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Designing Titanium TranTixxii™
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NIPPON STEEL

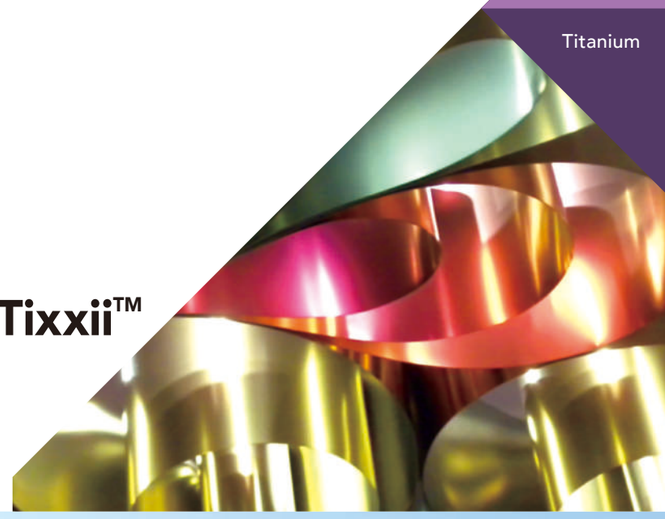
Titanium

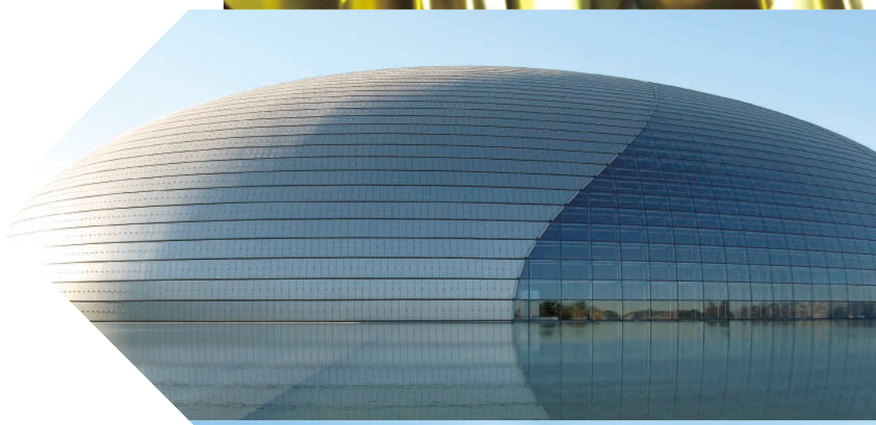
TranTixxii
DESIGNING TITANIUM

Designing Titanium TranTixxii™

GOOD DESIGN AWARD 2021

reddot winner 2022





NET ZERO
NIPPON STEEL
Green Transformation
initiative

NIPPON STEEL CORPORATION

Titanium, on the cutting edge of the times, is an environmentally friendly metal.

Titanium, an element found in 1790, was named after the Titans, earth giants in Greek mythology.
Its industrial production began around 1946. Thanks to its excellent characteristics of being "light," "strong" and "rust-free," it began to be applied in the aerospace, chemical, electric-power and other industries, finding its way further into architectural, civil-engineering, medical and general-purpose applications.
Architects began to use titanium in the 1970s. Titanium's unparalleled performance in corrosion-resistance makes many architectural designs possible for structures in severely corrosive, salty atmospheres of seashores and also in permanent architecture (e.g., museums, temples and shrines). Lately, titanium designs have begun to spread to general housing also.
Overseas, in the 1990s, the use of titanium on a massive scale by Frank O. Gehry in the Guggenheim Museum Bilbao (in Spain) attracted the attention of many architects and spread to many countries. Demand for designing titanium is expected to further grow in the future.

CONTENTS

Titanium's properties

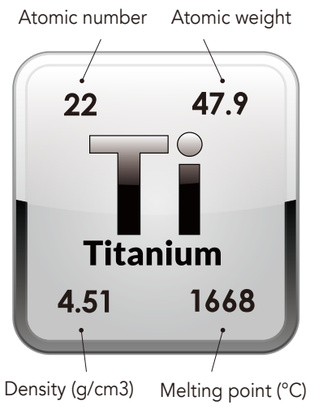
Light weight
The specific gravity is 4.51, equivalent to about 50% that of copper.
The weight is about 60% that of iron.

Weight reduction

High specific strength
The specific strength is about twice that of iron, and three times that of aluminum.
Higher performance & wider range of service environments

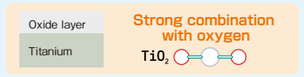
Higher performance & wider range of service environments

Making structures stronger & lighter



Extreme corrosion resistance
The corrosion resistance is comparable to that of precious metals.
(Seawater corrosion resistance: Comparable to that of platinum)

Long service life & less maintenance



Other excellent features
Biocompatibility
Low coefficient of linear expansion & non-magnetic

Environmental compatibility

Highly durable in extreme environments

Designing titanium /TranTixxii "Beautiful titanium"

TranTixxii
DESIGNING TITANIUM

State-of-the-art titanium, a highly functional metal with excellent material properties

① Extreme corrosion resistance: **Long service life & value that lasts into the future**
② Environmental friendliness: **Harmony with nature**
③ Light weight & high strength: **Making structures lighter & stronger**

Beauty that transcends time

Manifesting beauty in diverse ways

Color(beauty of color)
×
Texture(beauty of color tone)
×
Form (beauty of form)

Basic properties of Titanium & Designing Titanium TranTixxii (Basic Property)

1. Unparalleled corrosion resistance

Titanium, readily forming **stable oxide films (in a passive state)** at room temperatures, gives excellent performance in corrosion resistance. In ordinary service environments, the possibility of titanium becoming corroded is non-existent.

(1) Seawater corrosion resistance is comparable to that of platinum.
- Suited to application in **coastal areas.**

(2) Excellent corrosion resistance to corrosive gases (sulfurous acid gas, hydrogen sulfide gas, etc.)
- Suited to application in large cities, industrial areas, hot-spring resorts and the like.

Titanium is a metal that also resists such global environmental pollution as **acid rain and acid mist.**

(3) Titanium is quite free of **stress corrosion, pitting,** contact corrosion and other types of corrosion or problems inherent in stainless steel.

(4) Corrosion due to contact with different metals (Refer to "Table 3. Corrosion potential in seawater (flow)" on page 22.)
The corrosion potential of titanium is virtually equal to that of stainless steel, and it can be used in the same manner. In locations where protection against contact corrosion is paramount, consideration must be given to insulation and the prevention of condensation.

Table 1. Comparison of weather resistance between various metals (Source: Japan Titanium Society)

	Titanium	Stainless steel SUS 304	Copper
Sea salt particle resistance (pitting)	◎	△	○
Ultraviolet ray resistance	◎	◎	◎
Acid rain resistance (pitting)	◎	△	△
Acid rain atmospheric resistance	◎	△	×
Contact corrosion resistance*	◎	×	△
Corrosion fluidity resistance	◎	○	×
Thermal resistance	◎	◎	◎
Erosion resistance	◎	◎	○

Rating: ◎: < 0.05, ○: 0.05-0.5, △: 0.55-1.27, ×: > 1.27 mm/year
* Pitting and crevice corrosion are likely to occur.

Table 2. Comparison of chemical resistance between various metals (Source: Japan Titanium Society)

	Titanium	Stainless steel SUS 304	Stainless steel SUS 316	Copper
Seawater Room temperature	◎	◎*	◎*	○
Hydrochloric acid HCℓ 10% Room temperature	○	×	×	×
Sulfuric acid H_2SO_4 10% Room temperature	○	○	○	○
Nitric acid HNO_3 10% Room temperature	◎	◎	◎	×
Caustic soda NaOH 50% Room temperature	◎	◎	◎	◎
Sodium chloride NaCℓ 20% Room temperature	◎	○	○	◎
Chlorine gas $Cℓ_2$ 100% wet	◎	×	×	×
Hydrogen sulfide gas H_2S 100% wet	◎	○	◎	×
Sulfurous acid gas SO_2 30 to 90°C	◎	○	○	×

Rating: ◎: < 0.05, ○: 0.05-0.5, △: 0.55-1.27, ×: > 1.27 mm/year
* Pitting and crevice corrosion are likely to occur.

