TOSHIBA

Fine Ceramics

Toshiba Materials Co., Ltd.

We wish to be one of the sustainers of the affluent future.
Our minute materials can help a big dream come true.

Only One

We are pioneers aiming to be the industry leaders.
We answer the needs of the age with quality "Only-one" products.

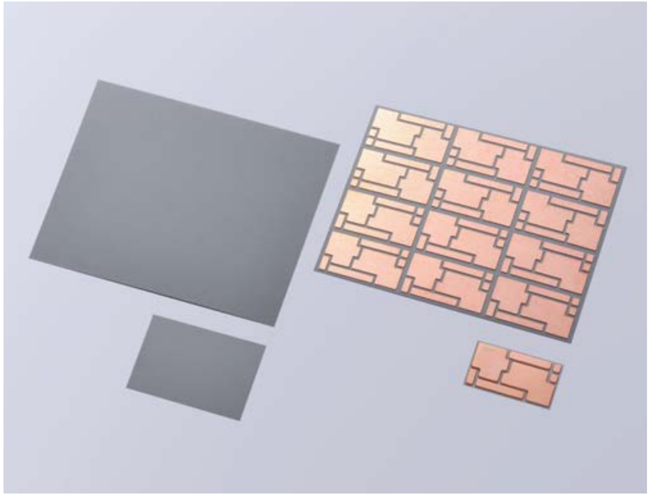
We began developing silicon nitride (Si_3N_4) ceramics in the 1960 s,
and by providing numerous products to industries such as bearings, automobiles, and semiconductors,
we have supported the foundations of various industries and the evolution of cutting edge technology.
By using rare earth oxides, especially yttria (Y_2O_3),
as a sintering agent for silicon nitride (Si_3N_4), we succeeded in creating tough fine ceramics.
Many highly reliable and high quality products are used in space and aircraft engine bearings
and power module boards such as IGBTs, and have received high praise.

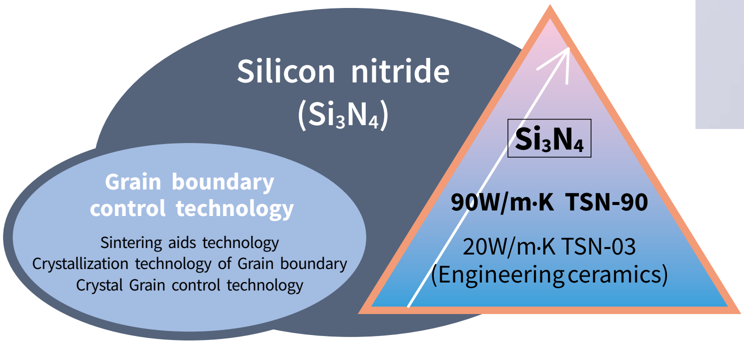
INDEX

Fine Ceramics for Electronics

Silicon nitride (Si_3N_4) ceramics

Fine ceramic substrates with high thermal conductivity are becoming indispensable components under the circumstances needs for high power, high integration, slim and lightweight, high frequency and environmental friendliness prevail. We take advantage of one of our core technologies, the grain boundary control of ceramic microstructure, to produce the silicon nitride (Si_3N_4) substrates with the world highest thermal conductivity on a commercial basis.





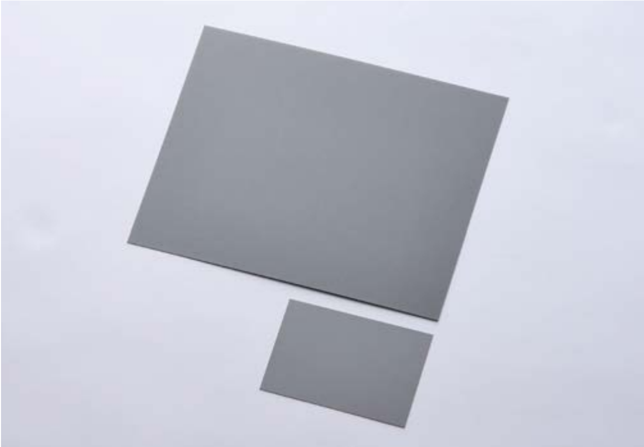
Typical values for properties of fine ceramics for electronics

