Processing – Property Relationship in Co-fired LTCC Structures

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PURPOSE OF THE PRESENTATION

- To present the electrical properties of selected TFR, processed by LTCC technology
- To highlight the direct effect of processing conditions on the properties
- To give an insight into the extent of physical and chemical interactions between the co-fired materials

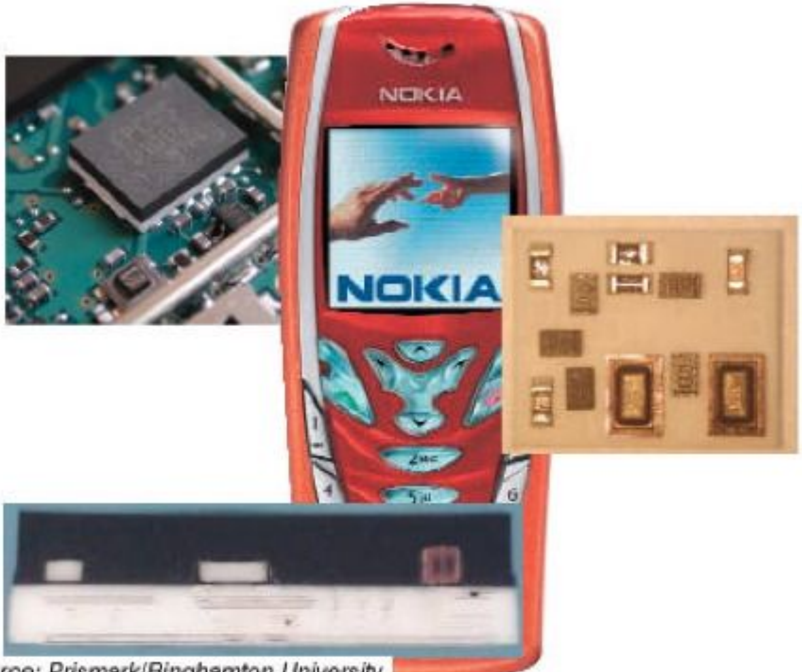
AN OVERVIEW

Situation → LTCC technology has been pointed as a smart packaging concept for a long time

Issue → In spite of its numerous advantages, challanges do arise due to material interactions during processing

Question → What are these challenges and their extent on final properties?

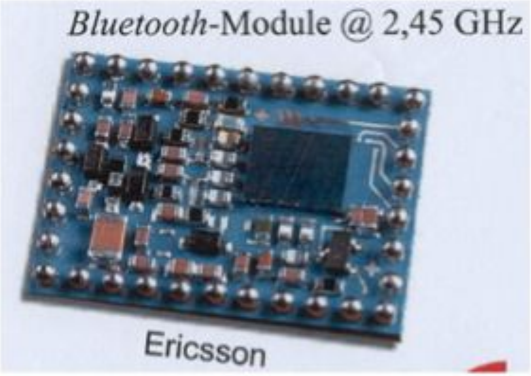
APPLICATION EXAMPLES



Source: Prismark/Binghamton University

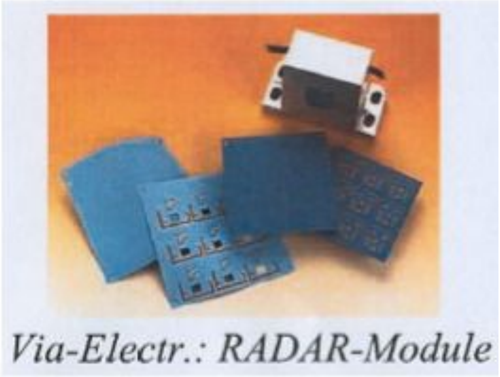
EPCOS FRONT END MODULE

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

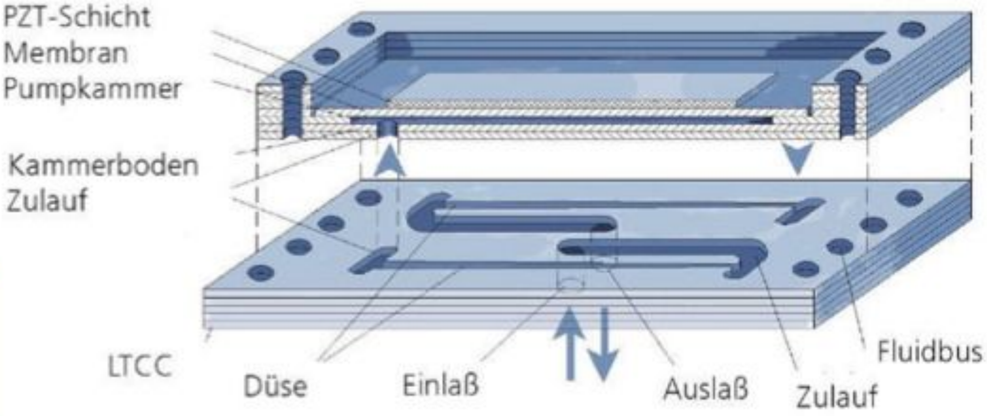


Bluetooth-Module @ 2,45 GHz

Ericsson



Via-Electr.: RADAR-Module



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OUTLINE OF THIS PRESENTATION

LTCC Technology

- →Introduction
- →Advantages

Electrical Properties

- →Preparation of test patterns
- →Properties
  - TCR and SR
  - Termination effects

Interpretation Of Results & Conclusions

- → Buried resistors
- →Compatibility
  - Ag:Pd system
  - Au system
- →Conclusions

WHAT IS LTCC TECHNOLOGY?

