CERAMIC COMPONENTS FOR SENSOR AND MEASUREMENT TECHNOLOGY

High-performance ceramics

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PROPERTIES OF KYOCERA'S HIGH-PERFORMANCE CERAMICS

For all applications shown in this brochure you will find these icons below the headline. They indicate which properties of our ceramics are most important in this specific application.

Mechanical properties
(e.g. strength, hardness, wear resistance)

Thermal properties
(e.g. high temperature resistance, thermal conductivity, thermal shock resistance)

Electrical properties
(e.g. resistivity, dielectric strength, dielectric loss)

Chemical properties
(e.g. corrosion resistance, chemical inertness)

Together with our customers we develop ceramic components for sensing applications which work even under extreme conditions.

PRESSURE MEASUREMENT

In various applications and devices, it is crucial to precisely measure and monitor the pressure. The most reliable sensors tend to use ceramic as one of their key components.

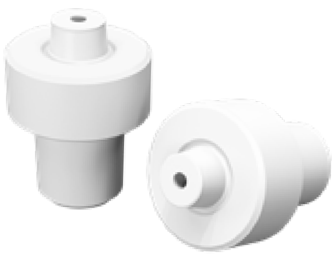
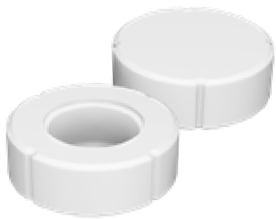
High rigidity and long lifetime of ceramics make it possible to measure a wide range of pressure with one sensor without maintenance or re-calibration for a long period of time. The parts keep their high Young's modulus under high temperature and high pressure and are fatigue-free.

Pressure sensor components from Kyocera are perfect for use in harsh environments such as contact with various liquids. They show excellent chemical resistance as well as temperature resistance and thermal stability over time. Thick film printing of conductor or resistor can be carried out directly without additional isolation process.

Technologies that are currently supported by Kyocera are:
- Substrate + membrane
- Monolithic ceramic
- Pedestal

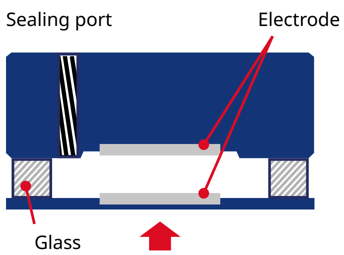
Kyocera offers proven and highly efficient series production up to very large scale, based on many years of experience.

High precision machining to reach tight tolerances is another specialty of Kyocera in this kind of application. By utilising a strong production infrastructure Kyocera can offer highly customized designs for different pressure ranges and according to customers' needs.

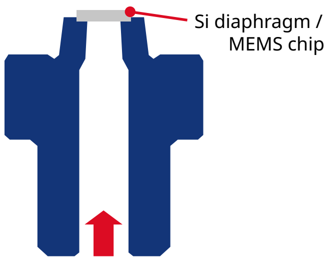




The above ceramic components can be used for different kinds of pressure measurement principles.

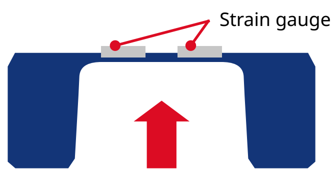
Capacitive pressure measurement



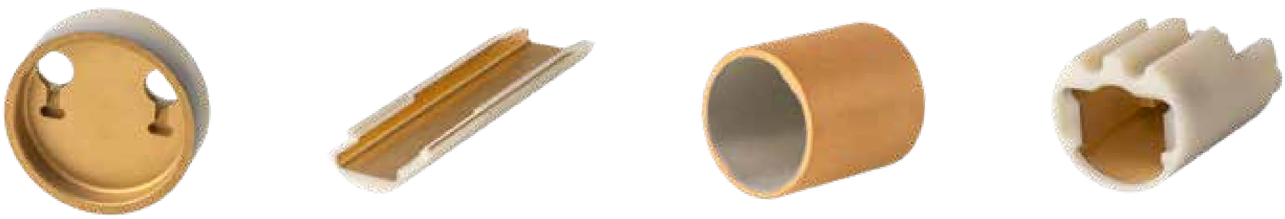
Pressure measurement with MEMS chip



Piezo-resistive pressure measurement



PRESSURE AND TEMPERATURE MEASUREMENT



Gold-coated alumina components for temperature and pressure sensor assembly

If measurements are supposed to be performed under demanding conditions like e.g. high-temperature or high-pressure suitable materials are needed to protect the sensitive measurement device and electronics. The influence of protection on the measurement and thus on the results should be kept as small as possible and ideally be zero. For inductive and capacitive sensors metal cannot be used as protection material due to its electric and magnetic properties. Most ceramic materials show a very low dielectric loss and are transparent for microwaves so that there is no influence on the measurement signal while their high mechanical strength and abrasion resistance makes them the perfect choice for protecting the sensor and its electronics. Kyocera offers customized ceramic parts for this purpose which in some applications already manage to resist a pressure of 1,400 bar under elevated temperatures and in a corrosive environment.