2. Great strength

Titanium is almost as strong as steel, and it is a metal with a high strength per mass—in other words, it has a **high specific strength.**
For the application of Designing Titanium TranTixxii, **JIS Type 1**, which is highly workable, is mainly used.

Table 3. Specifications for pure titanium for industrial use (JIS products)

	Chemical composition						Mechanical properties (thickness: 0.5–15 mm, excl.)			Bend test (thickness: 0.5–5 mm, excl.)	
	H	O	N	Fe	C	Ti	Tensile strength N/mm²	Proof stress N/mm²	Elongation %	Bend angle	Inside radius
JIS Type 1	≦0.013	≦0.15	≦0.03	≦0.20	≦0.08	Remainder	270 – 410	≧165	≧27	180°	Thickness by 2
JIS Type 2	≦0.013	≦0.20	≦0.03	≦0.25	≦0.08	Remainder	340 – 510	≧215	≧23	180°	Thickness by 2
JIS Type 3	≦0.013	≦0.30	≦0.05	≦0.30	≦0.08	Remainder	480 – 620	≧345	≧18	180°	Thickness by 2

3. Light weight

The specific gravity of titanium is 4.51—60% that of steel, half that of copper and 1.7 times that of aluminum.
Being such a lightweight metal, titanium imposes less burden on a structure, and permits ease of fabrication.
According to use, it eliminates the need for corrosion-combating expenses, and enables further weight reduction.

4. Excellent aesthetic qualities

[Privileged features of TranTixxii]

Titanium itself has an excellent texture and has a tastefully subdued silver color.
Titanium is also available in many varied colors developed by the anodic oxidation method.

5. Minimum thermal expansion

Titanium's coefficient of linear expansion is half that of stainless steel and copper and one third that of aluminum.
Having a thermal-expansion coefficient quite near those of glass and concrete, titanium can be used in combination with these materials.
Thus, **with little susceptibility to expansion or contraction from temperature changes,** titanium offers great ease and freedom in design and execution in long-term use.

6. Environmentally sound

Titanium is a nontoxic metal.
As dissolution of metal ions is minimal, titanium is a very friendly metal to humans and the environment.
Titanium has excellent recyclability.

7. Others

Among the other major properties titanium offers are:
① Non-magnetic
② Small **Young's modulus** (elastic modulus)
③ Small thermal conductivity

Table 4. Comparison of physical properties between titanium and other metals

Item \ Metallic materials	Titanium	Stainless steel SUS 304	Stainless steel SUS 316	Iron	Copper	Aluminum
Melting point ℃	1,668	1,398 to1,453	1,370 to1,397	1,530	1,083	660
Specific gravity	4.51	7.93	8.0	7.9	8.9	2.7
Coefficient of linear expansion ×10–6 / ℃ (20～100)	8.4	17.3	16.0	12.0	17.0	23.0
Thermal conductivity ca ℓ / cm² / sec / ℃ / cm	0.041	0.039	0.039	0.150	0.920	0.490
Electric resistance μ Ω – cm	47	72	74	9.7	1.7	2.7
Young's modulus kg / mm²	10,850	19,300	19,300	21,000	11,000	7,050

Titanium is officially certified as a non-combustible material.
(Minister of Land, Infrastructure and Transport Certification No. "NM-8596" (certified on May 17, 2002))

Basic properties of Titanium & Designing Titanium TranTixxii (Basic Property)

8. Survey data on corrosion resistance

(1) Data on corrosion tests of metallic materials in spa areas

Corrosion of metallic materials at spa areas is a frequent cause of a variety of environmental problems and accordingly it is necessary to pay prudent attention in selecting metallic materials for service in these areas. As a typical example of metal exposure tests conducted at spa areas, the test results obtained at the Zao spa, an area noted for its high acidity, are introduced below. (Source: Titanium and Zirconium, Vol. 35, No. 4, page 22, October 1987)

Table 5. Major constituents of the Zao springwater (unit: mg/kg)

	Temperature (°C)	pH	Cl^-	SO_4^{2-}	$Fe^{2+}+Fe^{3+}$
Springhead	52.5	1.30	738.6	5,070	94.3
Public bath	46.7	1.35	845.3	5,460	106.0

Due attention should be paid as corrosion conditions differ according to the composition of springwater.

Table 6. Degree of corrosion of various metallic materials at the Zao spa (Exposure period: 6 months) (unit: mg/dm2/day)

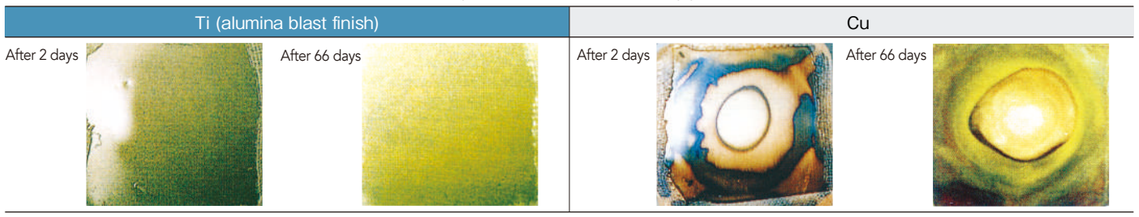
	Exposure at the springhead	Immersion at the springhead	Exposure at an interior wall of the bathhouse	Exposure at an interior wall of the bathhouse	Immersion in the bath
Pure titanium	0	0	0	0	0
Stainless steel SUS 304	–	Melted*1	1.99	–	Melted*1
Ordinary steel product SS 400	46.22	Melted*1	41.55	19.33	Melted*1
Tough-pitch coated steel	73.66	165.94	64.83	17.11	31.77
Pure zinc metal	0.66	Melted*2	2.39	0.55	Melted*2
Aluminum 5052	0	74.77	0	–	109.49
Nickel	0.66	341.44	3.83	1.83	58.49

*1: Melted within 2 months *2: Melted after immersion of up to 10 days, –: abnormal value

(2) Results of surveys on acid rain by Nippon Steel
(research into application of titanium for the protection of cultural assets)

Copper has been applied as the material for roofing of shrines and Buddhist temples because the copper surface develops deep verdigris. However, deterioration of the environment such as acid rain is causing diverse problems. The adverse effect of acid rain on copper application lies in that unstable basic copper sulfate is formed rather than stable basic copper carbonate (verdigris). This phenomenon poses not only aesthetic but also corrosion problems, in particular pitting corrosion (raindrop corrosion) caused by the dripping of acid raindrops. Further, the copper has a possibility of being corroded by decoction from mortar and fumigated tiles. Such corrosion and other problems affecting copper application have become a notable issue from the viewpoint of the protection of cultural assets and thus expectations are becoming high for titanium application.
(Application examples: priests' living quarters at Ikkyuji Temple, tea-ceremony houses at Koetsuji Temple, Naritaya and Yokuoin Temples, others)
Photo 1 shows the results of simulated raindrop corrosion tests by dripping synthetic acid rain (H2SO4:HNO3:HCl = 1.4:1.4 (mol ratio), pH = 4.6).