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Based on LTCC tapes of various thicknesses which

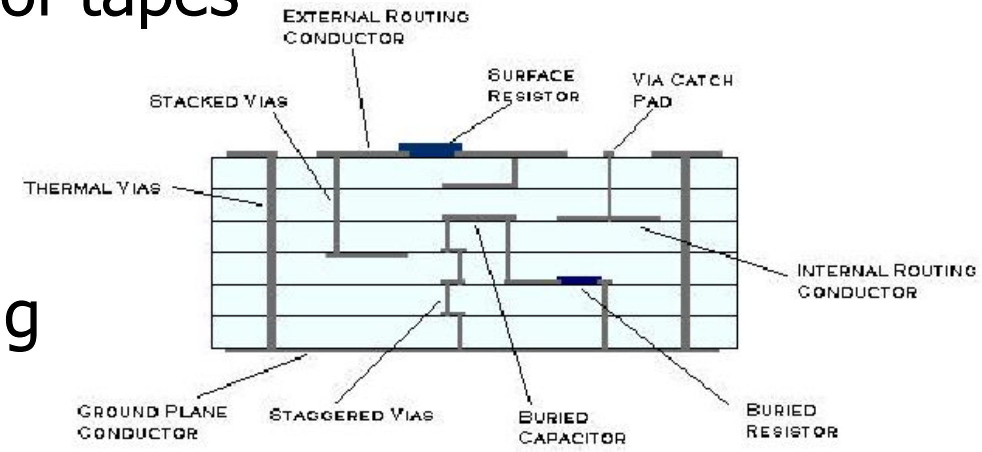
- sinter below 900°C
- are glass ceramics with excellent dielectric properties
- are screen-printed and co/post-fired with thick-film electronic passive components

LTCC MATERIALS SYSTEM

	COMPONENTS		
	SUBSTRATE	**PASSIVES**	
Components	**Tape**	**Conductor**	**Resistor**
Function	Dielectric layer	Thick-film paste	Thick-film paste
Functional group	Dielectric powder	Precious metal, fine size powder	Conductive oxide, fine size powder
Glass	✍ Lowers T_{firing}, ✍ increases dielectric strength and density	✍ Lowers T_{firing}, ✍ increases adhesion to substrate and density	✍ Lowers T_{firing}, ✍ increases density ✍ surrounds conductive powder
Organics	Binder, solvent, dispersant for appropriate rheology		

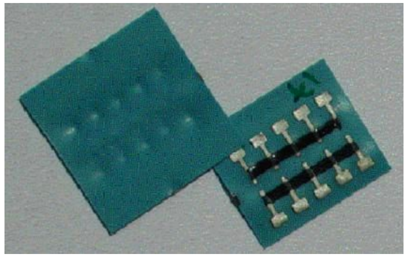
ADVANTAGES OF LTCC TECHNOLOGY AT A GLANCE

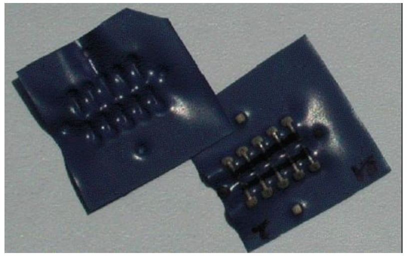
- Excellent chemical / thermal stability
- Ease of machinability of tapes
- Cost effective
- High density packaging
- Hermeticity of the structures
- Mechanical and electrical functions in one system
- Integration capability with other technologies



