

Integrated thick-film hybrid microelectronics applied on different material substrates

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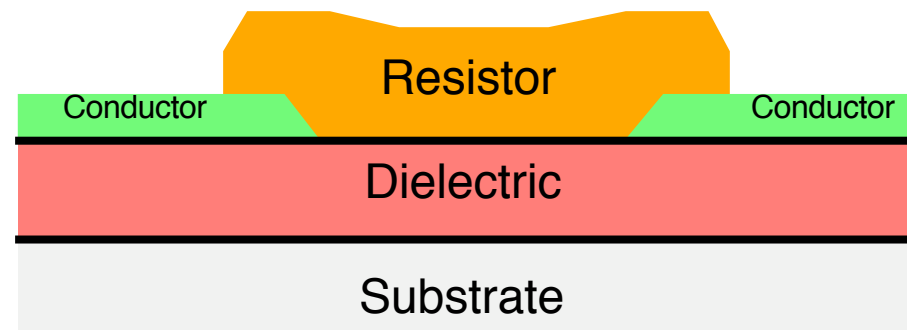
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Lausanne, Switzerland
lpmwww.epfl.ch

Objective

High temperature
thick-film system



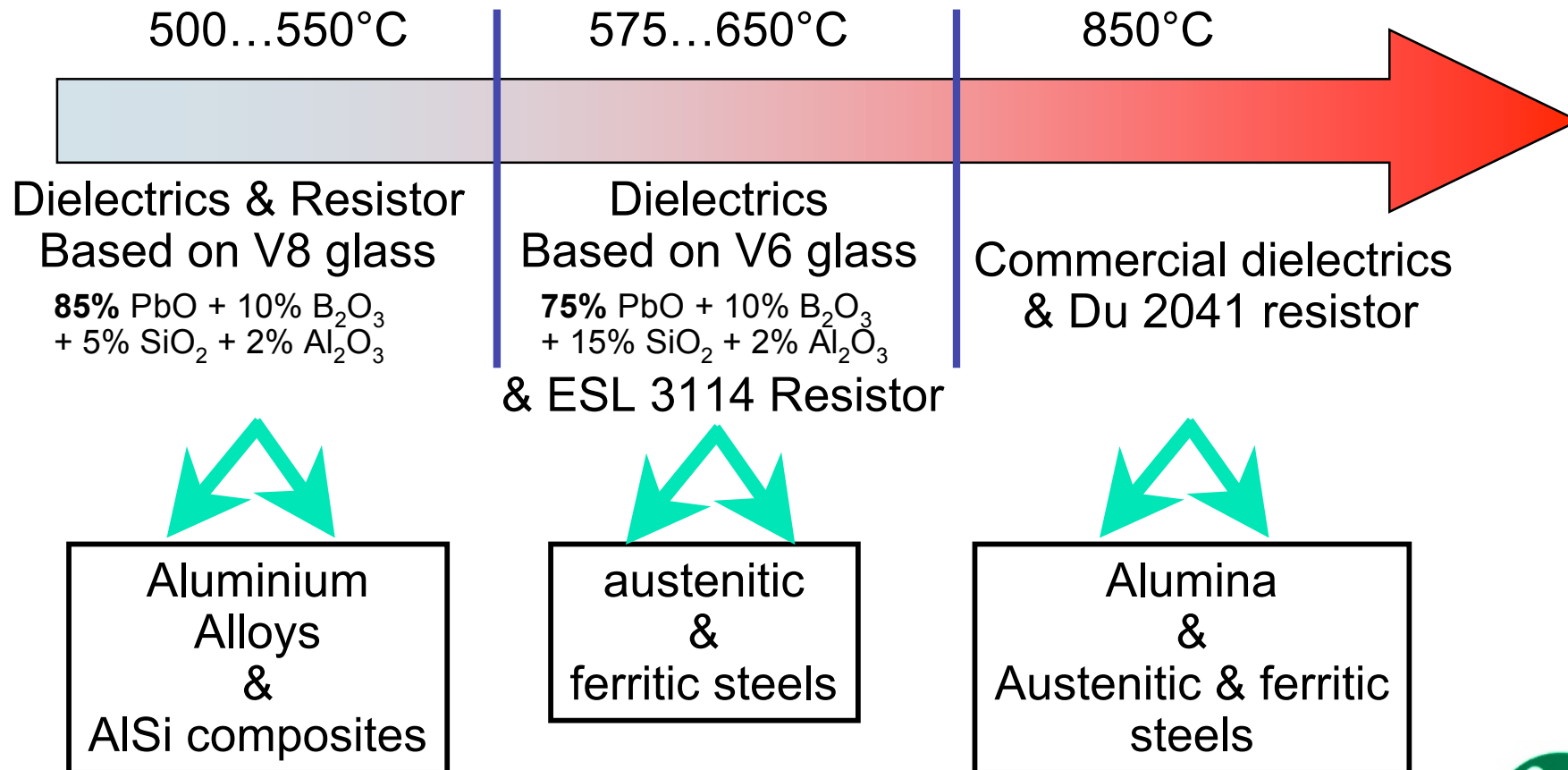
low temperature
thick-film system



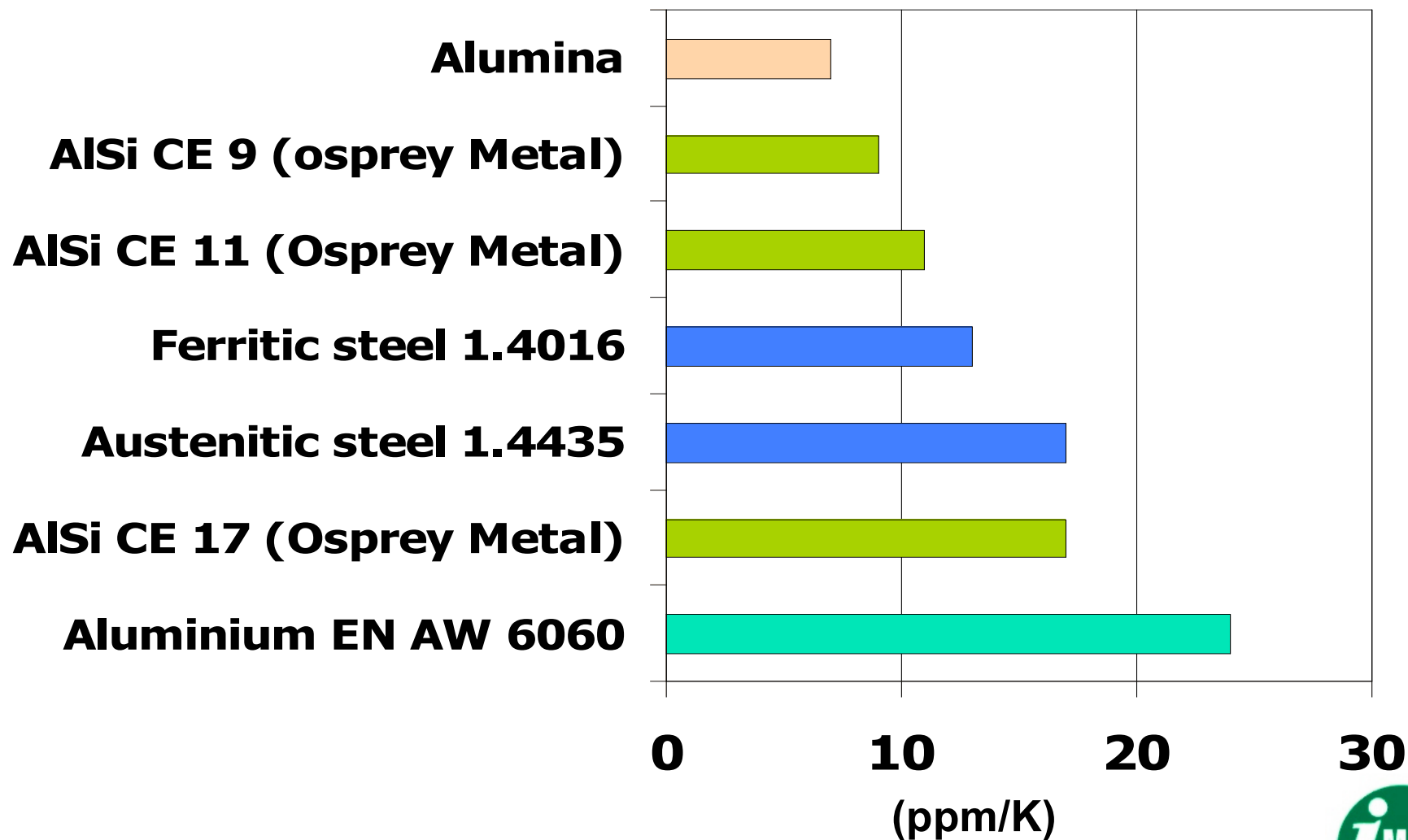
- Compatibility of thermal expansion
- Dielectric-resistor compatibility
- Adhesion
- Stability of the resulting circuits

