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FRAUNHOFER INSTITUTE FOR CERAMIC TECHNOLOGIES AND SYSTEMS IKTS

THICK-FILM COMPONENTS FOR INDUSTRIAL APPLICATIONS

Pasteme leons
by Fraunhofer IKTS

COVER PHOTO *Dispersion of powder with organic vehicle.*

1

THICK-FILM COMPONENTS FOR INDUSTRIAL APPLICATIONS

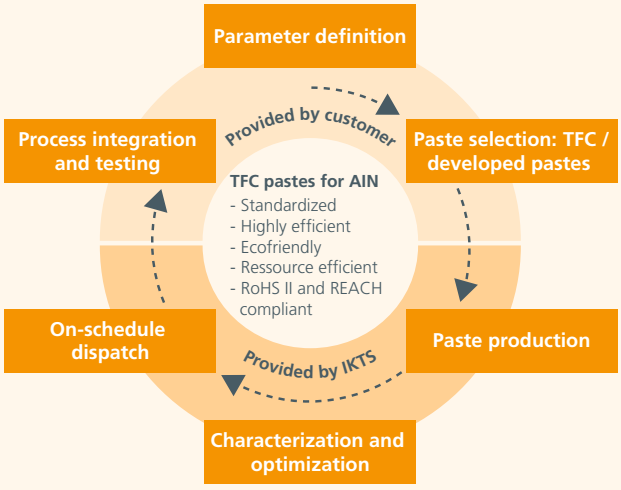
The TFC paste series offers customers the chance to obtain standardized and tested thick-film pastes for applications in microelectronics, microsystem and sensor technology. Fraunhofer IKTS guarantees reproducible manufacturing processes and product qualities, ensured in accordance with DIN/ISO 9000.

Fraunhofer IKTS offers a complete and unique thick-film paste system for aluminum nitride (AlN) ceramics. AlN is an outstanding substrate material for power electronics, radio frequency and microwave technology, because of its high heat conductivity (180 to 200 $W \cdot m^{-1} \cdot K^{-1}$), low thermal expansion coefficient (~4.4 · 10^{-6} K^{-1}) and dielectric properties. It is also well-suited as a basis for thick-film heating elements.

In addition to special pastes, which are researched and offered exclusively for customers, standardized and tested TFC thick-film pastes are also available. These are optimized for achieving constant film thicknesses and stable film properties through screen printing. They are environmentally friendly, spare resources and meet current legal requirements according to RoHS II (Directive 2011/65/EC) and REACH (Regulation (EC) No 1907/2006). Manufacturing processes controlled with ERP (enterprise resource planning) combined with a strict quality assurance system ensure reliable and reproducible results. Also, every paste delivery comes with an analysis certificate.

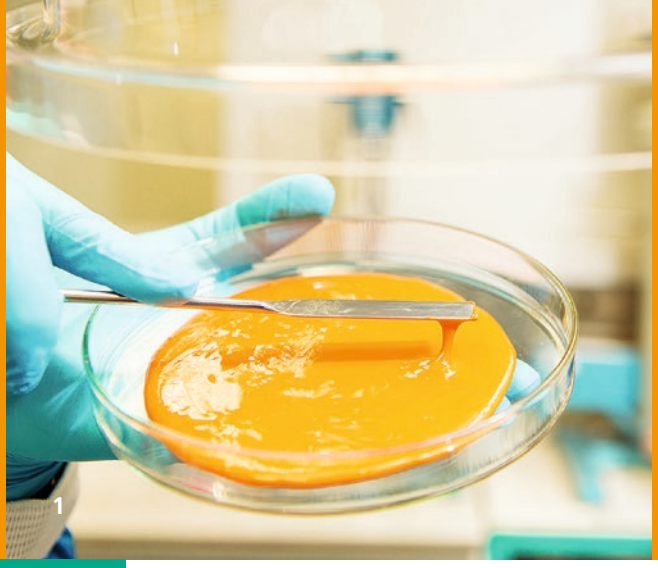
The following pages provide an overview of the available conductor, resistor, via filling, encapsulation and marking pastes. If you cannot find a specific combination of parameters, please do not hesitate to contact us in order to have the paste developed that best suits your process conditions.

Manufacturing cycle of TFC



1 *Thick-film pastes from the TFC special paste system of Fraunhofer IKTS.*

CONDUCTOR, GLASS AND RESISTOR PASTES



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GENERAL PROCESS CONDITIONS

Substrates

The pastes are designed for use on AlN substrates (with lapped surfaces) from CoorsTek/ANCeram. Substrates with other surface qualities or from other manufacturers may lead to variations in the results.

Screen printing

Use a stainless steel screen with 200 mesh, a wire diameter of 40 µm, as well as 25 µm emulsion thickness (10 to 12 µm EOM) to achieve the stated film thickness. This does not apply to the pastes FK9900M and FK3101. For the FK9900M series, stainless steel screens with 280 mesh, 32 µm wire diameter and 25 µm emulsion thickness are suitable. The paste FK3101 should be printed on a 150 mesh stainless steel screen with 25 µm wire diameter and 100 µm emulsion thickness.

Leveling

The printed films should be leveled for 10±2 minutes at room temperature (22 to 25 °C).

Drying

The printed films should be dried for 15 minutes at 150 °C in a drying oven with an exhaust air system or in a continuous flow dryer. For FK3101 and FK3201, the drying temperature is 120 °C.

Firing

Conductor and resistor pastes
The printed films should be fired under air atmosphere in a conveyor belt furnace at a peak temperature of 850 °C and with a dwell time of 10 minutes. For the silver-alloyed conductor pastes FK1071, FK1205, FK1282, FK1916 and FK1953, as well as for the resistor paste system FK9600, we recommend a total cycle time of 60 minutes. For the conductor pastes FK1572, FK1574 and the resistor paste system FK9900M the recommended cycle time is 30 minutes. Deviating from this, the copper conductor pastes FK3101 and FK3201 are fired for a cycle time of 60 minutes under a nitrogen atmosphere (residual oxygen content < 10 ppm) at a peak temperature of 950 °C.

Glass pastes
The printed films are fired under air atmosphere in a conveyor belt furnace at a peak temperature of 650 °C and with a dwell time of at least 2 minutes. The recommended total cycle time is 26 minutes (see firing profile on page 3).

Storage

The pastes can be stored at any temperature between 4 and 10 °C. The lower the temperature, the better long-term stability. The can must remain tightly sealed during storage. In order to prevent air humidity from condensing on the paste, the can may be opened only after the content has reached room temperature. The paste needs to be sufficiently homogenized before use, e.g. with a spatula.

Safety notice

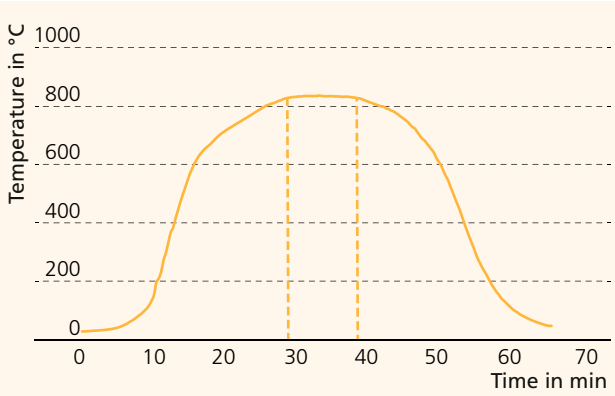
For safe handling of the pastes, please observe the notices in the safety data sheet accompanying each delivery.

Quality requirements

An analysis certificate comes included with each delivery. Instead of an expiration date, it states a date for retesting, which is six months after the date of delivery. During this period, IKTS warrants the values stated in the analysis certificate for unopened pastes. After the date for retesting has passed, it is the customer's responsibility to test the paste quality under the conditions stated in the data sheet.