Certain ceramic materials can still be used at 1,800 °C or above. Even when stressed by continuous strong vibration ceramic still shows sufficient impact toughness. Especially in the Oil & Gas industry as well as in the renewable energies sector ceramic components fully comply with the requirements concerning reliability and lifetime.

In close cooperation with our customers Kyocera develops customized components which can for example be optimized to a minimum need for space in the customer's assembly.

The above sensor components are an example of ceramic design for pressure and temperature sensors where the required material needed to be carefully selected.
When you need to monitor pressure, temperature, water, sand and more in the well to achieve maximum reservoir performance Kyocera's high-performance ceramics are successfully used since 1996 in the Oil & Gas industry.

Increasingly deeper wells give higher pressure and higher temperature. For downhole technology the requirements on the parts used are very high.

Requirements for this application:

- Pressure requirements 20,000 psi / 1,400 bar
- Temperature requirements -46 to 225 °C / 437 °F (Formerly existing instruments only withstood up to 180 °C and at lower pressures)
- Continuous and strong vibration and shock resistance
- Withstand corrosive and abrasive environment
- Long life time up to 25 years
- Small size of components (diameter < 25.4 mm = 1 inch)
- High demands on electrical properties
- Easier assembly thanks to miniaturization
- Stable dielectric constant leads to very good microwave properties

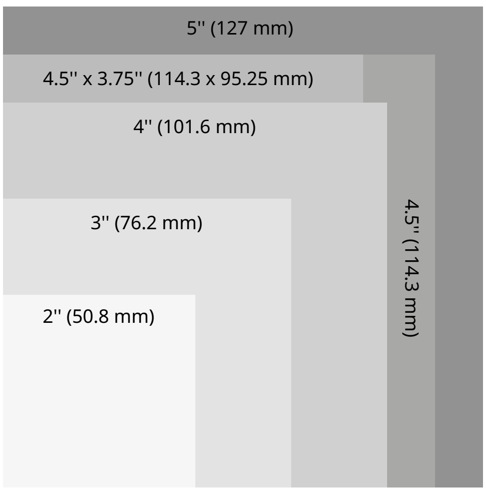
SUBSTRATES FOR
THIN FILM TEMPERATURE SENSORS

Ceramic substrates are mainly used as hybrid IC substrates, thin film IC substrates, heat dissipation substrates, and LED sub-mount substrates. Thin film substrates not only require a very smooth surface but also low thermal expansion in high temperature environments.

Kyocera's thin film substrates are made of high purity 99.6% alumina. Our micro-grain material structure enables substrates which have excellent surface quality with less voids, high flexural strength and electrical insulation in high temperature environments.

As additional feature, very fine through holes can be cut or electrode patterns (metallization) can be formed by printing or plating the substrate. Metallization is available with high adhesion strength Mo-Mn and there are various options for conductive layers incl. Ag or Cu. Customized pattern printing is possible.

Substrate sizes:
- Outer dimensions: 2'' - 5'', max. 165 mm sq.
- Thickness: 0.254 mm, 0.381 mm, 0.635 mm (other thicknesses available from 0.1 - 2.5 mm)
- Outer dimensions tolerances: Standard ± 0.8% of the outer dimension, min. ± 0.10 mm
- Thickness tolerances: Standard ± 10% of thickness, min. ± 0.05 mm



Scale 1:2

Substrates made of alumina A493

Visit our website at **https://kyocera-fineceramics.de/**

HIGH-TEMPERATURE MEASUREMENT

Tubes and capillary tubes made of alumina DEGUSSIT AL23 and AL24 are the best choice for the highest demands for thermocouple protective tubes. Because of their special structural properties they can also be used at temperatures above 1,800 °C. At the same time the material is very resistant against predominant corrosive load in the kiln or the melt. In addition it has a high heat conduction thus leading to very short response time of the thermocouple.

Of course the electrical isolation properties are excellent even at high temperatures. Kyocera uses a special closing technology for one-end closed tubes so that there is no joining zone with reduced resistance or stability. The excellent processing of the closed end of the tube ensures a uniform, dense structure and, in turn, protection against cracks and leaks.

Thermocouples made of DEGUSSIT AL23 can be used at temperatures above 1,800 °C.