3 Temperature Ranges

System Firing Temperature

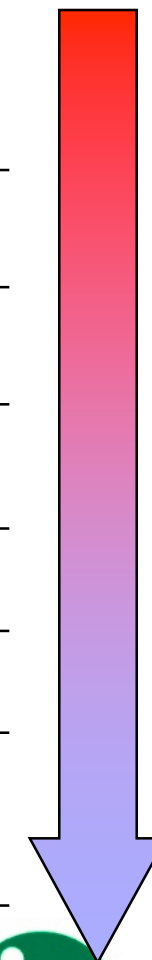


TCE of tested Substrates

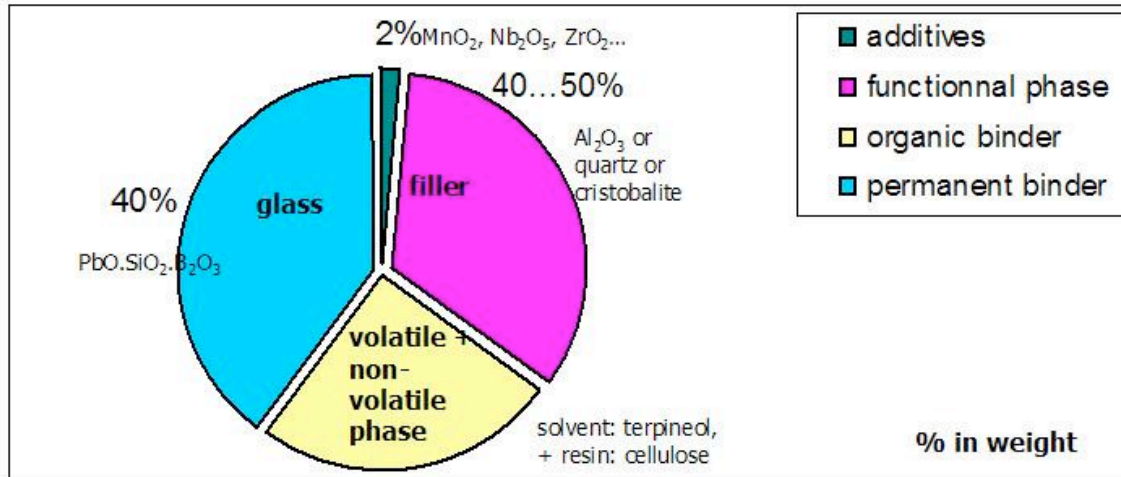


Studied dielectric compositions

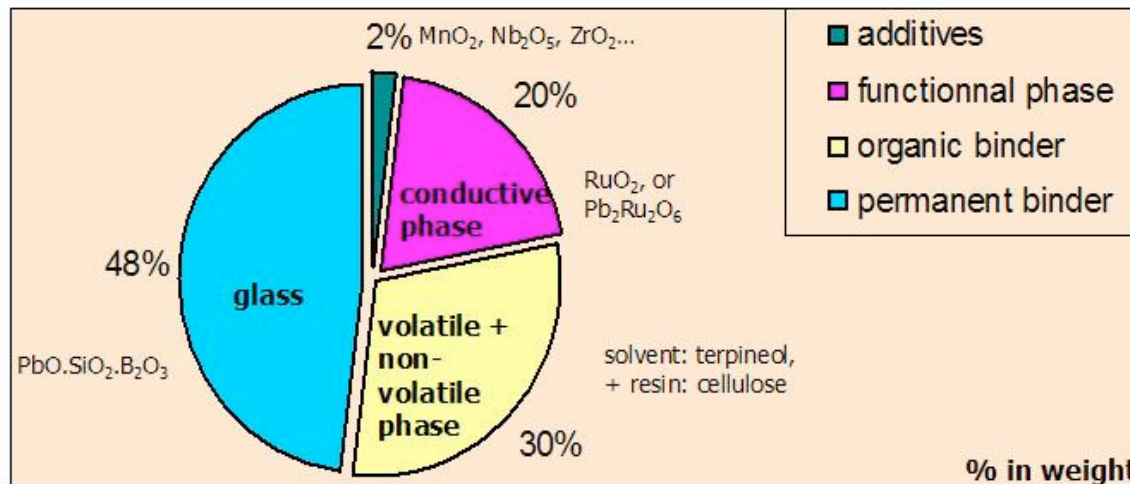
Deno- mination	glass	Filler	Grain Size (μ m)	% filler powder	T _f (°C)	TCE (ppm/K)	Substrate screen-printed
V8A40	V8	Al ₂ O ₃	~1	40	~500	~9	- Aluminium - AlSi composites
V8Q40	V8	quartz	~3	40	~500	~12	- Aluminium
V8C40	V8	Cristo- balite	10...20	40	~500	~13	- Aluminium
V6A40	V6	Al ₂ O ₃	~1	40	~600	~8	- Steels
V6Q50	V6	quartz	~3	50	~600	~10-11	- Steels
(ESL 4916) +Her GPA	-	-	-	-	850	~7-8	- Alumina - Steels
(ESL 4916) +ESL 4924	-	-	-	-	850	~7-8	- Alumina - Steels



