Surface Improvement Products/New Developed Products/Technical Services

At Toyo Tanso, we believe in the boundless possibilities of carbon, and our basic and applied research initiatives never stop.



Surface Improvement Products

PYROGRAPH™ Products

PYROGRAPH™ is a product created by coating the surface of highly purified isotropic graphite with a fine layer of pyrolytic carbon by means of a proprietary Toyo Tanso Chemical Vapor Deposition (CVD) process.

■ PYROGRAPH™ Characteristics

- the pyrolytic carbon layer is extremely fine
- ultrapure
- the layer coating ensures extremely low gas permeability
- excellent corrosion resistance against gas
- excellent oxidation resistance at low temperatures
- excellent heat resistance
- prevents the parting and scattering of graphite particles, and the emission of gas and impurities from the graphite substrate

PYROGRAPH™ Cross Section

The column-shaped structure of the pyrolytic carbon layer means that the structure is extremely fine.

■ Application

- Single crystal silicon manufacturing equipment
- Tube for atomic absorption spectroscopy
- OLED manufacturing equipment

■ PYROGRAPH™ Property Data

■ Impurity Analysis Example

Unit: mass ppm

Element	Content
B	<0.01
Na	0.03
Al	0.02
Cr	<0.10
Fe	<0.01
Ni	<0.01

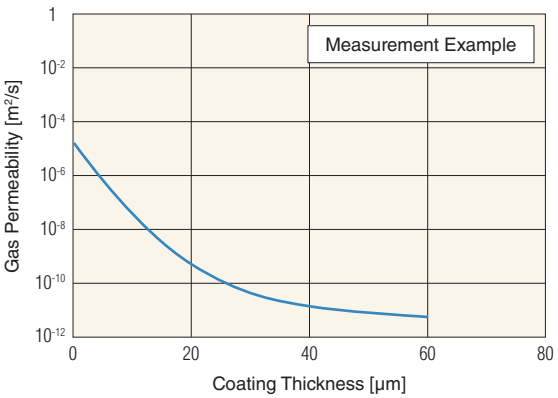
* Measurement method: Glow Discharge Mass Spectrometry
* The figures above are measurement examples, and are not to be guaranteed.

■ General Physical Properties

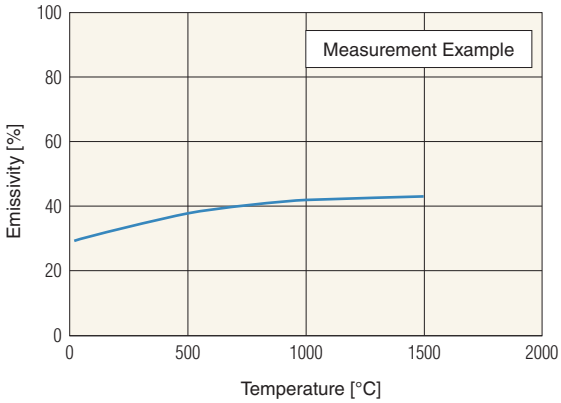
Item	Unit	Parallel to Coating Surface	Perpendicular to Coating Surface
Bulk Density	Mg/m^3	2.2	2.2
Hardness	HSD	100	—
Electrical Resistivity	µΩ·m	2.00 to 4.00	2 to 5 x 10^3
Coefficient of Thermal Expansion	10^{-6}/K	1.7	28
Tensile Strength	MPa	98 to 147	Extremely weak
Young's Modulus	GPa	29 to 39	—
Thermal Conductivity	W/(m·K)	170 to 420	2 to 4

* The temperature range for the coefficient of thermal expansion is RT to 1,000°C.
* The figures above are extracted from other publications, and are not to be guaranteed.

■ Gas Permeability



■ Emissivity



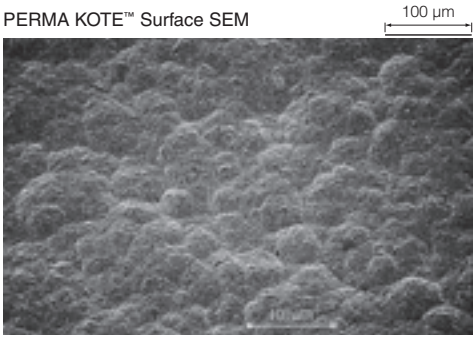
PERMA KOTE™ Products

PERMA KOTE™ is a product created by coating the surface of highly purified isotropic graphite with a fine layer of silicon carbide by means of a proprietary Toyo Tanso Chemical Vapor Deposition (CVD) process.

■ PERMA KOTE™ Characteristics

- The silicon carbide layer has excellent oxidation resistance, corrosion resistance and chemical resistance.
- The silicon carbide layer is stable at high temperatures and is extremely hard.
- Prevents the parting and scattering of graphite particles, and the emission of gas and impurities from the graphite substrate.
- Both the graphite substrate and silicon carbide layer are of high purity.
- Both the graphite substrate and silicon carbide layer have a high thermal conductivity, and excellent heat distribution properties.
- Material is designed so that cracks and delamination do not occur.

PERMA KOTE™ Surface SEM



■ Coating Thickness

The standard thickness is 120 µm; however this can be modified within a range of 20 to 500 µm.