Photo 1. Metallic surfaces after simulated raindrop corrosion tests by dripping synthetic acid rain



9. Workability

[Privileged features of TranTixxii]

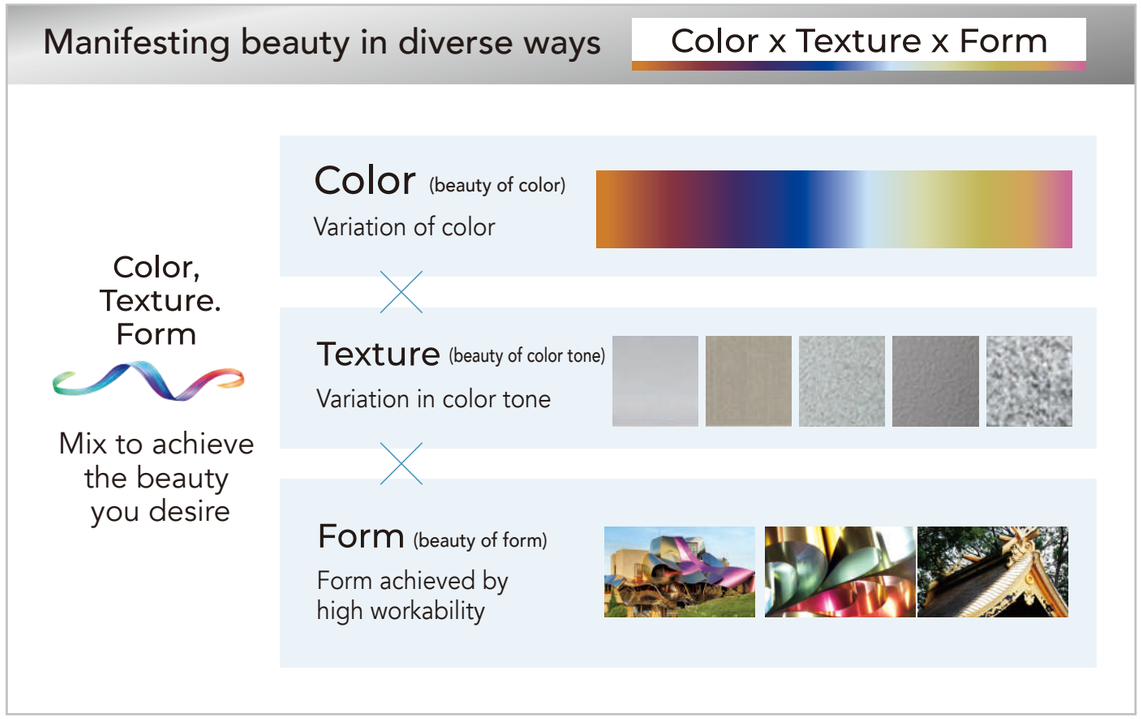
(1) Formability
There are no particular differences between titanium and ordinary and stainless steels.
In the case of titanium JIS Type 1, it can be formed employing practically the same tools, jigs and machines used for ordinary and stainless steels.
Due attention should be paid to the larger spring-back of titanium than ordinary and stainless steels.

(2) Weldability
Seam and spot welding can be applied to titanium under the same atmospheric conditions and manner as for stainless steel. When general welding methods (mainly TIG welding) are applied, stricter welding control than for stainless steel such as the necessity of argon gas shielding is required for titanium. There are no fears of weldment corrosion and stress-corrosion cracking.

(3) Bonding and adhesion performances
Titanium's bonding with visco-elastic and sealing materials and adhesion to coating film are identical to those of stainless steel and aluminum.

10. Aesthetic variation

[Privileged features of TranTixxii]



Designing titanium TranTixxii | Specification System (Material: Standards code)

Wide range of options for various purposes

No	Classification	Type	Standards code	Identification end code*3		Texture×Color×Form (×Texture) Surface finish			(×Color) Coloring	(×Color) Stabele Color	(×Form) Workability	Function (×Performance) Function	Main chemical composition C	H	O	N	Fe	Sn	Si	Cu	Nb	Al	Ti	Tensile properties 0.2% proof stress	Tensile strength	Elongation	Remarks	Application examples
				Identification end code	Shape																							
1	Standard type TTX	Pure titanium	JIS Type 1 ASTM/ASME Grade1	-TTX	Cold Rolled Coil/Sheet	ND20 SD3 HL15	AD09 AD06 AD03 CD05	–	–	○	○	–	≦0.08	≦0.013	≦0.15	≦0.03	≦0.2	–	–	–	–	–	Remainder	≧165	270 -410	≧27		General, building exteriors, interiors, exteriors, others,
						VP15		–	(Original design)																			
				-TTXC	Cold Rolled Coil/Sheet	ND20 SD3 HL15	AD09 AD06 AD03 CD05	–	Normal (Hard*) *For Sheet, can select both Normal and Hard.																			
2	Flatness-oriented type TTXH	Pure titanium	JIS Type 1 ASTM/ASME Grade1 (Those with t < 1.0 are MOD materials.)	-TTXH	Cold Rolled Coil/Sheet	ND20	AD09 AD06 AD03 CD05	–	–	○	– (Flatness-oriented)	–	≦0.08	≦0.013	≦0.15	≦0.03	≦0.2	–	–	–	–	–	Remainder	≧165	270 -440	≧20		General, building exteriors, interiors, exteriors, others,
				-TTXHC	Cold Rolled Coil/Sheet	ND20	AD09 AD06 AD03 CD05	–	Normal (Hard*) *For Sheet, can select both Normal and Hard.																			
3	Special design	Pure titanium	HYPERBETA (Nippon Steel's original standard)		Cold Rolled Sheet	–	–	HBM HBL	–	–	–	–	≦0.08	≦0.013	≦0.15	≦0.03	≦0.2	–	–	–	–	–	Remainder	–	–	–		General, building exteriors, interiors, exteriors, others,
									Hard																			
			IP GOLD TITANIUM (Nippon Steel's original standard)		Cold Rolled Sheet	ND20 'SD3 (TTX substrate)	–	HBM HBL (HBETA substrate)	IP Gold	–	–	–	≦0.08	≦0.013	≦0.15	≦0.03	≦0.2	–	–	–	–	–	Remainder	–	–	–		General, building exteriors, interiors, exteriors, others,
4	Good processing type TTXF	Pure titanium	JIS Type 1 ASTM/ASME Grade1	-TTXF -TTXFR	Cold Rolled Sheet	ND15 SD3 VP5	–	–	–	–	○	–	≦0.08	≦0.013	≦0.15	≦0.03	≦0.2	–	–	–	–	–	Remainder	≧165	270 -410	≧27		Drawn & formed products
			JIS Type 2	-TTXF -TTXFR	Wire Rod	–	–	–	–	–	○	–	≦0.08	≦0.013	≦0.20	≦0.03	≦0.25	–	–	–	–	–	Remainder	≧215	340 -510	≧23		
5	Super good processing type TTXS	Pure titanium	SUPERPUREFLEX (Nippon Steel's original standard)	-TTXS	Cold Rolled Sheet	SD3	–	–	–	–	◎	–	≦0.08	≦0.013	≦0.15	≦0.03	≦0.2	–	–	–	–	–	Remainder	≧120	≧250	≧40		Complex molded products
6	For watches TTXW	Pure titanium	JIS Type 1 ASTM/ASME Grade1	-TTXW	Cold&Hot Rolled Coil/Sheet·Plate	SD3 No.1	–	–	–	–	–	–	≦0.08	≦0.013	≦0.15	≦0.03	≦0.2	–	–	–	–	–	Remainder	≧165	270 -410	≧27	Material design intended for a bright gloss and color after processing.	Watches
			JIS Type 2	-TTXW	Cold&Hot Rolled Coil/Sheet·Plate	SD3 No.1	–	–	–	–	–	–	≦0.08	≦0.013	≦0.20	≦0.03	≦0.25	–	–	–	–	–	Remainder	≧215	340 -510	≧23		
			ASTM/ASME Grade2	-TTXW	Cold&Hot Rolled Coil/Sheet·Plate	SD3 No.1	–	–	–	–	–	–	≦0.08	≦0.015	≦0.25	≦0.03	≦0.30	–	–	–	–	–	Remainder	275 -450	≧345	≧20		
		Titanium alloy	Super-TIX-M70 (Nippon Steel's original standard)	-TTXW	Cold&Hot Rolled Coil/Sheet·Plate	SD3 No.1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Remainder					
			Super-TIX-20AFG** (Nippon Steel's original standard)	-TTXW	Cold&Hot Rolled Coil/Sheet·Plate	SD3 No.1	–	–	(Original design)	–	○*2	Mirror surface property	–	–	–	–	–	–	–	–	–	–	Remainder	≧250	≧370	≧18		
7	For automobiles TTXA	Pure titanium	JIS Type 1 ASTM/ASME Grade1	-TTXA*1	Cold Rolled Coil/Sheet·Pipe	SD3 No.1	–	–	–	–	–	–	≦0.08	≦0.013	≦0.15	≦0.03	≦0.2	–	–	–	–	–	Remainder	≧165	270 -410	≧27	Material design for aesthetic designs with a beautiful, uniform and strong impression.	Mufflers, fuel tanks
			JIS Type 2	-TTXA*1	Cold Rolled Coil/Sheet·Pipe	SD3 No.1	–	–	–	–	–	–	≦0.08	≦0.013	≦0.20	≦0.03	≦0.25	–	–	–	–	–	Remainder	≧215	340 -510	≧23		
			ASTM/ASME Grade2	-TTXA*1	Cold Rolled Coil/Sheet·Pipe	SD3 No.1	–	–	–	–	–	–	≦0.08	≦0.015	≦0.25	≦0.03	≦0.30	–	–	–	–	–	Remainder	275 -450	≧345	≧20		
		Titanium alloy	Super-TIX10CSSN (Nippon Steel's original standard)		Cold Rolled Coil/Sheet	SD3 No.1	–	–	–	–	○*2	Heat resistance (maximum)	≦0.08	–	≦0.15	≦0.03	≦0.2	0.90 -1.2	0.10 -0.50	0.8 -1.2	0.2 -0.5	0.2 -0.5	Remainder	≧270	≧360	≧20		Mufflers
			Super-TIX10CUNB (Nippon Steel's original standard)		Cold Rolled Coil/Sheet	SD3 No.1	–	–	–	–	○*2	Heat resistance (high)	≦0.08	–	≦0.15	≦0.03	≦0.2	–	–	0.8 -1.2	0.4 -0.6	0.2 -0.5	Remainder	≧270	≧360	≧35		
			Super-TIX10CU (Nippon Steel's original standard)		Cold Rolled Coil/Sheet	SD3 No.1	–	–	–	–	○*2	Heat resistance	≦0.08	–	≦0.15	≦0.03	≦0.2	–	–	0.8 -1.2	–	0.2 -0.5	Remainder	≧270	≧395	≧35		