Dielectrics & resistor Compositions



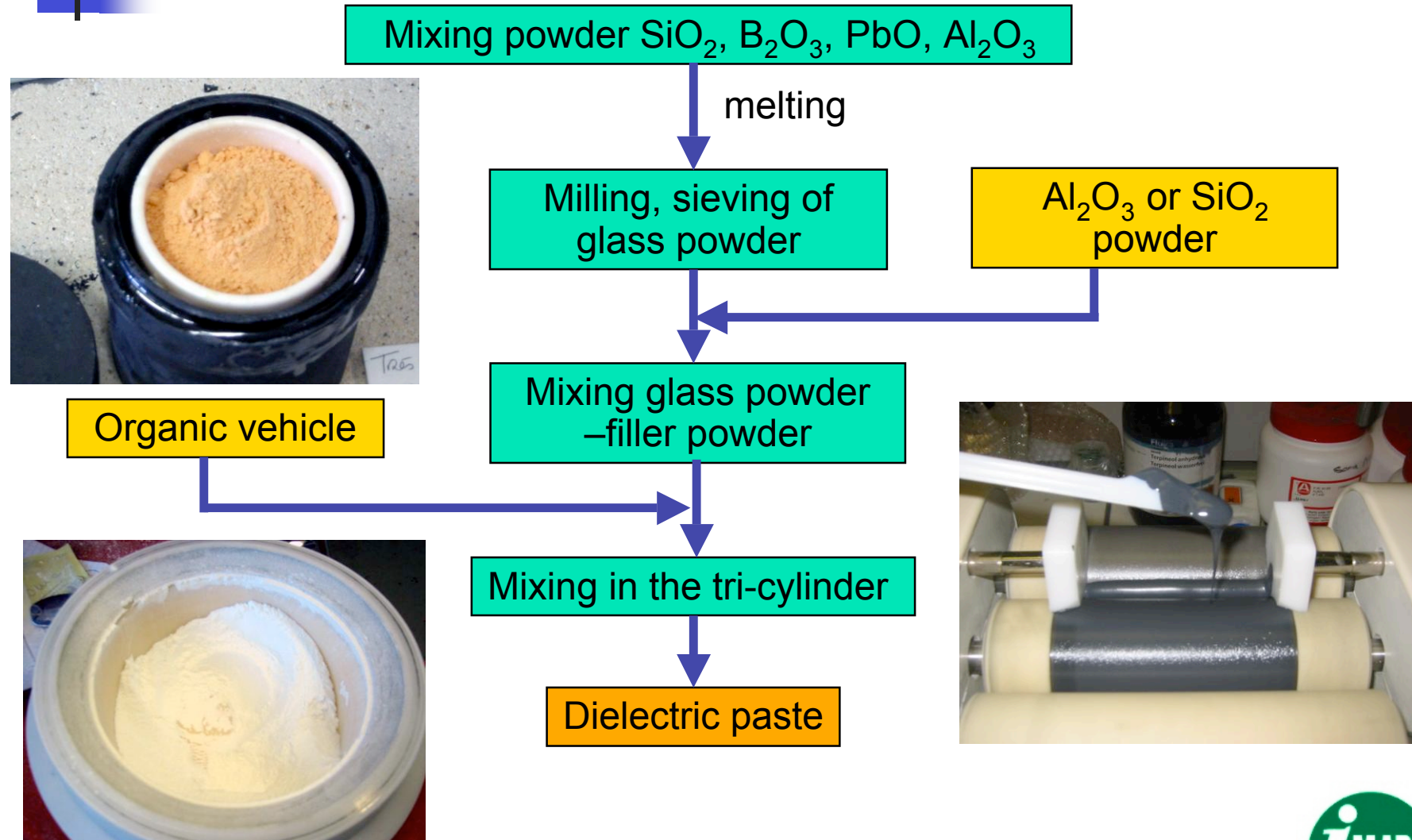
Dielectric
composition



Resistor
composition

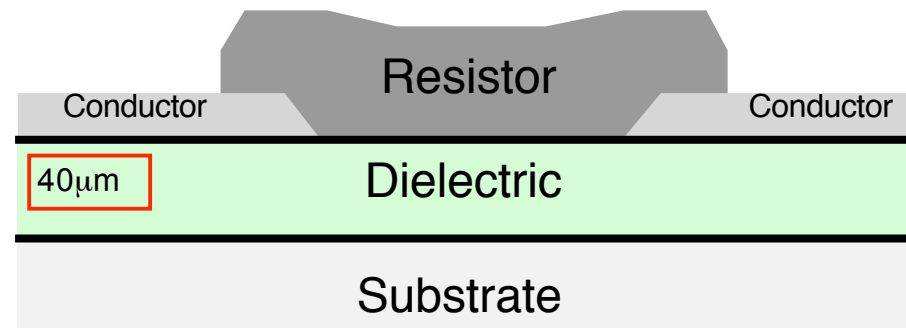
-400 nm
-Firing temperature 500°C

Paste preparation



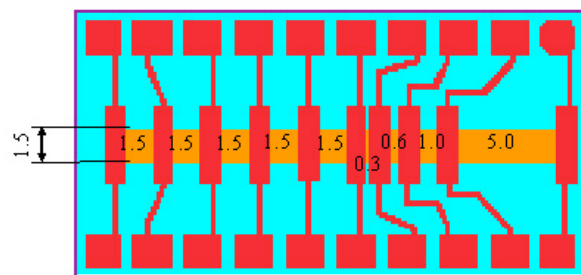
Screen-printing sequence

Basic structure



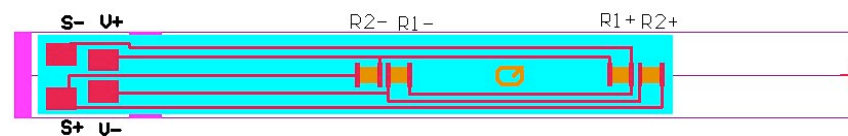
Samples for characterisation

- TCR measurement

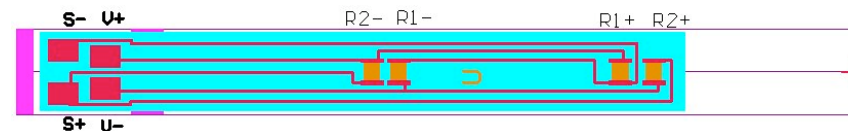


- Gauge Factor measurement

Longitudinal resistors



