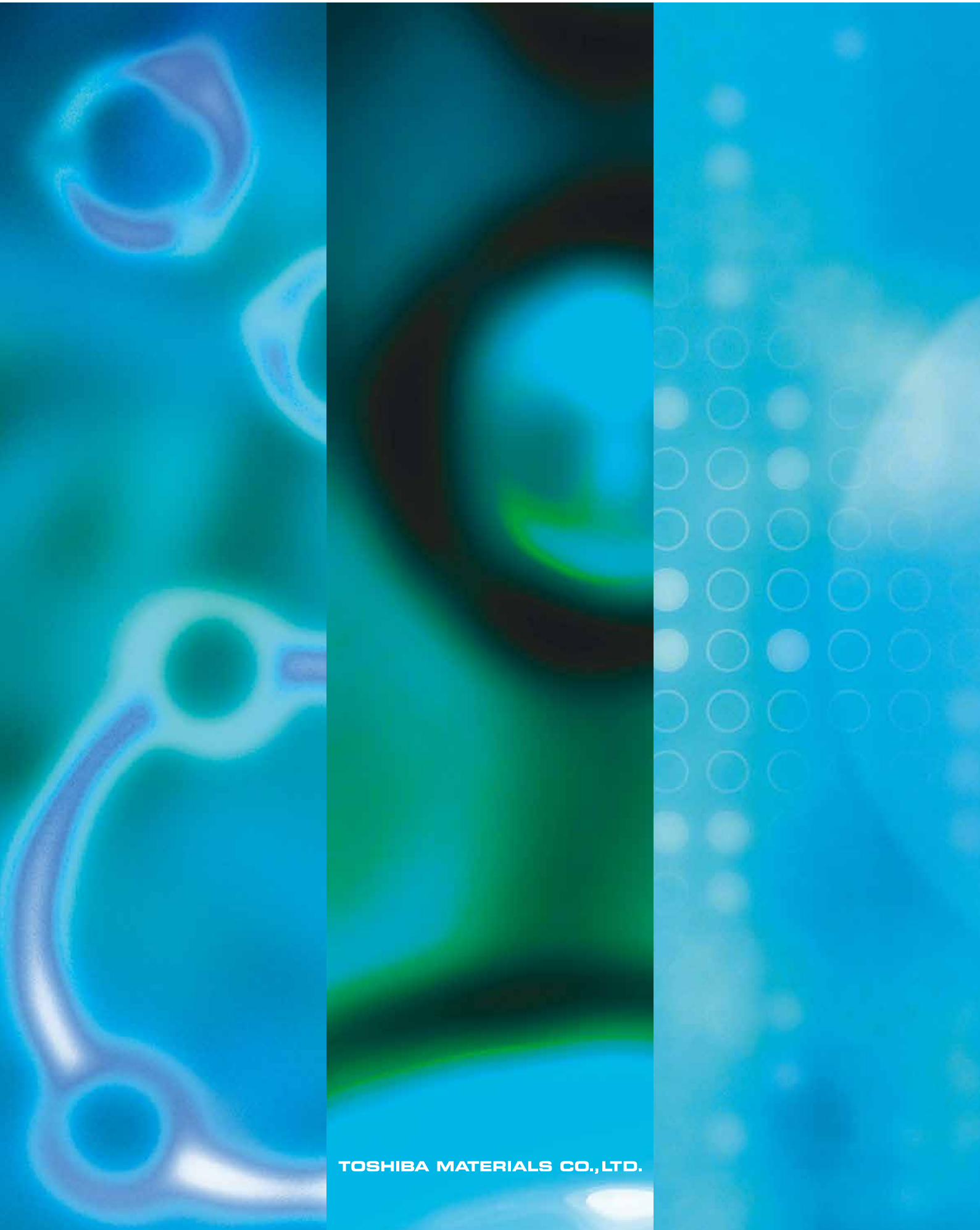
TOSHIBA

Leading Innovation

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 have already started to develop nitride ceramics of
both silicon nitrides (Si_3N_4) and aluminum nitrides (AℓN) since nineteen sixties
and have supplied a variety of nitride products to such high-tech industries as bearings,
automotives, semiconductors to support their footings. On the other hand,
we have found the first way in the world to strengthen fine ceramics, namely adding rare-earth oxides or
yttria (Y_2O_3) as the sinter aid to silicon nitrides (Si_3N_4) and aluminum nitrides (AℓN).
Our highly reliable and high quality products are agreeably evaluated
and widely applied to the key components of bearings for aero-spatial craft engines and substrates
for power modules including IGBTs.