	Item	Measuring method	Unit		Silicon nitrides (Si_3N_4) TSN-90
	Density	JIS Z8807	RT	Mg/m^3	3.35
Thermal properties	Specific heat	JIS C2141		J/kg·K	650
Thermal properties	Thermal conductivity	JIS R1611		W/m·K	90
Thermal properties	Coefficient of thermal expansion	JIS C2141	RT-500°C	$x10^{-6}/K$	3.4
Electrical properties	Dielectric strength	JIS C2110-1	50Hz	kV/mm	25.0
Electrical properties	Volume resistivity	JIS C2141	RT	Ω·m	$1x10^{15}$
Electrical properties	Dielectric constant	JIS C2141	1MHz		8.0
Electrical properties	Dielectric factor	JIS C2141	1MHz	$\tan\delta x10^{-4}$	8.0
Mechanical properties	3-point bending strength	JIS C2141	RT	MPa	680
Mechanical properties	Fracture toughness	JIS R1607	RT	$MPa·m^{1/2}$	6.5
Mechanical properties	Young's modulus	JIS R1602	RT	GPa	300
Mechanical properties	Poisson's ratio	JIS R1602			0.27
Features					High thermal conductivity High strength
Main applications					Substrates for semiconductor assembly Radiator plates (for compression force) Heat sinks

The values in the table are reference values, not guaranteed values.

Silicon nitride (Si_3N_4) plain substrates

Toshiba Materials' silicon nitride plain substrates utilize material technology and sintering technology cultivated over many years to achieve a dense and fine structure, and have excellent mechanical properties and high thermal conductivity.
Silicon nitride's coefficient of thermal expansion is close to that of Si chips, making it ideal as a substrate for semiconductor mounting, and meeting the diverse needs of our customers.

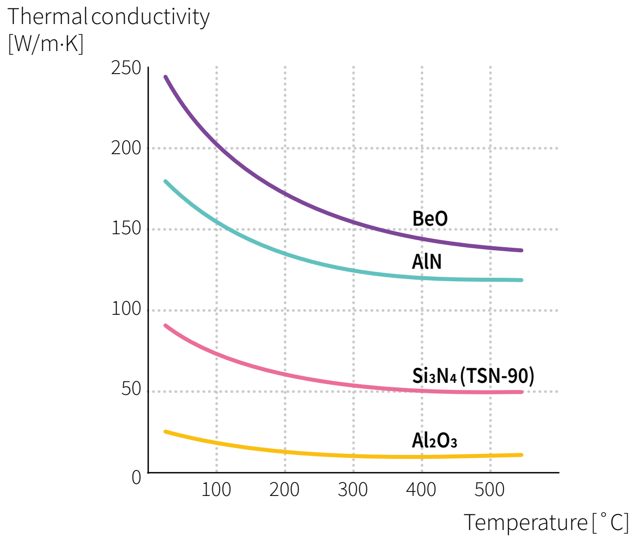


Standard design

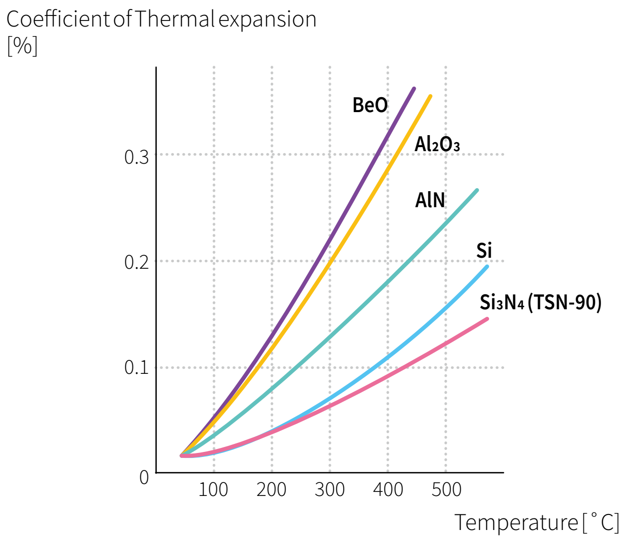
Item	Unit	Silicon nitride (Si_3N_4)
		TSN-90
Outer dimensions	mm	MAX 170 x 130
	Tolerance	±0.15 (Laser cut)
Thickness	mm	0.32
	Tolerance	±0.05mm
Warp	mm/mm	0.4% Under (≦50mm)
Surface area	—	Blast processing (Honing)

Values on the chart are standard design rule and not guaranteed value.
Please contact us for possibility of correponding to designs not covered in above chart.

