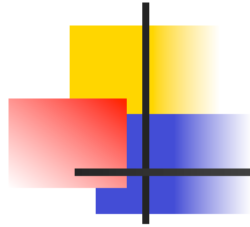

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Low-Temperature Thick-Film Nanograin Materials System

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Objective

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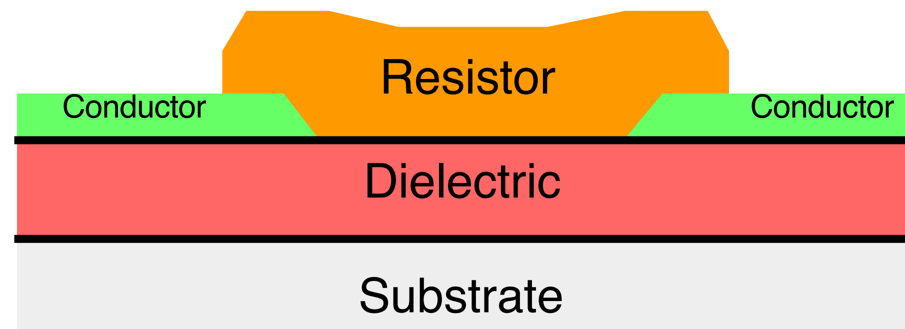
High temperature thick-film system

low temperature thick-film system



Issues with low-temperature thick-films

- Compatibility of thermal expansion
- Dielectric-resistor compatibility
- Burn-out of organics
- Adhesion
- Stability of the resulting circuits

Studied thick-film compositions

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- Dielectrics

Dielectric	Glass	Filler grain size (µm)	%vol Alumina powder
D611	V6	10	10
D612	V6	10	20
D613	V6	10	30
D643	V6	0.04	30
D811	V8	10	10
D812	V8	10	20
D813	V8	10	30
D814	V8	10	40

- Resistors

Resistor	R8	R6
Glass	V8	V6
Grain size RuO_2 particle	400 nm	40 nm
RuO_2 volume fraction	0.08	0.08
Firing temperature	450°C	575°C