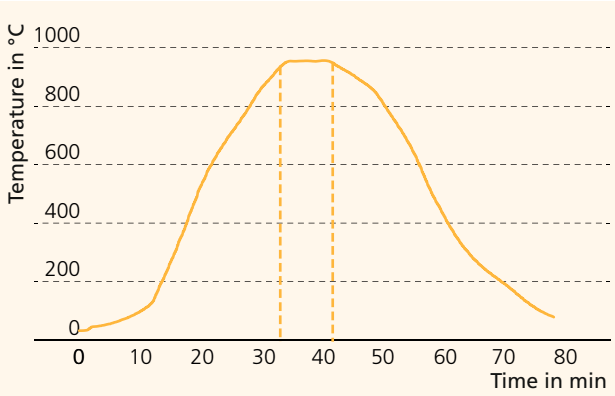
FIRING PROFILES

Conductor and resistor pastes: 60’ cycle time, 850 °C



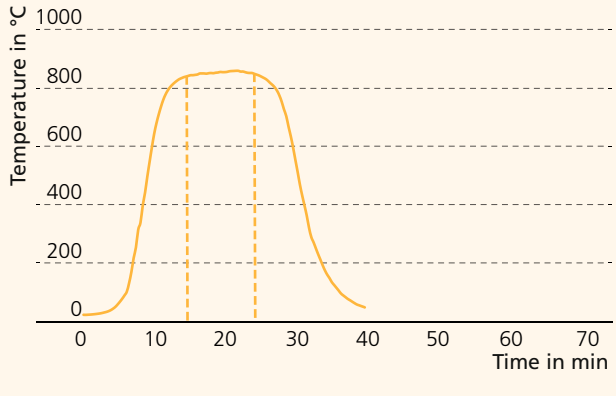
Firing profile: 60’ cycle time, peak 850 °C, dwell time 10 min
Pastes: FK1071, FK1916, FK1205, FK1953, FK1282, FK9600

Copper conductor pastes: 60’ cycle time, 950 °C



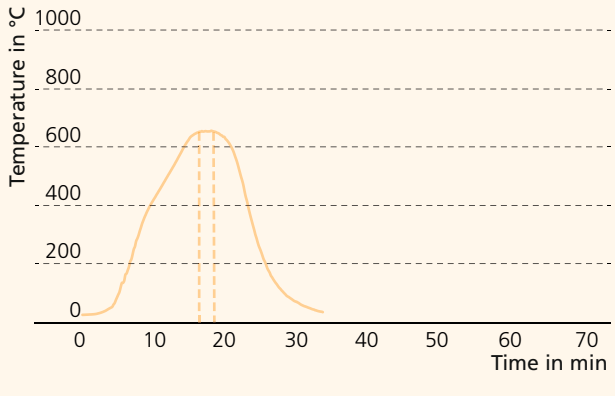
Firing profile: 60’cycle time, peak 950 °C, dwell time 10 min
Pastes: FK3101, FK3201

Conductor and resistor pastes: 30’ cycle time, 850 °C



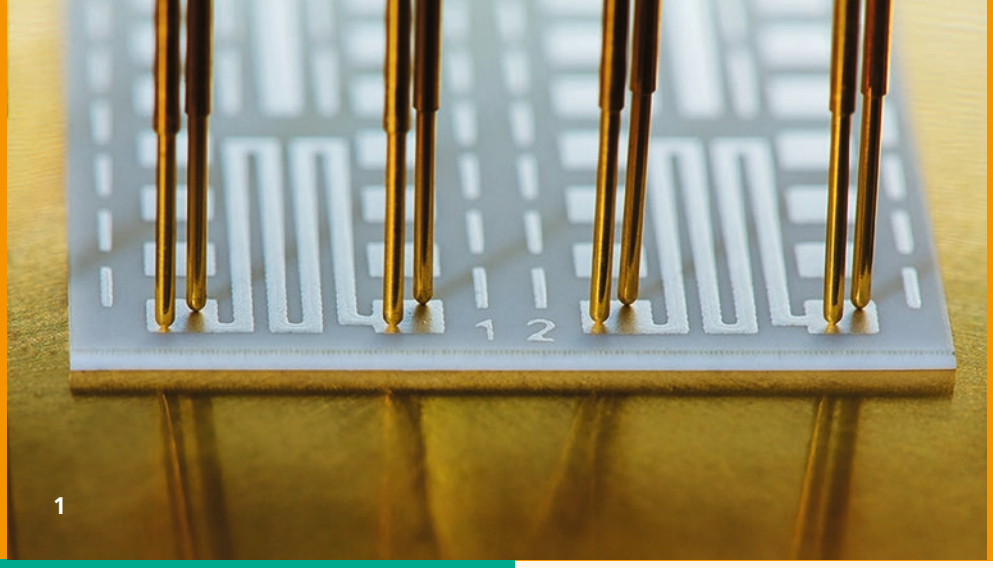
Firing profile: 30’ cycle time, peak 850 °C, dwell time 10 min
Pastes: FK1105, FK1572, FK1574, FK9900M

Glass pastes: 26’ cycle time, 650 °C



Firing profile: 26’ cycle time, peak 650 °C, dwell time 2 min
Pastes: FK4027, FKM4000

1 *Thick-film paste after rolling.*
2 *Reading the fineness of grind after rolling.*



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CONDUCTOR PASTES

Various conductor pastes are available when it comes to contacting resistors and applying conductor lines on AlN. Their specific properties vary: electrical conductivity, solderability, leaching resistance and adhesion. This allows customers to select pastes that are tailored specifically to the intended use and the required properties.

FK1071

Thick films produced with FK1071, an AgPt conductor paste, are characterized by their low film resistance and good solderability. It allows to produce thick-film conductors for AlN with a low resistance.

FK1205

With FK1205, a conductor paste with AgPd contained in a 3:1 ratio, the fired films provide excellent leaching resistance and solderability. FK1205 can be used as a conductor paste for the FK9600 and FK9900M paste systems.

FK1282

The fired films of FK1282, an AgPt conductor paste, are characterized by excellent leaching resistance and solderability.

FK1572

With FK1572, an Ag conductor paste, it is possible to cost-efficiently produce films with very low surface resistance below 3.5 mOhm/Sq.

FK1574

The fired films of FK1574, an AgPtPd conductor paste, provide excellent leaching resistance and solderability, in particular with regard to lead-free solder.

FK1916

With FK1916, a conductor paste with AgPd contained in a 6:1 ratio, it is possible to produce films with high solderability, leaching resistance and adhesion. The paste can be used as a conductor paste for the FK9600 and FK9900M paste systems.

FK1953

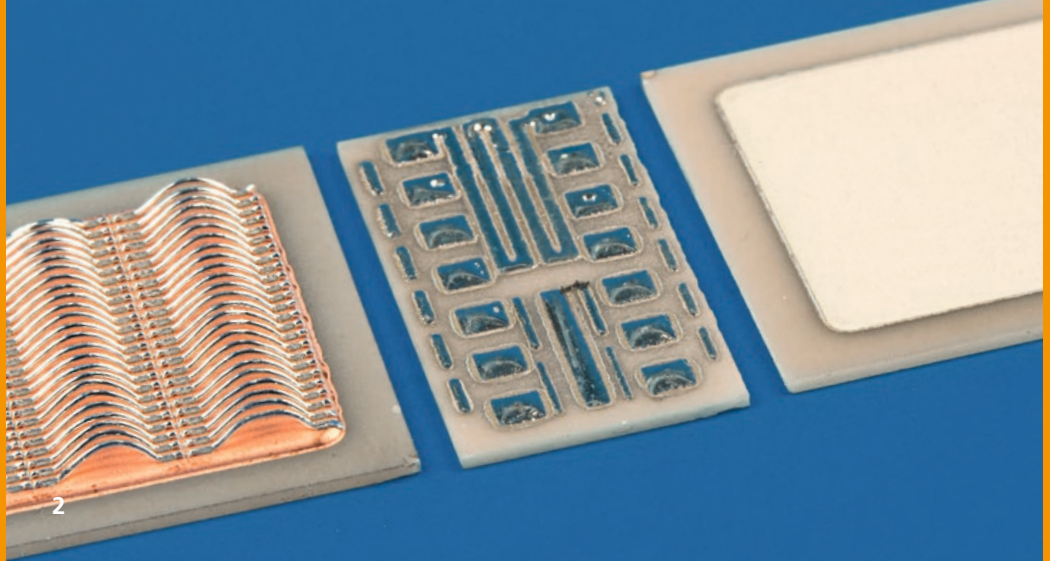
The fired films of FK1953, a conductor paste with an AgPd ratio of a 3:1, provide excellent leaching resistance and solderability. The paste is the RoHS II and REACH compliant successor of FK1220 and is a suitable conductor paste for the FK9600 and FK9900M resistor paste systems.

FK3101

The copper paste FK3101 can be used on Al_2O_3 and pre-oxidized AlN substrates, as well as on non-pre-oxidized AlN ceramics which have previously been thinly metalized with FK3201, in order to produce films with up to 300 µm height.

FK3201

The copper paste FK3201 is suitable for application on Al_2O_3, as well as on non-pre-oxidized AlN ceramics.