Temperature dependency of thermal conductivity and coefficient of thermal expansion



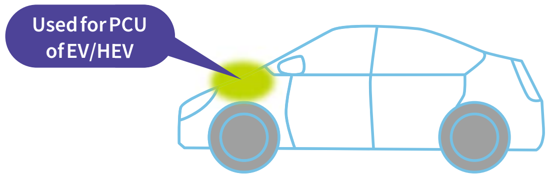
Measuring method : JIS R1611 Laser flash method

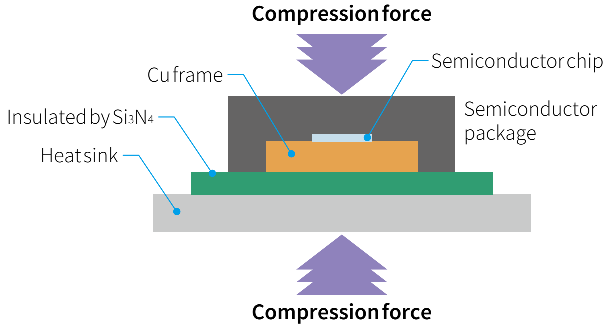


Measuring method : JIS C2141 10 Thermomechanical Analysis

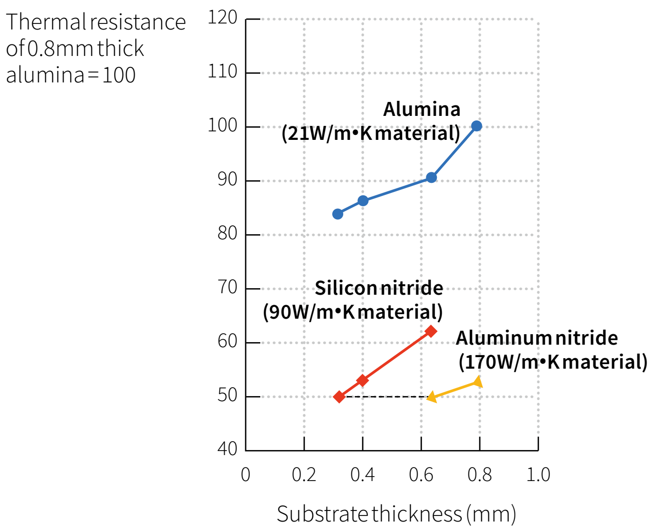
BeO, Al_2O_3 and Si are other companies' products.

In order to meet further needs for highly reliable semiconductor mounting substrates, we were quick to recognize excellent mechanical performances of silicon nitrides. As a result, we have taken the lead in the world in commercializing high thermal conductive silicon nitride insulated substrates for power semiconductors with more than four times thermal conductivity, which had been as low as alumina, while maintaining high strength.
Our high thermal conductive silicon nitride substrates are increasingly being used for PCUs (Power Control Units) of EVs (Electric Vehicles) and HEVs (Hybrid Electric Vehicles).