V6 = 75% PbO + 10% B_2O_3 + 15% SiO_2 + 2% Al_2O_3

V8 = 85% PbO + 10% B_2O_3 + 5% SiO_2 + 2% Al_2O_3

-ESL 590G for conductor
-Alumina and aluminium substrates

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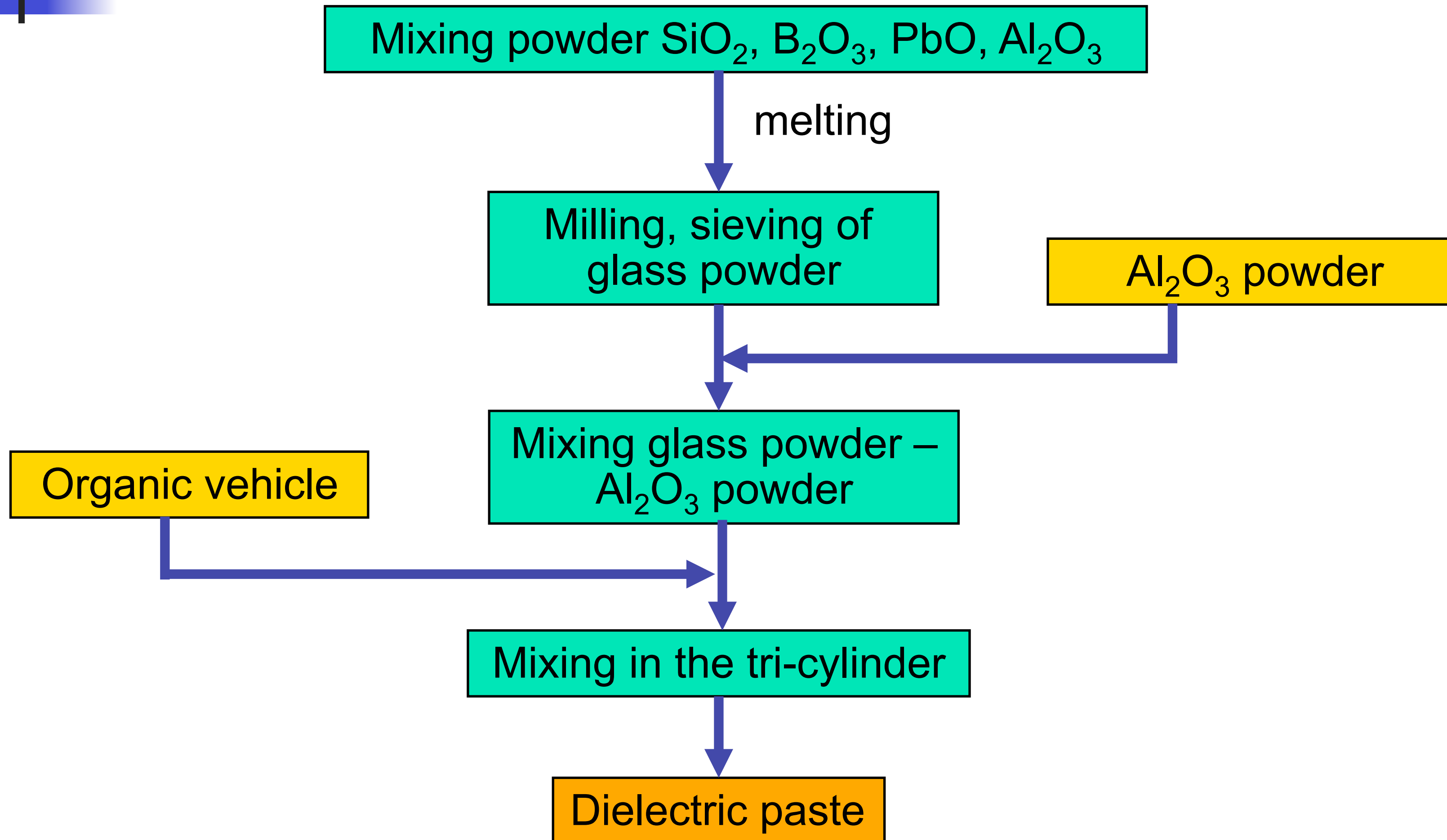
Paste preparation