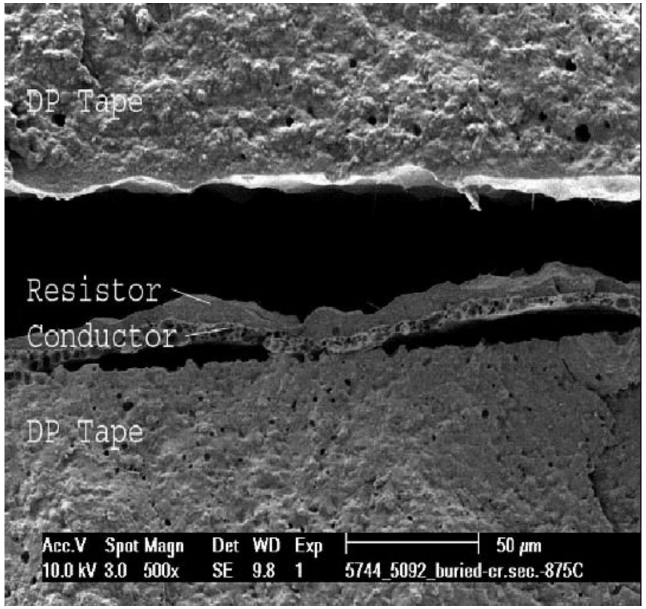
CHALLENGES

1. Physical Issues





- → differential shrinkage
- → degassing
- → lamination



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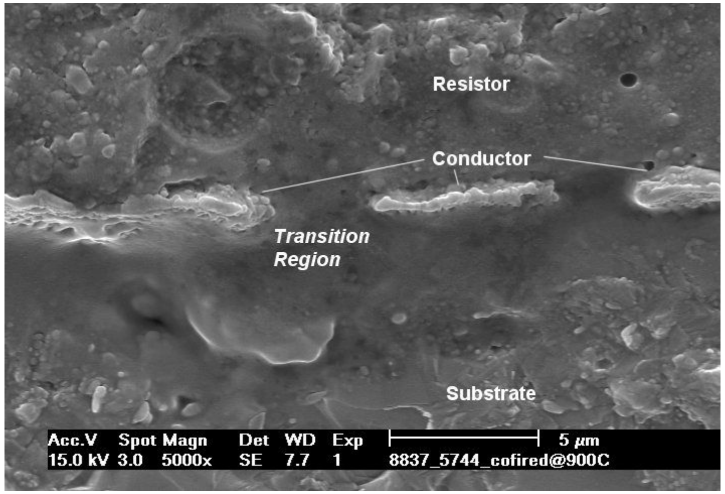
2. Chemical Issues

- → Interaction of components
- → Oxidizing /reducing conditions



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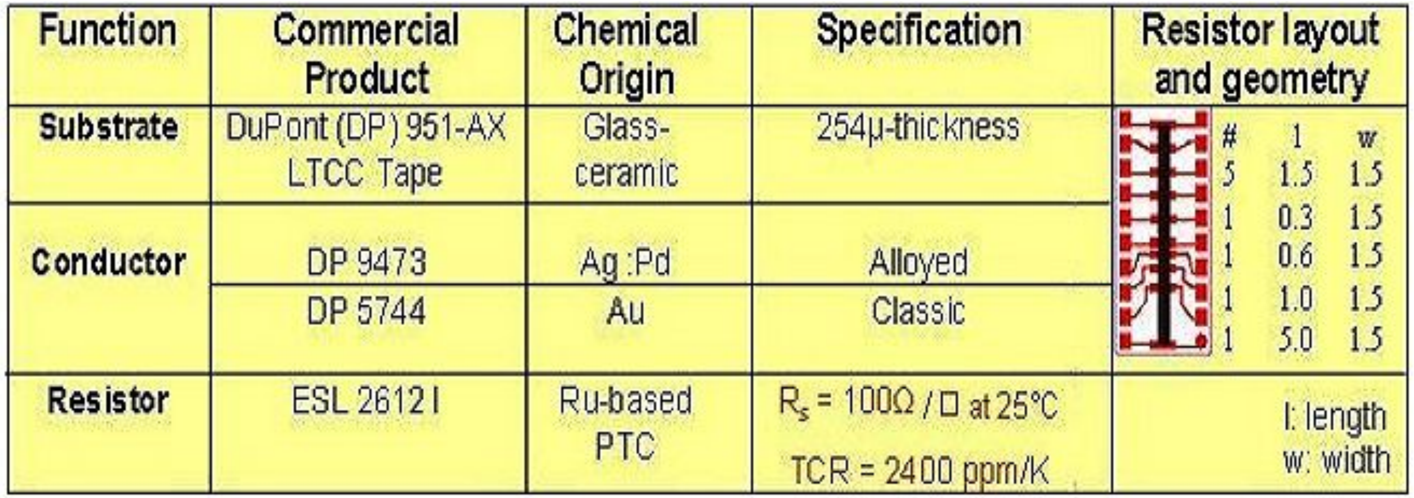
  - - Au system
- →Conclusions

PREPARATION OF TEST PATTERNS



Function	Commercial Product	Chemical Origin	Specification	Resistor layout and geometry
Substrate	DuPont (DP) 951-AX LTCC Tape	Glass-ceramic	254µ-thickness	# l w 5 1.5 1.5 1 0.3 1.5 1 0.6 1.5 1 1.0 1.5 1 5.0 1.5
Conductor	DP 9473	Ag:Pd	Alloyed	
	DP 5744	Au	Classic	
Resistor	ESL 26121	Ru-based PTC	R_s = 100Ω / □ at 25°C TCR = 2400 ppm/K	l: length w: width

Firing method	Screen-printing	Drying	Lamination	Firing (heating cycle)
Co-fired	+	+		+
Buried	+	+	+	+