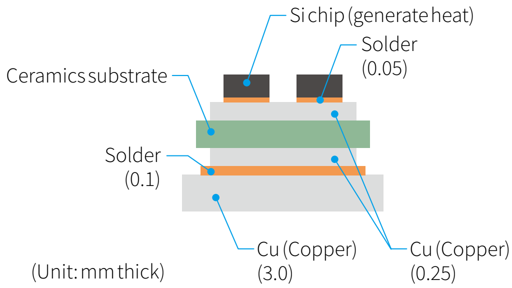


Comparison of thermal resistance (example)



Power module model

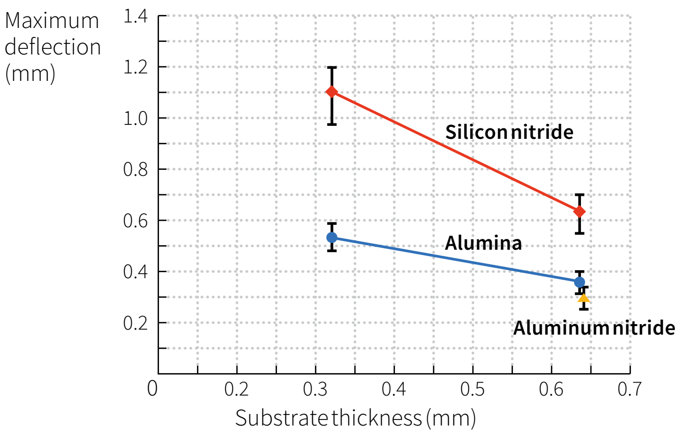
A current is passed through the Si chip in the figure below, and the temperature rise due to the heat generated by the chip is converted to the thermal resistance value (ΔmV method).



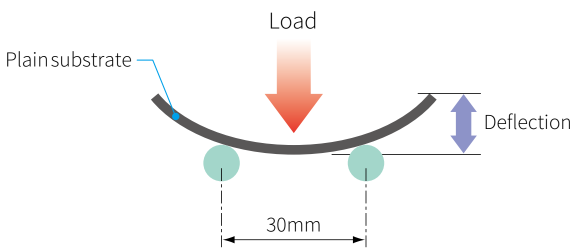
Thermal resistance of silicon nitride substrate of 0.32mm thick is almost equivalent to that of aluminum nitride substrate of 0.635mm thick, which has higher thermal conductivity.

Comparison of deflection characteristics of plain substrates

Size of the substrate: 40 x 33mm
Three-point bending test with the support span of 30mm
(two-point support at 40mm direction of the substrate)



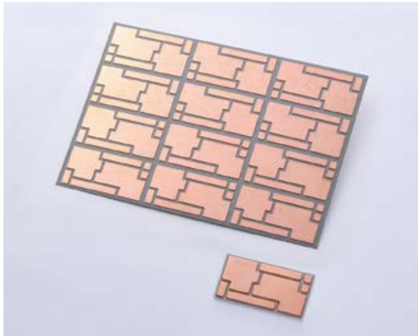
Three-point bending test



Comparison of maximum deflection of substrates: High thermal conductivity silicon nitride substrate has 1.5 times or more deflection than other materials irrespective of substrate thickness. This means that, if made even thinner, silicon nitride substrate does not crack and bends widely.

Silicon nitride (Si_3N_4) Active Metal brazed layer Copper (AMC) substrates

We offer all purpose copper plated ceramic substrates by active metal brazing method to meet diversified requirements that have arisen in power module substrates.
Active metal brazed copper (AMC) substrates are made by joining copper circuit plate onto ceramic substrates by brazing. They are suitable for making fine patterned power module circuits with high thermal cycle performance. We offer silicon nitride AMC (SIN-AMC) substrates for the basement ceramic substrates.
AMC substrates are best fit for high power semiconductor module substrates such as power transistor substrates like IGBTs. They directly dissipate heat with sufficient insulation.



[Characteristics of SIN-AMC substrates]

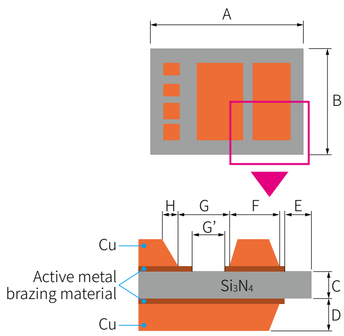
- Simple structure with low thermal resistance. Specifically, thermal resistance of SIN-AMC substrate with the thickness of 0.32mm is almost equivalent to that of ALN-AMC substrate with the thickness of 0.635mm.
- Excellent mechanical strength properties; They have high thermal cycle performance even if the copper circuit is made thick (up to 0.8mm) to lower thermal resistance and increase power output.
- Their high fracture toughness allows direct ultrasonic bonding of electrode terminals onto the copper circuit plate and securing the substrate onto heat sink by rivets.
- Coefficient of thermal expansion equivalent to that of ceramics substrates enables direct mounting of Si chips onto the copper circuit plate.
- High joint strength of copper circuit plate • High voltage resistance

[Applications]

- Power transistor module (IGBT, MOSFET, etc.)