Transverse resistors



Adhesion & Crack problems

■ Adhesion



Non adherence on
non-oxidised substrates



Oxidation 1h @ 900°C

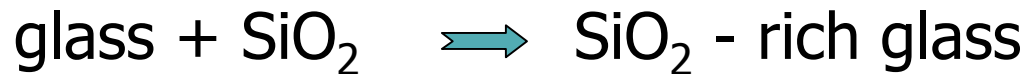
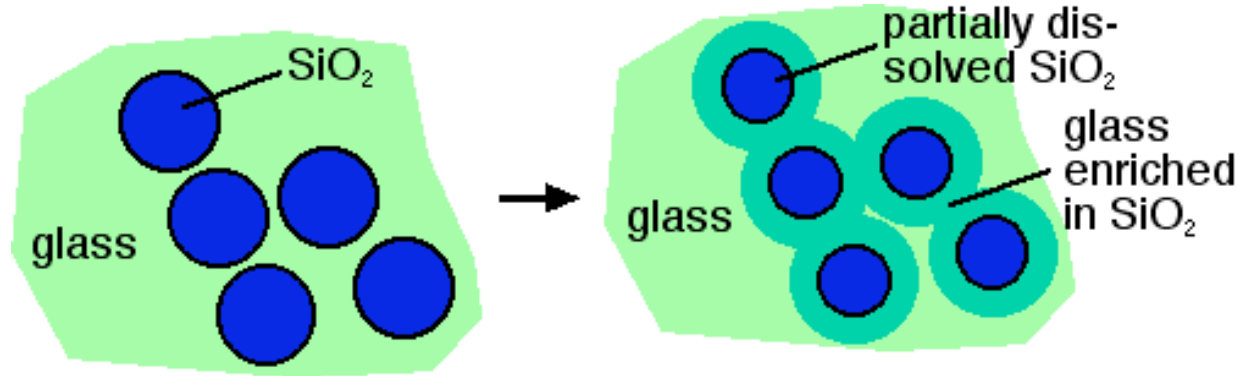
■ Crack problems



Match TCE

Dissolution of SiO₂ powder in glass

SiO₂
particles &
low-temp.
glass



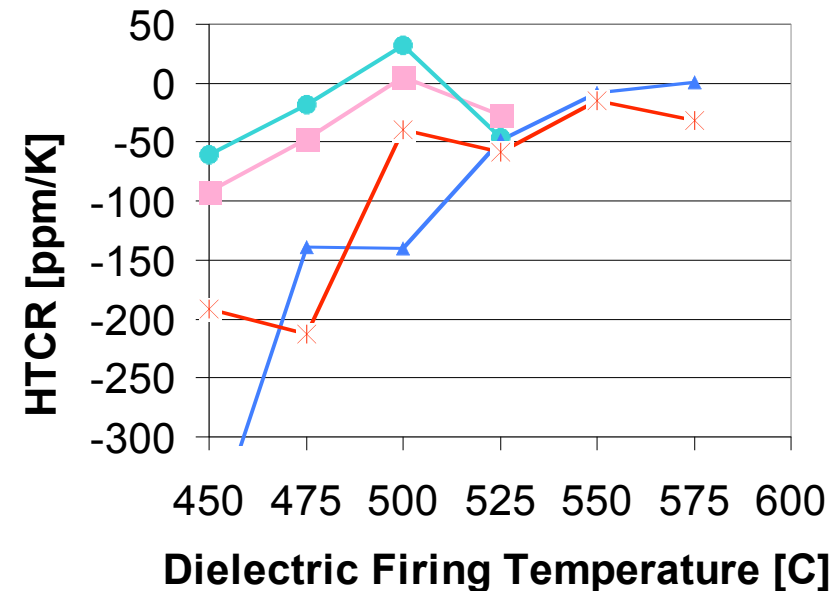
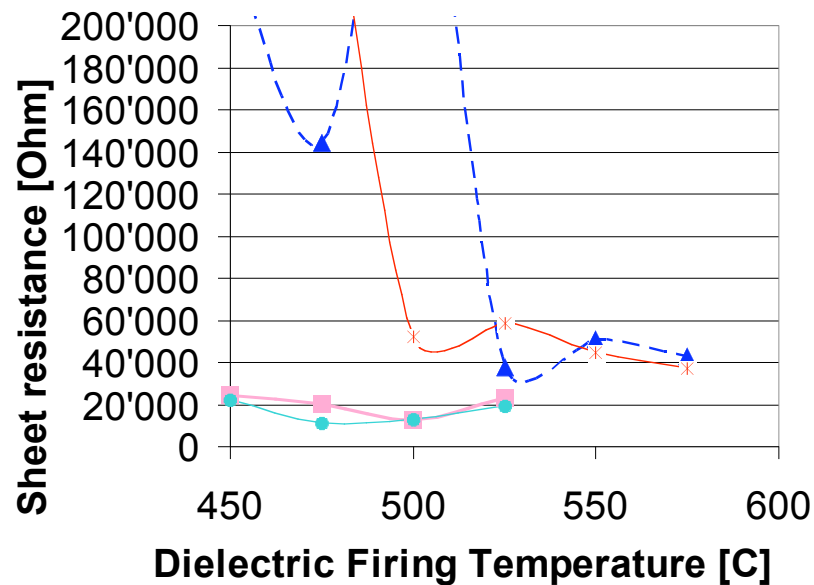
	V8 glass	V6 glass
Dissolution Temperature of SiO ₂ (10% filled)	600 °C	625°C