Heating Cycle

STEP1: 25°C → 440°C
5°C/min, t_{dwell} = 120min

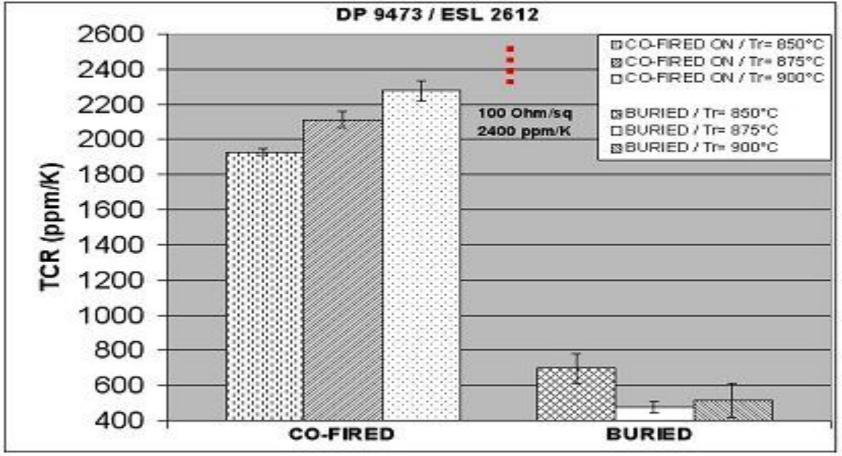
STEP2: 440°C → T_{firing}
5°C/min, t_{dwell} = 25min

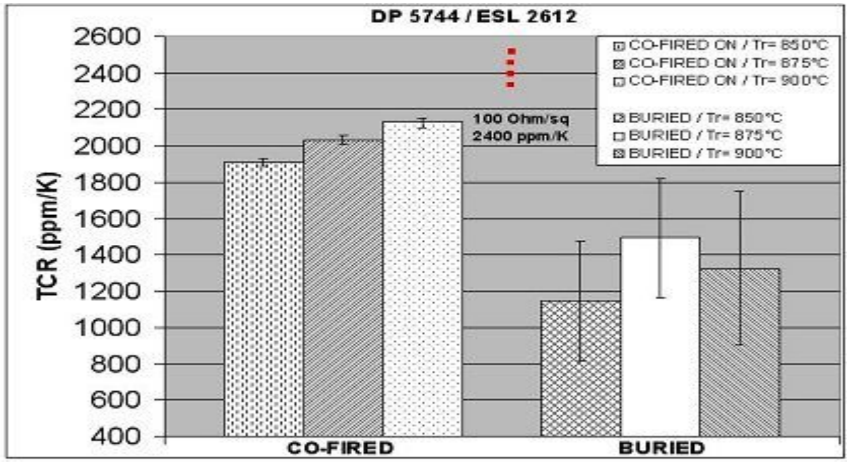
STEP3: T_{firing} → 25°C
10°C/min

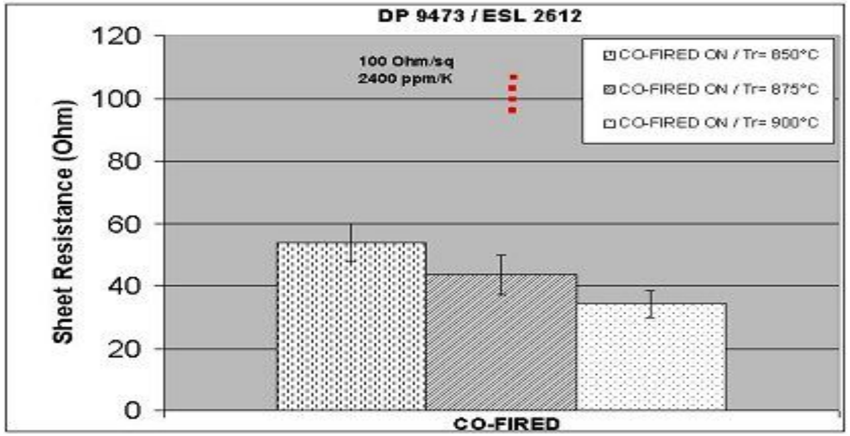
Properties of Interest

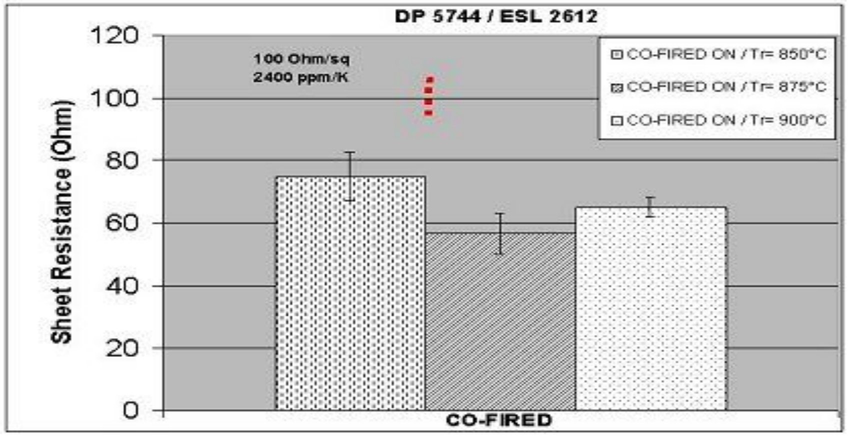
- Temperature Coefficient of Resistance (**TFR**)
- Sheet Resistance (**SR**)