Source: Keramischer OFENBAU GmbH

FLOW MEASUREMENT

In a lot of industrial environments, it is essential to measure the flow and in some situations at the same time also the composition of flowing goods.
Key requirements are precision, reliability and high lifetime.
Kyocera provides ceramic components for different types of flow meters.

MAGNETIC-INDUCTIVE FLOW METER

The extraordinary properties of technical ceramics ensure precise and safe processes in filling systems for liquids and pasty substances. The cermet electrode is unique and patented, an electrically conductive compound of magnesia-stabilized zirconia FZM, a material with very high mechanical strength, and platinum. These cermets are e.g. used in magnetic-inductive flow meters. They are tested in accordance with pressure equipment standards with tenfold nominal pressure safety allowing components made of advanced ceramics to be used under very demanding corrosive and/or abrasive conditions and enabling accurate and precise filling. They show no deformation over time which makes a re-calibration unnecessary.

FLOAT-TYPE FLOW METER

Float bodies made of alumina F99.7 extend the application spectrum of measuring devices to flow monitoring. As the material is extremely resistant to corrosion and wear, precise control of the liquid flow can be guaranteed even for aggressive materials. To ensure a precise measurement of the flow rate the body must be machined to very tight tolerances of a few hundredth of millimeters.

Flow meter in zirconia FZM for the food processing industry

Assembly situation

Float bodies in alumina F99.7 for flow monitoring in the chemical industry

Components for highest flow measurement

WATER-CUT METER

Another flow measurement principle is based on capacitive sensors. It utilizes ceramic sensor components and sensor rings, partially metallized and brazed, in so called watercut meters. These sensors allow a capacitive analysis of the ambient media and an exact determination of the proportion of different substances in liquid and gaseous media. Such systems are successfully used in the offshore and subsea industry for 25 years under pressures of more than 1,000 bars.

MULTI-PHASE FLOW METER

In the Oil & Gas industry the requirements regarding performance, reliability and lifetime are very high in general and were specifically of highest priority in this very application. The materials and components used should be resistant to extremely high erosion, abrasion, and corrosion. This type of multi-phase flow meter can constantly measure the flow in the oil well and distinguish between oil, water and saline (saltwater). The ceramic resonator was developed to be suitable for microwave measurement principle and is made of FZM zirconia ceramic with a partial gold coating and shrunk into an inconel housing. In this case the resonator itself was supposed to have a dielectric constant of 35 which Kyocera's material could exactly meet. The gold-coated ceramic resonator is able to give very precise Q-values and was proven to be suitable for the multi-phase measurement setup.

Water-cut meter for the Oil & Gas industry

Resonators for microwave based measuring in flow meters

LEVEL MEASUREMENT

Reliable and flexible measurement of the level in silos, tanks or other storage containers: no problem with sensors made of Kyocera's technical ceramics.

GUIDED WAVE RADAR

Customized electric feedthroughs and coated components from Kyocera enable our customers to enter new fields of applications with their guided wave radar level measurement devices due to the excellent properties of our ceramic materials. The ceramic components work as isolators and mechanical support for the wave antenna. The electromagnetic waves emitted are guided along cable or rod probes and reflected on the surface of the product.
Adhesives, dust, or vapors do not influence the measurement result. This ensures that liquids, bulk materials and separating layers are simply and reliably measured. Well-engineered and tailor-made products are the basis for precise measurements in the most demanding environments.

High-pressure and high-temperature microwave feedthrough and TiN-coated mechanical sealing made of zirconia-toughened alumina FZT

RADAR/FREE PROPAGATION

Level sensors operate more and more frequently with radar or ultrasonic transmitters made of alumina F99.7 or F99.7 hf. Examples are level sensors in silos and tanks. When measuring the level, Kyocera's aluminum oxide ceramics are used as antennas or transmitters of the radio waves, microwaves, or ultrasonic waves. By means of the connected electronic measurement device precise measurements of the level in the container or tank can be obtained, based on travel time or frequency changes. Kyocera offers a large variety of different materials and technologies to comply with the requirements.

Level sensor antenna made of alumina F99.7

Liquids, bulk materials and separating layers are simply and reliably measured.

CAPACITIVE

Safety and sturdiness are essential requirements for most sensors in the Oil & Gas industry. Capacitive level sensors with advanced ceramics are suitable for such applications. They are lined up along a measuring rod and each sensor can detect what is in front of it, e.g. sand, water oil, foam or gas. They are resistant to wear, corrosion and dirt. By knowing the position of each sensor one can calculate the level of all phases present in the tank. This is true multi-phase level measurement.

Sensor heads made of alumina F99.7 and titanium with laser marking

Source: ACO Automation Components Johannes Mergl e.K.