(*1: Identification symbol "-TTXA" cannot be applied in actual use due to the relationship with users.
*2: Products provide high strength, heat resistance and other functions as well as workability.)
*3: Standard with end trailing R Recycled Titanium Series / TranTixxii-ECO Applicable Standards

Designing titanium TranTixxii | Surface Finishes System (Texture × Color)

Manifesting beauty in diverse ways

Texture

	1	2		3				4	5	6
	Glossy	Roll dull(Enbossed)		Blasted				Hairline	Crystalization (HYPERBETA)	Others
Item	SD3	ND20	ND15	AD09	AD06	AD03	CD05	HL15	Hyperbeta	VP15
										
Application examples										

Color

	1	2	3
	Interference color	Object color	Others
Item	#0 to #124	IP Gold	Original design (Black) *1
	 #44 #48 #8 #52 #12 #104 #58 #16 #62 #64 #68 #20 #26 #32 #70 #72 #74 #76 #80 #88	 IP Gold	 Black
Application examples		Enoshima Station, Odakyu Railway Ryuou Shrine	

Texture×Color (The following introduces popular designs made by mixing the textures and colors shown above.)

				Application examples
Selections for traditional designs	Verdigris coloring Blast [AD09] and Interference color [Green] 	Wood chips coloring Blast [AD03] and Interference color [Brown] 	Brown coloring Blast [AD03] and Interference color [Brown] 	
Selections for modern designs	Roll dull [ND20] and Interference color [Gold] 	Roll dull [ND20] and Interference color [Blue] 	Gloss [SD3] and Interference color [Pink] 	

For details, scan the QR code.

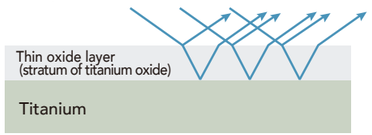
Designing titanium TranTixxii | Color features

Hotel Marques de Riscal (Spain)
Surface: Roll dull (SD3)
Gold & pink coloring
Area: 2,400 m²
Weight: 12 tons
Completed: 2004

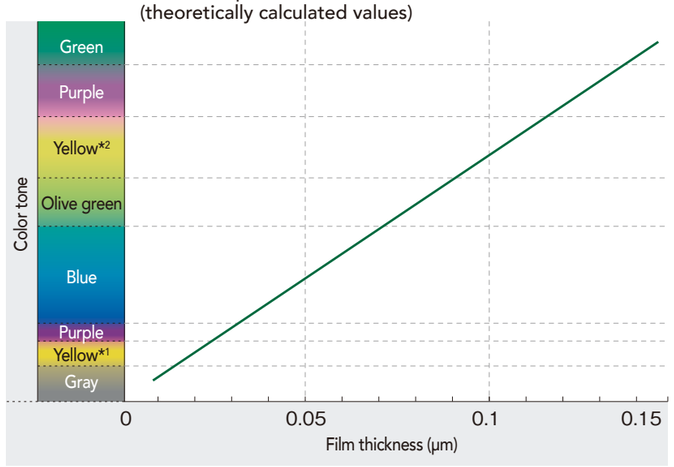
Principle of coloring of titanium

Coloring (Anodic oxidation)
When a thin oxide layer (colorless and transparent) is formed on the titanium surface by means of the anodic oxidation method, color can be seen as a result of interference of light. A wide range of colors can be produced by changing the film thickness.

Principle of interference color



Relationship between film thickness and interference color (theoretically calculated values)



Interference color: An optical phenomenon created by Co-work of "light" and a "transparent thin oxide layer (stratum of titanium oxide)"

This is the same principle as that of soap bubbles and rainbows in the natural world.

When using colored titanium, please understand the following points.

① **The oxide layer on the surface of titanium is extremely thin, so the color tone is strongly influenced by the surface conditions of the base metal.**
Titanium sheets that have different surface finishes may appear different in color, even if the titanium oxide layer formed on them is the same thickness. Also, even if sheets have the same surface finish, the color will differ slightly from one coil to the other due to the color differences of the base metal.
For this reason, in addition to checking the color using color samples, we ask you to check the color of the actual ordered material by coloring a part of the material prior to the actual coloring process. When you intend to use two or more coils, we recommend that you control the coils jointly with the fabricator so as to minimize color differences.

② **Because titanium is colored by light interference, the color may sometimes appear different depending upon the season, weather, time of day and viewing angle.**
When it rains, for example, the same color can look completely different. This is a feature of interference colors, and you may find that such a color change is a pleasing aspect of colored titanium.

③ **The oxide layer may grow depending upon the weather atmospheric conditions, causing the color to change.**
With our titanium products, before the development of STABLE COLOR (Less-Discoloration Technology) described below, there were cases in which the color of a material to which this technology was not applied changed from yellow (gold) to purple, whereas the materials to which the developed technology has been applied maintain their initial colors and tones even in properties built over 10 years ago.
However, please note that the colors of materials to which the technology has been applied may change with time depending upon the environmental and weather conditions.
* The hue changes in the sequence of gray, yellow, purple, blue, olive green, yellow, purple and green, as the thickness of the oxide layer increases.

④ **Titanium becomes dirty like other metals, and finger marks get on it.**
Depending upon the type of extraneous matter (contamination), the titanium surface may appear discolored. Such contamination can be removed with detergent, but the material may not return to its original color due to the deposition of such matter (contamination). Please note that extraneous matter is likely to cause the color of colored titanium to change, especially in regions where much volcanic ash falls.
We recommend that you use a neutral detergent or our recommended detergent to clean titanium. Note that if you use a detergent that contains a strong acid or alkaline, the oxide layer on the surface may dissolve, preventing the original color from being restored. (See page 17.)