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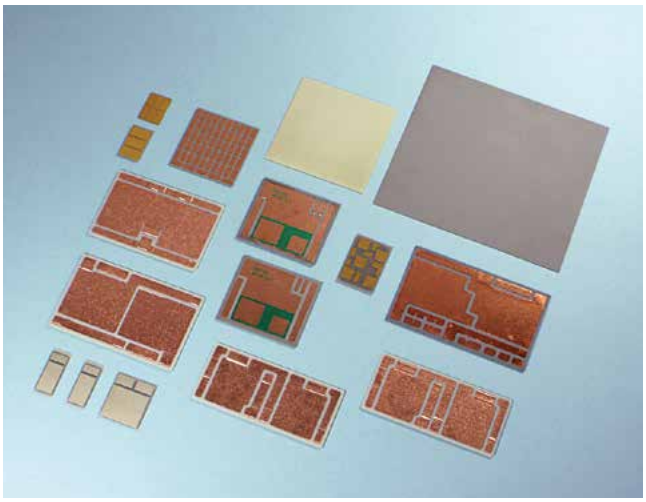
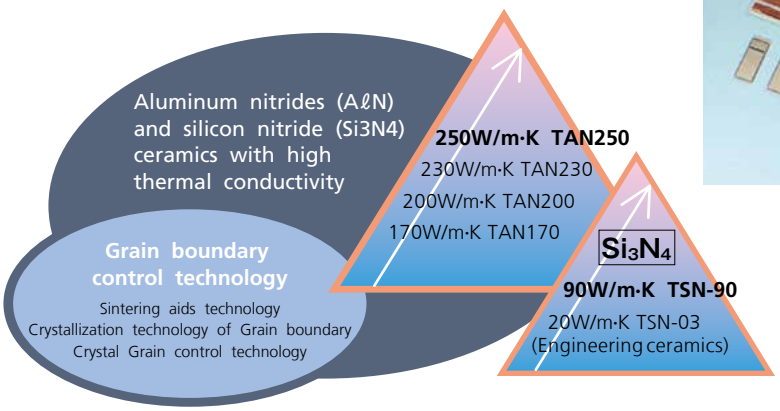
Fine Ceramics for Electronics

Aluminum nitride (AℓN), 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 aluminum nitride (AℓN) and the silicon nitride (Si_3N_4) substrates with the world highest thermal conductivity on a commercial basis.



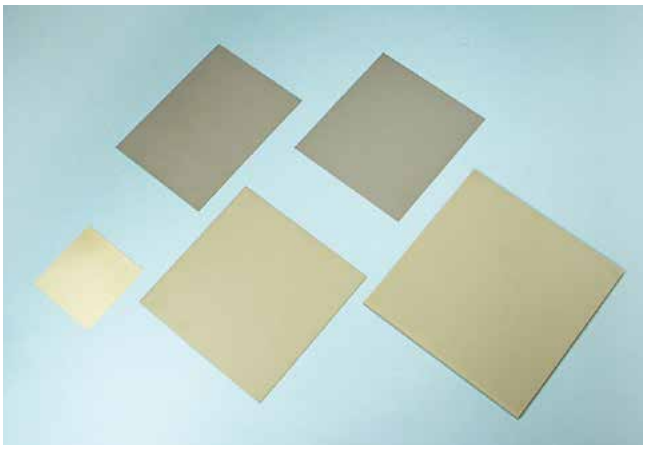


Properties of fine ceramics for electronics

Item		Unit		Aluminum nitride (AℓN)				Silicon nitride (Si_3N_4)
				TAN-170	TAN-200	TAN-230	TAN-250	TSN-90
Density		Mg/m³		3.3				3.2
Water absorption		%		0.00				0.00
Color				White				Gray
Thermal properties	Specific heat		J/kg·K	740				680
	Thermal conductivity		W/m·K	160-180	190-210	220-235	240-255	85-95
	Coefficient of thermal expansion	RT-500℃	x10⁻⁶/℃	4.6				2.6
	Critical diff. temperature	(ΔTc)	℃	600				800
Electrical properties	Dielectric strength	50Hz	kV/mm	15				15
	Volume resistivity	25℃	Ω·m	>10¹²				>1012
	Dielectric constant	1MHz		8.8				8.1
	Dielectric factor	1MHz	tanδx10⁻⁴	5.0				3.0
Mechanical properties	Hardness	Hv(500g)		1,000				1,500
	Bending strength		MPa	>300				600-700
	Fracture toughness	at RT	MPa·m$^{1/2}$	2.5-3.5				6-7
	Young's modulus	at RT	GPa	330				317
	Poisson's ratio			0.24				0.27
Chemical resistance		Acid		Excellent				Excellent
		Alkali		Good				Excellent
Features				High thermal conductivity Low loss at high frequency				High thermal conductivity High strength
Main applications				Substrates for semiconductors Radiator plates Heat sinks				Substrates for semiconductors Radiator plates (for compression force) Heat sinks