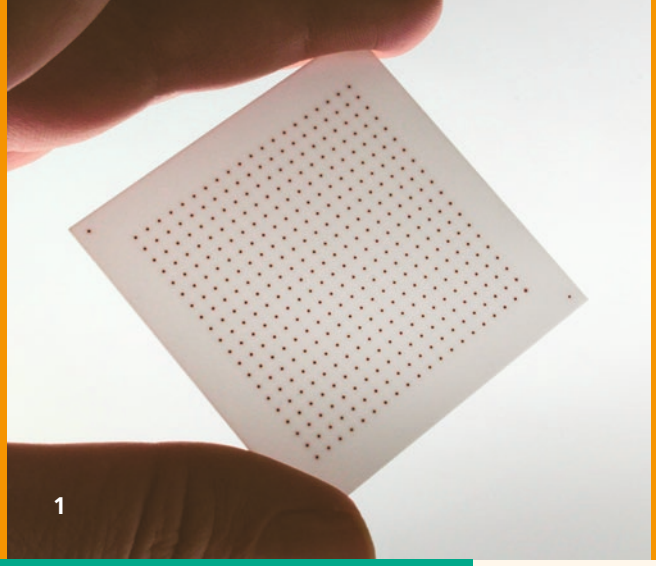
Technical specifications

Characteristics	Unit	FK1572	FK1071	FK1916	FK1205	FK1953	FK1282	FK1574	FK3101	FK3201
Material	--	Ag	AgPt	AgPd	AgPd	AgPd	AgPt	AgPtPd	Cu	Cu
Alloy ratio	--	--	97:3	6:1	3:1	3:1	3:1	13:3:1	--	--
Viscosity	Pa·s	140...220	320...450	180...350	180...350	150...350	180...350	180...350	TBD	TBD
Sheet resistance	mOhm/Sq	≤ 3,5	≤ 6	≤ 15	≤ 25	≤ 25	≤ 35	≤ 60	TBD	TBD
Solderability	%	--	≥ 95	≥ 95	≥ 98	≥ 90	≥ 95	≥ 90	≥ 90	≥ 90
Leaching resistance	Dips/result	--	≥ 3	≥ 3	≥ 3	≥ 3	excellent	excellent	TBD	TBD
Adhesion (number of firings)										
- Initial (1x)	N/4mm²	--	≥ 16	≥ 28	≥ 28	≥ 30	≥ 30	≥ 28	TBD	TBD
- Aged (1x)		--	≥ 16	≥ 18	≥ 18	≥ 22	≥ 22	≥ 22	TBD	TBD
- Initial (3x)		--	--	≥ 22	≥ 22	≥ 30	≥ 20	≥ 27	--	--
- Aged (3x)		--	--	≥ 16	≥ 16	≥ 21	≥ 18	≥ 19	--	--
Fired film thickness	µm	15±1	15±1	15±1	15±1	15±1	15±1	15±1	90±1	15±1
Coverage	cm²/g	65±5	61±5	70±5	71±5	63±5	58±5	58±5	15±5	47±5

The film parameters that can be achieved depend on the process conditions during processing (firing profile, solder material, soldering conditions, etc.), which are described in detail in the respective paste specification sheets and must be observed in all cases. Deviations from these conditions can lead to variations in the parameters.

1 *Resistance measurement of a conductor line.*

2 *Silver and copper metallization on AlN ceramics, solderable and bondable.*



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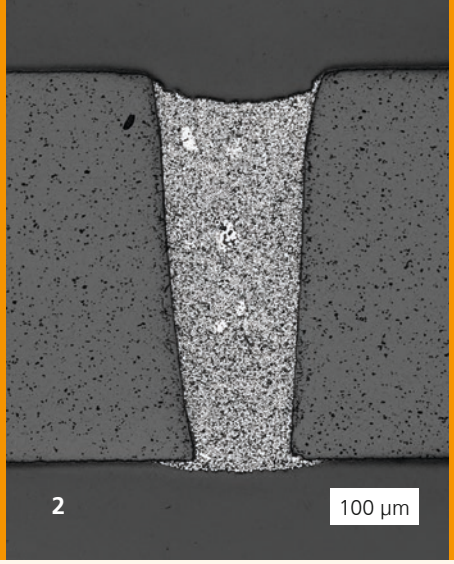


2

VIA FILLING PASTE

The via filling paste was developed for use on AlN and Al_2O_3 substrates.

FK1105

The AgPt via filling paste FK1105 is specified for use on "AN180" AlN substrates, by CoorsTek (formerly ANCeram), and "Rubalit 708S" Al_2O_3 substrates, by CeramTec. Substrates with other surface qualities or from other manufacturers may lead to variations in the results. The paste exhibits very little sinter shrinkage, in order to fill the via as completely as possible. This helps to establish contact between buried and surface metalizations of multi-layer ceramics.

Stencil printing

The paste can be used for the metalization of vias in aluminum nitride and alumina. To fill the vias as fully as possible, stainless steel stencils should be used which are adapted to fit the thickness of the substrates. With regard to the via openings in the stencils, Fraunhofer IKTS recommends making the openings approx. one to five percent wider than the via diameters introduced in the ceramics.

Firing

The printed films should be fired under air in a conveyor belt furnace at 850 °C and with a dwell time of 10 minutes. We recommend a total cycle time of 30 minutes. In order to achieve gas-tight fillings, a special infiltration glass paste of the FK4800 series needs to be applied in a subsequent step.

All other specifications correspond to the general process conditions.

Technical specifications

Parameter	Unit	FK1105
Material	--	AgPt
Viscosity[1]	Pa·s	TBD
Sheet resistance[2, 6]	mOhm/Sq	≤ 10
Solderability[3, 6]	%	TBD
Leaching resistance[4, 6]	Dips	TBD
Adhesion[5] (number of firings)		
- Initial (1x)[6]	N/4mm²	TBD
- Aged (1x)[6]		TBD
Fired film thickness	µm	15±1
Coverage[7]	cm²/g	63±5

[1] Brookfield viscometer HB with spindle/cup combination SC4-14/-6RP(Y) at n=10 rpm and 25±0.2 °C.

[2] Sheet resistance, calculated for a fired thickness of 15±1 µm.

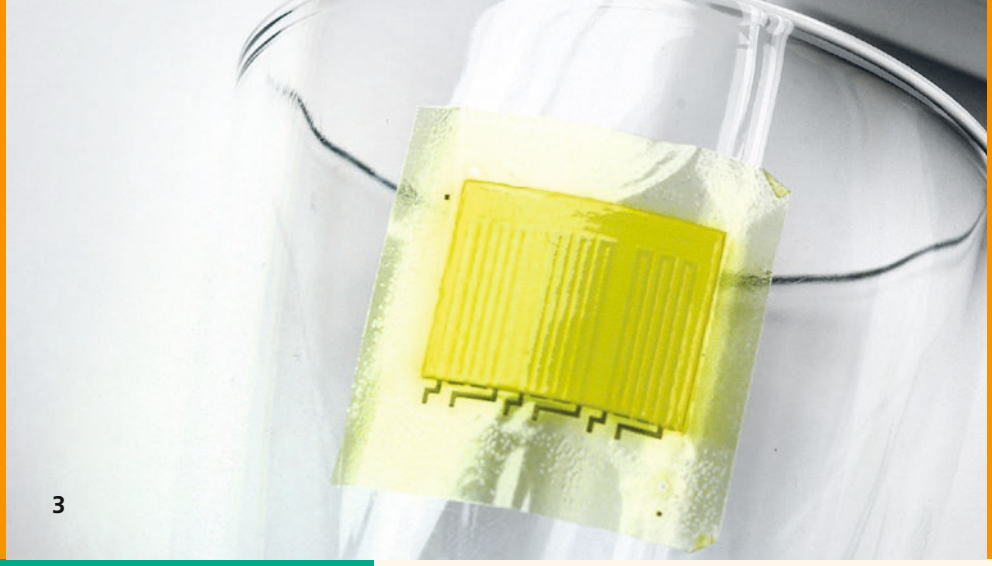
[3] Solder Sn/Pb/Ag 63/35.5/1.5; flux: Alpha 611, soldering time: 5 s, soldering temperature: 220±2 °C.

[4] Solder Sn/Pb/Ag 63/35.5/1.5; flux: Alpha 611, soldering time: 5 s, soldering temperature: 230±2 °C.

[5] 90° wire peel test in accordance with DIN 41850-2, 2x2 mm² pad size, solder: Sn/Pb/Ag 63/35.5/1.5, artificial aging time 100 h at 150 °C.

[6] Firing profile: total cycle time 30 min, 10 min at 850 °C.

[7] Calculated area that can be printed with one gram paste in the recommended thickness.



3

GLASS PASTES

The glass pastes include the encapsulation paste FK4027 and the FKM4000 marking paste system. The glass pastes were developed for AlN substrates.