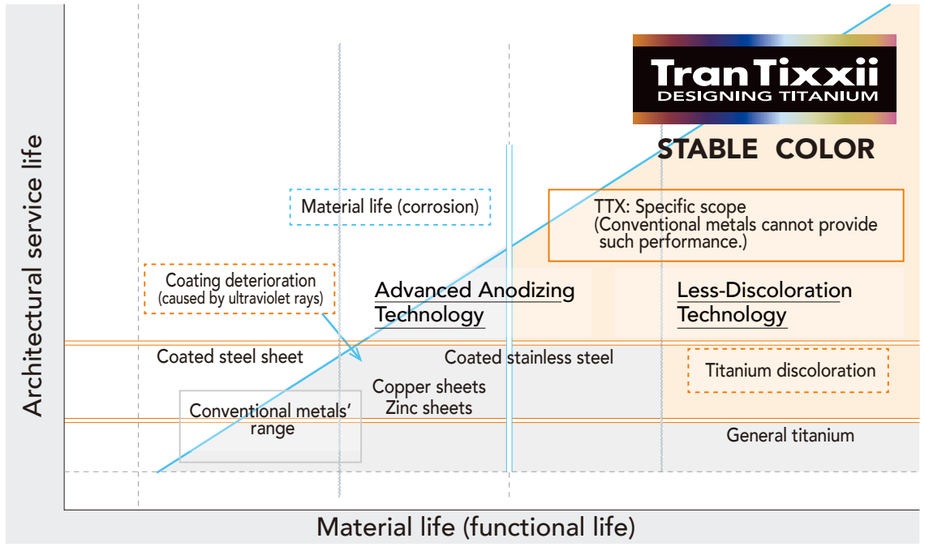
Designing titanium TranTixxii | Color features

World's Only 1: STABLE COLOR

STABLE COLOR
(TranTixxii)

Original core technologies to support STABLE COLOR

- Advanced Anodizing Technology
- Less-Discoloration Technology
- IP Gold Technology（IP：Ion Plating）



TranTixxii achieves an unparalleled, stable architectural service & material life that conventional metals do not, realizing "beauty that transcends time."

(Scope: TTX, TTXH, TTXC, TTXHC, IPGOLDTITANIUM)

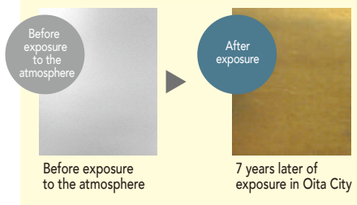
Mechanism of discoloration

Explanation of discoloration

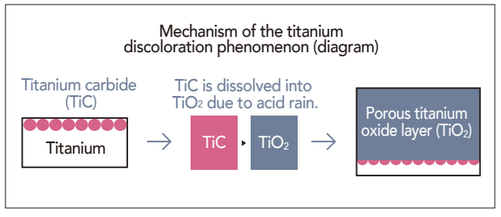
In the early 1990s, there were reports of phenomena in which the color of titanium roofing tiles changed from silver to brown in parts of constructed buildings. Titanium is colored by means of the formation of an oxide layer on its surface. The reported phenomenon is attributable to the fact that the oxide layer thickened due to acid rain and other environmental factors, resulting in a color change in which a silver color appeared brown due to the interference color of light.

* This phenomenon has nothing to do with titanium's corrosion resistance.

Example of discoloration [The test piece is a conventional vacuum annealed (VA) material.]



In 2001, at the start of the 21st century, Nippon Steel was the first in the world to successfully clarify the mechanism, thereby clearing a path toward titanium's evolution in the field of color, one of the element technologies of TranTixxii.



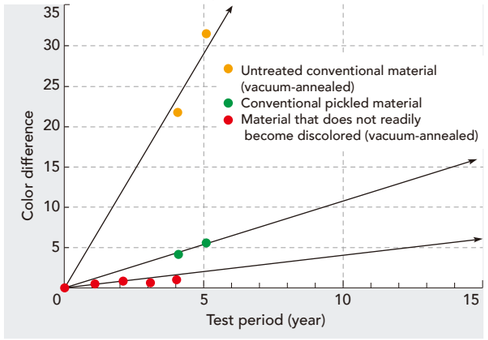
Mechanism of discoloration

As a result of an investigation of the discolored areas, a minute amount of carbide and fluorides was found to remain in the magnetized oxide layer and on the surface of the titanium base metal. Following various experiments, it was found that these substances react with acid rain, causing the film to grow. In addition, the higher the atmospheric temperature, the more pronounced is this trend.

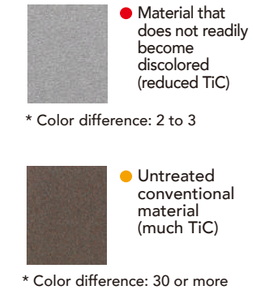
Effect of resistant-to-discoloration treatment

While the acidity of rainwater in Okinawa is equivalent to the average value, Okinawa is one of Japan's most discoloration-prone regions due to its hot and humid climate.
The discoloration of designing titanium that does not readily become discolored is minimal even after 4 years of exposure.

Results of a 4-year exposure test in Okinawa



Exposure test in Okinawa



STABLE COLOR

Points to note for STABLE COLOR (Less-Discoloration Technology)

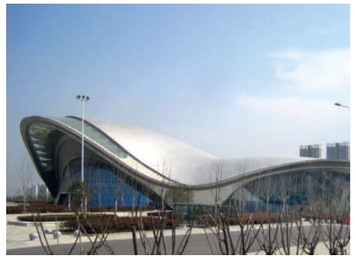
- This technology reduces the rate of growth of the oxide layer in a natural environment, and thus slows down the speed of discoloration. It does not stop discoloration from occurring.
A material that does not readily become discolored which was installed during or after 2000 and also a material that has been subjected to an exposure test have presently undergone little change in the base material or the color, and maintain a satisfactory condition.

It is considered that there is a possibility of discoloration occurring in tropical regions of high temperature and humidity or regions where severe acid rain falls.
Like other metals, titanium sometimes appears discolored due to dirt or finger marks. Contamination can be removed by carrying out appropriate cleaning. If the contamination is allowed to remain, it will become difficult to remove.

<Portfolio 1> Standard type & flatness-oriented type TTX TTXH TTXC TTXHC

Building exteriors

Fuji Television Headquarters, Spherical Observation Room
Surface: Roll dull (ND10),
equivalent to gloss SD3 (ND10 (no longer offered))
Area: 2,800 m² Weight: 14 tons Completed: 1996



Hefei Lakeside International & Convention Center
Surface: Roll dull (ND20) Area: 13,000 m²
Weight: 21 tons Completed: 2011

Shimane Art Museum
Surface: Pickled dull (VP20),
equivalent to VP15 (PD25NX (no longer offered))
Area: 10,000 m² Weight: 60 tons Completed: 1998

Saemangeum Exhibition Center
Surface: Roll dull (ND20) Area: 4,300 m²
Weight: 10.4 tons Completed: 2011

Uchinada Town Office
Surface: Roll dull (ND20) (green coloring)
Area: 1,700 m² Weight: 6 tons Completed: 1998

- 2003 Good Design Award
  "Titanium temple roof/Titanium project for protecting historical buildings"
- Fiscal 2004 Otani Art Museum Award
  "A roof made of dream material that has traditional beauty
  Alumina blasting finish titanium roofing and exterior materials"

Koetsuji Temple, Main Hall
Surface: Alumina blasting (AD03) Area: 700 m²
Weight: 1.2 tons Completed: 1997

Nara National Museum (No. 2 Annex)
Surface: Alumina blasting (AD03), brown coloring
Area: 6,000 m² Weight: 12 tons Completed: 1998

Daichuji Temple
Surface: Alumina blasting (AD03) Area: 660 m²
Weight: 1.2 tons Completed: 2006

National Showa Memorial Museum
Surface: Alumina blasting (AD09)
Area: 4,200 m² Weight: 56 tons Completed: 1998

Ashitaka Shrine
Surface: Alumina blasting (AD09), verdigris coloring
Area: 440 m² Weight: 0.4 tons Completed: 2006

**Sagawa Art Museum,
Teahouse (Raku Kichizaemon-Kan)**
Surface: Alumina blasting (AD03)
Area: 400 m²
Weight: 1 ton
Completed: 2007

Miyajidake Shrine
Surface: Roll dull (ND20)
Gold coloring
Area: 220 m²
Weight: 0.86 tons
Completed: 2010

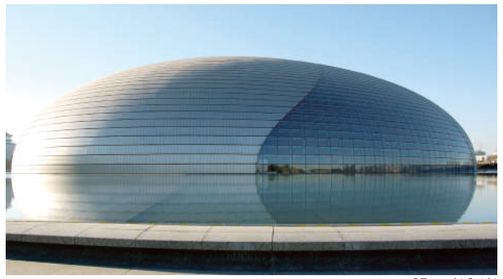
Kitano Tenmangu, Treasury
Surface: Alumina blasting (AD09), verdigris coloring
Area: 1,000 m² Weight: 4 tons Completed: 1998