Plain substrates (AℓN, Si_3N_4)

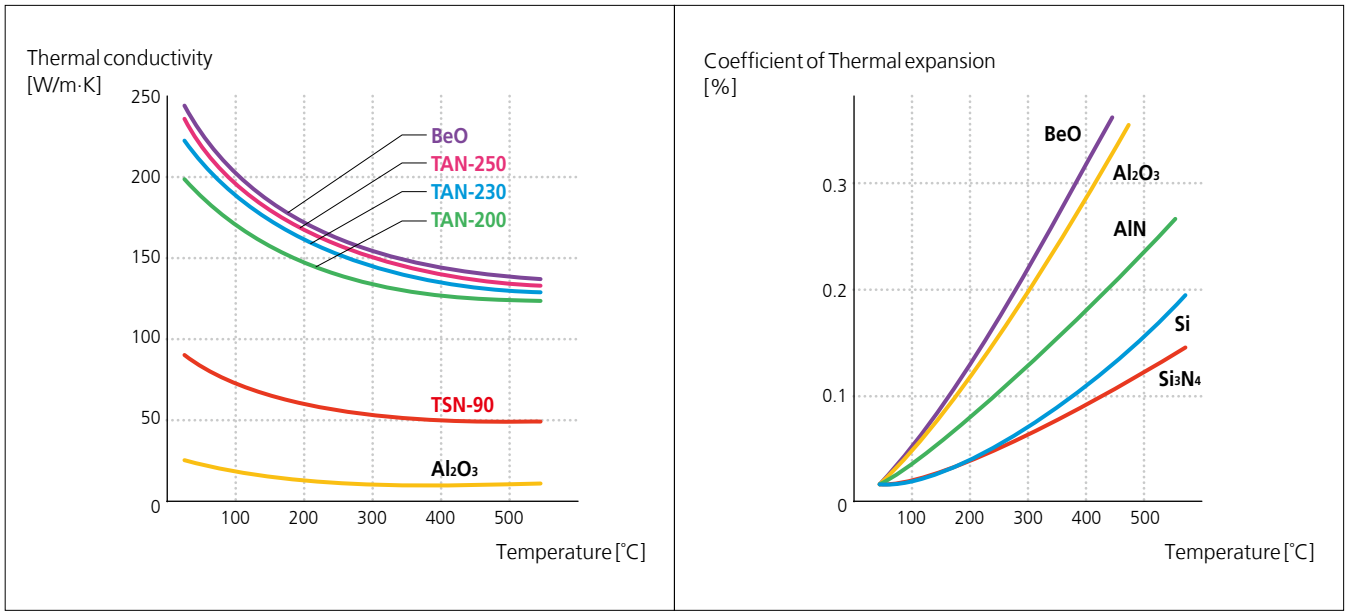
We offer plain substrates, which have a dense, minute microstructure made by our material and sintering technology that took a long time to develop. To meet diversified needs of customers, we line up four kinds of aluminum nitride (AℓN) plain substrates that differ in thermal conductivity and a high thermal conductive silicon nitride (Si_3N_4) plain substrate with excellent mechanical properties. Our plain substrates have a low thermal expansion coefficient similar to those of silicon semiconductor chips, which means that they are best fit for semiconductor mounting substrates. They are widely applied to various substrates including submount substrates and thick/thin microwave circuit substrates.