■ Application

- Susceptors for silicon epitaxial growth
- Single crystal silicon manufacturing equipment
- MOCVD susceptors
- Heaters
- Heat spreaders
- Oxidation resistance components

Silicon Epitaxial Growth System

■ PERMA KOTE™ Property Data

■ Corrosion Resistance

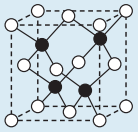
Name	Chemical Formula	Concentration (%)	Temperature (°C)	Time (h)	Change in Mass (g/m²)
Hydrofluoric acid	HF	47	80	144	-1.0
Hydrochloric acid	HCl	36	Boiling point	144	0
Sulfuric acid	H_2SO_4	97	110	144	0
Nitric acid	HNO_3	61	Boiling point	144	0
Hydrofluoric acid + nitric acid	HF + HNO_3 (1:1)	100	80	288	-1.0
Nitric acid + sulfuric acid	HNO_3 + H_2SO_4 (1:1)	100	25	288	-1.0
Sodium hydroxide	NaOH	20	80	288	0
Phosphoric acid	H_3PO_4	100	100	192	-1.0
Nitrohydrochloric acid	HCl + HNO_3 (3:1)	100	80	192	0

■ Reactivity with Various Substances (In a Vacuum)

Reactant	Chemical Formula	1200°C x 3h	1600°C x 3h
Aluminum	Al	○	△
Boron	B	◎	◎
Cobalt	Co	△	×
Chromium	Cr	△	×
Copper	Cu	○	△
Iron	Fe	×	×
Molybdenum	Mo	◎	○
Nickel	Ni	◎	×
Lead	Pb	△	×
Silicon	Si	◎	○
Tin	Sn	◎	△
Tantalum	Ta	◎	◎
Titanium	Ti	◎	○
Vanadium	V	◎	×
Tungsten	W	◎	○
Alumina	Al_2O_3	◎	×
Boron oxide	B_2O_3	◎	◎
Chromium oxide (III)	Cr_2O_3	◎	×
Iron oxide (III)	Fe_2O_3	×	×
Magnesium oxide	MgO	◎	△
Manganese oxide (IV)	MnO_2	◎	×
Lead oxide (II)	PbO	○	△
Silicon dioxide	SiO_2	◎	△
Titanium oxide (IV)	TiO_2	◎	○
Vanadium oxide (V)	V_2O_5	◎	△
Zirconium oxide (IV)	ZrO_2	◎	○

* ◎···No reaction ○···Slight reaction
△···Reaction ×···Significant reaction

■ Layer Properties

Crystal Structure	ß-SiC (Cubic System) Structure 
Bulk Density	3.2 Mg/m³
Hardness	2800HK
Electrical Resistivity	0.2 Ω·m (through the fall-of-potential method)
Flexural Strength	170 MPa (through 3-point bending)
Young's Modulus	320 GPa (through the deflection method)

* The figures above are extracted from other publications or are measurement examples, and are not guaranteed.

■ Impurity Analysis Example

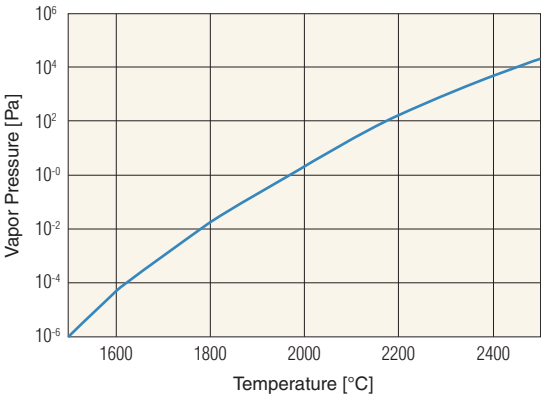
Unit: mass ppm

Element	Content
B	0.15
Na	0.02
Al	0.01
Cr	<0.1
Fe	0.02
Ni	<0.01

* Measurement method: Glow Discharge Mass Spectrometry
* The figures above are measurement examples and are not to be guaranteed.

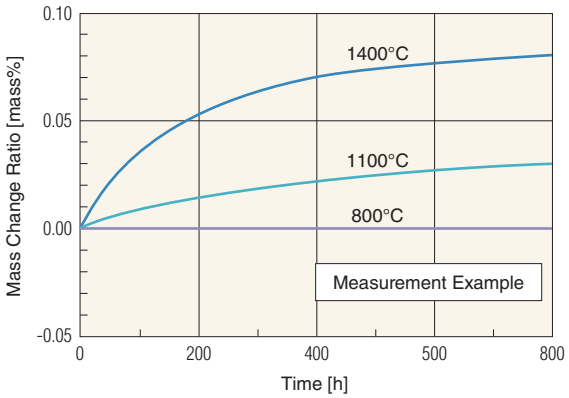
■ Silicon Carbide Vapor Pressure

*Extracted from the ultra high temperature melting point material handbook



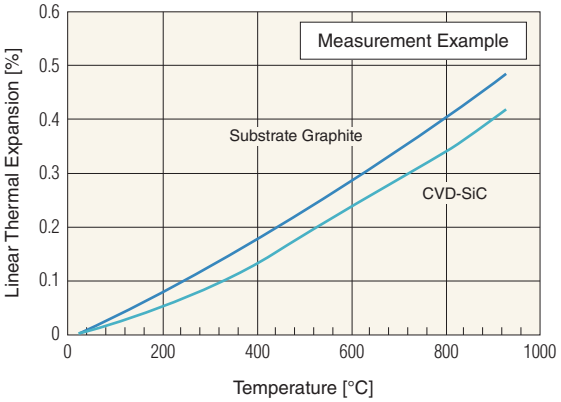
PERMA KOTE™ is extremely stable at high temperatures.