Building interiors, art, monuments

**Flame Holder at
the Nagano Winter Olympic Games**
Surface: Mirror surface
Sheet thickness: 2.0, 3.0 mm
Designed by: Kiyoyuki Kikutake
(information sculptor)
Installed by: Tig
Completed: 1998

Chigasaki Southern C
Surface: Shot blasting
Designed by: Kotobuki
Installed by: Toho Technical Service
Completed: 2002

Sculpture "Koka"
Surface: Mirror surface
Sheet thickness: 3.0 mm
Designed by: Minami Tada
Constructed by: JV of Sakamoto, Ishizuka and partners
Installed by: Minami Tada Associates
Completed: 1994



National Grand Theater (China)
Surface: Roll dull (ND20)　Area: 43,000 m²
Weight: 65 tons　Completed: 2007
©Tsuyoshi Onishi

Taipei Arena (Taiwan)
Surface: Roll dull (ND20)　Area: 20,000 m²
Weight: 50 tons　Completed: 200

Hangzhou Grand Theatre (China)
Surface: Roll dull (ND20)
Area: 10,000 m²　Weight: 15 tons　Completed: 2003

Hotel Marques de Riscal (Spain)
Surface: Roll dull (SD3), gold and pink coloring
Area: 2,400 m²　Weight: 12 tons　Completed: 2004

Oita Sports Park Stadium
Surface: Roll dull (ND20)
Area: 32,000 m²　Weight: 80 tons　Completed: 200

Kinkakuji Temple, Teahouse (Josokutei)
Surface: Alumina blasting (AD003)
Area: 100 m²　Weight: 0.5 tons　Completed: 2003

JR Hakodate Station
Surface: Roll dull (ND20)　Area: 1,000 m²
Weight: 7 tons　Completed: 2003

Hozomon of Sensoji Temple
Surface: Alumina blasting (AD03, AD06)
Area: 1,000 m²　Weight: 8 tons　Completed: 2007

● Awarded the Fiscal 2006 Otani Art Museum Award

"Titanium stepped Japanese tile roof and ridge-end tiles"

Focus: TTX/TTXH Application technology to enable various usages

Reduction of color-tone from one lot to another

We have provided materials for a number of major properties. In the process, we have amassed the know-how in control technologies to make products in a sufficient quantity to extensively cover a large area, with the least possible variations in color tones between lots (coils).
In addition, we are also able to provide roofing and exterior-execution companies with information required for lot control.

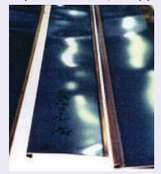
* Lot control
Base metal (uncoated) for use as a building material may often come in delicately varied color tones between manufacturing lots. Titanium is no exception. In order to prevent impairment of the class of the whole building by such an element, it is a common practice to use coils (panels) in the order of approximation and gradation in color to make color variations inconspicuous.

A wealth of application technology

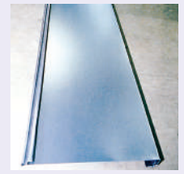
Distortion of the material after rolling is small,
and the design performance as a roof is maintained.

- Sometimes during rolling, pocket waves occur on titanium. We have developed technology to reduce this phenomenon.
- We have succeeded in significantly reducing pocket waves by carrying out the following subsequent to vacuum annealing.
  (1) Performing skin pass rolling by using dull rolling.
  (2) Applying waves in advance to the edges of the titanium sheet.

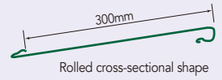
Shape after rolling (stepped roofing)



No edge waves⇨Rolling

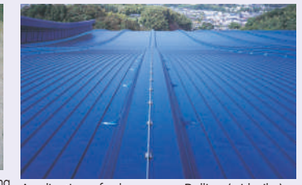


Application of edge waves⇨Rolling



Rolled cross-sectional shape

Kyushu National Museum
(Constructed by Sanko Metal Industrial Co., Ltd.)



Application of edge waves　Rolling (with ribs)
Seam welding

Shape after installation
(welding method)

Cleaning method (reference)

① **Removing adhesive remaining on the protective film**
Wipe off adhesive using a sponge or cloth moistened with alcohol, benzene or thinners, or a mixed solution consisting of alcohol and toluene or acetone (in sequence from the weakest acting liquid). It is important to wipe the surface of the titanium with an unused, clean cloth before these solvents have dried.

② **Removing contamination due to finger marks or dirt from the hands**
In almost all cases, you can remove contamination using a neutral detergent or soapy water. If you are unable to do so, use an organic solvent (alcohol, benzene, etc.). In this case, you must observe the abovementioned precautions.

③ **Removing contamination due to roofing material and concrete**
Wipe away contamination using a sponge or cloth moistened with a 5% solution of hydrochloric acid in water.

④ **Removing contamination due to zinc from scaffolding material**
Wipe away contamination using a sponge or cloth moistened with a 15% solution of nitric acid in water.

⑤ **Removing contamination due to rainwater or dust**
In almost all cases, you can wipe away contamination using a sponge or cloth moistened with a neutral detergent or an alkaline detergent. If you are unable to do so, you may be able to remove the contamination by applying a cleaner containing an abrasive to a soft cloth, and then rubbing gently and uniformly.
The above is a description of the various cleaning methods. In all cases, thoroughly wash the surface with water after cleaning, and ensure that no traces of cleaning agent remain.

⑥ **Removing contamination from colored titanium**
Of the abovementioned cleaning methods, do not remove contamination using hydrochloric acid, nitric acid or a cleanser, because the film that produces the color will be affected, preventing the surface from being restored to its original condition.

Precautions for cleaning (reference)

① There are various causes and states of contamination and discoloration of designing titanium, so it is necessary to use a cleaning method that matches the particular circumstances. Do not abruptly start cleaning the entire surface. First carry out test cleaning on a small area, and check the removal of the contamination or discoloration. If the result of the test is satisfactory, use that method to clean the entire surface.

② When using a cleaning implement such as a cloth, sponge, loofah, scrubbing brush, cleaning brush or fine nylon pad, be sure to move it in the direction parallel to the polishing marks on the titanium. Also, move your hand in such a way as to apply a uniform force as far as possible. If you move the cleaning implement in circles, the contamination will be difficult to remove, and also the luster lines will be erased and color irregularity will occur, marring the appearance of the titanium surface.

③ Even in the case of fairly stubborn contamination, avoid using a coarse polishing agent, sandpaper, steel wool or the like. Not only will this erase the luster lines on the titanium, but the surface will become scratched, which may cause it to become contaminated.

④ When using a commercially available cleaning reagent to remove contamination from the surface of titanium, clean not only the contaminated part but also the vicinity as well. If you clean the titanium surface only partially, irregular color will occur, marring the appearance of the titanium.

⑤ When cleaning building tiles, marble or aluminum, if the cleaning reagent that you used splashes on the surface of the titanium, be sure to wipe away the reagent with a damp cloth. If you leave the reagent on the titanium, discoloration may occur.

⑥ In the case of colored titanium, consult with the manufacturer prior to cleaning.

(Source: Japan Titanium Society)

<Portfolio 2> **Special Finishing** HYPERBETA & IPGOLD TITANIUM

©Maison Edouard François and ©Pierre L'Excellent

M6B2 Tower of Biodiversity
Location: Paris, France
Designed by: Edouard François
Completed: 2016
Product: Hyperbeta™ (green coloring)
Product thickness: 0.4 mm

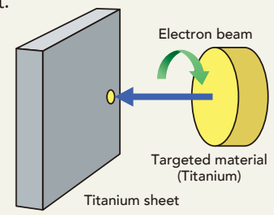
Ryuou Shrine
Genre: Shrine, Buddhist temple, religion-related
Usage: Roofing
Surface finish: ND20
Color: Gold
Material standard: IPGOLDTITANIUM

Focus: IP GOLD TITANIUM Application technology to enable various usages

Color [Beauty of color] Coloring: Ion plating

Ion plating

Ion plating is technology to firmly coat a titanium surface with a titanium nitride compound, which is nearly as bright as real gold, by ionization and charging to add electric suction force.
The coated titanium nitride has satisfactory atomic stability as well as weather resistance and corrosion resistance from the base metal that are equivalent or superior to those of conventional titanium colored in gold. Further, it will not come off when bent.