Firing temperature

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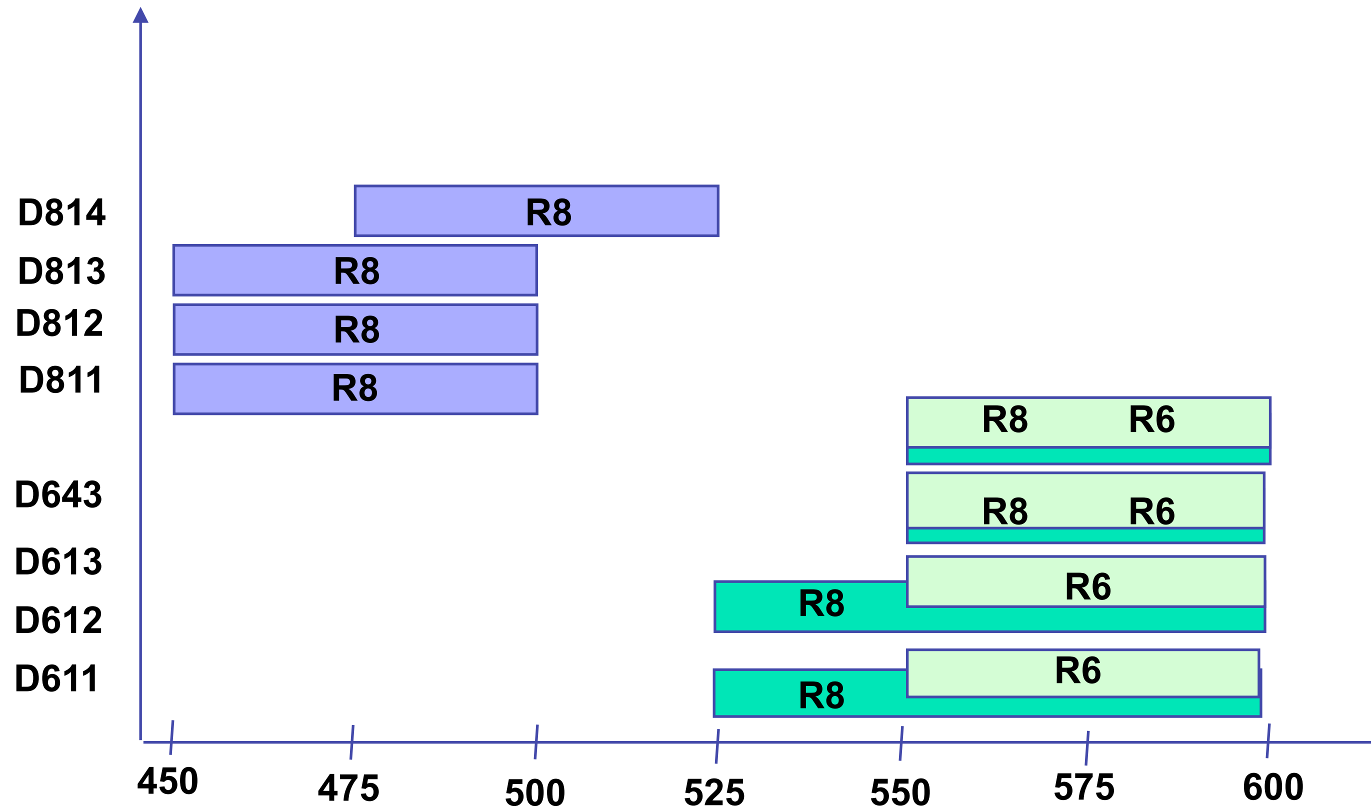

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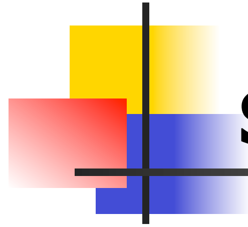

Screen-printing sequence

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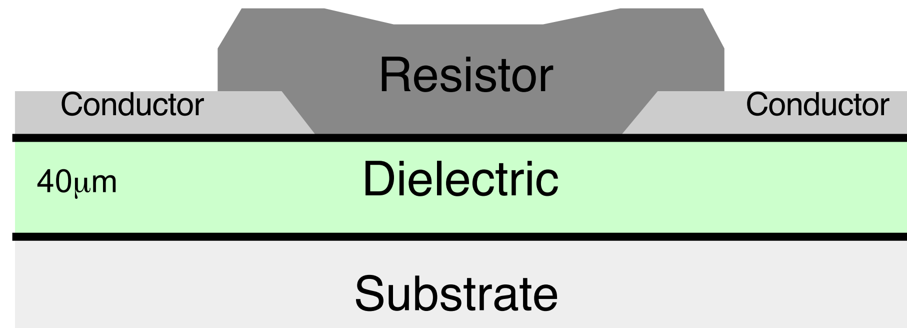
Basic structure



Samples for characterisation

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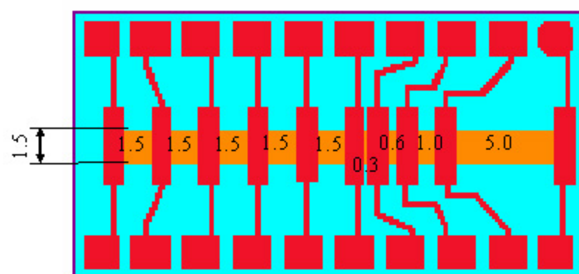
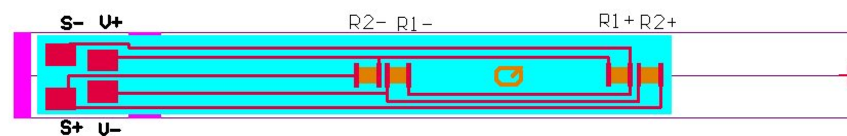
- TCR measurement