■ Effect on resistors...



Results: Aluminium alloy Substrates

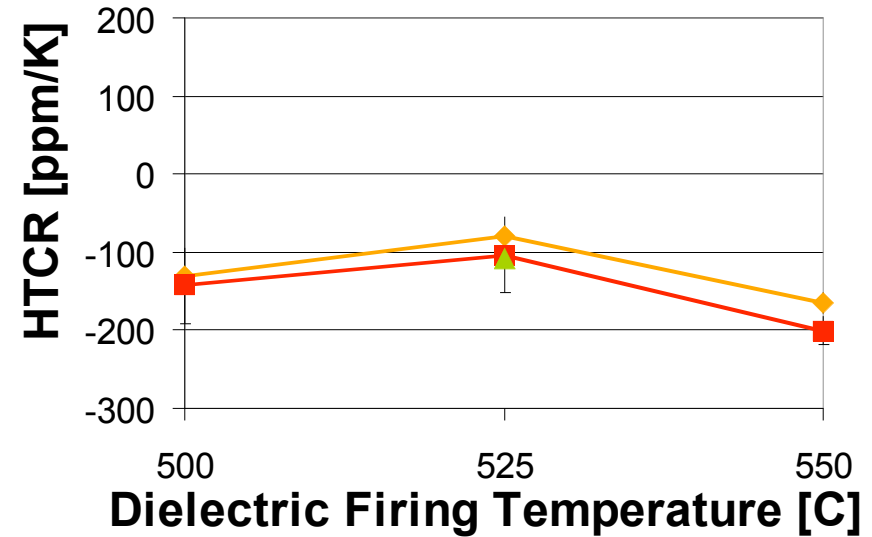
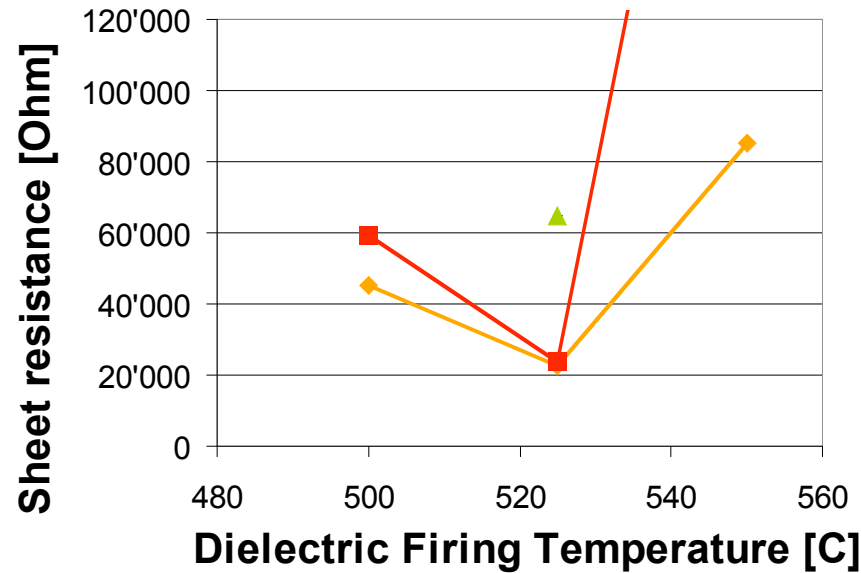
Low Temperature range



- V8 glass + 40% cristobalite
- V8 glass + 40% quartz
- V8 glass + 50% cristobalite
- V8 glass + 50% quartz