■ Oxidation

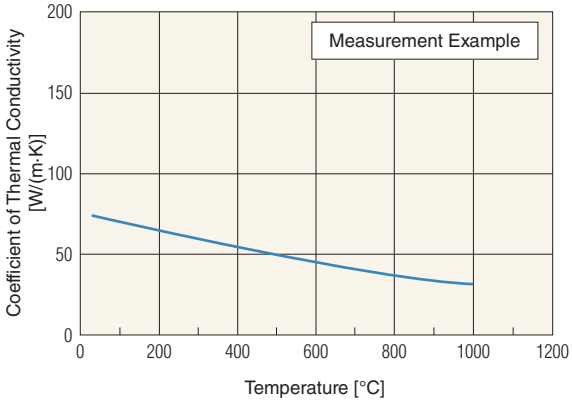


PERMA KOTE™ is resistant to oxidation; and because the SiO_2 protective layer is formed at over 800°C, the substrate graphite is protected from oxidation.

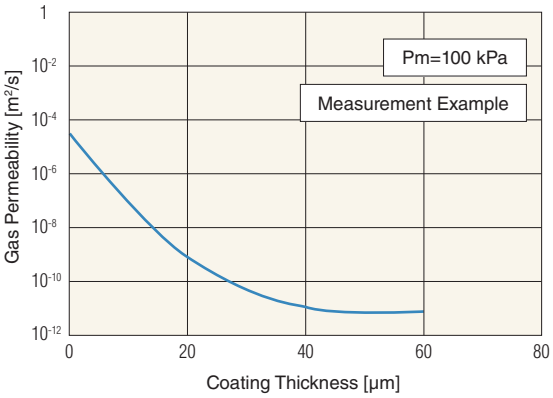
■ Coefficient of Thermal Expansion for CVD-SiC and Substrate graphite



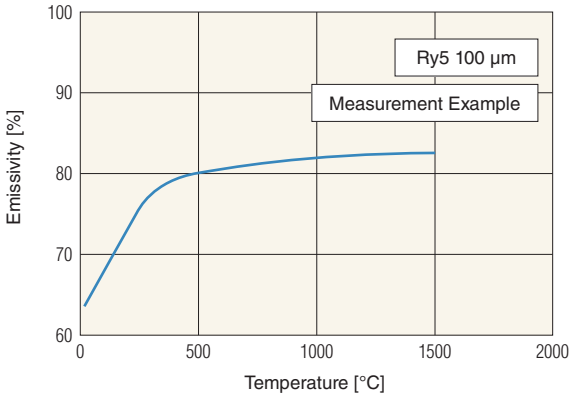
■ Thermal Conductivity



■ Gas Permeability



■ Emissivity



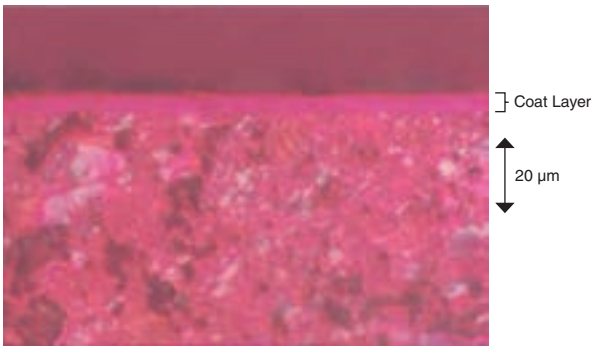
Glass-like Carbon Coated GLASTIX KOTE™

GLASTIX KOTE™ is a material impregnated or coated with glass-like carbon on a graphite or neighboring surface.
It enables use of various Toyo Tanso graphite materials as a substrate, and it does not lose its substrate properties. Not only does this material offer enhanced durability against scratching and other friction, it also reduces the generation of dust.

■ Features

- Able to use various Toyo Tanso graphite materials as a substrate.
- Does not lose graphite substrate properties.
- Able to reduce the generation of graphite powder.
- Enhanced durability against scratching and other friction.

"GP2B" Cross-section



■ Application

- Parts for silicon single crystal pulling devices
- Parts for epitaxial growth
- Dies for continuous casting
- Glass sealing jigs

■ Properties/Test Data

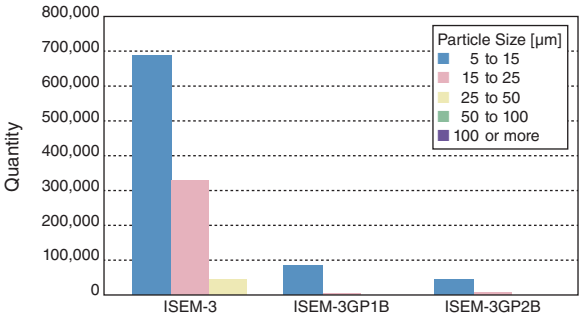
■ General Physical Properties

Grade	Bulk Density	Hardness	Electrical Resistivity	Flexural Strength	Compressive Strength
ISEM-3	0	0	0	0	0
GP1B	0	+3%	0	+8%	+3%
GP2Z	0	+3%	–	+7%	+4%
GP2B	0	+3%	0	+13%	+3%