Standard specifications

Item	Unit	Standards
Outer dimensions	mm	□10-□160
Dimensional tolerances	mm	±1% NLT ±0.1
Thickness tolerances	mm	±10% NLT ±0.05
Thickness	mm	0.32-1.0
Warping tolerances	mm	0.1/25.4 or less
Surface roughness by Ra	μm	0.5-1.5

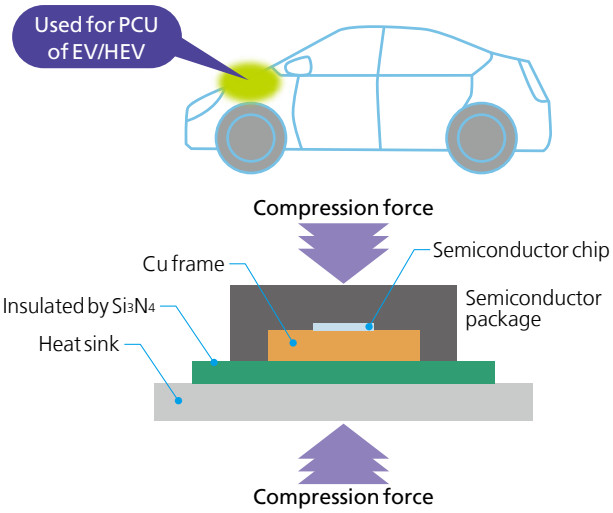
Temperature dependency of thermal conductivity and coefficient of thermal expansion



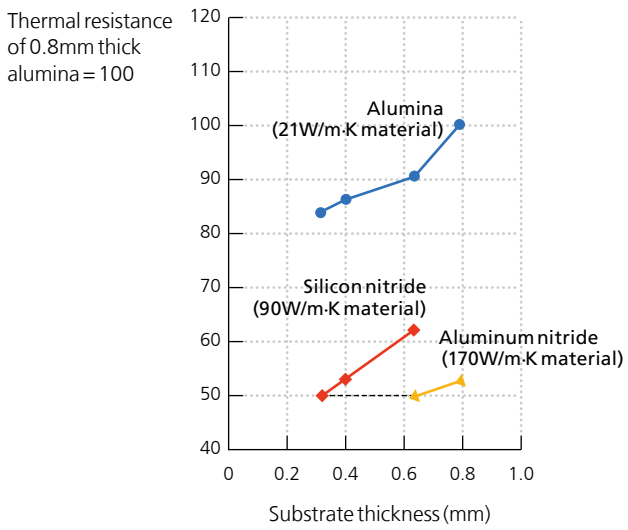
Silicon nitride (Si_3N_4) plain substrates

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.

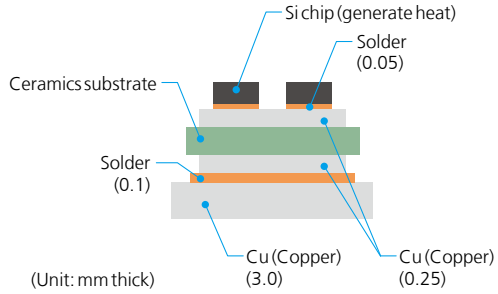
Our high thermal conductive silicon nitride substrates are increasingly being used for PCUs (Power Control Units) of EVs (Electric Vehicles) and HEVs (Hybrid Electric Vehicles).



Comparison of thermal resistance (example)



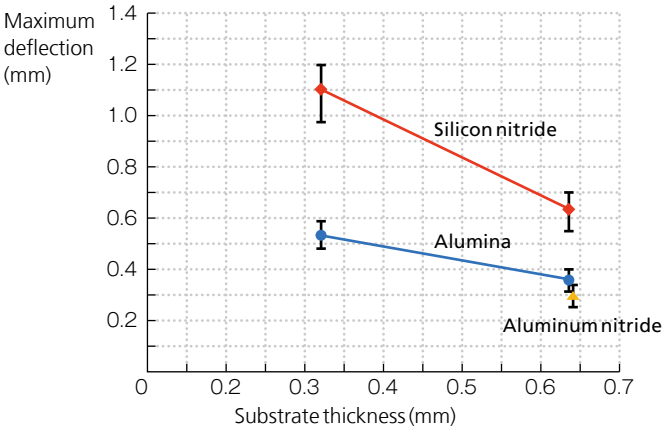
Power module model



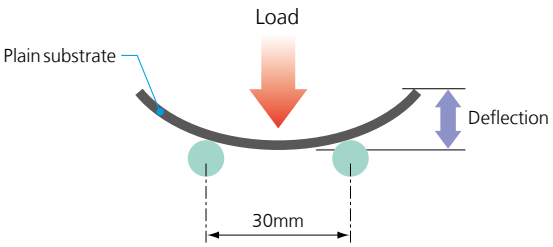
Thermal resistance of silicon nitride substrate of 0.32mm thick is almost equivalent to that of aluminum nitride substrate of 0.635mm thick, which has higher thermal conductivity.