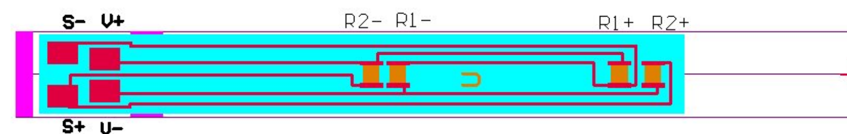


- Gauge Factor measurement

Longitudinal resistors



Transverse resistors



Dielectric Strength

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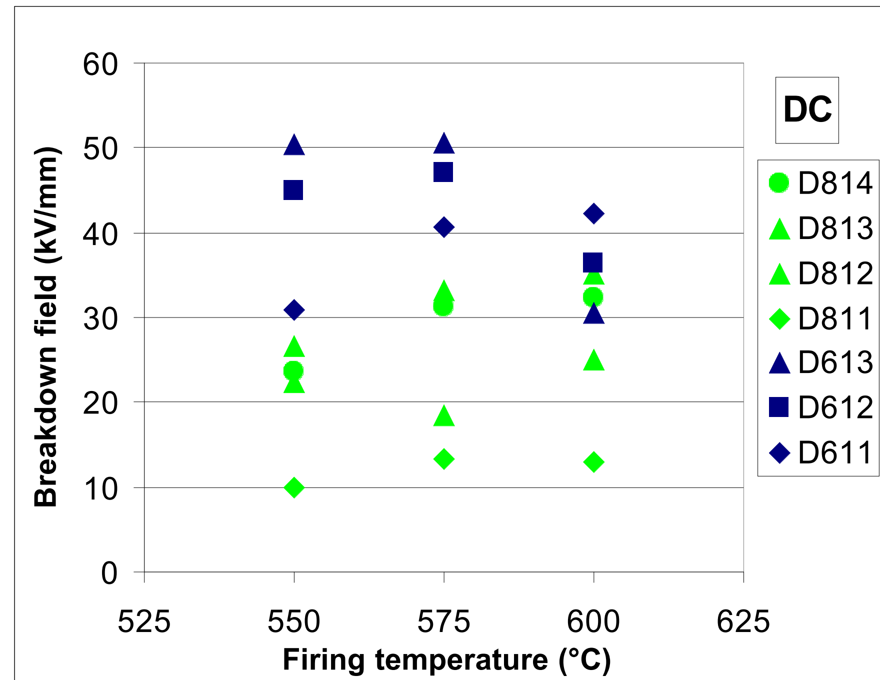
- V6-based dielectrics have a higher breakdown strength.
- Low-temperature glass & low filler concentration favour diffusion of conductor, leading to low breakdown strength.
- Breakdown strength is improved by alumina filler.
- AC & DC follow same trend.