* Example of physical properties when using ISEM-3 as a graphite substrate and applying GLASTIX KOTE™ GP series processing.
(Rate of change with measured value of ISEM-3 substrate as the standard)

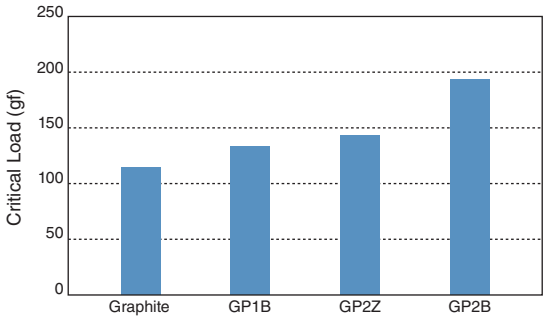
Test piece dimensions:
10 × 10 × 60 mm: Bulk density, hardness, electrical resistivity, flexural strength
10 × 10 × 10 mm: Compressive strength

■ Dust Reduction Effect



GLASTIX KOTE™ processing can greatly reduce the amount of carbon dust generated.
* This is the result of measuring the number of fine particles in the cleaning solution.

■ Scratch Strength Comparison



The durability against scratching with GLASTIX KOTE™ processing nearly doubled, and a similar improvement in wear resistance can be expected.
* Critical load indicates the vertical load when the surface begins to show damage.

Toyo Siliconized Graphite SiC/C Composites

Toyo Siliconized graphite is a material with a composite layer of silicon carbide (SiC) and graphite (C).
The material has excellent properties of both silicon carbide and graphite, and not only are they ideal for sliding material applications, the surface layer of the graphite substrate is covered with a fine SiC layer, making it ideal for high-temperature atmosphere applications as well.

■ Features

- SiC/C composite layer can be applied to an entire product or just the areas required.
- Composite layer can be formed from the surface to deep within the material.

[Sliding Material Applications]

- Excellent blister resistance and enhanced wear and oxidation resistance.
- Graphite substrate does not lose workability.

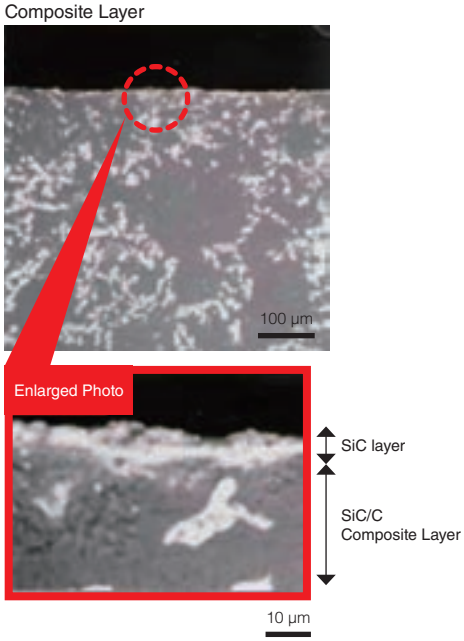
[High-temperature Atmosphere Applications]

- A SiC layer forms on the processing surface, enhancing oxidation resistance and reducing scattering from the graphite substrate.

■ Application

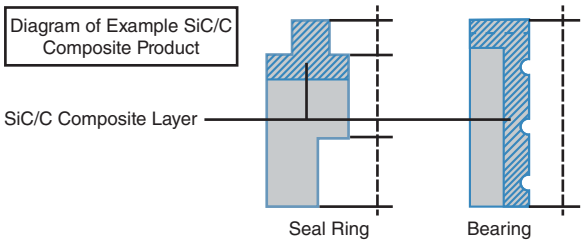
- Metallurgic members
- Mechanical seals
- Bearings

Cross-sectional Photo of SiC/C Composite Layer



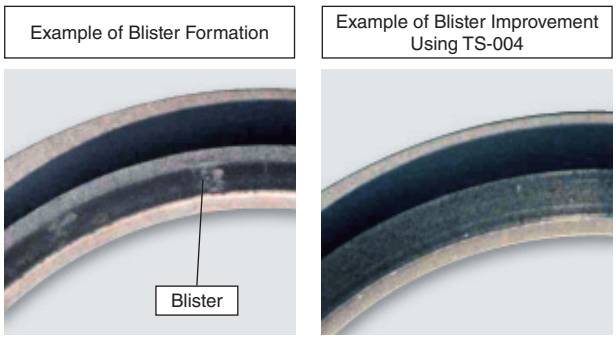
■ Properties/Test Data

■ Diagram of Example SiC/C Composite Product



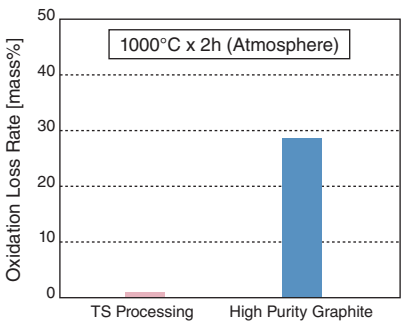
SiC/C composite layer can be applied to an entire product or just the areas required.
The inner diameter of the bearing can be processed after becoming a composite, thereby falling within the tolerance.