ELECTRICAL CHARACTERIZATION -TCR and SR-









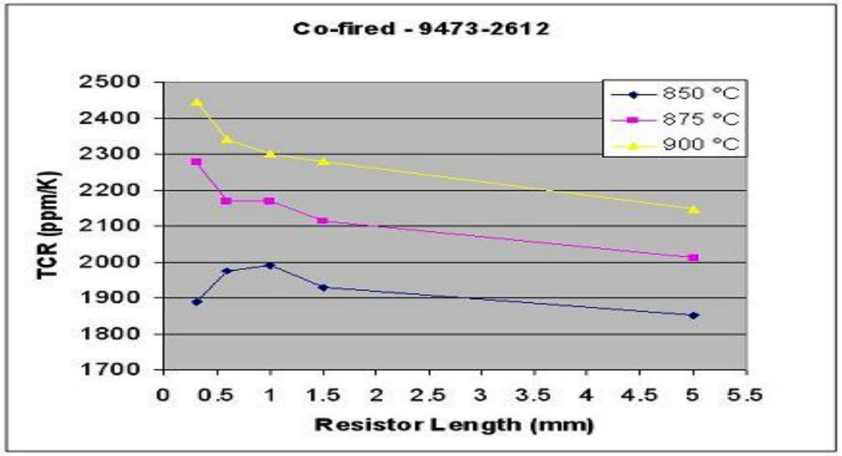
Co-fired Resistors

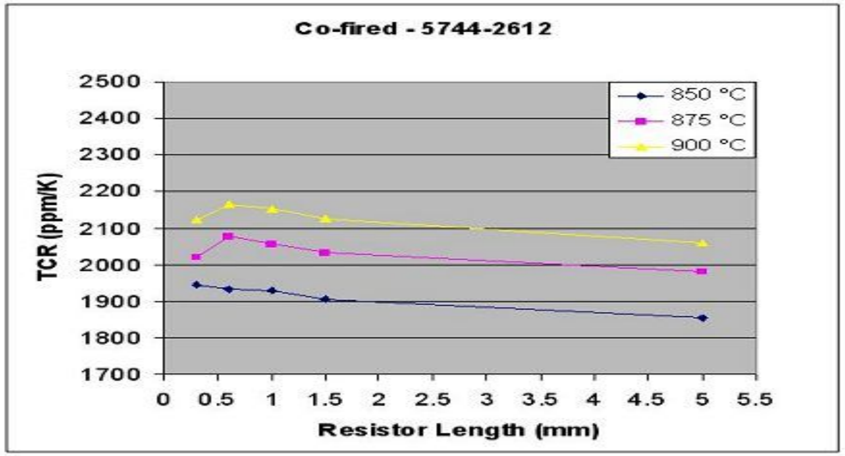
-in a TCR/SR range by specified values
-standard deviation is small
- Au closer to SR than Ag:Pd