FK4027

The encapsulation paste FK4027 is applied as a protective film onto thick-film resistors of the FK9600 and FK9900M resistor paste series, and onto its contacts. This prevents resistance drifts which could result from environmental factors, such as high air humidity or slight mechanical abrasion. Where high film thicknesses are required, the paste should be processed in multiple separate screen printing and firing steps.

FKM4000

The FKM4000 marking paste system is used to apply marking, labels and logos onto AlN substrates. However, the FKM4000 pastes should not be printed over electric functional films, such as conductors or resistors, as this could change their properties.

Technical specifications

Characteristics	Unit	Encapsulation paste	Marking pastes				
		FK4027	FKM4128	FKM4889	FKM4891	FKM4893	FKM4939
Color	--	Green	Blue	Green	White	Black	Dark red
Viscosity[1]	Pa·s	20...50	TBD				
Film surface[2]	--	Smooth, glazed	Smooth, dull				
Resistance change[2, 3]	%	< 5	--				
Fired film thickness	µm	12±2	12±2				
Coverage[4]	cm^2/g	120±5	120±5				

[1] Brookfield viscometer HB with spindle/cup combination SC4-21/-13RP(Y) at n=10 rpm and 25±0.2 °C.

[2] Firing profile: Total cycle time 26 min, 2 min at 650 °C. Transmitted light.

[3] Resistance drift, calculated from resistance values with the geometry 2x2 mm^2 and a sheet resistance of approx. 50-100 Ohm/Sq before and after firing of films of FK4027 printed on top.

[4] Calculated area that can be printed with one gram paste in the recommended thickness.

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1 *Via demonstrator with 100 percent filled vias, in transmitted light.*

2 *Via demonstrator with 100 percent filled vias, as cross section in SEM.*

3 *Technical decal before sintering on a glass with convex surface.*

1

RESISTOR PASTES

FK9600, FK9900M-100 and FK9900M-200 resistor paste systems were developed for use on AlN substrates. This allows to produce high-precision thick-film resistors onto AlN for use in power electronics.

FK9600

The RuO_2-based FK9600 resistor paste system, with sheet resistance values of 6 to 6,000 Ohm/Sq, is compatible with the conductor pastes FK1205, FK1916 and FK1953, as well as with the encapsulation paste FK4027. Other pastes can be used as conductor paste, but this may result in differing sheet resistance values or temperature coefficients. The pastes of the FK9600 paste system as listed in the table below can be mixed with each other as needed. We do not recommend mixing with the resistor pastes of the FK9900M series.

Technical specifications

Characteristics	Unit	FK9606	FK9611	FK9615	FK9621	FK9631	FK9632	FK9636
Viscosity[1]	Pa·s	220±30	220±30	220±30	220±30	220±30	220±30	220±30
Sheet resistance[2, 3]	Ohm/Sq	6	10	50	100	1000	2000	6000
Shipping specification	%	±10	±10	±10	±10	±10	±10	±10
Hot TCR[2, 4]	ppm/K	0±200	0±100	0±100	0±100	0±100	0±200	0±300
Cold TCR[2, 4]	ppm/K	0±200	0±100	0±100	0±100	0±100	0±300	0±300
Dried film thickness	µm	22±2	22±2	22±2	22±2	22±2	22±2	22±2
Coverage[5]	cm^2/g	105±5	105±5	105±5	110±5	110±5	110±5	110±5

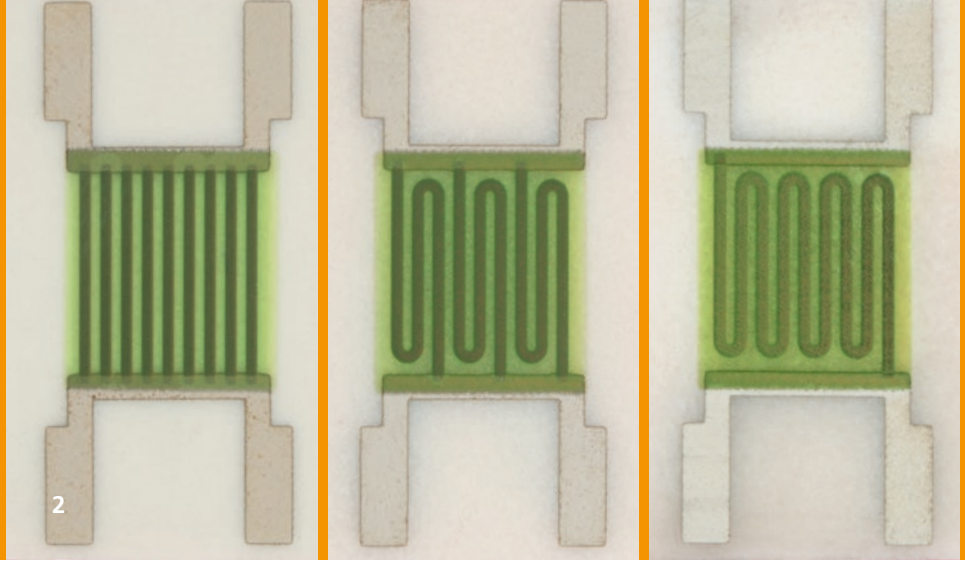
[1] Brookfield viscometer HB with spindle/cup combination SC4-14/-6RP(Y) at n=10 rpm and 25±0.2 °C.

[2] Firing profile: total cycle time 60 min, 10 min at 850 °C.

[3] Calculated for resistors with the geometry 2x1 mm^2 and a dried thickness of 22±2 µm.

[4] Hot temperature coefficient of resistance (TCR) between 25 °C and 150 °C, cold temperature coefficient of resistance between -55 °C and 25 °C.

[5] Calculated area that can be printed with one gram paste in the recommended thickness.



FK9900M-100 and FK9900M-200

The AgPd-based resistor paste systems FK9900M-100 and FK9900M-200, with a temperature coefficient of resistance lower than 100 ppm/K, or lower than 200 ppm/K, respectively, are compatible with the conductor pastes FK1205, FK1916 and FK1953, as well as the encapsulation paste FK4027. Other pastes can be used as conductor paste, but this may result in differing sheet resistance values or temperature coefficients.

The pastes listed below may be mixed with each other. It is possible to combine these pastes with those of the FK9600 series without an additional contact film. To do this, it is required to fire the paste film before printing the next one. We do not recommend mixing the FK9900M with pastes of the RuO_2-based FK9600 paste series.

Technical specifications

Parameter	Unit	FK9900M-100			FK9900M-200		
		FK9921M	FK9931M	FK9941M	FK9921M	FK9931M	FK9941M
Viscosity[1]	Pa·s	TBD	TBD	TBD	TBD	TBD	TBD
Sheet resistance[2, 3]	mOhm/Sq	100	1000	10 000	100	1000	10 000
Shipping specification	%	±20	±20	±20	±20	±20	±20
Hot TCR[2, 4]	ppm/K	0±100	0±100	0±100	0±200	0±200	0±200
Cold TCR[2, 4]	ppm/K	0±100	0±100	0±100	0±200	0±200	0±200
Dried film thickness	µm	21±2	21±2	21±2	21±2	21±2	21±2
Coverage[5]	cm^2/g	80±5	95±5	100±5	80±5	95±5	100±5

[1] Brookfield viscometer HB with spindle/cup combination SC4-14/-6RP(Y) at n=10 rpm and 25±0.2 °C.

[2] Firing profile: total cycle time 60 min, 10 min at 850 °C.

[3] Calculated for resistors with the geometry 100x0.5 mm^2 and a dried thickness of 21±2 µm.

[4] Hot temperature coefficient of resistance (TCR) between 25 °C and 150 °C, cold temperature coefficient of resistance between -55 °C and 25 °C.

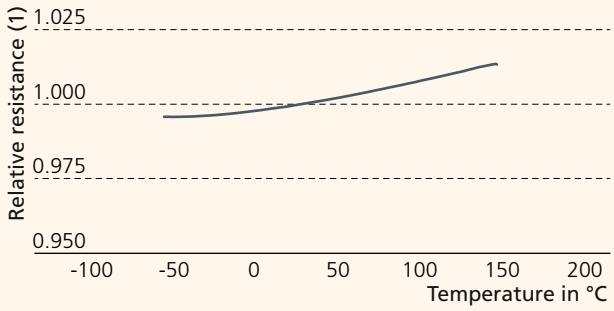
[5] Calculated area that can be printed with one gram paste in the recommended thickness.