■ Sliding Application (Blister Test)



Because the material retains a high mechanical strength and the sliding surface has a moderate surface roughness, it is easy to form a lubricating layer on the sliding surface, and it is difficult for blisters to form when using liquid oil.

■ High-temperature Atmosphere Application (Oxidation Loss Test)



New Developed Products

To deliver unique products to you, the customer, Toyo Tanso works constantly on cutting-edge research and development. By pursuing the possibilities offered by alternatives to conventional materials, we conduct joint research with users around the world and will continue to be proactively involved in product development for generations to come.

■ Porous Carbon CNovel™

Manufactured using our unique technologies, porous carbon contains numerous holes of even size of approximately several tens of nanometers in diameter and features a special structure in which these holes are interconnected. Unlike activated carbon and other existing porous carbon materials, CNovel™ is a new material with controlled mesopores (2 to 50 nm), which until now have been considered difficult to manufacture and obtain as an industrial material. Depending on preparation conditions, it is possible to (1) control specific surface area and (2) adjust pore size. CNovel™ is starting to attract attention for use in applications such as those in the environment and energy sector and in machine applications, in which it has conventionally been difficult to use porous carbon materials, in addition to conventional activated carbon applications.

Product appearance

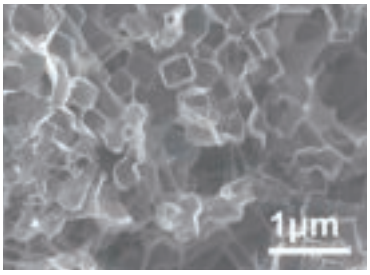
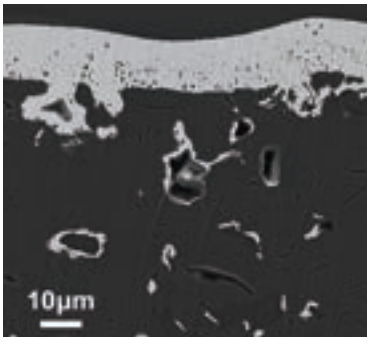


Image of transmission electron microscope

■ Metal Carbide-coated Graphite MetalizeKote™

MetalizeKote™ is a coating product that forms a layer of metal carbide (carbonized metal) on the surface of a graphite material via a proprietary Toyo Tanso method, and is available in Cr- and Fe-based coatings. The formation of a metal carbide causes the graphite surface to become metal-like, making it possible to prevent the generation of graphite particles as well as control the carburization (denaturation) of the other material. Utilizing this property, MetalizeKote™ is starting to attract attention for use in jig and industrial furnace applications, in which it has conventionally not been possible to use graphite materials and coating products.

Product appearance

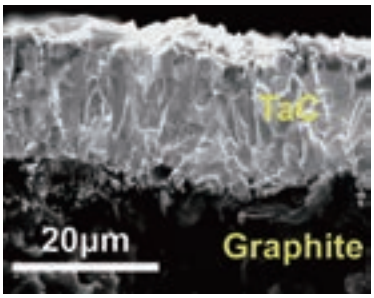


SEM cross-section image

■ TaC-coated Graphite EVEREDKOTE™-B

In recent years, silicon carbide (SiC), gallium nitride (GaN), aluminum nitride (AlN), zinc oxide (ZnO), and other materials have attracted attention as next-generation power devices. These monocrystalline manufacturing processes involve high temperatures and harsh environments using corrosive gases such as ammonia and hydrogen chloride. The use of conventional components under such environmental conditions shortens lifetimes due to heat and corrosive gases. EVEREDKOTE™-B is a composite material consisting of a graphite material coated with TaC. With a melting point of approximately 4,000°C, this TaC coating provides ultra-high thermal durability. Moreover, it is crack-free and has excellent thermal shock resistance. These properties of the TaC coating protect the graphite substrate, extending component life.

Product appearance

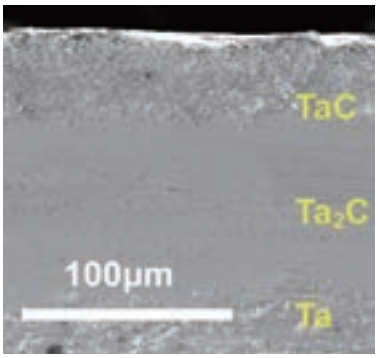


SEM cross-section image

■ TaC-Ta Composite EVEREDKOTE™-K

EVEREDKOTE™-K is a composite material jointly developed with Kwansei Gakuin University that consists of tantalum carburized so that the surface forms a layer of TaC. Like EVEREDKOTE™-B, EVEREDKOTE™-K has high-temperature characteristics, and moreover has many other characteristics such as seize resistance and mechanical strength. It can therefore be used in high-temperature environments such as those experienced by structural parts used in furnace interiors.