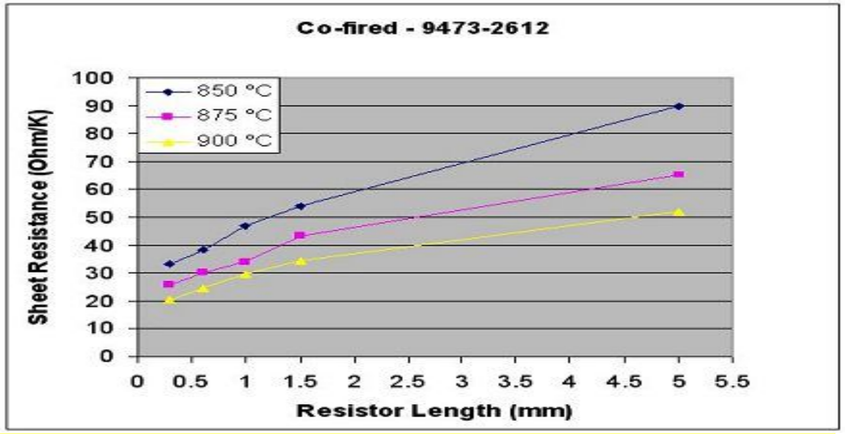
Buried Resistors

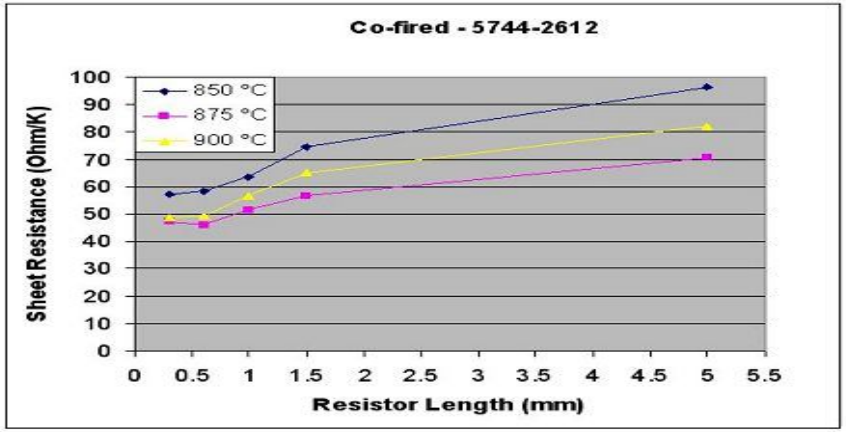
- non-reproducible TCR values
-SD is very broad

ELECTRICAL CHARACTERIZATION -Termination Effects









Ag:Pd system

-Steeper TCR - SR vs resistor length curve indicating an increased influence

- Increasing SR at all resistor lengths

Au system

-Shallower curves closer to zero slope

-Closer SR value to expected values

-Constant SR value at short lengths

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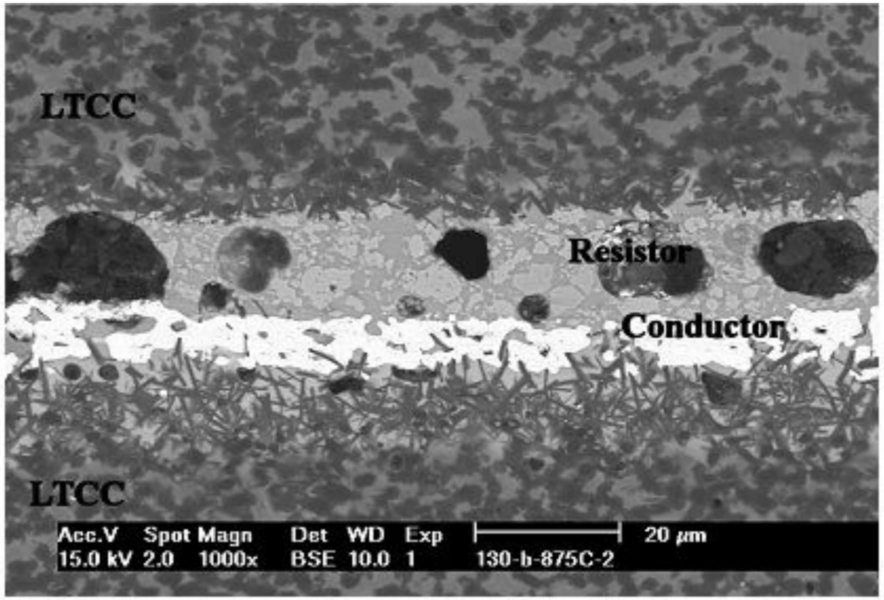
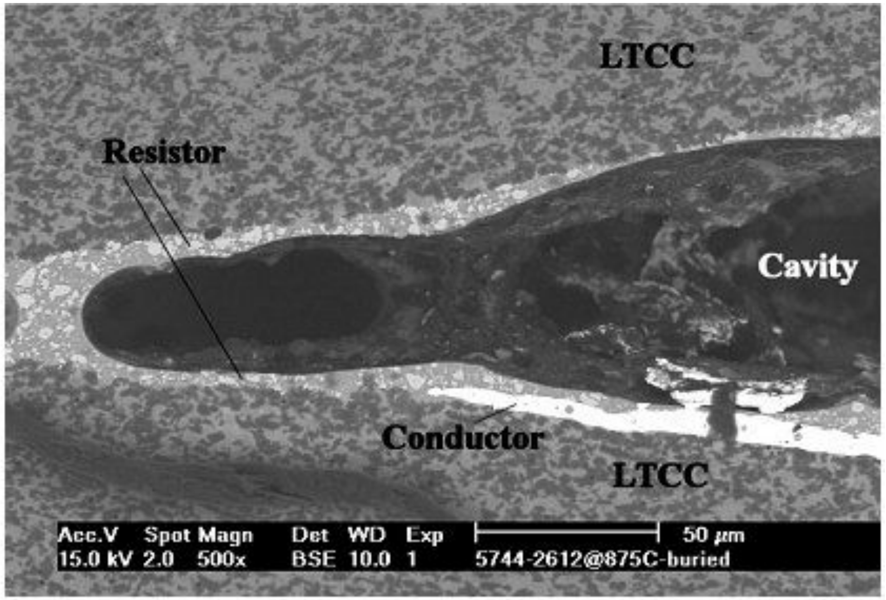
BURIED RESISTORS





Ag:Pd system

-Reaction zone (light grey) going only along the conductor pad (at all T's):

