

A large, stylized graphic of a hydrogen molecule (H₂) in a blue color. The molecule is composed of two large, overlapping spheres representing hydrogen atoms, with a smaller sphere in the center representing the shared electron pair. The graphic is set against a background of smaller, translucent hydrogen molecules and a teal-to-white gradient.

TECHNICAL CERAMICS FOR HYDROGEN APPLICATIONS

High-performance ceramics

OVERVIEW OF HYDROGEN TECHNOLOGIES FOR HYDROGEN INDUSTRY AND APPLICATIONS



PRODUCTION

- ▶ Tubes (Alumina/Zirconia/SiC/SiN)
- ▶ Multilayer porous alumina tube
- ▶ Ceramic chamber
- ▶ Heat exchanger
- ▶ Hermetic seal
- ▶ Heat insulator
- ▶ Alumina window
- ▶ Alumina parts for SOEC

TRANSPORT/STORAGE

- ▶ Sapphire tube
- ▶ Containment shell
- ▶ High pressure plunger
- ▶ Feedthrough for LH₂
- ▶ Magnetic material

USAGE

- ▶ Ceramic hermetic terminals
- ▶ Sapphire window
- ▶ Sintering jig
- ▶ Plunger/Cylinder
- ▶ Ball valve
- ▶ Solid Oxide Fuel Cell (SOFC)
- ▶ Silicon Nitride Igniter



CERAMICS FOR HYDROGEN PRODUCTION – A RELIABLE ALTERNATIVE TO METALS

Our advanced ceramics offer superior resistance against hydrogen embrittlement compared to traditional metal materials, enhancing durability in harsh hydrogen environments.

- ▶ Superior hydrogen resistance
- ▶ Stable performance at elevated temperatures
- ▶ Longer lifetime in harsh environments

PROPERTIES COMPARISON

Property		Fine ceramic	Metal
	Hydrogen permeability	Very low	High
	Thermal stability	Excellent (> 1,000°C)	Limited
	Corrosion resistance	Excellent	Moderate
	Density	Lightweight	Heavy

TECHNICAL CERAMICS FOR HYDROGEN APPLICATIONS



Brazed ceramics compatible with liquid hydrogen



Ceramic rods for hydrogen processes

FEEDTHROUGHS IN CRYOGENIC ENVIRONMENT

It is expected that the demand for products that can be used in a liquid hydrogen environment (-253 °C) will increase toward the realization of a hydrogen society. Kyocera is conducting joint research with Japan Aerospace Exploration Agency (JAXA). It has been confirmed that Kyocera feedthroughs can be used in a cryogenic environment.

DENSE AND POROUS PROTECTION TUBES

Precision ceramics for a hydrogen-powered future
Dense and porous ceramic tubes enabling clean, safe, and efficient hydrogen processes.

KEY ADVANTAGES

- ▶ **Excellent gas tightness and thermal stability**
Ensures reliable sealing and performance even under high temperature and pressure.
- ▶ **Controlled porosity for gas diffusion and separation**
Precisely tailored pore structures enable efficient hydrogen permeation or filtration.
- ▶ **Superior chemical and corrosion resistance**
Inert to hydrogen, steam, and reactive gases — ideal for harsh process environments.
- ▶ **Mechanical strength and long-term durability**
High reliability for continuous operation in demanding hydrogen systems.
- ▶ **Customizable design and geometry**
Available in various diameters, lengths, and porosity levels for flexible integration.



Ceramic pistons and containment shells



Insulation tubes

PUMP COMPONENTS

Zirconia FZM has proven itself as an ideal ceramic material for pump components.

Ceramic pistons are used to transfer media ranging from liquids to high viscosity substances, even with an abrasive filler. High resistance to wear and optimal sliding properties ensure a long operational life.

Renewable energies, for example, use hydrogen, which is pumped under high pressure and in liquid form. Additional heat input should therefore be avoided in that process to minimize evaporation effects. Ceramic containment shells provide a suitable solution here, as they are non-magnetizing and thermally insulating. Ceramics material also provide high electrical insulation.

With the development of FZM+, the application range of our materials can be extended even further. The white zirconia is characterised by improved flexural strength and high fracture toughness. This allows test pressures of up to 95 bar (pressure rating PN 63) for a temperature range from -200 °C to over 450 °C.

INSULATORS FOR CRYOGENIC APPLICATIONS

Insulators and insulation tubes made of alumina F99.7 and F99.7 hf can be fitted with ribs and glaze on the outside. The rib structure increases the creepage distance, leading to higher electric strength when used in atmospheric applications. The glaze facilitates handling and cleaning of the component. The ceramic-to-metal assemblies can be customised to suit the requirements of the respective application by selecting suitable metal parts and brazing materials as well as appropriate constructions and wall thicknesses. They are ideally suited to withstand stresses from pressure, corrosion and temperature. Depending on the type of construction, the insulating tubes can be used in temperatures ranging from -271 °C to 450 °C and for internal pressures up to approx. 100 bar. Electrical insulators made of alumina F99.7 are used e.g. for four liquid argon based neutrino detectors ProtoDUNE installed at CERN (France) and the Short Baseline Far and Near Detectors installed at FERMILAB (Batavia/Chicago US).