Results: AlSi composite Substrates

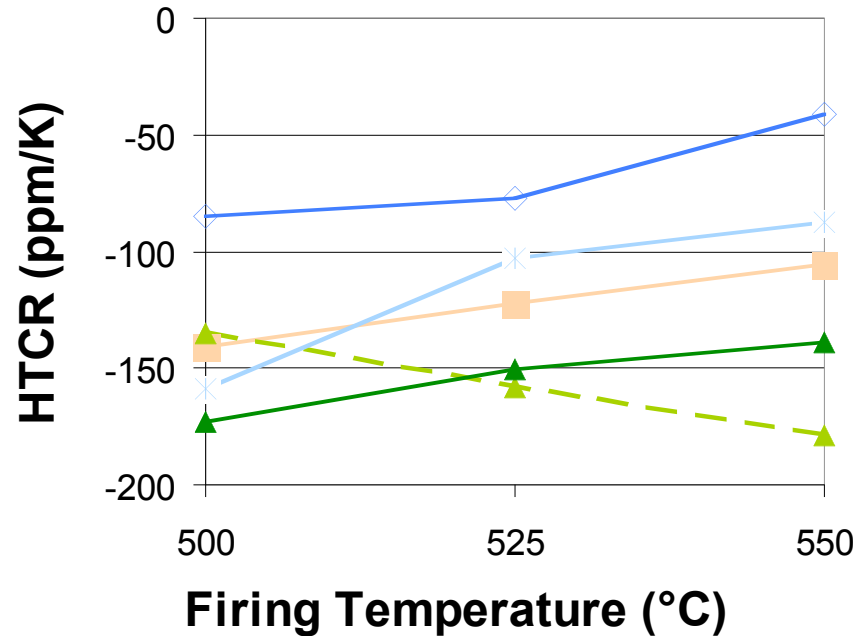
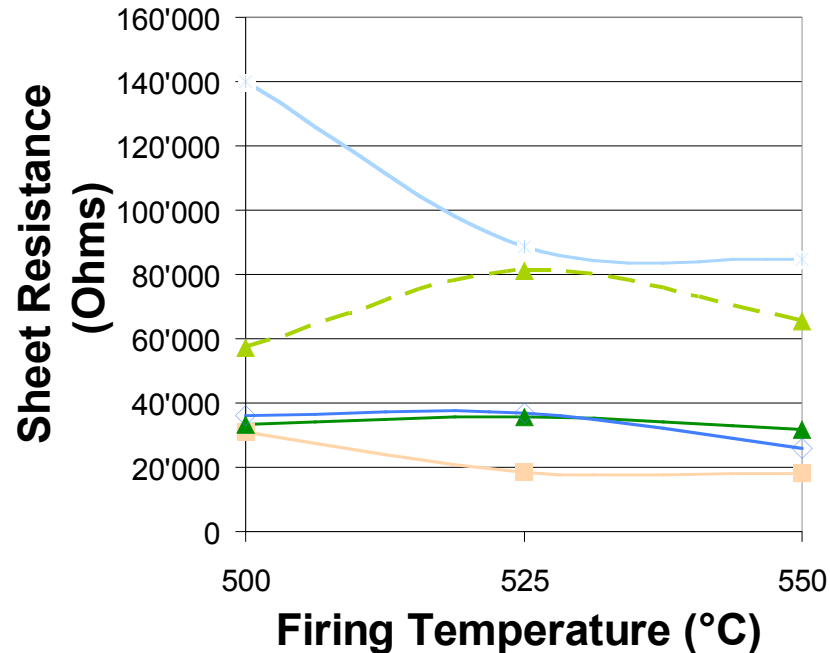
Low Temperature range



- AlSi CE 9
- AlSi CE 11
- AlSi CE 17

Results: Steel Substrates

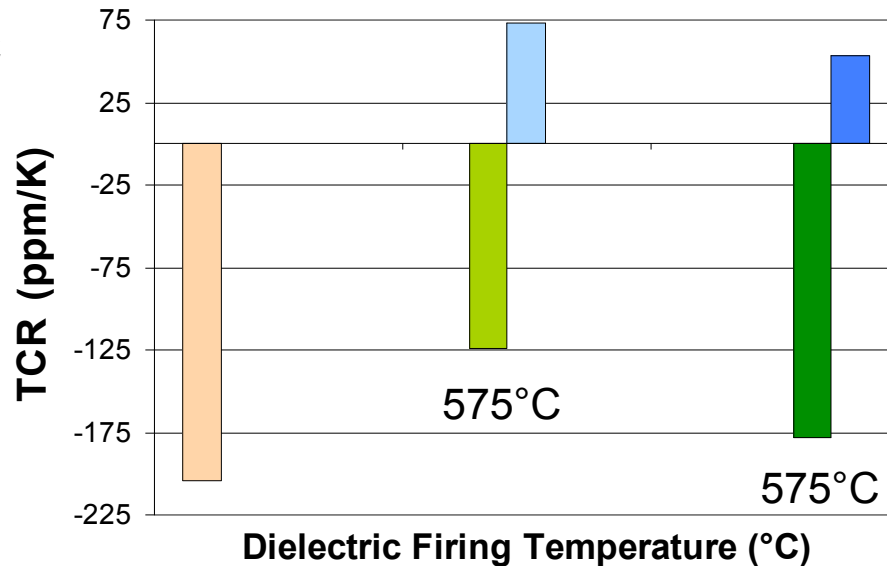
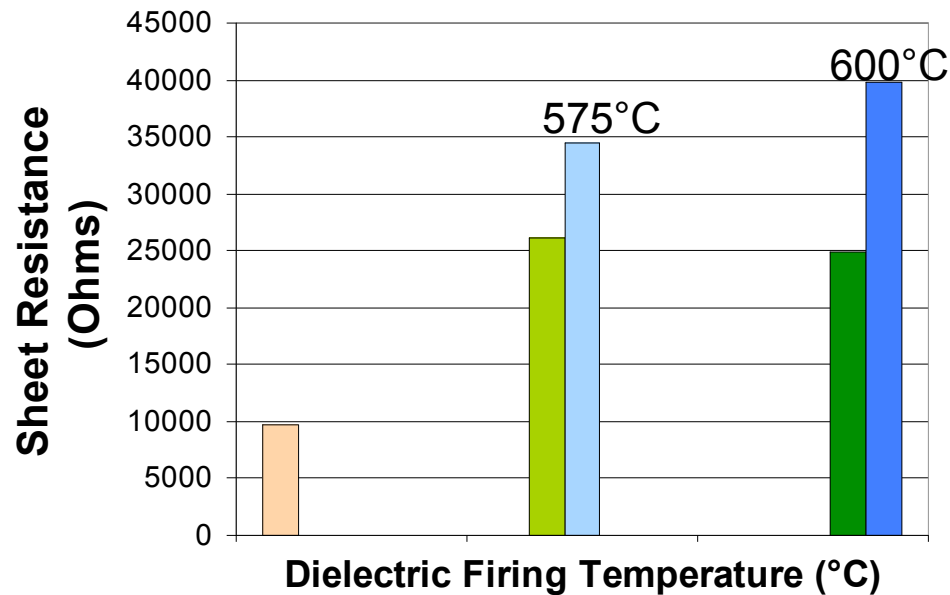
Low Temperature range



- Alumina
- V8 glass + 40% alumina on 1.4016
- V8 glass + 40% alumina on 1.4435
- V8 glass + 40% quartz on 1.4016
- V8 glass + 40% quartz on 1.4435