<Portfolio 3> **Formability Type/Super-FormabilityType TTXF TTXS**

[Application example 1]
Snow Peak Inc.
Snow Peak's titanium products use Tran Tixxii Titanium /Formability Type(TTXF) which is optimized for press forming in order to achieve both their Luxuryous Product Design & Product's Functionality (The lightness and heat/cold retention required for outdoor)

Single mug · Double mug

Aurora Bottle (Water Bottle)

[Application example 2]
Fujifilm Corporation [FUJIFILM X-Pro3]
TranTixxii Titanium /Formability Type(TTXF) is used for the top cover and base plate parts of X-Pro3's body exterior, which require advanced aperture and overhang processing techniques. TTXF contributes to the realization of intricate designs with attention to detail while maintaining high strength.

Focus: TranTixxii-TTXF/TTXS

TranTixxi-TTXF/TTXS contributes to the realization of products with highly processed shapes and designs in the field of consumer products, such as outdoor goods (containers, etc.) and housings for electronic devices (PCs, digital cameras).
Titanium is often referred to as a difficult-to-machine material. The crystal structure of titanium (tight-lattice hexagonal crystal) is characterized by anisotropy, a low Young's modulus, and large springback, so there have been problems with partial cracking and shape adjustment in press working.
TranTixxii-TTXF/TTXS is a material designed to solve these difficulties by pursuing optimal machinability and lubrication during stamping.
This has enabled us to create a material that combines TranTixxii's characteristic design with excellent workability.

<Portfolio 4> For watches TTXW

Casio Computer Co., Ltd.

- Creation of a material suitable for watch surfaces
- Production in line with the customer's specifications

[Application example]
Casio Computer Co., Ltd.

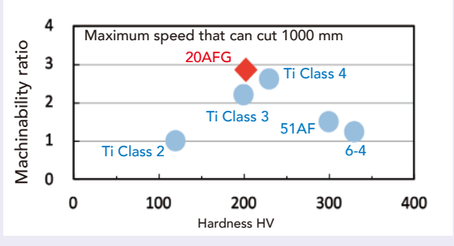
A full mirror-finish was provided for the first time to the G-SHOCK titanium model with a high mirror surface property by presenting the beauty of ion plating.

Focus: Super-TIX20AFG Realization of high strength, a surface with elegant design performance and workability

●Properties of Super-TIX20AFG

Rated item	Unit	Parameter	Super-TIX 20AFG	Pure Ti 2	SUS304	SUS316
Mirror surface property (DoI)	%	The higher the percentage, the higher the property.	○	△	○	○
Density	g/cc	The lower, the lighter.	4.47	4.51	7.93	7.98
Electrical resistivity	μΩ・cm	The higher, the more sensitive the radio waves.	95	45	72	74
Relative permeability (annealed material)	—	The closer to 1, the more sensitive the radio waves.	1.0002	1.0002	1.004	1.003
Vickers hardness	HV1.0	The higher, the harder.	203	120	170	170
Seawater corrosion resistance	—		○	○	×	△
Comprehensive rating			◎	△	△	○

●Cutting workability (drill-cutting)



Providing cutting workability superior to that of conventional materials with appropriate hardness.

●Microstructure

Providing a mirror surface property with micron level structure control.

<Portfolio 5> For automobiles TTXA heat-resistant alloy series

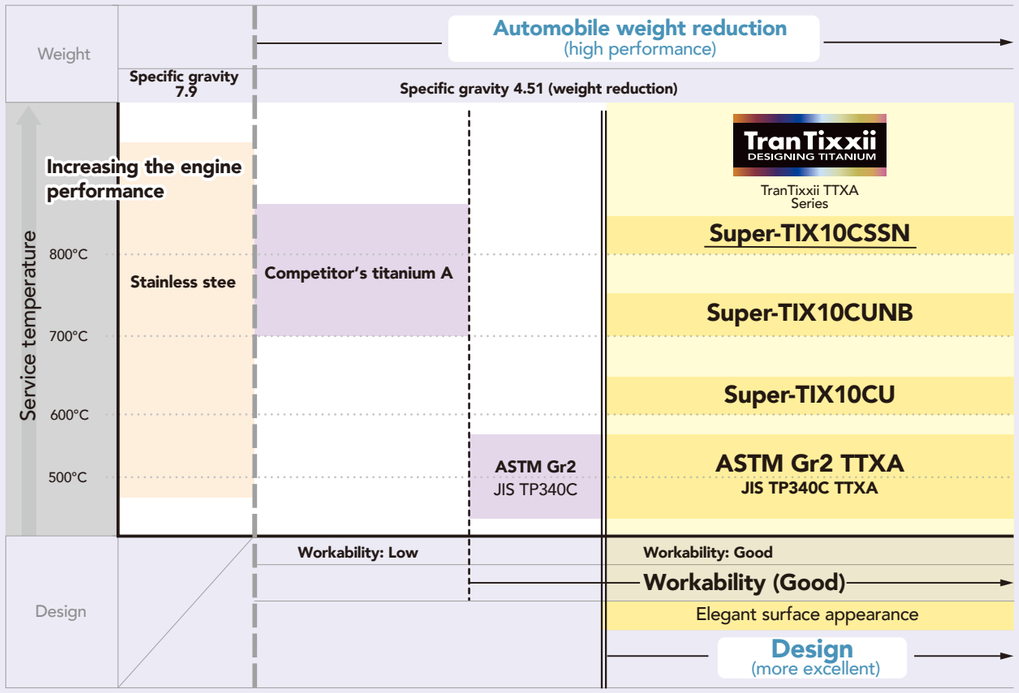
Application to the muffler of NISSAN GT-R

Application to the fuel tank of HONDA's off-road bike CRF450R (TP270C)

Focus: Provision of high performance and excellent design

Realizing both high performance and excellent design with the world's No. 1 titanium alloy

● Realizing both high performance and excellent design with the world's No. 1 titanium alloy



Seeking to attain high performance (motion performance) = **performance engine** (high-temperature resistance) × **Automobile weight reduction**

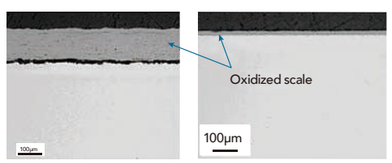
Contributing to automobile design = **Design** (workability, elegant surface appearance) **Designed and formed more freely**

High-temperature oxidation resistant properties

Our original alloy exhibits excellent properties in terms of the oxidation resistance required for exhaust system materials.

At 800°C for 100 hours
Cross-section of exposed area near the surface

High-temperature oxidation resistant properties of titanium alloy for mufflers



JIS Type 2 pure Ti　　Super-TIX10CUNB

High temperature strength

Our original Super-TIX10CU and 10CUNB demonstrate high temperature strength about 1.5 times and our Super-TIX10CSSN about 1.8 times that of pure titanium in an atmosphere of 700°C.

High temperature and fatigue resistance

Super-TIX10CU and 10CUNB demonstrate fatigue strength about twice that of pure titanium at 600 and 700° C, respectively, and our Super-TIX10CSSN about thrice that of pure titanium.