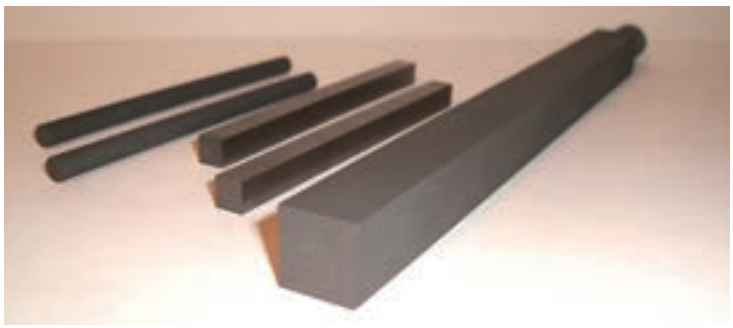
Product appearance



SEM cross-section image

■ Metal/Carbon Composites KLASTA MATE™

KLASTA MATE™ has a structure in which metal is homogeneously dispersed in a carbon material. It can be used with a wide range of dopant species and concentrations as well as with two or more elements. Like graphite, KLASTA MATE™ has excellent workability and can be processed into complex shapes. As a vapor source for arc discharge, KLASTA MATE™ is suitable for manufacturing metallofullerenes and carbon nanotubes. Moreover, as a vapor source for arc ion plating and a target material for sputtering, it is also suited to metal-doped DLC film formation.



Product appearance

Technical Services

Toyo Tanso can offer various machining or treatments for materials which customer supplies. Our outstanding technologies based on carbon manufacturing enable us to respond to the high expectations of customers request, such as high difficult manufacturing, quality progress of materials.

■ Graphite and Carbon machining

● High difficulty machining

- Thin-wall machining
  We can successfully perform challenging thin-wall machining work by optimizing jigs and machining methods. (Example: Hollow cylinder with thickness of 0.2 mm)
- 3D machining
  We prepare a 3D model based on drawings and write programs to manufacture the desired product. Upon request, we are also able to measure an actual product and produce items based on the actual dimensions.
- Special internal-diameter machining
  We can perform special, internal-diameter machining work to make monolithic items without cutting the workpiece into sections. (Maximum machinable dimensions: ø300 mm L = 400 mm)

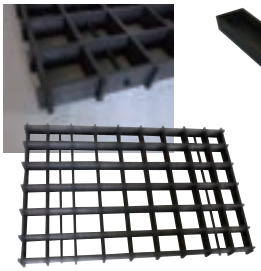
Thin-wall machining

3D Machining

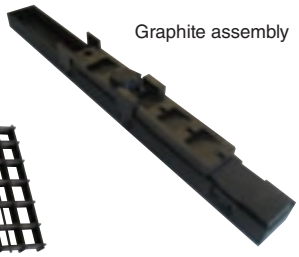
Special internal-diameter machining

● Assembly Services

- Graphite assembly
  Our ability to manufacture products from the design stage right through to the machining and assembly stages allows us to put products together and conduct operation tests after assembly.
- C/C composite assembly
  Our ability to manufacture products from the design stage right through to the machining and assembly stages allows us to ship products after checking assembly precision.



C/C composite assembly



Graphite assembly

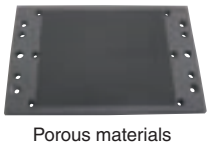
● Other machinings

- Large sealing rings
  We can produce sealing rings for large machinery, which are notoriously hard to manufacture. By producing products with precise parallelism, flatness, surface roughness, and other, we ensure that our sealing rings are able to maintain highly airtight seals. (Maximum machinable diameter: ø500 mm)
- Shrink fitting and assembly
  We can shrink fit carbon and metal, and can also assemble products using adhesion. (Maximum machinable diameter: Up to ø600 mm)
- Sectional machining
  We can perform sophisticated machining tasks such as ensuring that there are no gaps (no light leakage) between mating surfaces, as required in sectioned products used in compressor piston rings and similar applications. Consult us regarding shapes and numbers of sections. (Maximum machinable diameter: ø1,400 mm)
- Porous materials
  By using a multi-head machining center we are able to precision-machine very demanding porous items quickly.
- Vanes
  From mass-produced products for automobiles to low-volume made-to-order products for general industry, we can produce a wide range of vanes—which require very demanding dimensional precision—with consistent quality.

Large sealing rings

Shrink fitting and assembly

Sectional machining



Porous materials

Vanes

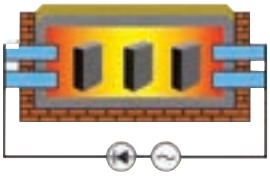
■ Heat Treatment

● Baking Treatment

- Heat treatment up to 1000°C
  We can conduct heat treatment (at a temperature of up to around 1000°C) under non-oxidizing atmospheres.
  Even when organic gases are produced, we can take measures for it.

● Graphitizing Treatment

- Heat treatment up to 3000°C
  We can conduct heat treatment (at a temperature of up to around 3000°C) , filling supplied material together with coke powder into the furnace, and then applying electrical resistance heating.



● Various Heat Treatments

- Toyo Tanso's various heat treatment
  Various heat treatments using treatment furnaces other than those described above are also available.

Article	Conditions for Heat Treatment			
Treatment Method	Vacuum Treatment	N_2 or Ar Treatment	H_2 Treatment	Halogen Treatment
Available size (mm)	1500W x 1400H x 2000L		ø1050 x 830H	
MAX Temperature (°C)	2000	2300	1500	
Pressure	Vacuum (Less than 0.5 KPa)	Decompression Control (20 to 86 KPa)	Normal Pressure	

■ High Purity Treatment

By heat treating a graphite material in a halogen gas environment, impurities in materials are removed. Using high purity treatment makes it possible to keep metal impurities in the graphite material to 5 ppm or below.