-- beltween the conductor and LTCC
-- between the resistor and LTCC

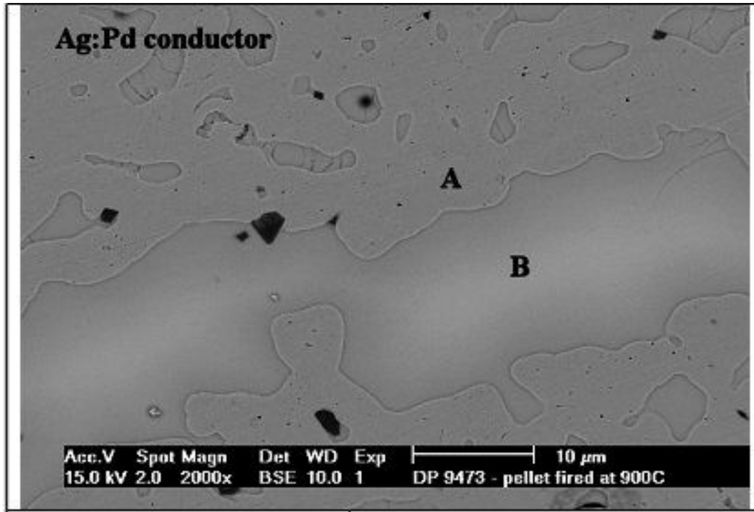
-Its thickness depends on temperature

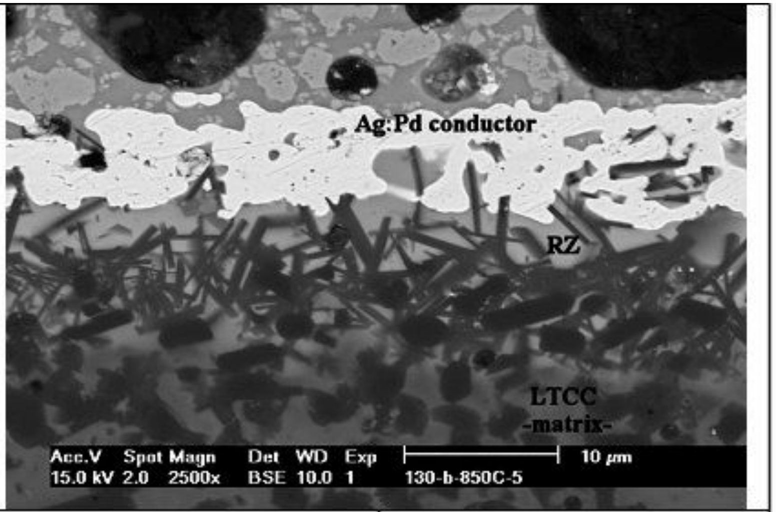
Au system

-Severe deformation at the termination as a result of:

-swelling due to entrapped organic burnout products
- delamination
-high-temperature reaction (?)

COMPATIBILITY ISSUES
Ag:Pd System

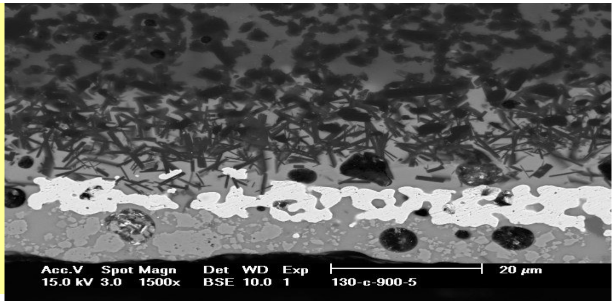




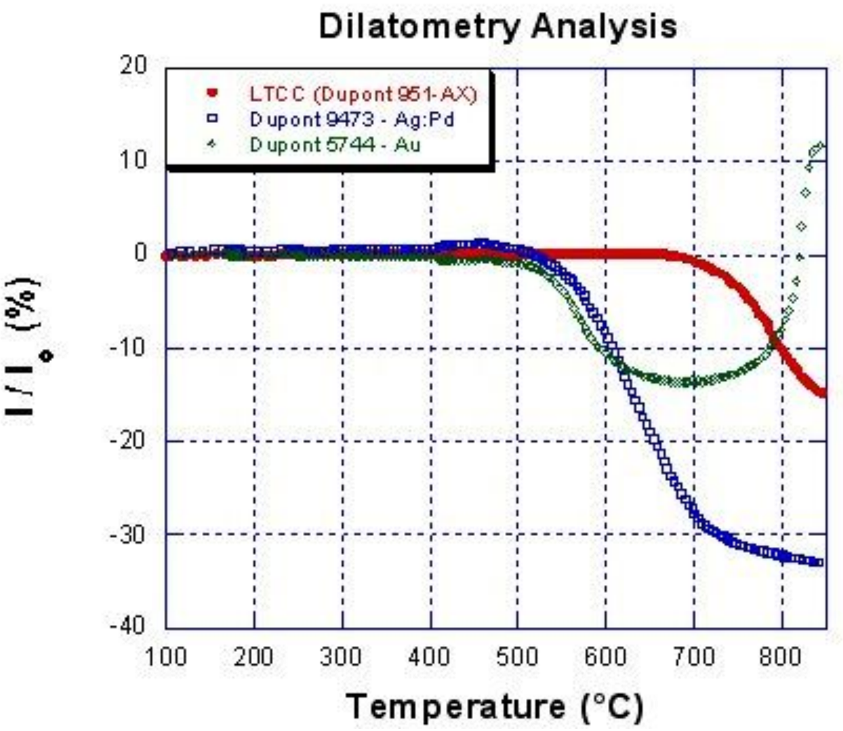
A		B		RZ (reaction zone)		Matrix in LTCC	
Element	**Atomic %**	**Element**	**Atomic %**	**Element**	**Atomic %**	**Element**	**Atomic %**
Ag	24	O	57	O	59	O	55
Pd	76	Zn	10	Na	4	Al	10
		Al	4	Al	10	Si	26
		Si	8	Si	15	Pb	2
		Bi	18	Pb	4	Ca	3
		Others	3	Bi	6	Na	2
				Others	2	Others	2