<Reference materials>

Table 1. Orders of stabilization of metals

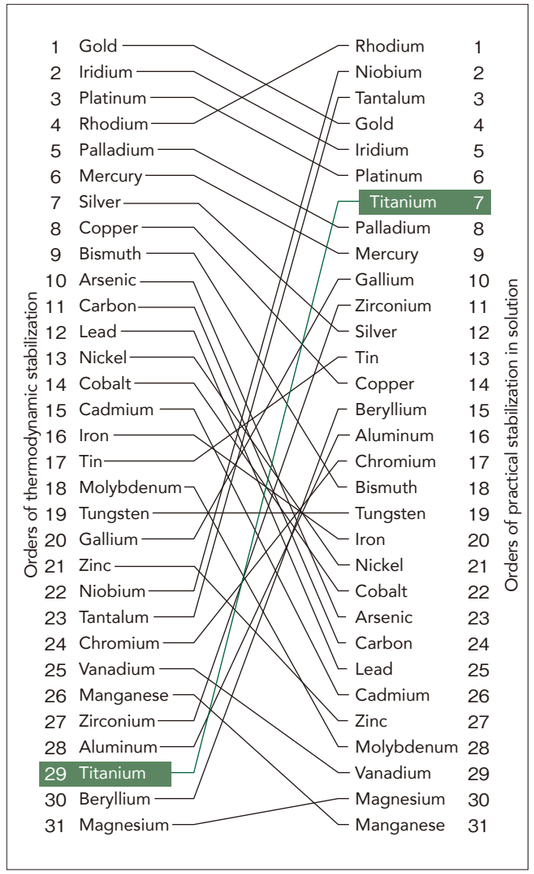
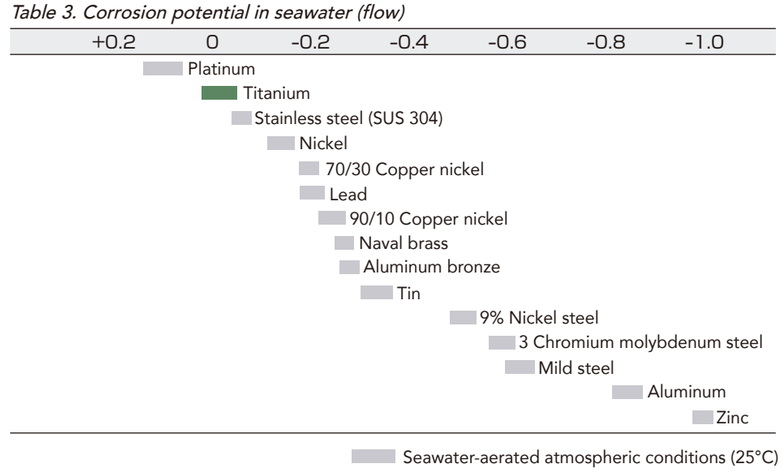


Table 2. Clarke number (Note)

Order	Element		Existing ratio (%)	Accumulated total
1	Oxygen	O	49.50	49.5
2	Silicon	Si	25.80	75.3
3	Aluminum	Al	7.56	82.9
4	Iron	Fe	4.70	87.6
5	Calcium	Ca	3.39	91.0
6	Sodium	Na	2.63	93.6
7	Potassium	K	2.40	96.0
8	Magnesium	Mg	1.93	97.9
9	Hydrogen	H	0.87	98.8
10	Titanium	Ti	0.46	99.2
11	Chlorine	Cl	0.19	99.4
12	Manganese	Mn	0.09	99.5
13	Phosphorus	P	0.08	99.6
14	Carbon	C	0.08	99.7
15	Sulfur	S	0.06	99.7
16	Nitrogen	N	0.03	99.8
17	Fluorine	F	0.03	99.8
18	Rubidium	Rb	0.03	99.8
19	Barium	Ba	0.02	99.9
20	Zirconium	Zr	0.02	
21	Chromium	Cr	0.02	
22	Strontium	Sr	0.02	
23	Vanadium	V	0.015	
24	Nickel	Ni	0.010	
25	Copper	Cu	0.010	
26	Tungsten	W	0.006	
27	Lithium	Li	0.006	
28	Cerium	Ce	0.005	
29	Cobalt	Co	0.004	
30	Tin	Sn	0.004	

(Note) Clarke number: The ratio of elements found in the upper layer of the earth's crust. Named after the American geochemist F. W. Clarke. (Source: The Chemistry Encyclopedia Kagaku Daijiten)
Titanium is the 10th most common element found in the upper layers of the earth's crust, and in terms of metals that are of practical use, it comes fourth after aluminum, iron and magnesium.

Table 3. Corrosion potential in seawater (flow)



Website information

www.nipponsteel.com/en/product/trantixxii/

Tel +81-3-6867-5635
Mail Email us from “Contact” on the website.

TranTixxii　Designing titanium

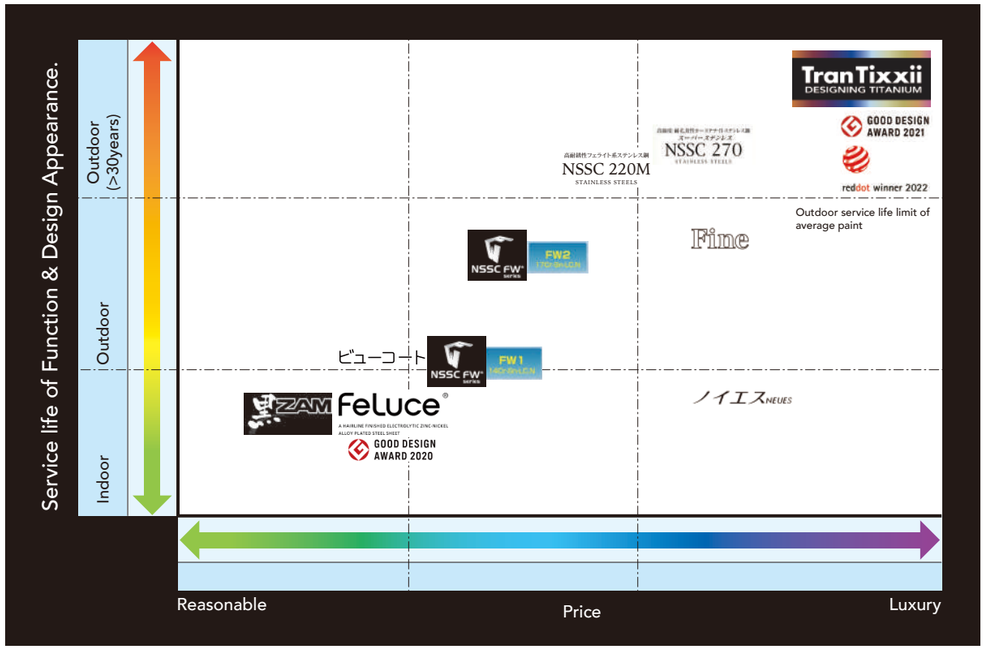
Customer registration & requests for information materials

www.nipponsteel.com/en/product/trantixxii/contact

Sample Purchase

TERRADA PIGMENT LAB | TOKYO

NIPPON STEEL GROUP/Brands for Design Use



[Vertical]Service life × [Horizontal]Price

Brands for Design Use/URL

Titanium	TranTixxii DESIGNING TITANIUM	**Titanium Nippon Steel Designing Titanium TranTixxii** https://www.nipponsteel.com/product/trantixxii/	
Stainless Steel	Fine	**NS Stainless Steel Art Corp Fine-Color** https://www.ms-art.co.jp/products/fine-color/	
Stainless Steel	ノイエス NEUES	**NS Stainless Steel Art Corp Neues** https://www.ms-art.co.jp/products/neues/	
Stainless Steel	NSSC 270 STAINLESS STEELS	**NS Stainless Steel Corp NSSC270** (PDF) https://stainless.nipponsteel.com/assets/pdf/product/grade/nssc_series/austenite/PJ004.pdf	
Stainless Steel	NSSC 220M STAINLESS STEELS	**NS Stainless Steel Corp NSSC220M** (PDF) https://stainless.nipponsteel.com/assets/pdf/product/grade/nssc_series/ferrite/SJ001_SPEC22.pdf	
Stainless Steel	NSSC FW	**NS Stainless Steel Corp FW Series** https://stainless.nipponsteel.com/campaigns/fw/	
Steel	ビューコート®	**【Painted Steel】Nippon Steel VIEWKOTE** https://www.nipponsteel.com/product/sheet/list/14.html	
Steel	ZAM	**【Galvanized Steel】Nippon Steel BLACK-ZAM** https://www-zam.nipponsteel.com/about/cromfree/ZBK/	
Steel	FeLuce®	**【Electro-Galvanized Steel】Nippon Steel FeLuce** https://www.nipponsteel.com/product/feluce/	