OXYGEN MEASUREMENT

DEGUSSIT FZY (Y-PSZ, zirconia partially stabilized with yttria) was specifically developed to be used on oxygen sensors. The measurement principle corresponds to that of the λ-sensor (lambda-sensor) in cars. However, sensors with DEGUSSIT FZY material are mainly used in industrial high-temperature processes to precisely and reliably measure the oxygen content of the atmosphere. The measurement is based on a special property of this material: it becomes conductive for oxygen ions at elevated temperatures of around 400 °C and above. Oxygen sensors based on this principle and material normally work well in a temperature range of 400 °C – 1,500 °C.

There are unheated oxygen sensors which are used directly in high-temperature processes and others which are used at room temperature but have to be heated up before measurement. Typical fields of application are monitoring of annealing processes or protection gases, surface treatment (e.g. hardening processes), monitoring of redox reactions or diffusion processes, biotechnical processes and quality control of food packaging.

Components for oxygen measurement
made of zirconia DEGUSSIT FZY

Brazed component for oxygen measurement
made of zirconia DEGUSSIT FZY

HUMIDITY MEASUREMENT

In humidity sensors often several unique properties of technical ceramics are needed: Besides its rigidity, corrosion and wear resistance, ceramic to a large extent is transparent for electromagnetic radiation and electrically isolating. In most cases ceramic does not affect the measurement signal and is already successfully used e.g. as mechanical protection of the very sensitive continuous capacitive humidity sensor. Especially measuring abrasive materials like sand, grit or ore requires the use of ceramic as protection of the sensor.

With DEGUSSIT F99.7 hf a material can be offered which was specifically developed and optimized for use in high frequency applications, and which has constantly very low and accurate dielectric losses. Applications are e.g. as RF window, a window transparent for electromagnetic radiation in an assembly otherwise completely made of metal. Different joining methods are available to connect ceramic and metal parts. Applying conductive layers of different thicknesses and compositions as well as ceramic and/or metal is also possible, so that the production of quite complex components is a challenge but not a problem for us.

Humidity sensors

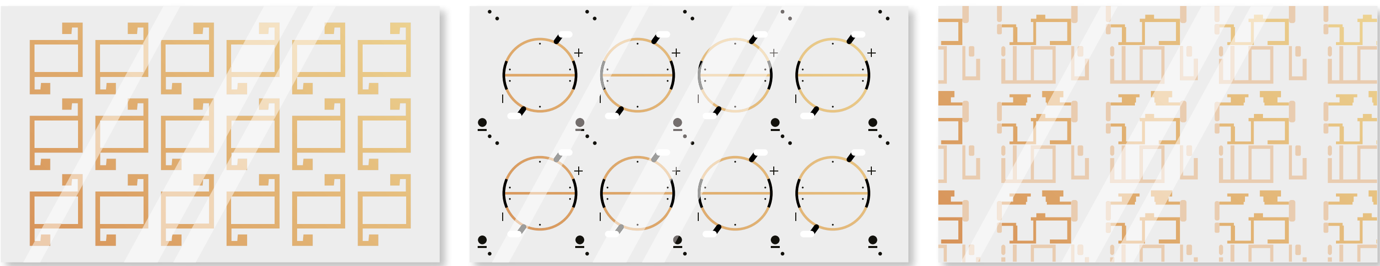
Source: ACO Automation Components Johannes Mergl e.K.

FORCE, POSITION AND OTHERS

THICK FILM SUBSTRATES

Kyocera's thick film substrates are perfectly fit for the high density and precision of thick film switches which are used, for example, in force sensors with cantilever measurement principle.

Kyocera's alumina substrates are suitable as reliable components for a variety of thick film processes: strictly controlled outer dimensions (±0.25% max.) and small holes (0.2 mm max.) are possible, which comply with the high density and precision needed in thick film applications.



Examples for different thick film substrate designs

CERAMIC CAP

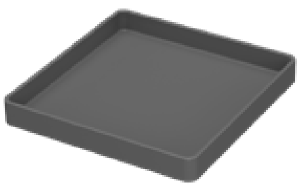
Ultra-thin ceramic caps enable devices to become smaller in size and lower in height. By these features the miniaturization requirements from electronics industry are supported.