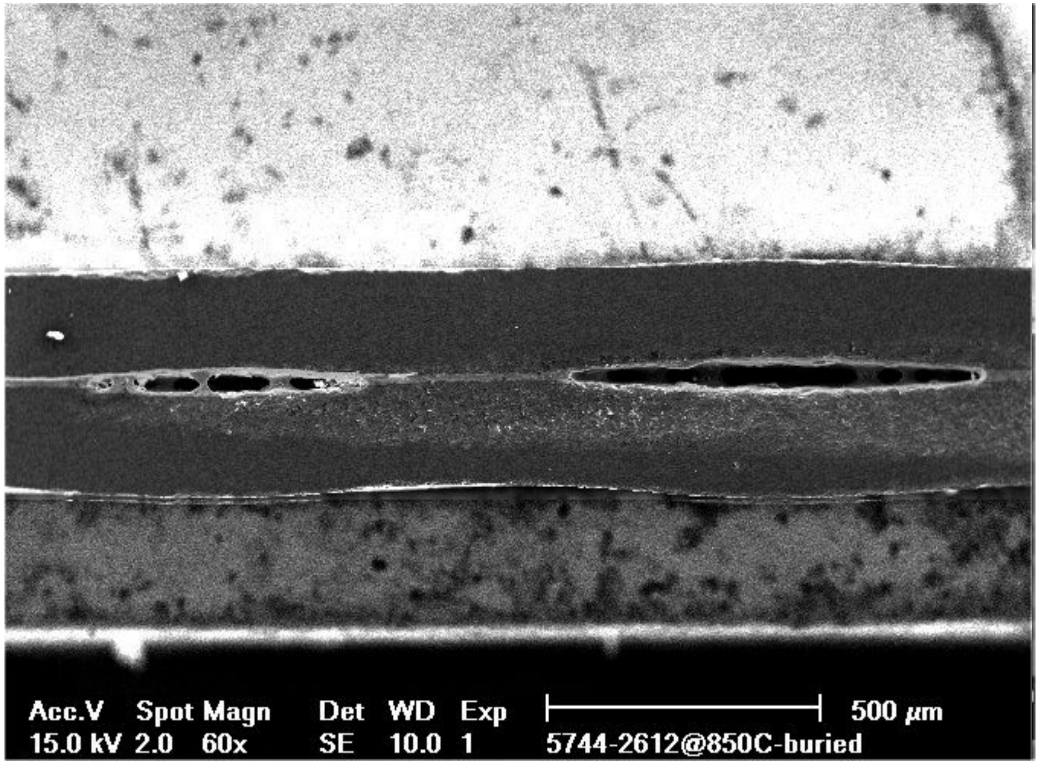
Ag:Pd system

-reaction zone (RZ) due to interaction of glasses in LTCC and conductor (at all T's)
-discontinuous conductor line



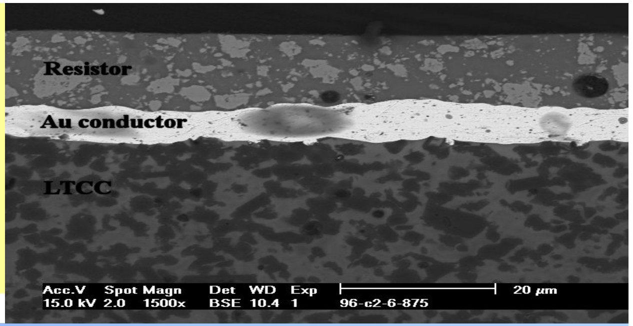
COMPATIBILITY ISSUES
Au System





Au system

-expansion after 700°C resulting in deformation of the pads for buried resistors
-continuous conductor line for co-fired ones



CONCLUSIONS

- Buried resistors deviate from expected values
- The deviation arises from various mechanical (Au) and/or chemical (Ag:Pd) sources
- The chemistry of the material in addition to the processing conditions effect properties directly

NEXT STEPS

→ Fundamental understanding of the mechanism of formation of deformation in buried structures

→ Characterization of glass used in the components

→ Manufacturing of conductors those having shrinkage behavior similar to LTCC tape