Article	Conditions for High Purification
Temperature (°C)	«MAX» 2300
Available Size (mm)	1500W x 1400H x 2000L
Thickness	Depends on the grade of product
Purity (mass ppm)	Less than 5

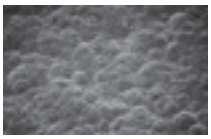
* The treatment results above were obtained using Toyo Tanso graphite material.

■ Surface Improvement

● SiC Coating PERMA KOTE™

A dense layer of silicon carbide (SiC) is created via chemical vapor deposition (CVD).
- Protects substrate from ambient environment
- Controls generation of particles and gas from substrate
- Allows modification, etc., of substrate surface
- Maximum dimensions: ø1,050 x 830 mm

PERMA KOTE™ Surface SEM



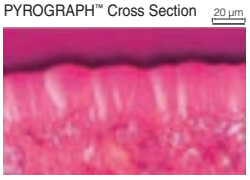
Article	Conditions for SiC Coating
MAX size (mm)	ø1050 x 830H
Thickness of SiC layer (µm)	120±30
Metal impurities content (mass ppm) *by GDMS method	B: 0.15 / Na: 0.02 Al: 0.01 / Cr: <0.1 Fe: 0.02 / Ni: <0.01

* Please consult on deciding the thickness of SiC layer.

● Pyrolytic Graphite Coating PYROGRAPH™

Pyrolytic carbon is coated via chemical vapor deposition (CVD).
- Improves gas impermeability
- Controls generation of particles and gas from substrate
- Improves chemical resistance

PYROGRAPH™ Cross Section



The column-shaped structure of the pyrolytic carbon layer means that the structure is extremely fine.

● Glasslike carbon

Glasslike carbon impregnates or covers the substrate.
- Improves gas impermeability
- Controls generation of particles from substrate

Glasslike Carbon Cross Section

● SiC/C compostes

Technology developed utilizing Toyo Tanso's isotropic graphite manufacturing technology and silicon carbide (SiC) research results.

Structure of SiC/C composite layer

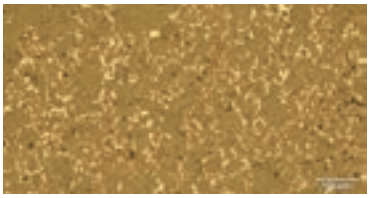
■ Impregnation

● Pitch impregnation

- Pressure-based pitch impregnation treatment
  We can impregnate the porosities in the supplied material with pitch by pressure and can also be add baking to carbonize it.
  Example applications: Refractory materials, electrode materials, ceramics, etc., in applications such as increasing product size, new product development, and more.

● Metal impregnation

We can impregnate the porosities in the supplied material with metal (copper, metals containing copper, and antimony) by pressure under high temperature.
● Improvement of strength, electrical conductivity, thermal conductivity, and impermeability



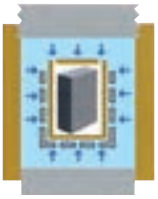
● Resin impregnation

We can impregnate the porosities in the supplied material with resin (phenol and furan resins) by pressure under room temperature and then heat it (at a temperature of up to around 250°C).
● Improves strength and impermeability (airtightness)

■ Forming

● Hydraulic forming

Cold Isostatic Pressing (CIP) is widely-accepted as an effective molding method in the fields of ceramics, refractories and powder metallurgy. We can conduct powder molding into various shapes by applying uniform pressure.



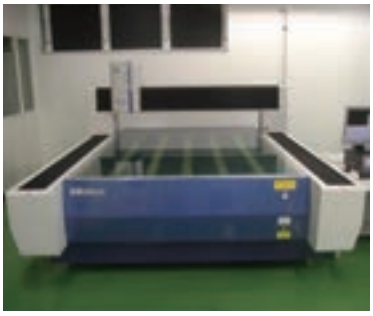
■ Measurement

● Dimension measurement

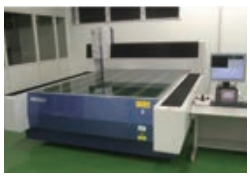
- 3D measurement machine (contact type)
  We use manual equipment, automatic CNC measurement equipment, and other equipment, to measure objects with dimensions of up to 1,600 (X) x 3,000 (Y) x 1,200 (Z) mm. We also have microscopes, and probes as small as ø0.5 mm (contact), allowing high precision measurement of a variety of shapes regardless of workpiece size.

Crysta-Apex (Mitutoyo Corporation)
Specification
1. Measurement Range (X.Y.Z)
   Max size 1600 x 3000 x 1200 mm
2. Max weight 3500 kg
3. Accuracy (µm)
MPEE 6.0 + 5.5 L/1000

- CNC image measurement equipment (non-contact type)
  We perform non-contact measurement using CCD cameras and laser equipment. This ensures that there is no plastic deformation of the workpiece due to measurement pressure, allowing stable, high-precision measurement.
  Workpieces as large as 1,500 x 1,750 x 100 mm (X, Y, Z) can be measured.