Material options:
- A445F (dark alumina)
- A476 (white alumina)

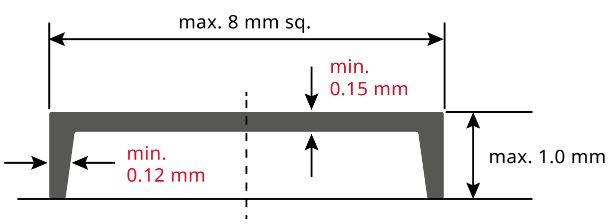
These caps are used as covers for:
- gyro sensors
- power semiconductors
- oscillators
- resonators

Thickness [mm]	Conventional technology	New technology
Side wall thickness	0.24	0.12
Top wall thickness	0.20	0.15

Minimum wall thickness comparison



Ceramic cap made of black alumina

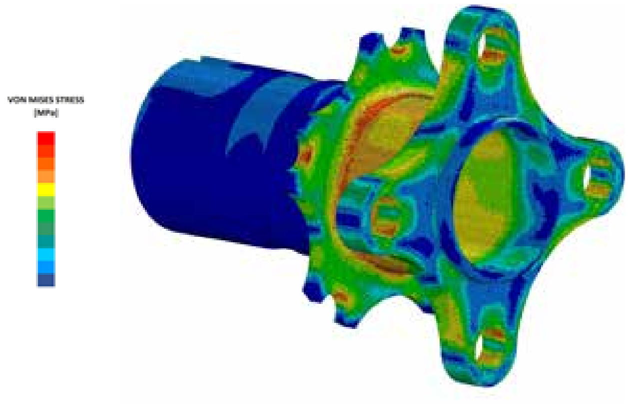


Minimum and maximum dimensions of a Kyocera ceramic cap

Kyocera supplies reliable components for a variety of thick film processes.

SIMULATION TECHNOLOGY

In some cases, especially for new applications of ceramic materials, it can be very useful to do a simulation beforehand. This can save a lot of time as well as costs. Critical factors as point loads, thermal stresses and fatigue can be identified and the construction can be adapted accordingly before any failure or damage occurs. The Kyocera engineering team is familiar with the specialties of ceramic components and offers a broad expertise in choosing the right parameters for simulation. Most common simulation approaches are available within Kyocera, mainly based on FEM analysis. So based on the assembly situation and customer’s requirements e.g. the tensile stress distribution on a pump impeller, the heat distribution on a ceramic heater or fracture probability of a turbine blade, taking into account the Weibull modulus, can be simulated and calculated.



Kyocera's simulation technology

COATING TECHNOLOGY

Different kinds of coatings grant different properties and serve different purposes. Depending on the application it might for example be necessary to apply an electrically conductive layer onto the normally electrically isolating ceramic body. Coatings or metallization are also used as preparation for subsequent joining processes as brazing or welding.

Kyocera offers a variety of different coating technologies and materials. An overview can be found in the following table. If your required coating is not mentioned in the tabel please contact us.

We do not necessarily do all coatings in house. For very special requirements and specific technologies we rely on our excellent network of coating partners and suppliers.

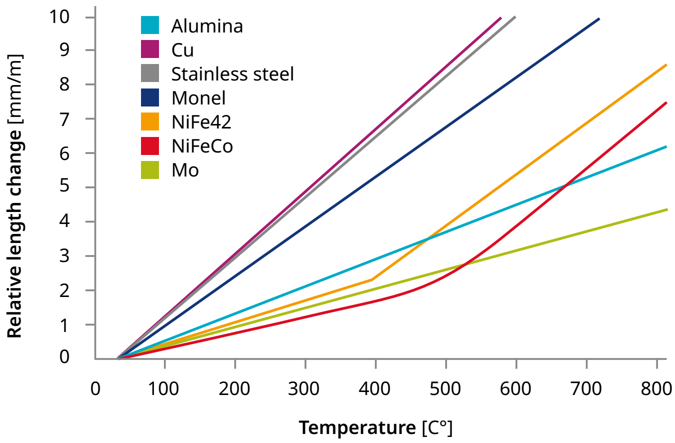
Material	Ag	Au	Pt	Ag-Cu-Ti	MoMn	Ti	TiN	Ni / MoMn	Cu / MoMn	Sn / MoMn
Screen printing	■	■	■	■	■			■		
Manual applications	■	■	■	■	■			■		
PVD	■	■				■				
CVD							■			
Galvanic								■	■	■

Materials and processes for coating of ceramics

BRAZING TECHNOLOGY

Many applications require mechanically stable and highly vacuum-tight joining of ceramic parts with each other and/or with metal parts. Components made of high-performance ceramics are generally metallized using the molybdenum-manganese procedure (MoMn procedure) and subsequent nickel-plating. The starting point for this process is a compound of molybdenum and manganese. The compound is applied to the ceramic surface to produce a firmly bonded metallized coating through a firing process. As the majority of commercial vacuum hard solders do not wet the metallized surface, it is nickel-plated using a galvanic or autocatalytic method. The component can be brazed on this base metallized coating.