1 *R(T) measurement of a resistor paste.*

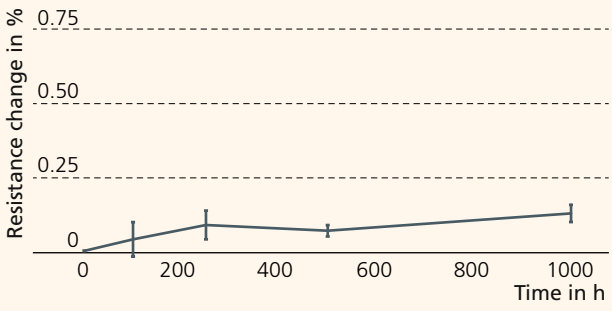
2 *Encapsulated AgPd resistors of various resistance decades for the comparative characterization of properties.*

INFLUENCES ON FILM PROPERTIES

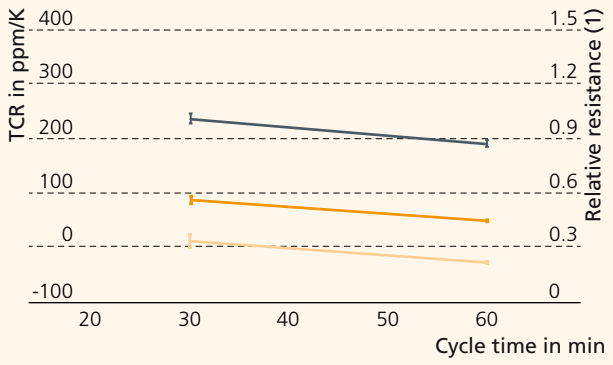
FK9611



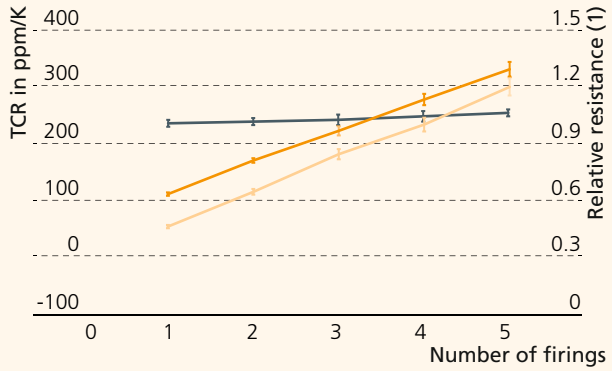
Resistance change depending on the temperature



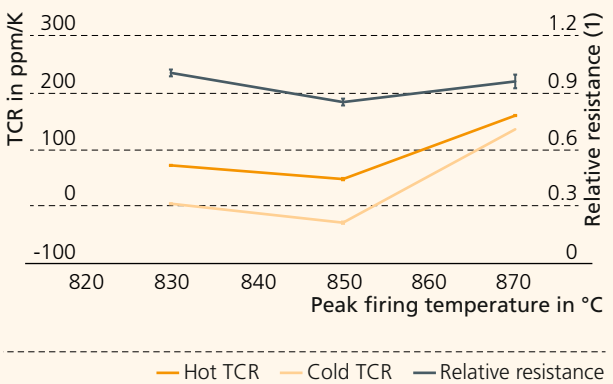
Resistance change depending on aging at 85 °C and 85 % humidity



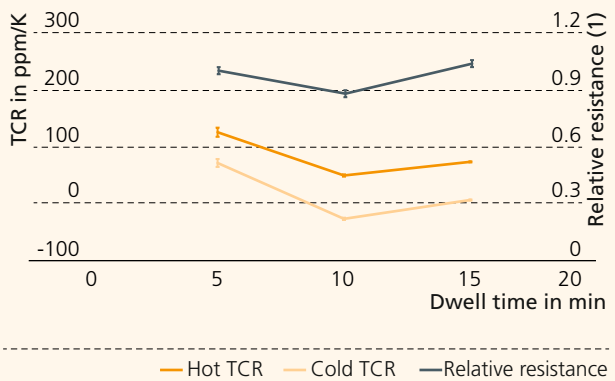
TCR and relative resistance at 30‘ and 60‘ cycle time



TCR and relative resistance depending on the number of firings

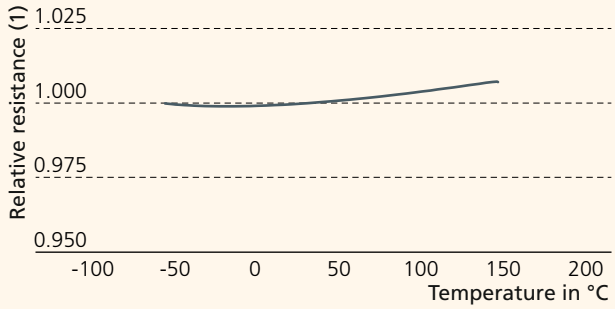


TCR and relative resistance depending on peak firing temperature

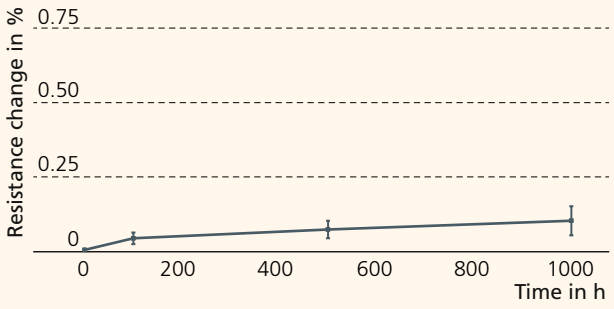


TCR and relative resistance depending on dwell time at 850 °C

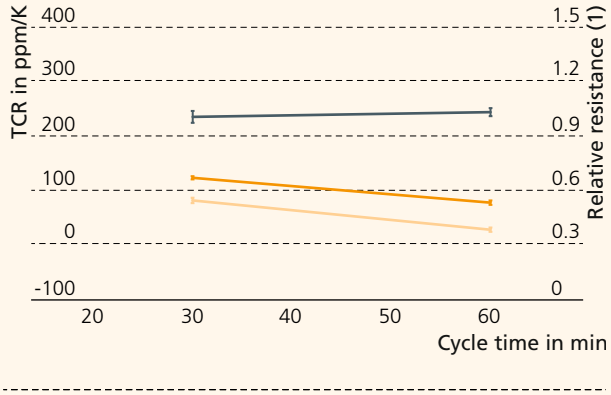
FK9615



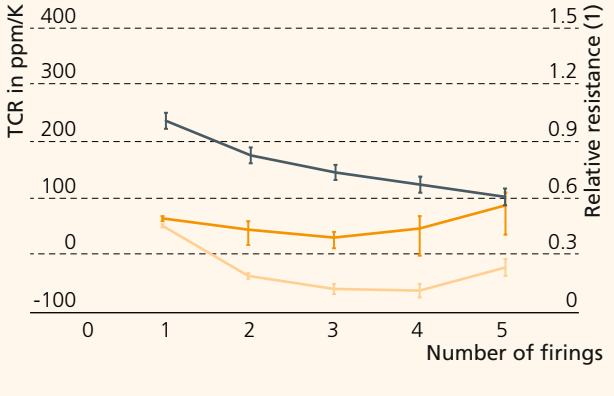
Resistance change depending on the temperature



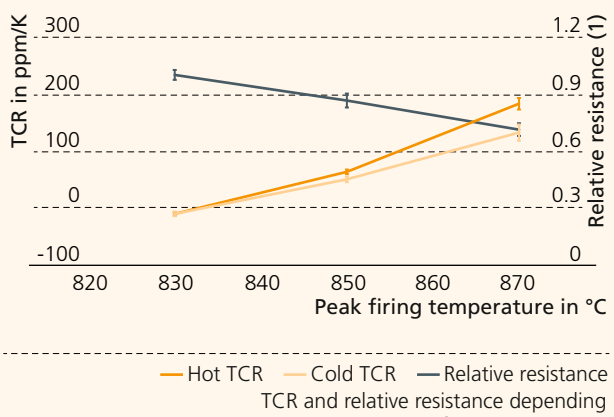
Resistance change depending on aging
at 85 °C and 85 % humidity



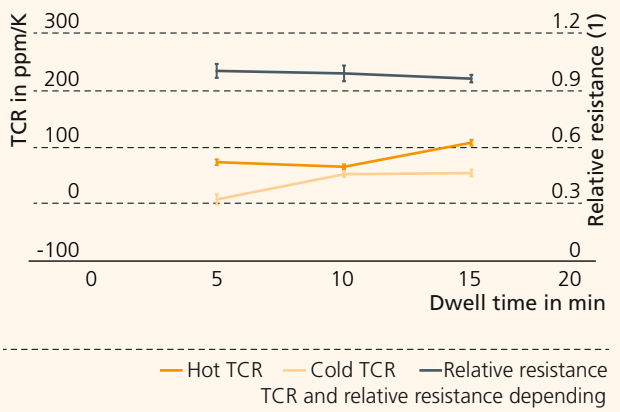
TCR and relative resistance at
30‘ and 60‘ cycle time