Results: Steel Substrates

Intermediate Temperature range

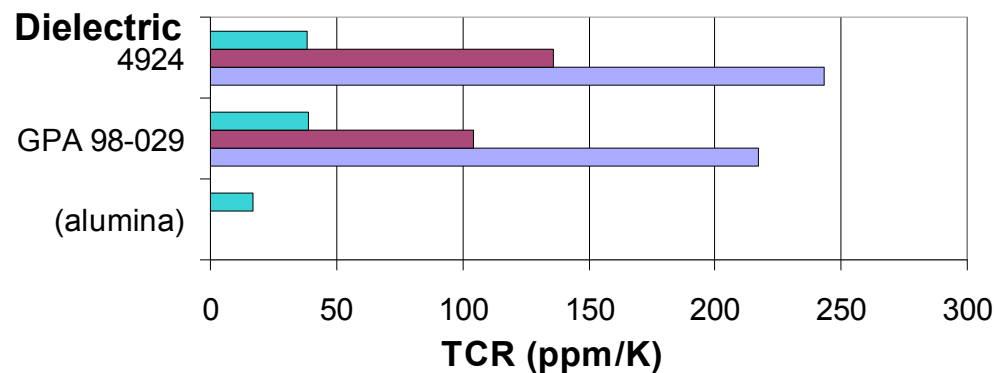
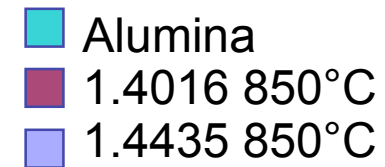
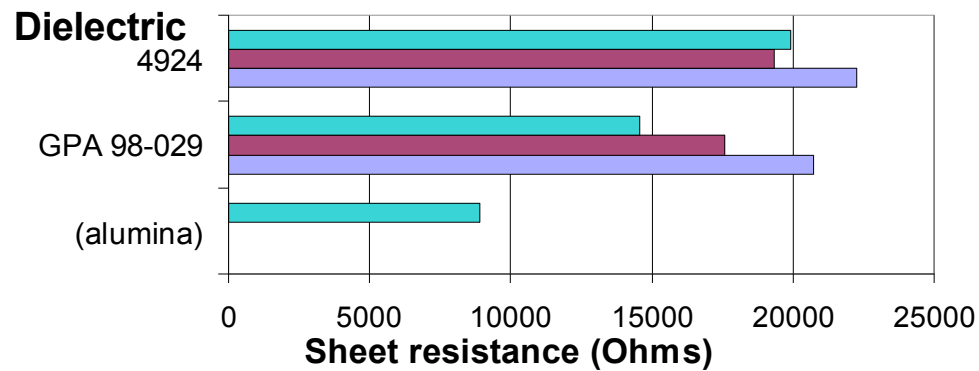


- Alumina
- V6 glass + 40% alumina on 1.4016
- V6 glass + 40% alumina on 1.4435
- V6 glass + 50% quartz on 1.4016
- V6 glass + 50% quartz on 1.4435