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.

Active metal brazed copper (AMC) substrates

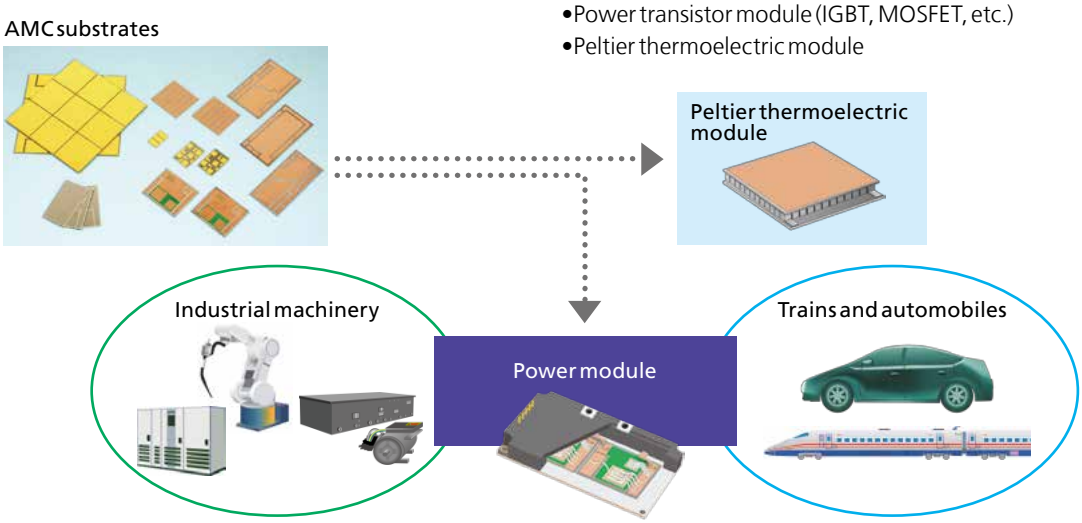
We offer all purpose copper plated ceramic substrates by active metal brazing method to meet diversified requirements that have arisen in power module substrates.
Active metal brazed copper (AMC) substrates are made by joining copper circuit plate onto ceramic substrates by brazing. They are suitable for making fine patterned power module circuits with high thermal cycle performance. We offer silicon nitride AMC (SIN-AMC) substrates and aluminum nitride AMC (ALN-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 0.6mm) 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.)
- Peltier thermoelectric module

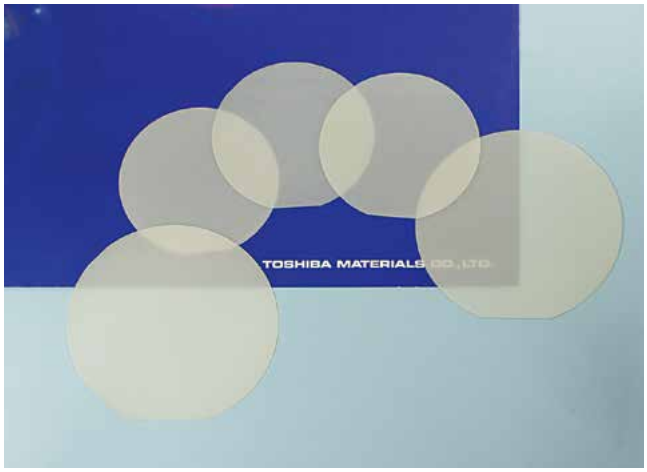


Standard specifications

Item	Unit	Ceramics							
		TSN-90 (Si_3N_4)				TAN-170 (AℓN)			
Thermal conductivity	W/m·K	85-95				160-180			
Ceramics thickness	mm	0.32/0.635				0.635/0.8/1.0			
Thickness tolerances for ceramics	mm	±0.05							
Outer dimensions	mm	□10-135×120							
Outer dimensional tolerances	mm	±0.15							
Copper plate thickness	mm	0.1	0.15	0.2	0.25	0.3	0.4	0.5	0.6
Copper pattern width	mm	Min.0.4		Min.0.5				Min.0.6	
Copper pattern intervals	mm								
Pull back	mm								
Tolerances for copper pattern	mm	±0.2		±0.3				±0.4	
Thickness for nickel plating	mm	2-6							
Thickness for solder resist	mm	5-45							
Tolerances for solder resist dimension	mm	±0.3							
Distortion	mm	Under 0.2/50							
Surface roughness	μm	Under Rmax 15							
Peel strength	kN/m	Min.4.9							