Metallization allows for brazing at temperatures above 1,000 °C under protective gas atmosphere or in vacuum. A silver copper eutectic alloy is used as a standard brazing material. Brazing materials with increased melting properties are applied when higher requirements are imposed on the operating temperature, corrosive properties and use of metals that are hardly wetted by the silver-copper eutectic alloy. The table below gives an overview of available brazing alloys. Our metallized ceramics are also available with galvanic coating such as Au, Ni or Cu to allow for the use of soft solders at low temperatures.



Thermal expansion characteristics of metallic materials and alumina ceramics

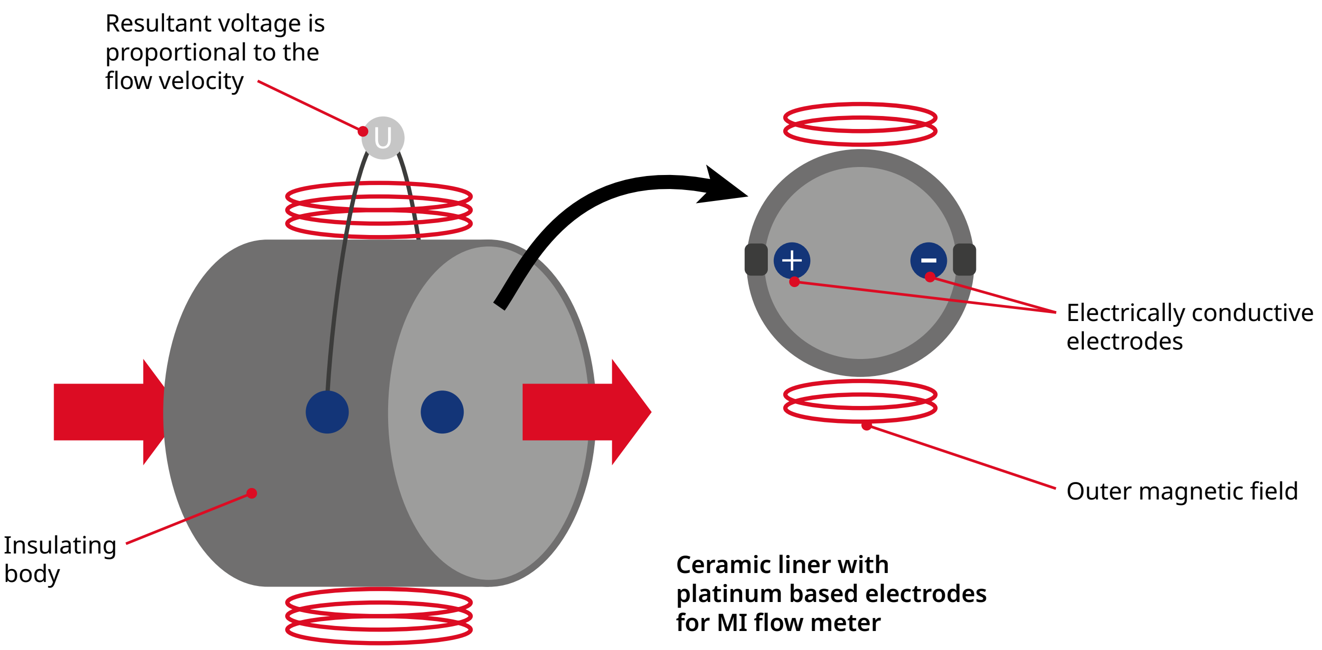
Brazing material	Brazing temperature [°C]
Ag Cu 28	780
Ag Cu 26,6 Pd 5	800 – 850
Ag Cu 21 Pd 25	900
Au Ni 18	950
Cu Ge 10	1,000
Au Cu 65	1,020
Au	1,070

Brazing materials and brazing temperatures

SINTER-IN TECHNOLOGY

Either pure platinum pins or “cermets” can be used for our sinter-in technology. Platinum is a precious metal with a similar level of corrosion resistance as ceramic and is protected against mechanical effects by the surrounding ceramic. Cermets are a mixture of ceramic and platinum (cermet = ceramic & metal) and have even better attributes as an electrode material than pure platinum. Kyocera has a special and unique technology to sinter e.g. electrodes into a ceramic body and to manufacture suitable cermet electrodes. This is an established procedure in our production processes and we have many years of experience in this technology. The benefit of this joining method is that no further aids are required and therefore, the final product does not contain any metallic (apart from the platinum for the electrodes) or organic substances. Cermets are more resistant to corrosion and wear than platinum. Furthermore, the connection between the cermet electrode and ceramic is even more robust and withstands high pressure and fast temperature changes without problems.