TCR results

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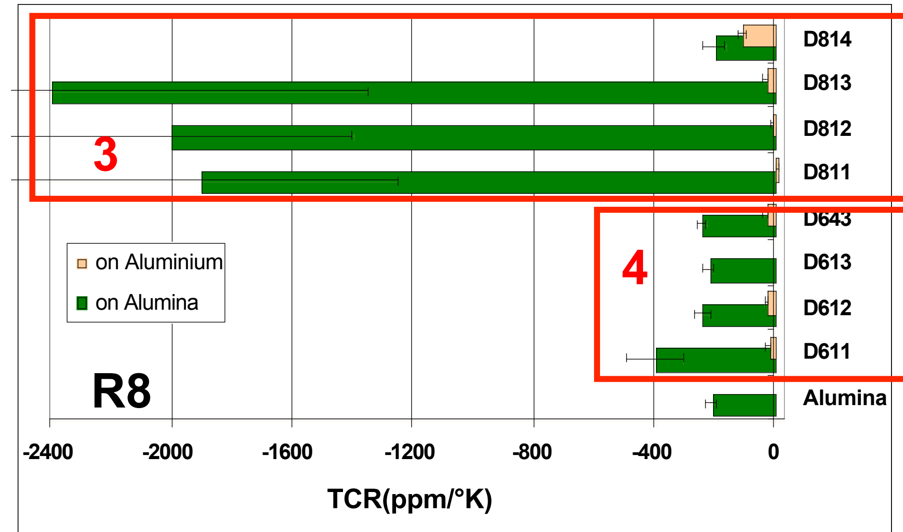
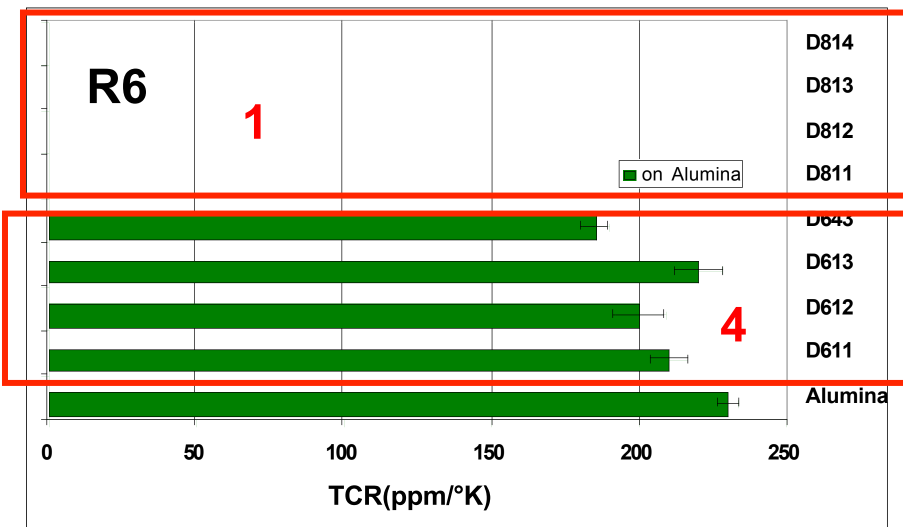
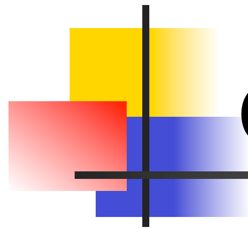
1. Incompatibility Firing process
2. Excessive compressive thermal mismatch stresses
3. Cracking due to tensile stresses arising upon cooling
4. Close to expected values