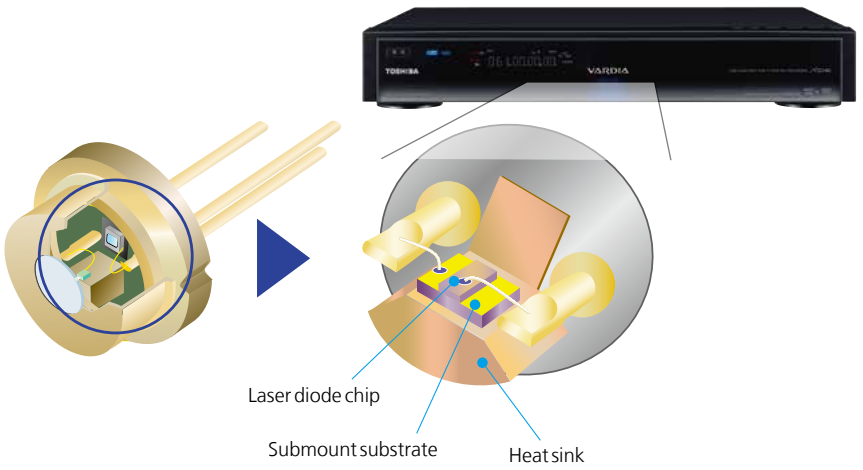
AℓN submount substrate

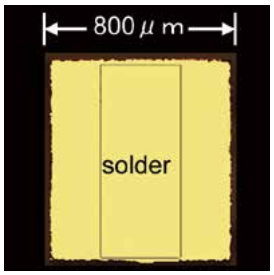
We offer submount substrates for laser diodes and LED modules. The substrate is made of an AℓN ceramic plate that has a Ti/Pt/Au thin film patterned by the lift-off process.
We have well understood excellent properties such as high thermal conductivity and strength of nitride ceramics from early-stages of the research. Then we have developed a grain boundary control technology and applied it to make AℓN ceramics into stable, high-performance, high-functional materials and components. We offer AℓN submount substrates that have as high heat dissipation as that of beryllia substrates whose dust and powders are known to be toxic.



Standard specifications

Item		Unit	Ceramics			
			TAN-170	TAN-200	TAN-230	TAN-250
AℓN materials	Thermal conductivity	W/m·K	160-180	190-210	220-235	240-255
	Thickness	mm	0.20-0.35			
	Thickness tolerances	mm	±0.02			
Conductive films	Film structure	—	Ti/Pt/Au			
	Film thickness	μm	0.5-3.5 (With patterns)			
	Thickness tolerances	%	±20			
	Adhesive strength of the film	MPa	20			
Solder film	Film structure	—	Au-Sn (Au: 64-78wt%)			
	Film thickness	μm	0.5-3.5 (With patterns), 0.5-5.0 (Without patterns)			
	Thickness tolerances	%	±20			
Patterns	Patterning tolerances	μm	±20			
Dicing	Dicing tolerances	μm	±30			
	Packing		Mounted on tape			





AℓN Thin Film
Metalized Substrate
(submount)

Engineering ceramics

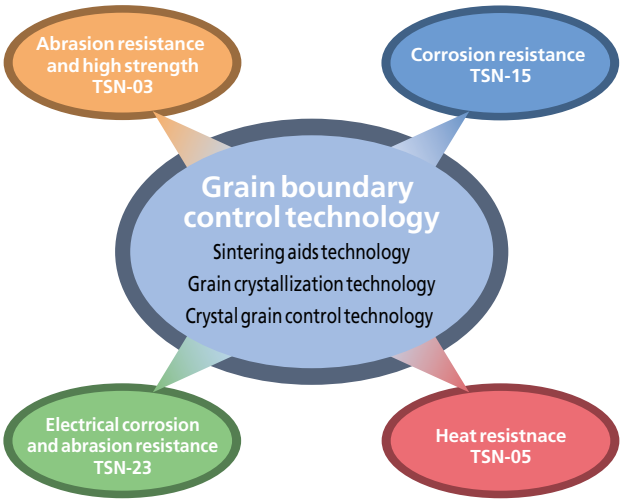
Silicon nitride (Si_3N_4) ceramics

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, high rigidity. We are looking forward to meet customer's diversified requirements with our silicon nitride ceramics.