TECHNICAL CERAMICS FOR HYDROGEN APPLICATIONS



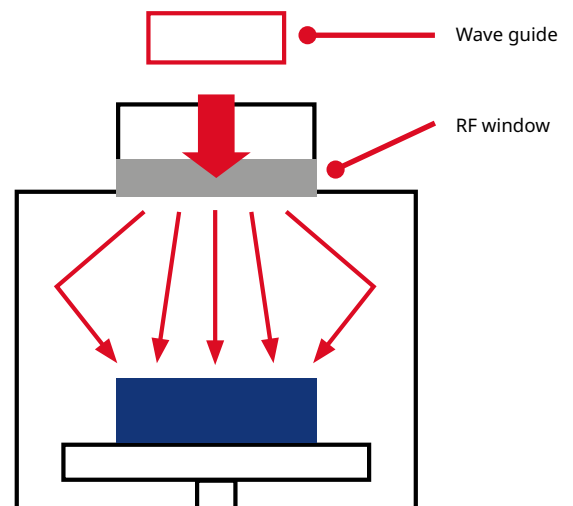
Bare sapphire window for optical sensor | Sapphire embedded in metal flange

RF WINDOWS

Reliable RF transmission under extreme conditions ceramic windows that stay strong when glass and plastic fail.

KEY ADVANTAGES

- ▶ High temperature resistance and thermal stability
- ▶ Excellent corrosion and gas resistance
- ▶ Low dielectric loss and high RF transparency
- ▶ High mechanical strength and vacuum compatibility
- ▶ High purity and cleanliness



Applications of low dielectric materials



One-layer SiC heat exchanger | Stacked heat exchangers

HEAT EXCHANGERS FOR THERMAL MANAGEMENT

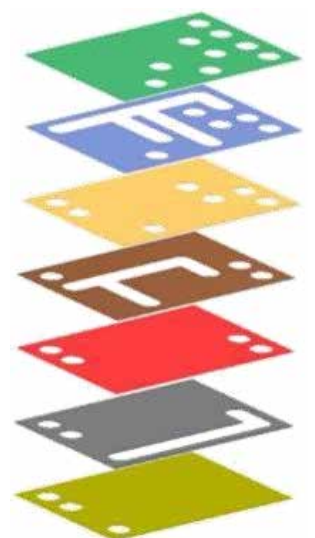
FEATURES

- ▶ High chemical resistance
- ▶ High temperature resistance
- ▶ High thermal conductivity up to 180 W/mK

LAMINATION TECHNOLOGY

Integration by laminating and co-sintering ceramic sheets

- ▶ Internal channels
- ▶ Near net shape
- ▶ Embedded electrode



MATERIAL OVERVIEW

Properties	Standard	Specification	Unit	F99.7	F99.7 hf
Main component			-	α - Al ₂ O ₃	α - Al ₂ O ₃
Colour			-	ivory	ivory
Density (ρ_b)	DIN EN ISO 18754		[g/cm ³]	≥ 3.90	≥ 3.90
Open (apparent) porosity (π_a)	DIN EN ISO 18754		[vol.-%]	0	0
Average crystal size (g_{ml})	ISO 13383-1	A1	[μm]	10	20
Mechanical characteristics					
Vickers Hardness (HV1.0)	DIN EN ISO 14705	Procedure A	[GPa]	17.3	16.1
Compressive strength ($\sigma_{c,m}$)	DIN ISO 17162		[MPa]	2,500	2,500
Flexural strength ($\sigma_{f,4}$)	DIN EN 843-1	Four-Point-Bending	[MPa]	350	350
Young's modulus of Elasticity (E)	EN 843-2	dynamic	[GPa]	380	380
Poisson's ratio (μ)	EN 843-2	resonance	[-]	0.24	0.22
Fracture toughness ($K_{Ic, SEVNB}$)	DIN EN ISO 23146	SEVNB	[MPa·m ^{0.5}]	5	3.5
Weibull modulus (m)	EN ISO 20501		[-]	>10	≥10
Thermal characteristics					
Max. operating temperature (T_{max})		in air	[°C]	1,950	1,950
Thermal conductivity (λ)	DIN EN ISO 18755	20 °C	[W/(m·K)]	34.9	34.9
Specific heat capacity (c_p)	DIN EN 821-3	20 °C	[J/(g·K)]	900	900
Mean coefficient of linear thermal expansion (α)	DIN EN ISO 17562	20-1,000 °C	[10 ⁻⁶ /K]	8.2	8.2
Thermal shock resistance	DIN EN 820-3	R ₁ , Type A, in water	[°C]	180	-
Electrical characteristics					
Dielectric strength	DIN EN 60243-1		[kV/mm]	> 30	> 30
Volume resistivity (ρ)	DIN EN 62631-3	20 °C	[Ω·cm]	10 ¹⁵	-

AO4760	SA100	SC140A	FZM Mg-PSZ	FZM+ Mg-PSZ
Al ₂ O ₃	Sapphire	SiC	ZrO ₂ , MgO	ZrO ₂ , MgO
white	transparent	black	yellow	white
3.7	3.97	3.1	≥ 5.70	≥ 5.75
-	-	-	0	0
-	-	-	50	25
13.7 (HV9.807N)	22.5 (HV9.807N)	23 (HV9.807N)	12.0	11.8
-	-	-	2,000	2,000
350	690	450	500	800
320	470	430	207	215
0.23	-	-	0.31	0.32
-	-	-	6.3	8.7
-	-	-	>15	>20
-	-	-	900	900
24	41	180	3	3.8
0.78	0.75	0.67	400	400
7.9	-	-	10.6 (20 - 900 °C)	10.3 (20 - 500 °C)
-	-	-	-	-
15	48	-	-	-
>10 ¹⁴	>10 ¹⁴	5.0 x 10 ⁸	10 ¹⁰	10 ¹⁰

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Other materials and data are available online at www.kyocera-fineceramics.de/en/download

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. Kyocera is one of the most experienced technology producers, with more than 65 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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