Standard design

Ceramics	Type of ceramics: Silicon nitride (Si_3N_4)。Thermal conductivity 90W/mK (JIS R1611)		
[C] Ceramic thickness (mm)	0.25	0.32	0.635
Tolerance (mm)	±0.05		
[A,B] Ceramic dimention (mm)	Maximum effective area 90x110 ※For ceramics with a thickness of 0.25mm/0.32mm, we may be able to make sizes up to 125mm x 165mm, so please contact us for details.		
Tolerance (mm)	±0.15		±0.20



Electrode material	Cu									
[D] Cu thickness (mm)	0.10	0.15	0.20	0.25	0.30	0.40	0.50	0.60	0.70	0.80
[E] Insulation distance (mm)	min.0.5						min.0.7		min.1.0	
[F] Pattern dimention (mm) ※The bonding surface on the ceramic side is used as the reference. ※Please contact us if you have any specifications for the top side dimensions of the copper pattern.	min.0.4		min.0.5				min.0.7		min.1.0	
[G] Insulation distance (mm) ※The insulation distance between patterns[G']must satisfy the minimum dimensional distance.	min.0.4				min.0.5	min.0.6	min.1.0		min.1.2	
Pattern Tolerance (mm)	±0.2		±0.3				±0.4		±0.5	
[H] Taper dimention (mm)	≦0.5D (less than 1/2 of the Cu)									
Warp (mm)	0.2/50 Under									
Surface roughness (JIS B 0601:2001)	Rz≦15, (Ra≦6)									
Peel Strength (JIS C 6481:1996)	≧9.8kN/m									
Plating	Electroless plating Ni / NiAu									
Plating thickness (any measurement point)	Ni:2〜6µm / Ni:2〜6µm, Au:0.05〜0.1µm									
Solder Resist ※Please contact us if you have a specific solder resist.	UV curing type / Thermosetting type									
Solder Resist Thickness	5〜45µm									

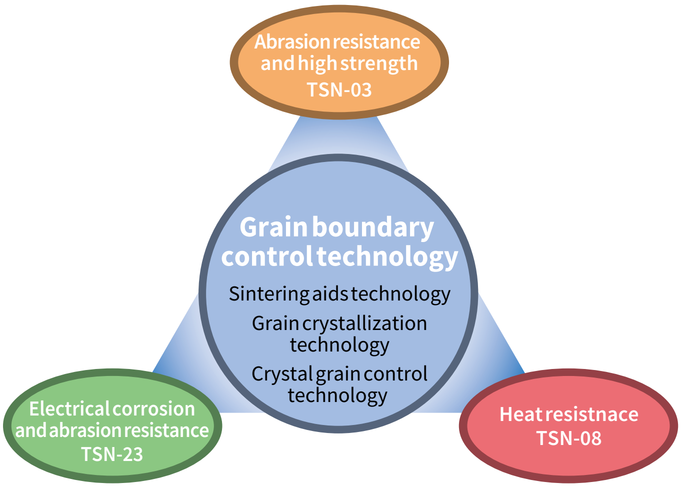
*The value of a table is not a guaranteed performance
*Please contact us for possibility of correponding to designs not covered in above chart.

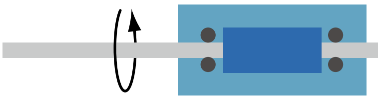
Engineering ceramics

Silicon nitride (Si_3N_4) ceramics

Among many ceramic materials, namely zirconia, silicon carbide and alumina, which are known to be used as engineering fine ceramics, we persistently produce silicon nitride ceramics as the only material for engineering ceramics.
We have well understood excellent properties such as high thermal conductivity and high strength of nitride ceramics from early-stages of the research. Then we have developed a grain boundary control technology and applied it to make Silicon nitride ceramics into stable, high-performance, high-functional materials and components.
Silicon nitride ceramics will show their well-balanced mechanical properties under high-speed rotation, high-speed sliding and high vacuum as they have good abrasion resistance, good corrosion resistance, insulation, heat resistance, etc.
We are looking forward to meet customer's diversified requirements with our silicon nitride ceramics.