When sinter-in the cermet electrodes, diffusion processes between the electrode and the ceramic form a solid ceramic connection so that the joint zone is no longer a mechanical weak point. This is proven impressively in the mechanical load test, in which the measuring tube does not generally break at the electrode but in the middle of the ceramic structure. Of course, this technology is also subject to certain limitations. Therefore, the electrodes must have a shape as simple and round as possible. Furthermore, sinter-in is limited to relatively small electrode dimensions of several millimeters depending on the material. A minimum electrode length of several millimeters is required for a reliable and stable connection between the ceramic and the electrode.



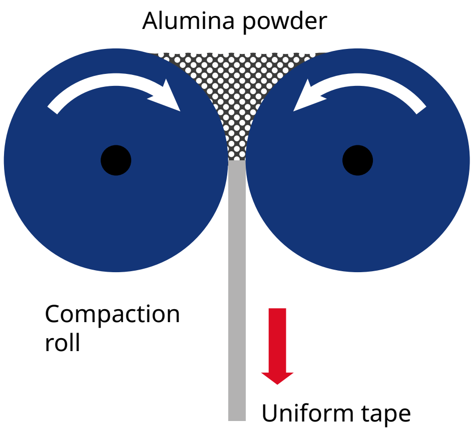
Working principle of magnetic-inductive flow meter

ROLL COMPACTION TECHNOLOGY

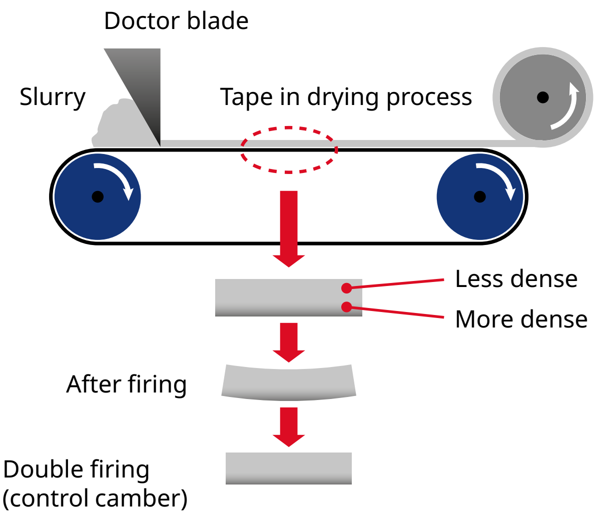
Roll compaction is a unique technology of Kyocera to form thin plates directly from granules. This technology is in direct competition with (e.g. doctor blade) tape casting and offers a very efficient process without need to prepare the ceramic slurry as well as a high material output without need to dry the tape before sintering.

Roll compaction uses the same material that was prepared for die pressing or isostatic pressing, e.g. A476. The granules are soft due the organic binder they contain and thus can easily be deformed by metallic rolls. The rolls deform and compact the granules so that they connect to each other and form a dense surface and microstructure. The tape produced can be handled in the same way like a tape made by doctor blade tape casting after drying and e.g. easily be cut to size or stored on a roller.

This technology requires deep knowledge of the binder composition and granule behaviour and the process parameters have to precisely adapted to form a tape that meets the requirements of our customers.



Kyocera's unique method: Roll compaction method (R/C)



Classic method: Doctor blade method (DB)