QV ACCEL (Mitutoyo Corporation)
Specification
1. Measurement Range (X.Y.Z)
   Max size 1500 x 1750 x 100 mm
2. Max weight 50 kg
3. Accuracy (µm)
Mesurement Accuracy of Flantness (X.Y) 3.5 + 4 L/1000



Analytical technologies

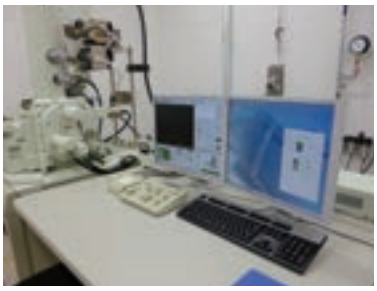
Toyo Tanso employs analytical technologies using a diverse range of analysis equipment to develop new materials and pursue research and development into material design and new applications. We also respond to a wide range of customer requests such as manufacturing process improvement, and also contribute to identifying and problem solving. In this way, we continually strive to provide better products and more sophisticated technologies and services through analytical technologies.

■ Thermal analysis

Graphite material has excellent thermal durability, and as it is often used in high-temperature environments, it is important to understand the way it behaves when heat is applied to a material. Toyo Tanso has a wide variety of thermal analysis equipment (TMA, TG-DTA, etc.), and can provide data to meet your usage conditions. Based on this data, we provide a range of services that can help with material selection including: heat stress calculation and FEM analysis, etc., for component design; analysis of chemical reactions and state changes due to heat; and analysis of material wear in oxidizing atmospheres.

■ Structural and surface analysis

Graphite material is polycrystalline and porous in nature, and differs greatly in terms of surface shape and internal structure due to differences in raw materials and manufacturing methods. To select and develop materials suited to your application, it is therefore important to have an understanding of a variety of structures. Toyo Tanso uses all sorts of measurement equipment suited to these analyses (XRD, FE-SEM, polarizing microscopes, etc.,) depending on the purpose, and conducts a range of analysis from the macro to the nanoscale level.

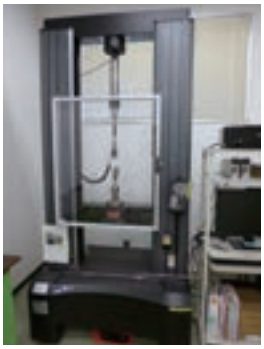


■ Element analysis

As graphite materials can be made with a high degree of purity, they are frequently used in applications where it is necessary to avoid contaminants such as semiconductor fabrication equipment. In applications where a high degree of purity is required, analysis of trace contaminants is an important analysis tool. Toyo Tanso has a variety of element analysis equipment (ICP-OES, XRF, etc.,) and is ready to respond to your requests.

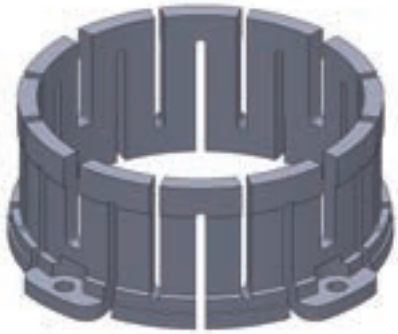
■ Physical properties

We provide data on basic physical properties such as tensile, compression, and flexural strength as well as modulus of elasticity, all of which are essential for component/material design.



■ 3D CAD drawings

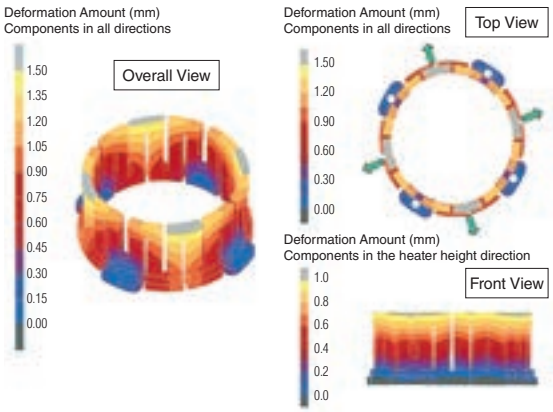
Toyo Tanso recreates three-dimensional images of products on a computer via 3D CAD, and improves the quality of the finished product by checking shape details before product processing. We also offer design support via 3D CAD based on your schematic diagrams and design information.



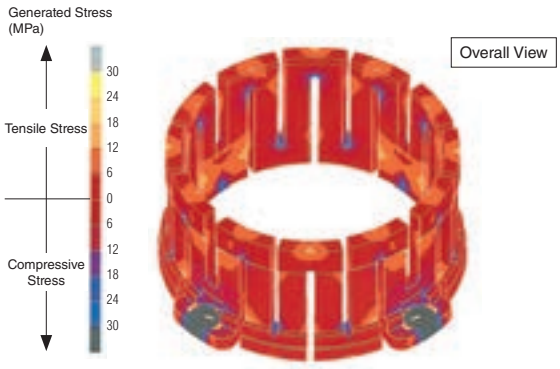
■ Finite element method (FEM analysis examples)

By analyzing heat deformation, heat stress, current density distribution, and other factors in complex product shapes using FEM computer simulations depending on your environment, Toyo Tanso offers comprehensive support of design processes for improving product performance, reducing costs, improving product development speed, etc.

■ Thermal Deformation Analysis Results



■ Thermal Stress Analysis Results



■ Current Density Distribution Results