High performances of silicon nitride ceramics





Typical values for properties of engineering ceramics

Items		Measuring method	Unit		Silicon nitrides (Si_3N_4) TSN-03	TSN-08	TSN-23
Density		JIS Z8807	RT	Mg/m^3	3.23	3.27	3.27
Hardness		JIS R1601	HV (20kgf)		1,500	1,600	1,500
Mechanical and thermal properties	Three point bending strength	JIS R1601 ASTM C1239	RT	MPa	1,000	1,000	900
			1000°C	MPa	750	900	700
			1200°C	MPa	450	850	400
	Conpression strengh		RT	MPa	5,000	4,500	4,000
	Young's modulus	JIS R1602	RT	GPa	308	308	313
	Poisson's ratio	JIS R1602			0.29	0.29	0.28
	Fracture toughness	ASTM F2094	RT	$MPa \cdot m^{1/2}$	6~8	6~8	5~7
	Specific heat	JIS R1611		J/kg・K	680	680	680
	Thermal conductivity	JIS R1611		W/m・K	20	20	25
	Coefficient of thermal expansion	JIS R1618	RT-800°C	$x10^{-6}/K$	3.0	3.0	3.0
	Thermal shock temperature dierence		(△Tc)	°C	800	900	700
Electrical properties	Dielectric strength	JIS C2110-1	50Hz	kV/mm	>14	>14	>14
	Volume resistivity	JIS C2141	RT	Ω・m	$>10^{12}$	$>10^{12}$	$>10^{12}$
Corrosion* resistance	Acid				Good	Good	Good
	Alkali				Good	Good	Good
Features					High strength Abrasion resistant	Heat resistant Abrasion resistant	Abrasion resistant Corrosion resistant (Electrical corrosion)
Recommendatory applications					Bearings Engine parts Mechanical parts	Mechanical parts Refractory tools Heat-resistant and abrasion-resistant parts	Bearings Engine parts

*Corrosion resistances were measured under following conditions.
Acid; 96 hours immersion at RT in 36%HCℓ, 95%H_2SO_4 and 60%HNO_3　Alkali; In 5%NaOH and 40%NaOH
The values in the table are reference values, not guaranteed values.

Silicon nitride (Si_3N_4) Bearing Balls

We offer light-weight, high strength, high rigidty and high abrasion resistant silicon nitride (Si_3N_4) ceramics for structural parts. They are especially fit for bearing balls and applied to various lines of industrial use.

Comparison of properties between silicon nitride (Si_3N_4) ceramics and high carbon chrome bearing steels; and features of ceramic bearings

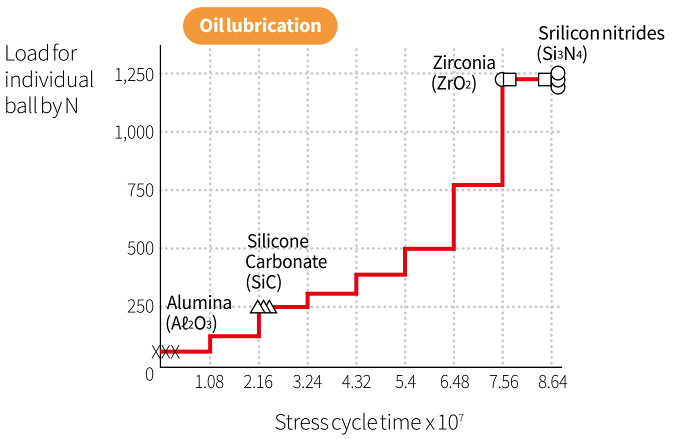
Item	Unit	Silicon nitrides	Bearing steels (SUJ)	Features of ceramic bearings
Thermal resistance	°C	800	180	Heavy-duty bearings under elevated temperature
Density	Mg/m^3	3.24	7.8	Low centrifugal force to rolling balls, causing long life and low temperature rising
Coefficient of thermal expansion	x10^{-6}/K	3.0	12.5	Minimum dimensional deviation in inner clearances by temperature rising, causing low vibration and small change in pressurization
Hardness	Hv (20kgf)	1500	750	Minimum deformation in rolling contact members, causing high rigidness
Young's modulus	GPa	308	208	
Poisson's ratio		0.29	0.3	
Corrosion resistance		Good	Not good	Serviceable under chemical environments including acidic and alkaline solutions
Magnetism		Nonmagnetism	Ferromagnetic material	Minimum rotational fluctuation made by magnetization under strong magnetic field
Electric conductivity		Insulator	Conductor	No electric corrosion especially in generators and motors
Mode of bonding		Covalent bonding	Metallic bonding	Minimum adhesion of contact parts caused by oil film breaking