Gauge factor results

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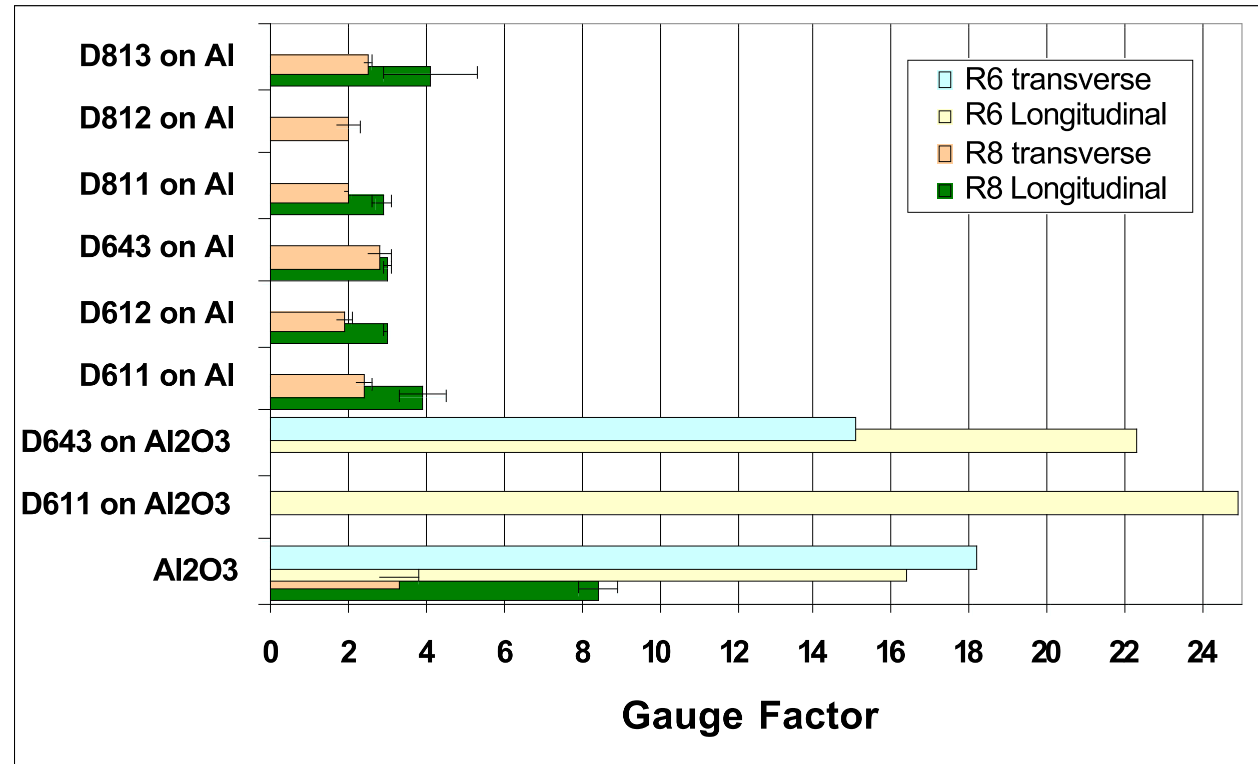
- GF(R6) high
- GF(R8) low