High performances of silicon nitride ceramics



Physical properties of engineering ceramics

Item			Unit	Silicon nitrides(Si3N4)			
				TSN-03	TSN-05	TSN-15	TSN-23
Density			Mg/m^3	3.23	3.20	3.17	3.27
Mechanical and thermal properties	Hardness	Hv(500g)		1,500	1,400	1,500	1,500
	Bending strength by JIS1601 three points bending strength	RT	MPa	1,000	700	900	900
		1000℃	MPa	750	600	750	700
		1200℃	MPa	450	400	450	400
	Compression strength	RT	MPa	5,000	3,200	3,500	4,000
	Young's modulus	RT	GPa	308			313
	Poisson's ratio			0.29			0.28
	Fracture toughness	KIC	$MPa{\cdot}m^{1/2}$	6-8	5-6	6-7	5-7
	Specific heat		J/kg·K	680	680	670	680
	Thermal conductivity		W／m·K	20	22	28	25
	Coefficient of thermal expansion	RT-800℃	$\times 10^{-6}$/K	3.0			
	Thermal shock temperature difference	(△Tc)	℃	800	600	600	700
	Service temperature		℃	800	800	600	700
Electrical properties	Dielectric strength	50Hz	kV/mm	>14			
	Volume resistivity	25℃	Ω·m	$>10^{12}$			
Corrosion* resistance	Acid			Good	Approvable	Excellent	Excellent
	Alkali			Good	Approvable	Good	Good
Features				High strength Abrasion resistant Corrosion resistant	Heat resistant Abrasion resistant Corrosion resistant	Corrosion resistant High strength Abrasion resistant	Abrasion resistant Corrosion resistant (Electrical corrosion)
Recommendatory applications				Bearings Engine parts Mechanical parts Heat-resistant and abrasion-resistant parts	Mechanical parts Refractory tools	Bearings Chemical parts 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

Silicon nitride (Si_3N_4) Bearing Balls

We offer light-weight, high strength 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.

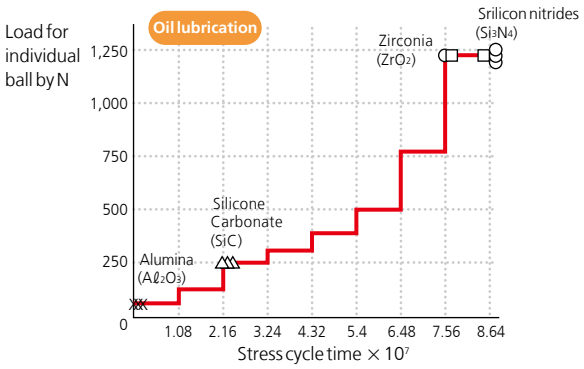
Comparison of properties between silicon nitride (Si_3N_4) ceramics and high carbon chrome bearing steels; and features of ceramic bearings

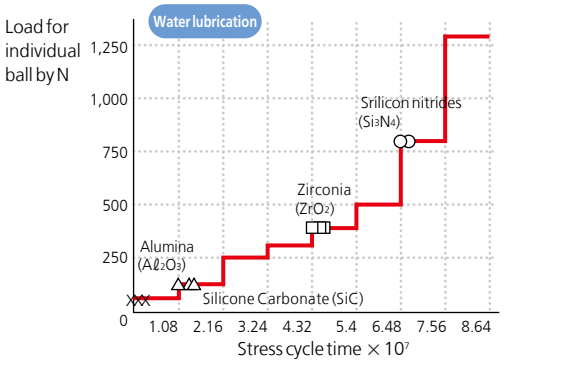
Item	Unit	Silicon nitrides	Bearing steels	Features of ceramic bearings
Thermal resistance	℃	800	180	Heavy-duty bearings under elevated temperature
Density	Mg/m^3	3.24	7.8	Low centrifugal force to rolling balls, causing long life and low temperature rising
Coefficient of thermal expansion	$\times 10^{-6}$/℃	3.0	12.5	Minimum dimensional deviation in inner clearances by temperature rising, causing low vibration and small change in pressurization
Hardness	HV	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