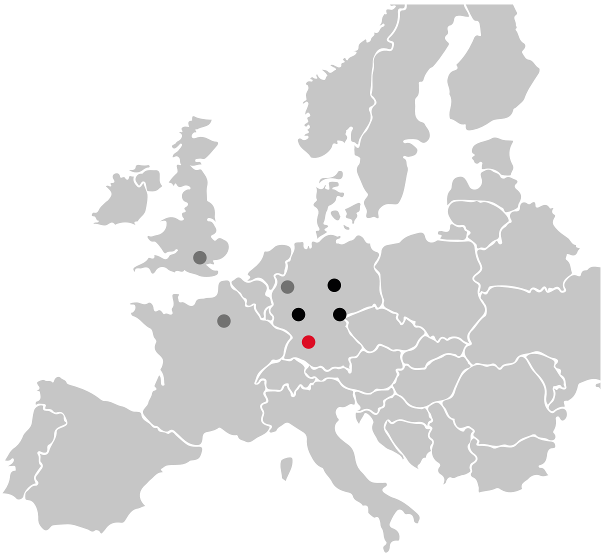
MATERIAL OVERVIEW

Properties		Unit	F99.7	FZM	DEGUSSIT FZY
Main component		-	α - Al_2O_3	ZrO_2, MgO	ZrO_2, Y_2O_3, Al_2O_3
Colour		-	ivory	yellow	white
Density		g/cm^3	> 3.90	≥ 5.70	≥ 5.60
Open porosity		vol.-%	0	0	0
Average crystal size		µm	10	50	30
Mechanical characteristics					
Hardness		-	1,760 (HV1)	1,220 (HV1)	1,400 (HV1)
Compressive strength		MPa	2,500	2,000	2,000
Bending strength σ_m	DIN EN 843-1	MPa	350	500	400
Young's modulus	static	GPa	380	185	200
Poisson's ratio		-	0.24	0.3	-
Fracture toughness	SEVNB	$MPa*m^{0.5}$	5	6.3	-
Thermal characteristics					
Max. operating temperature		°C	1,950	900	1,700
Thermal conductivity 20 °C		W/(m*K)	34.9	3	2.5 (100 °C)
Specific heat 20 °C		J/(g*K)	900	400	400
Thermal expansion coefficient 20-500 °C		10^{-6}/K	7.3	10.4	10.4
Electrical characteristics					
Dielectric strength 20 °C		kV/mm	> 30	-	-
Specific electrical resistance 20 °C		Ω•cm	10^{15}	10^{10}	10^{10}

F99.7 hf	A476	A493	A445F
α - Al_2O_3	Al_2O_3	Al_2O_3	Al_2O_3
ivory	white	white	dark brown
≥ 3.90	3.7	3.86	3.8
0	0	0	0
20	-	-	-
1,640 (HV1)	13.7 (HV9.807N)	16.0 (Vickers Hardness)	12.7 (Vickers Hardness)
2,500	-	-	-
350	350	550	390
380	320	390	320
0.22	0.23	-	-
3.5	-	-	-
1,950	-	-	-
34.9	24	26	12
900	0.78	-	-
7.3	7.2	7.2	7.2
> 30	15	15	15
10^{14}	$>10^{14}$	$>10^{14}$	10^{12}

This is only an excerpt of all available materials at Kyocera.
The data indicated on this table (are in line with the introductory German Industrial Standard DIN 60672-2 and) relate to test specimens from which they were obtained.
They are not unconditionally applicable to other forms of the same material.
The data must be regarded as indicative only.
All data refer to a temperature of 20 °C, unless otherwise specified.

ABOUT KYOCERA



The global Kyocera corporation - a strong partner.

- **Headquarters:** Kyoto, Japan
- **Foundation:** 1959
- **Employees:** over 80,000 worldwide
- **European headquarters:** Esslingen, Germany
- **European production sites:** Mannheim, Germany; Selb, Germany; Erfurt, Germany (further subsidiaries in Europe)

KYOCERA = KYOTO CERAMICS

KYOCERA – it all began with ceramics

KYOCERA Fineceramics Europe GmbH is a subsidiary of KYOCERA Europe GmbH, which has been successful in Europe for over 50 years. The Kyocera Group is one of the world's leading providers of high-performance ceramic components for the technology industry, offering over 200 different ceramic materials, as well as state-of-the-art technologies and services tailored to the specific needs of each market.

KYOCERA Fineceramics Europe GmbH has grown steadily in recent years – and is now one of the leading European suppliers of customised solutions made of technical ceramics. Working in partnership, we develop and manufacture products that offer our customers added value in their respective markets and secure their technological lead in the long term. We are committed to this every day.

We have also been active in the field of environmental technology for 30 years. Our solutions for treatment of exhaust air and waste water from chemical laboratories and industrial processes are known worldwide under the FRIDURIT brand.

Throughout Europe, we are represented by three production and development sites in Mannheim, Selb and Erfurt (Germany), as well as six sales offices – in Mannheim, Selb, Esslingen, Neuss (Germany), Rungis (France) and Frimley (United Kingdom).

Our business partners benefit from the fact that we think and work across divisions within the Kyocera Group. Because innovations and real milestones can only be achieved together – across industries and national borders.

This is what we believe.

About the KYOCERA Group

KYOCERA Europe GmbH is a company of the KYOCERA Corporation headquartered in Kyoto/Japan, a renowned supplier for semiconductor, industrial and automotive components as well as electronic components, printing and multifunction systems, and communications technology. The technology group is one of the world's most experienced manufacturers of smart energy systems, with more than 45 years of industry expertise. The Kyocera Group comprises of around 300 subsidiaries.

Kyocera aims to create a better future for the world, using the power of technology to solve issues we face as a global society. This ambition is rooted in our Kyocera Management Rationale: to contribute to the advancement of society and humankind.

We will continue to work together with people around the world to solve issues critical to society leveraging all of the technologies and management capabilities we have accumulated during our 60-plus year history.

The company also takes an active interest in cultural affairs. The Kyoto Prize, a prominent international award, is presented each year by the Inamori Foundation established by Kyocera founder Dr Kazuo Inamori to individuals worldwide who have contributed significantly to the scientific, cultural, and spiritual betterment of humankind.

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