TCR and relative resistance depending
on the number of firings

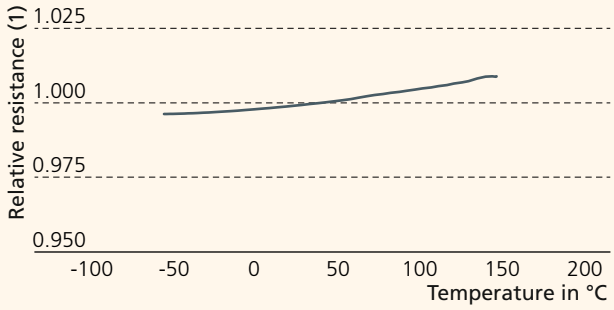


TCR and relative resistance depending
on peak firing temperature

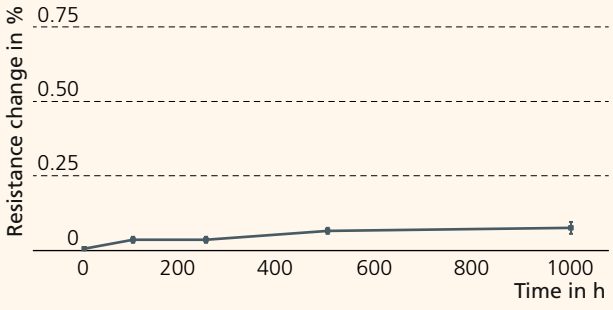


TCR and relative resistance depending
on dwell time at 850 °C

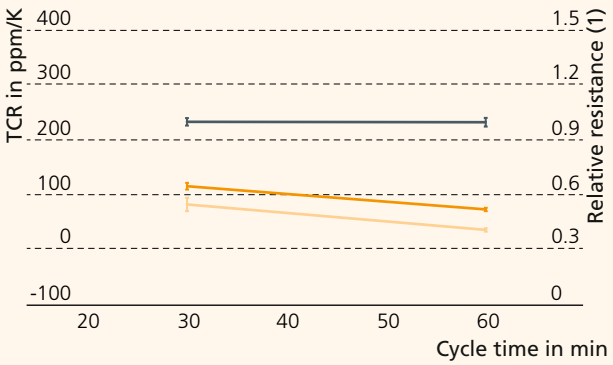
FK9621



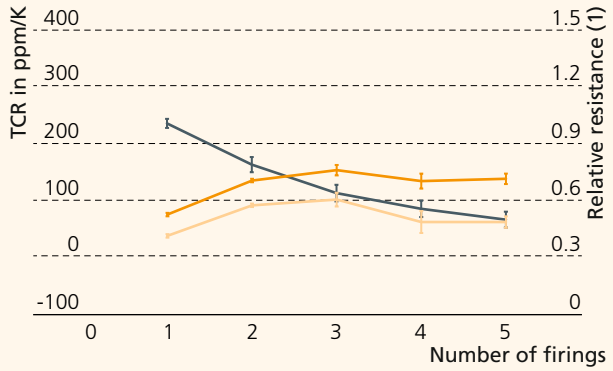
Resistance change depending on the temperature



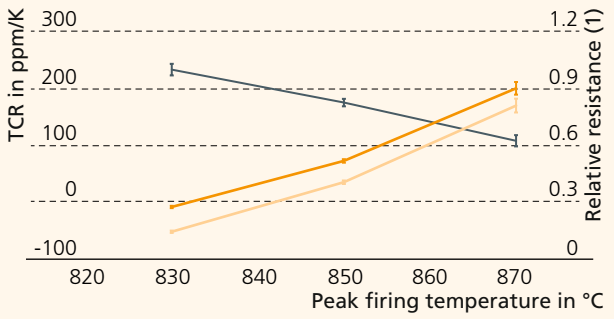
Resistance change depending on aging
at 85 °C and 85 % humidity



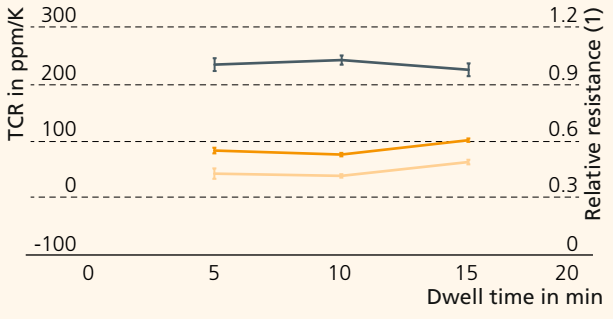
Hot TCR Cold TCR Relative resistance
TCR and relative resistance at
30' and 60' cycle time



Hot TCR Cold TCR Relative resistance
TCR and relative resistance depending
on the number of firings

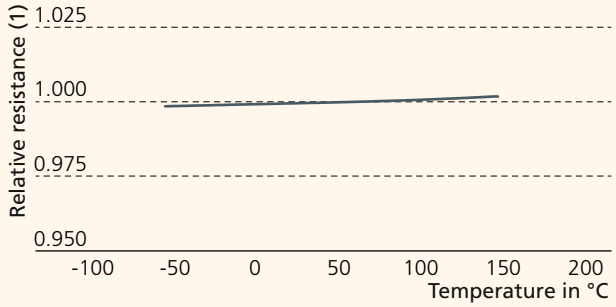


Hot TCR Cold TCR Relative resistance
TCR and relative resistance depending
on peak firing temperature

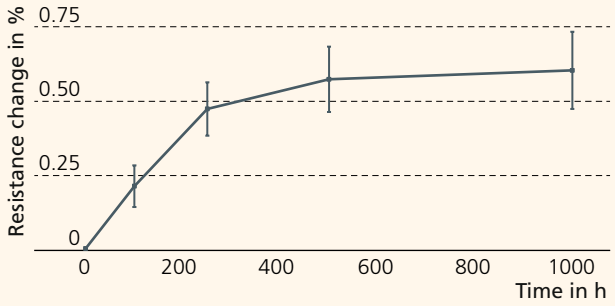


Hot TCR Cold TCR Relative resistance
TCR and relative resistance depending
on dwell time at 850 °C

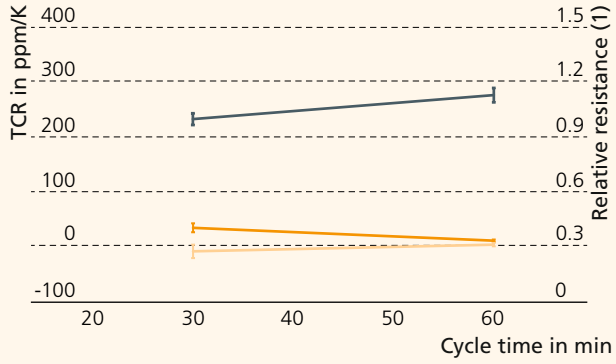
FK9631



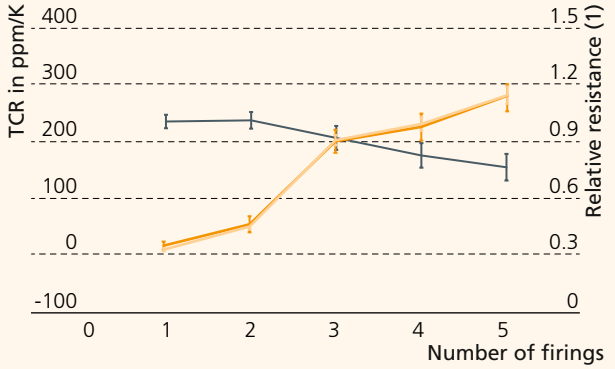
Resistance change depending on the temperature



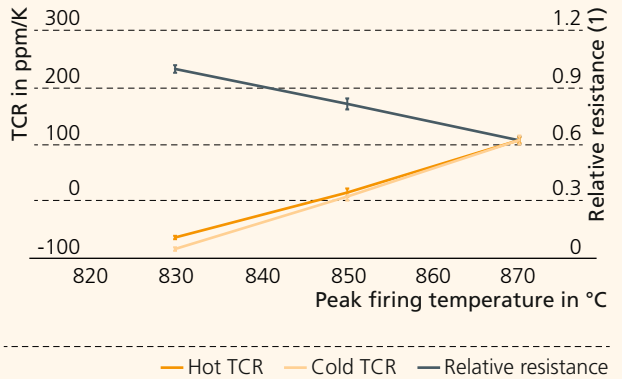
Resistance change depending on aging
at 85 °C and 85 % humidity



