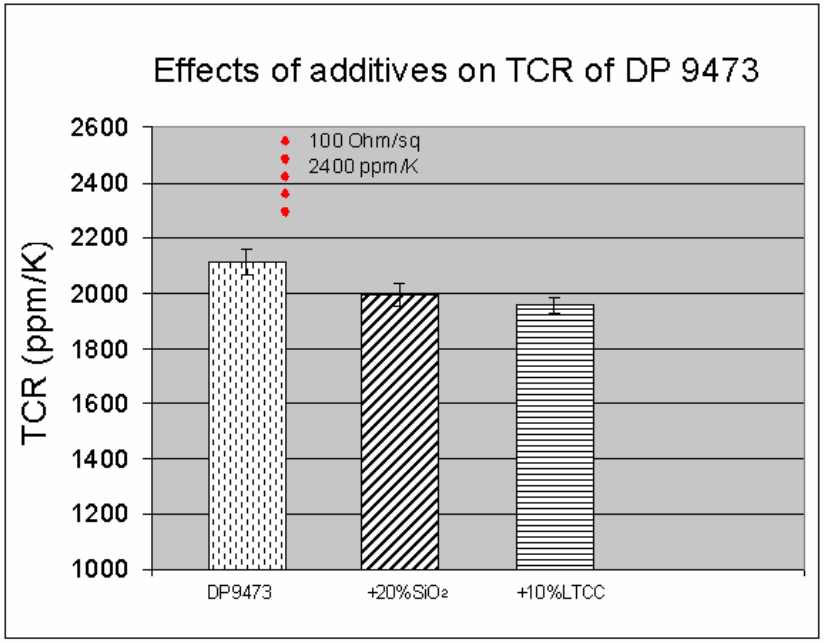
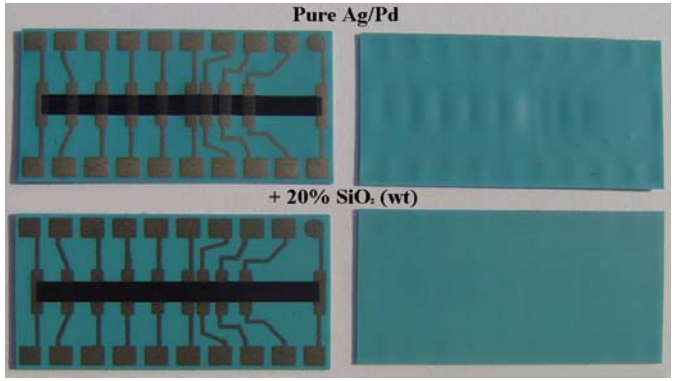
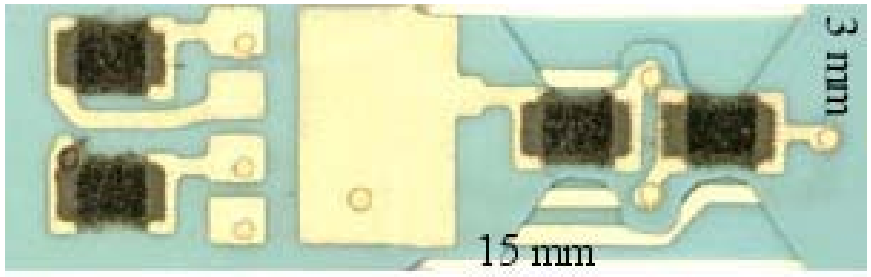




PTC



MFS



CONCLUSIONS

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

→For increased reliability, materials incompatibility issues must be well-controlled:

chemical interaction & thermo-mechanical differences between materials

→Differential shrinkage of components are shown to be matched efficiently, avoiding warpage, curling, etc...by:

mixing the commercial conductors with selected additives

→The effect of modification has been verified to be close to expected values of PTC resistors

favors the application of the technology in multi-disciplinary areas very soon