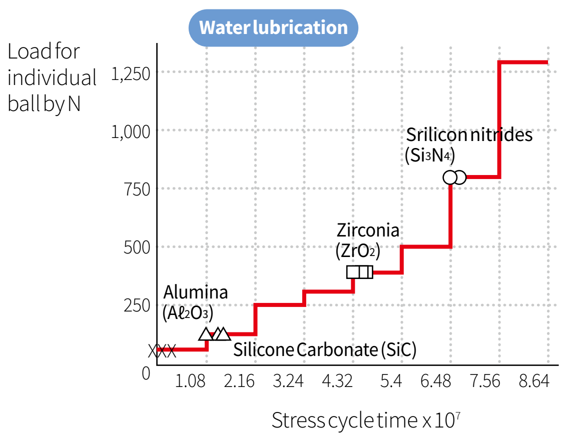
The values in the table are reference values, not guaranteed values.

Results of load withstanding test for various ceramics

Test conditions

	Oil lubrication	Water lubrication
Lubrication	Spindle oil	Tap water
Mating material	3/8″ high carbon chrome bearing steel (SUJ2) balls	3/8″ silicon nitrides (Si_3N_4) bearing balls
Load	Step-up cyclic stress loading every 1.08 x 10^7 times	
Rotation number	1,200rpm	





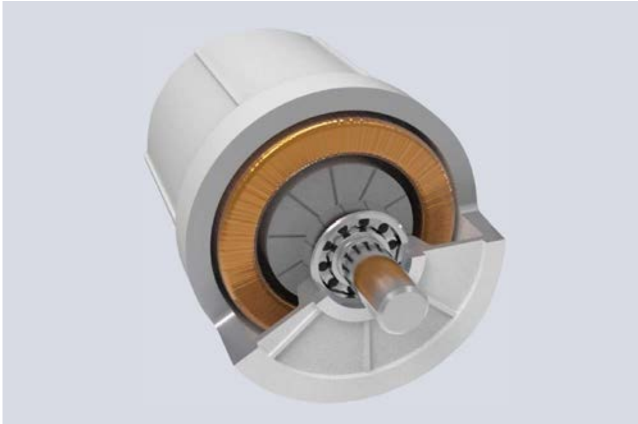
Courtesy of JTEKT Corporation

Silicon nitride (Si_3N_4) ceramics for automobiles

Silicon nitride ceramics, which are lighter than conventional metal parts, have high wear resistance, and have excellent corrosion resistance, were jointly developed in 1987 with Cummins Engine, the largest diesel engine manufacturer in the United States at the time, and it has been adopted for wear-resistant parts of the fuel system of diesel vehicles. Today, it is also used in parts of common rail systems for diesel fuel injection equipment.

Recently, silicon nitride ceramic balls, which have excellent wear resistance, have been adopted as a countermeasure against electrolytic corrosion of bearings used in electric vehicle (EV) motors, and are used as materials that can contribute to environmental problems.

By fusing "product technology" and "material technology" cultivated over 30 years in this way, we will provide products with excellent cost performance.



Bearing of motor for electric vehicle (EV)

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