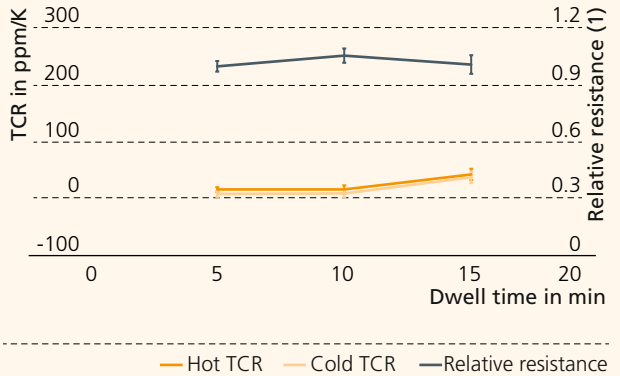
TCR and relative resistance at
30' and 60' cycle time



TCR and relative resistance depending
on the number of firings

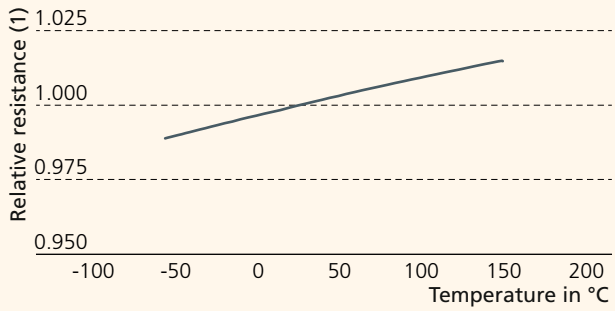


TCR and relative resistance depending
on peak firing temperature

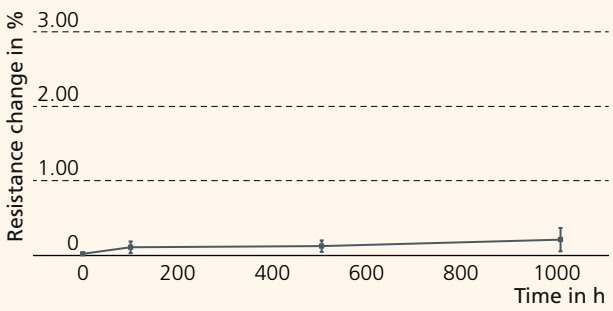


TCR and relative resistance depending
on dwell time at 850 °C

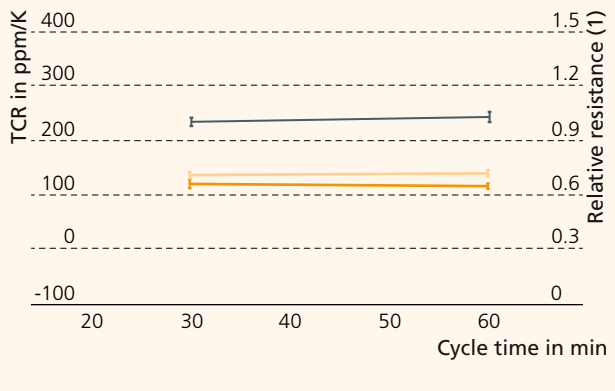
FK9921M



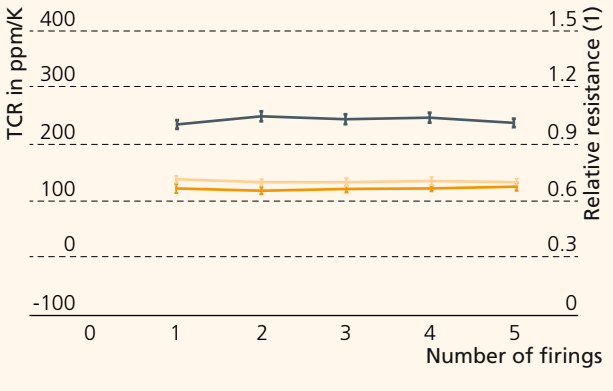
Resistance change depending on the temperature



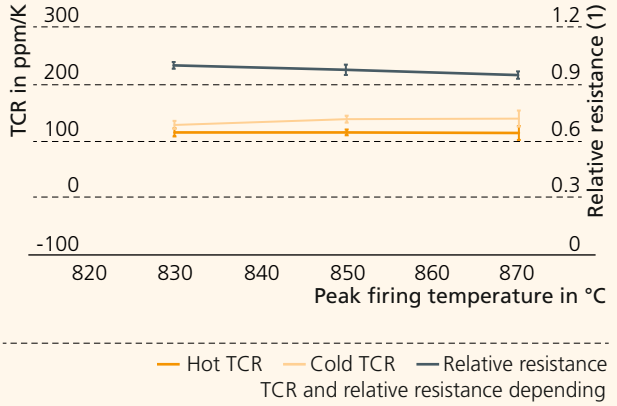
Resistance change depending on aging at 200 °C



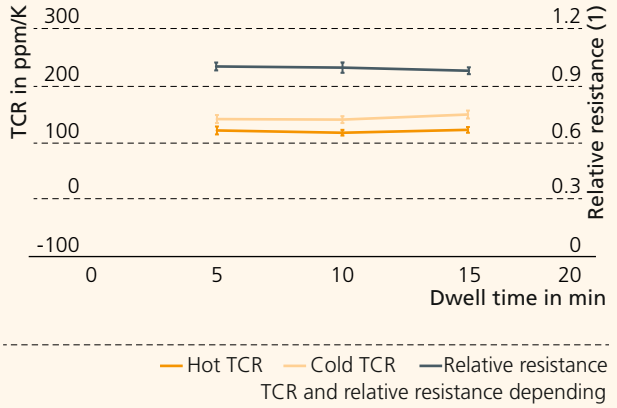
TKR and relative resistance at 30' and 60' cycle time



TCR and relative resistance depending on the number of firings

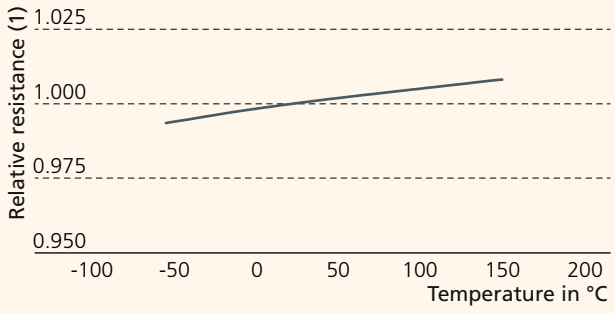


TCR and relative resistance depending on peak firing temperature

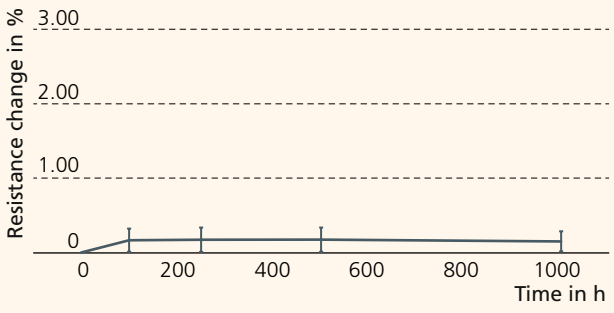


TCR and relative resistance depending on dwell time at 850 °C

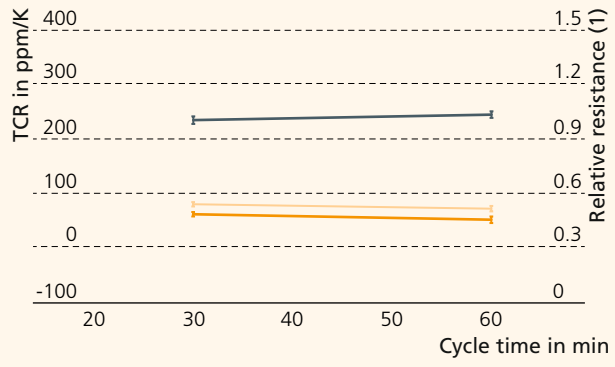
FK9931M



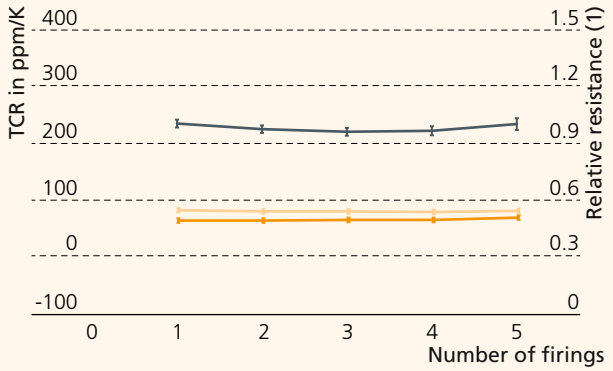
Resistance change depending on the temperature