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 1.08×10^7 times	
Rotation number	1,200rpm	

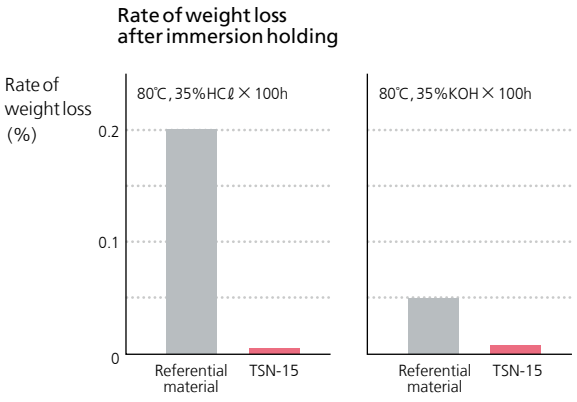


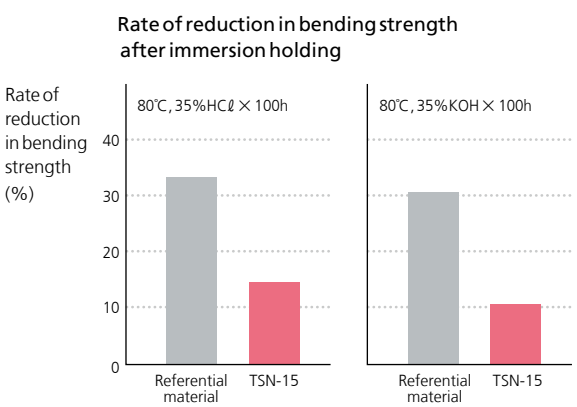


Courtesy of JTEKT Corporation

Results of abrasion resistance test for silicon nitrides TSN-15

Weight loss and reduction in bending strength after immersion holding in acidic and alkaline solutions

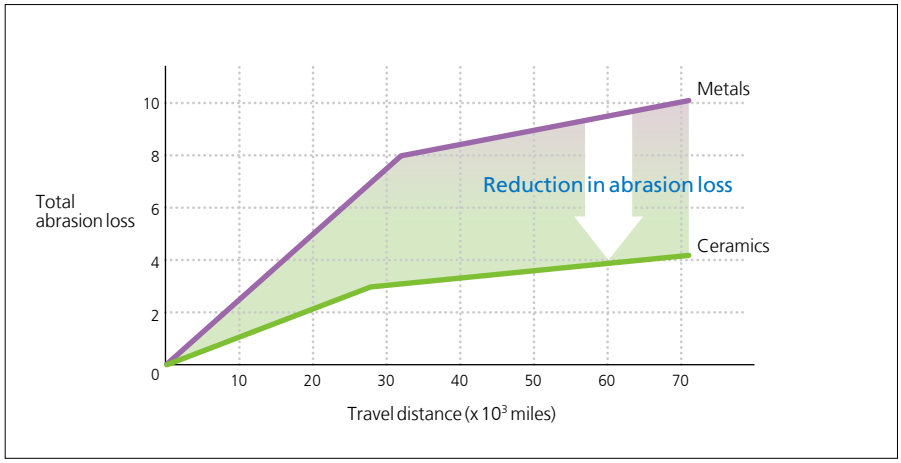




Silicon nitride (Si_3N_4) ceramics for automobiles

We have started joint development with Cummins Engine Company, Inc., one of the biggest diesel engine manufactures, since 1987 and have lots of successful experiences in practical application of silicon nitride fine ceramics mainly in the field of abrasion resistant parts for diesel engine fuel system.
Thanks to their light weight, high abrasion resistance and excellent corrosion resistance, silicon nitride ceramics can make environmentally friendly engine parts that help complete the combustion required by world-wide exhaust gas regulations.
We are very sure to offer ceramic products that have superior cost performance and are manufactured on a basis of the experiences of over twenty years both in product technology and material technology.

Comparison of abrasion loss between metals and ceramics



Silicon nitride (Si_3N_4) ceramics for industrial facilities

We offer a variety of ceramics parts for industrial facilities taking advantage of their superior properties of abrasion resistance, thermal resistance, thermal shock resistance and poor wettability with molten metals. We are supplying silicon nitride center bulbs, contact collets, masks and so on to semiconductor manufacturing facilities that keenly require low dusting and long life components.

[Application examples]

•Jigs for semiconductor manufacturing facilities

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