- Chemical interaction
- Thermal expansion influence



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Resistors properties

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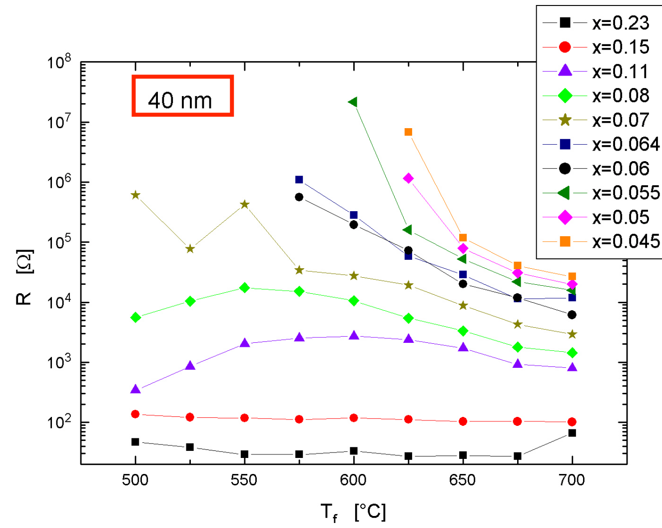
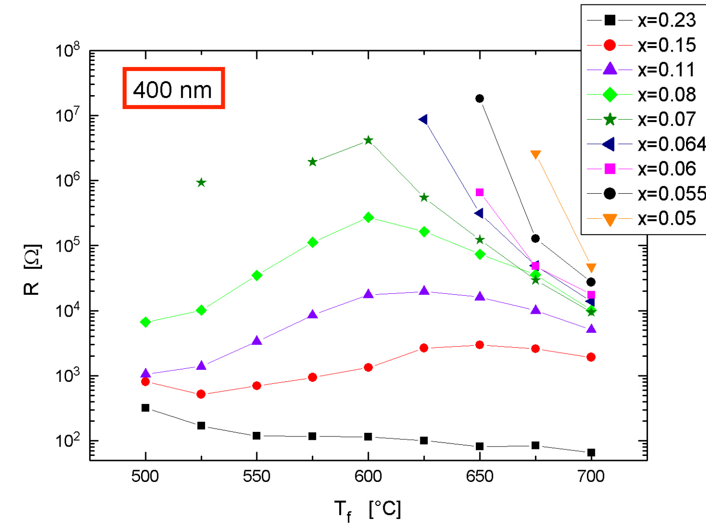
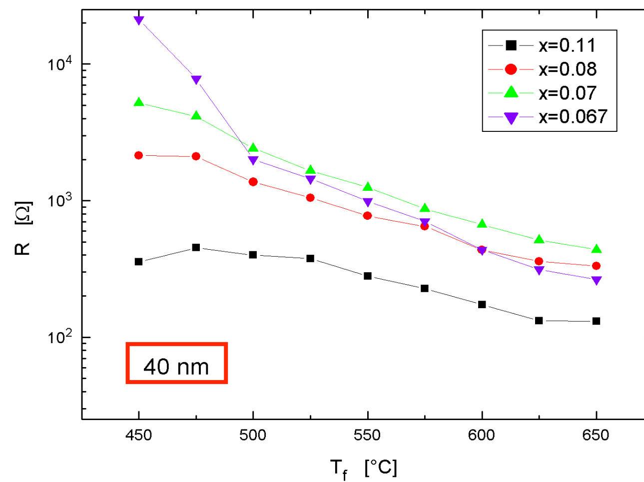
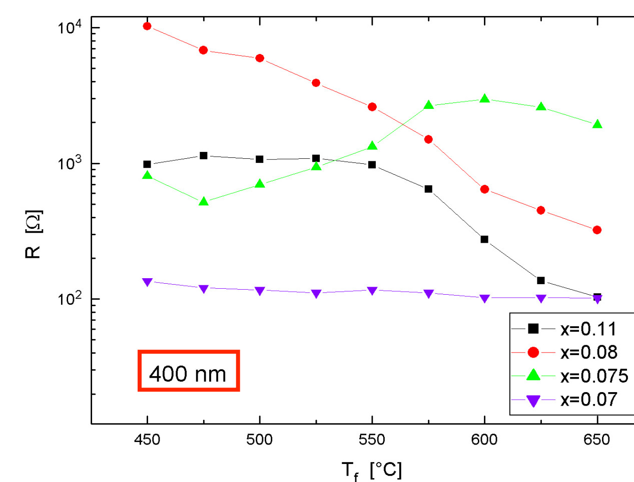
R6





R8





Conclusions

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- Dielectric – resistor chemical compatibility
- Electrical insulation demonstrated
- Very low processing temperature achieved
- Matching of thermal expansion is critical

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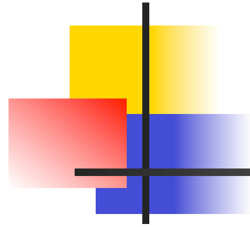
Outlook

- Substrates with lower TCE: Al-Si, Al-SiC
- Fillers: TCE matching with substrate (cristobalite, CaF_2, quartz, a-SiO_2, …)
- Control of TCR through additives (CuO, NiO, TiO_2, SbO_3)
- Materials without Pb or precious metals



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$$\Delta TCR = (GF_L + GF_T) \times \Delta\alpha$$

TCR

	R8		**R6**	
	Alumina	**Aluminum**	**Alumina**	**Aluminum**
(alumina)	-210 ± 30	-	230 ± 7	-
D611	-400 ± 190	-20 ± 14	210 ± 13	-
D612	-240 ± 50	-25 ± 14	200 ± 17 5	2
D613	-220 ± 30 4	- 1	220 ± 16	-
D643	-240 ± 30	-29 ± 19	185 ± 9	-
D811	-1900 ± 1300	+14 ± 9	-	-
D812	-2000 ± 1200 3	-5 ± 9	- 1	2
D813	-2400 ± 2100	-30 ± 14	-	-
D814	-200 ± 70	-110 ± 30	-	-