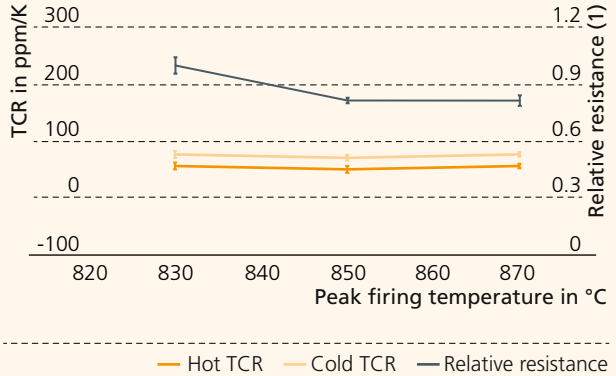
Resistance change depending on aging at 200 °C



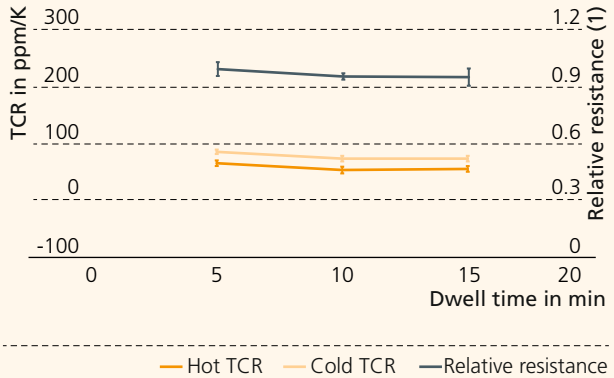
TKR and relative resistance at 30‘ and 60‘ cycle time



TCR and relative resistance depending on the number of firings

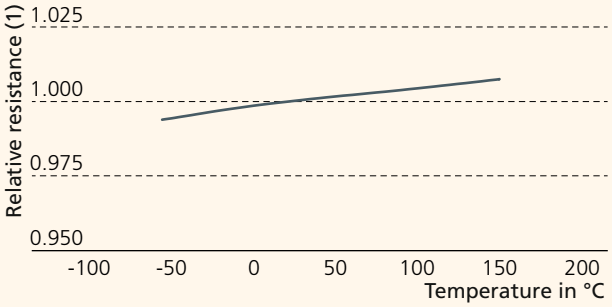


TCR and relative resistance depending on peak firing temperature

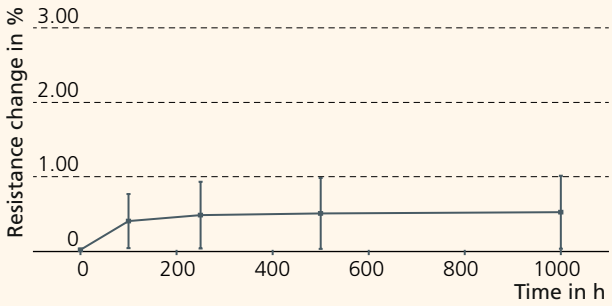


TCR and relative resistance depending on dwell time at 850 °C

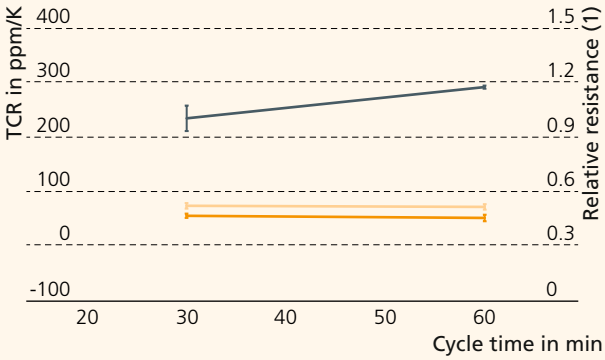
FK9941M



Resistance change depending on the temperature

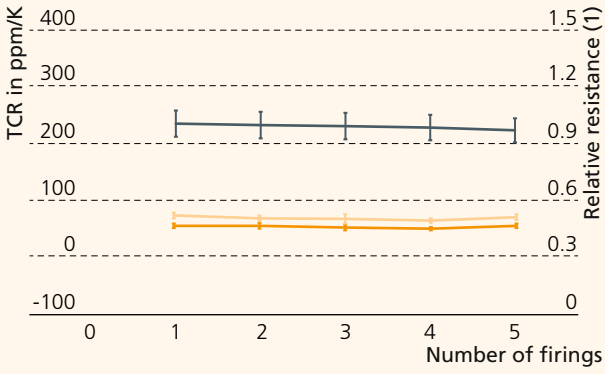


Resistance change depending on aging at 200 °C



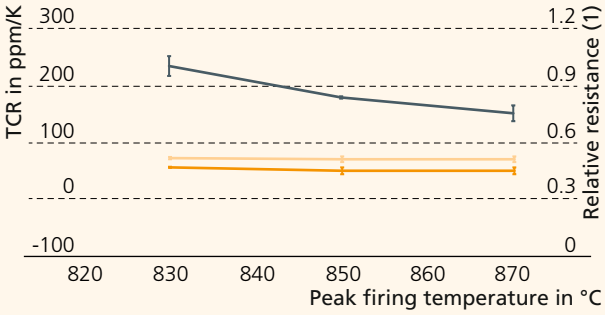
Hot TCR Cold TCR Relative resistance

TKR and relative resistance at 30‘ and 60‘ cycle time



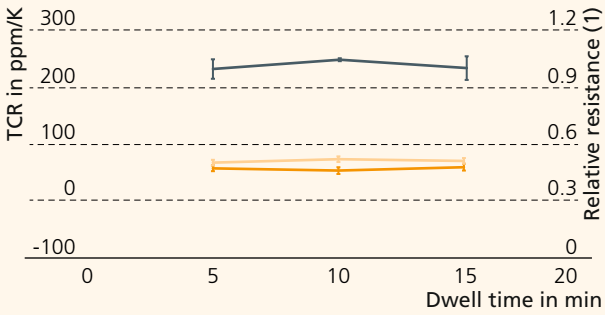
Hot TCR Cold TCR Relative resistance

TCR and relative resistance depending on the number of firings



Hot TCR Cold TCR Relative resistance

TCR and relative resistance depending on peak firing temperature



Hot TCR Cold TCR Relative resistance

TCR and relative resistance depending on dwell time at 850 °C

THINNER

The thinners of the FK0xx0 series are adapted to the respective paste type and its organic vehicle. The following table lists compatible thinners for the conductor, via filling, marking, encapsulation and resistor pastes.

Technical specifications

Paste	Thinner		
	FK0110	FK0120	FK0200
Conductor pastes			
FK1071		x	
FK1205		x	
FK1282		x	
FK1572	x		
FK1574	x		
FK1916		x	
FK1953		x	
FK3101		x	
FK3201		x	
Via filling paste			
FK1105	x		
Encapsulation paste			
FK4027	x		
Marking pastes			
FKM4000	x		
Resistor pastes			
FK9600	x		
FK9900M			x

1 *Powder as functional phase in thick films.*

FRAUNHOFER IKTS IN PROFILE

The Fraunhofer Institute for Ceramic Technologies and Systems IKTS conducts applied research on high-performance ceramics. The institute's three sites in Dresden (Saxony) and Hermsdorf (Thuringia) represent Europe's largest R&D institution dedicated to ceramics.

As a research and technology service provider, Fraunhofer IKTS develops modern ceramic high-performance materials, customized industrial manufacturing processes and creates prototype components and systems in complete production lines from laboratory to pilot-plant scale. Furthermore, the institute has expertise in diagnostics and testing of materials and processes. Test procedures in the fields of acoustics, electromagnetics, optics, microscopy and laser technology contribute substantially to the quality assurance of products and plants.

The institute operates in nine market-oriented business divisions to demonstrate and qualify ceramic technologies and components as well as non-destructive test methods for new industries, product concepts and markets beyond the established fields of application. Industries addressed include ceramic materials and processes, mechanical and automotive engineering, electronics and microsystems, energy, environmental and process engineering, bio- and medical technology, non-destructive testing and monitoring, water as well as materials and process analysis.

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