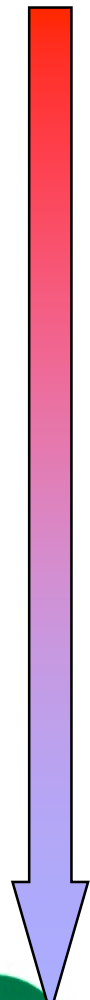
Results: Steel Substrates

High Temperature range



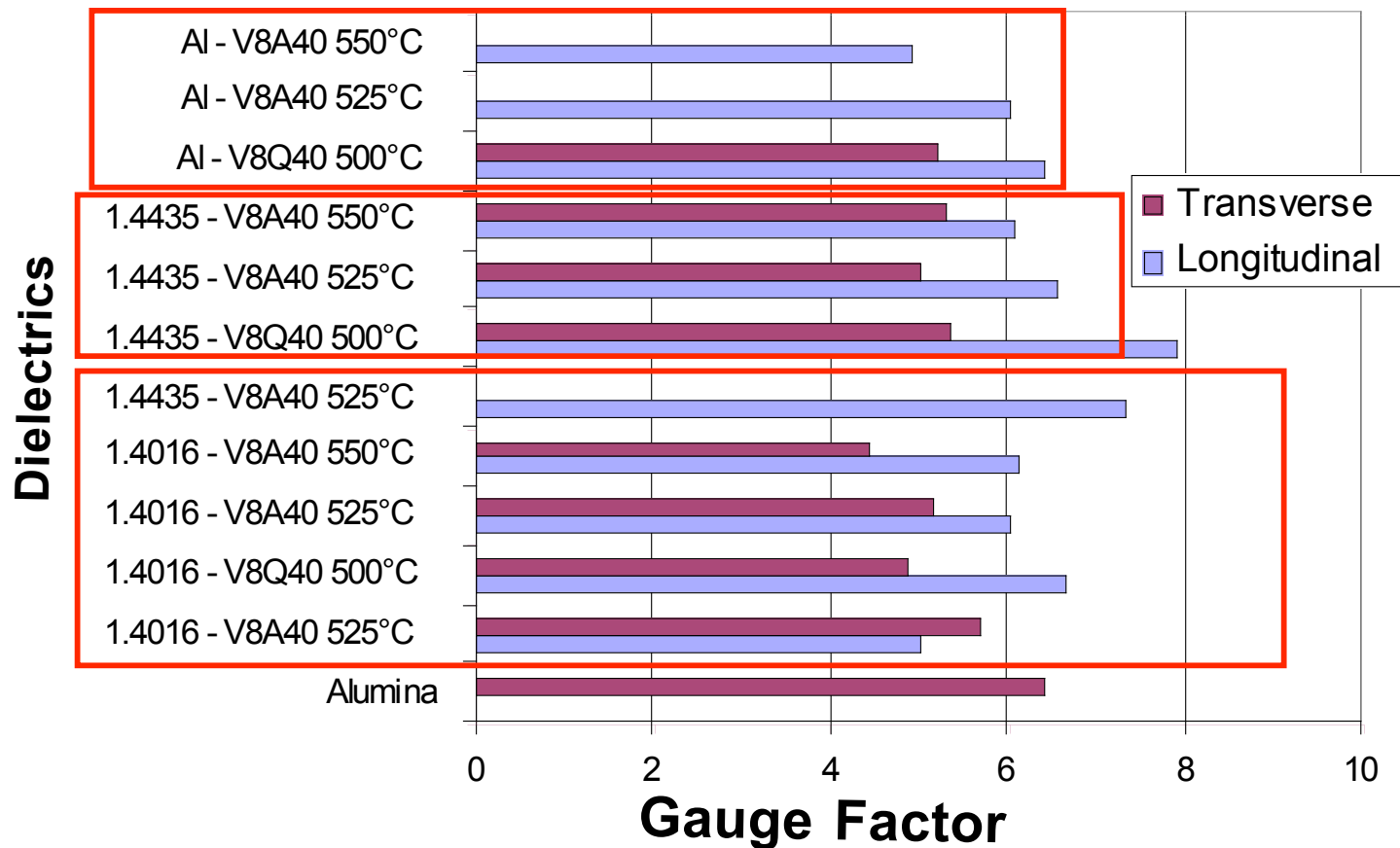
Electrical results

Insulating Dielectric	Dielectric TCE (ppm/K)	Substrate	Resistor paste	System Firing Temp.(°C)	Sheet resistance (kOhms)	TCR (ppm/K)	GF	
V8A40	9	AISi comp. CE 9	V8 Resistor	500	22.7	-79	-	
		AISi comp. CE 11			23.9	-104	-	
V8C40	13	Aluminium		525	23.4	-27	-	
V8Q40	12	Aluminium		525	19.3	-47	6	
		1.4016		550	28.6	-145	-	
		1.4435			25.9	-41	-	
V6A40	8	1.4016		ESL 3114	575	26.1	-124	-
		1.4435				34.5	73	-
V6Q50	10-11	1.4016	600		24.9	-178	-	
		1.4435			39.8	53	-	
Her GPA (+ ESL 4916 as under-layer on steel)	~7-8	Alumina	Du 2041	850	14.6	39	12.4	
		1.4016			17.6	104	10.6	
		1.4435			20.7	218	-	
ESL 4924 (+ ESL 4916 as under-layer on steel)	~7-8	Alumina			19.9	38	-	
		1.4016			19.3	136	9.9	
		1.4435			22.2	243	12.1	



Gauge factor results

Similar gauge factors

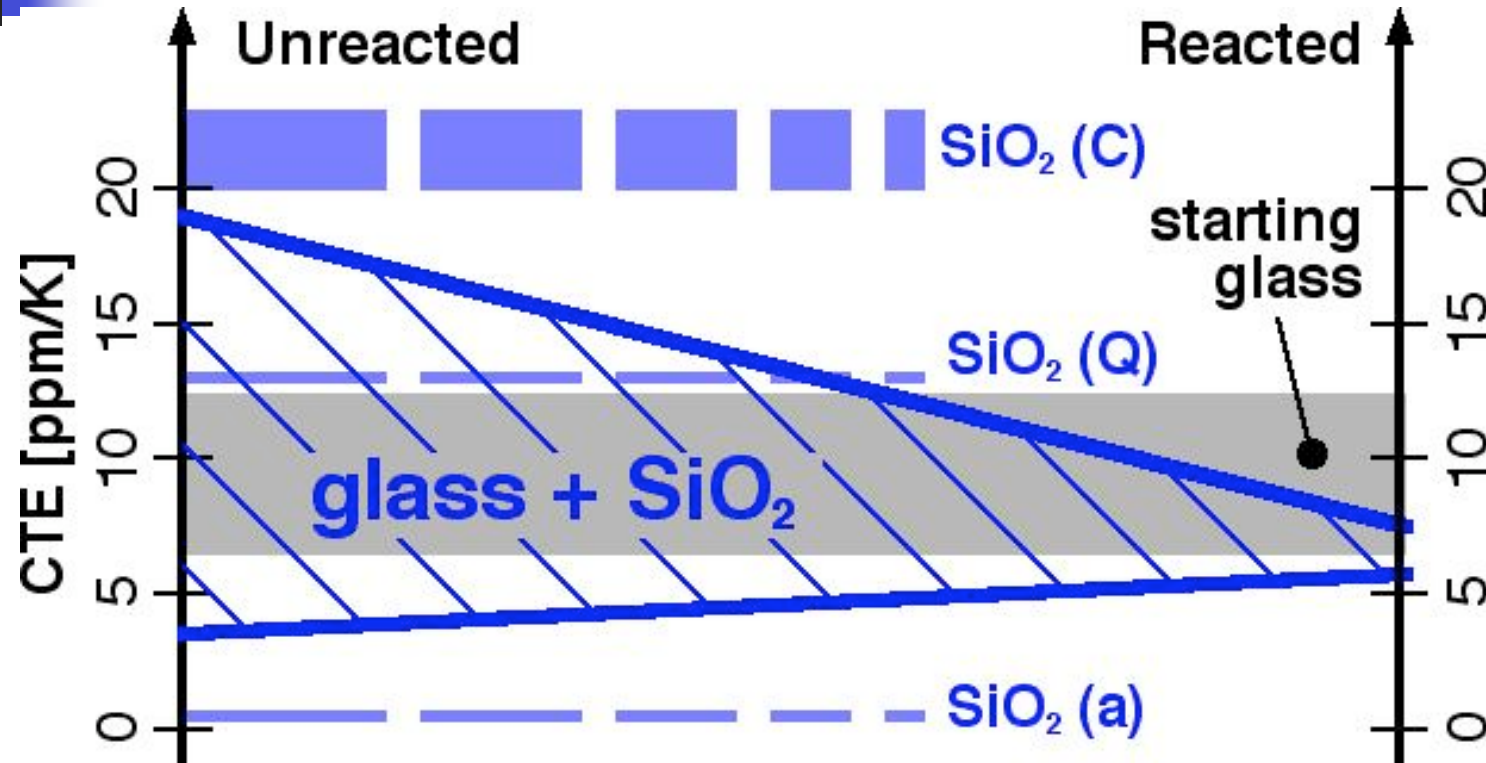




Conclusions

- Dielectric – resistor chemical compatibility
- Very low processing temperature achieved
- Compatible with wide range of substrates
- Matching of thermal expansion is critical

CTE range: glass + SiO₂



- **Little reaction:** very wide range of CTE values possible due to different forms of SiO₂
- **Fully reacted:** OK for alumina, float glass & Ti

- Fillers: improve stability and reproducibility of dielectrics
- Control of TCR of our resistors through additives (CuO, NiO, TiO₂, Sb₂O₃)
- Materials without Pb or precious metals



Explanation 1

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