Titanium, an element found in 1790, was named after the Titans, earth giants in ancient Greek mythology.

Its industrial production began in around 1946. 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 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 (Spain) attracted the attention of many modern architects and spread to many countries. Demand for titanium building materials is expected to further grow in the future.
1. Basic characteristics of titanium building materials

1. Unparalleled corrosion resistance

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

(1) Seawater corrosion resistance is comparable to that of stainless steel, suited to application in coastal areas.

(2) Excellent corrosion resistance to corrosive gases (sulfuric 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 environmental pollution as acid rain.

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

(4) Corrosion due to contact with different metals (Refer to “Corrosion potential in sea water” on page 21). 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.

2. Great strength

Titanium is almost as strong as steel, and it is the strongest of all metals for its mass or the strongest in terms of specific gravity. For application as a building material, JIS Type 1 — which is highly workable — is mainly used.

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. Minimum thermal expansion

Titanium’s coefficient of thermal expansion is half that of stainless steel and copper and one third 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.

5. Excellent aesthetic qualities

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.

6. Environmentally sound

Titanium is an innocuous metal. Only slight dissolution of metal ions makes titanium a very friendly metal to humans and the environment.

7. Others

Among the other major properties titanium offers are:

- Small Young’s modulus (elastic modulus).
- Small thermal conductivity.
- A high melting point.
- Non-magnetism.

---

Table 1. Comparison of weather resistance between various metals

<table>
<thead>
<tr>
<th>Environment</th>
<th>Stainless steel SUS 304</th>
<th>Stainless steel SUS 316</th>
<th>Copper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea water</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Ultraviolet ray resistance</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Acid rain resistance</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Acid rain resistance (pitting)</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Contact corrosion resistance</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Corrosion fluidity resistance</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Thermal resistance</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Erosion resistance</td>
<td></td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>

Table 2. Comparison of chemical resistance between various metals

<table>
<thead>
<tr>
<th>Chemical composition</th>
<th>Stainless steel SUS 304</th>
<th>Stainless steel SUS 316</th>
<th>Copper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea water</td>
<td>X</td>
<td>X</td>
<td>0</td>
</tr>
<tr>
<td>Hydrochloric acid</td>
<td>X</td>
<td>X</td>
<td>0</td>
</tr>
<tr>
<td>Sulfuric acid</td>
<td>X</td>
<td>X</td>
<td>0</td>
</tr>
<tr>
<td>Nitric acid</td>
<td>X</td>
<td>X</td>
<td>0</td>
</tr>
<tr>
<td>Acetic acid</td>
<td>X</td>
<td>X</td>
<td>0</td>
</tr>
<tr>
<td>Chlorine acid</td>
<td>X</td>
<td>X</td>
<td>0</td>
</tr>
<tr>
<td>Sulfuric acid gas</td>
<td>X</td>
<td>X</td>
<td>0</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>H</th>
<th>O</th>
<th>N</th>
<th>Fe</th>
<th>C</th>
<th>Ti</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.013</td>
</tr>
<tr>
<td>0.013</td>
<td>0.03</td>
<td>0.30</td>
<td>0.20</td>
<td>0.08</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Item</th>
<th>Metal</th>
<th>Titanium</th>
<th>Stainless steel SUS 304</th>
<th>Stainless steel SUS 316</th>
<th>Iron</th>
<th>Copper</th>
<th>Aluminum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melting point</td>
<td>°C</td>
<td>1,668</td>
<td>1,398~1,453</td>
<td>1,375~1,397</td>
<td>1,530</td>
<td>1,083</td>
<td>660</td>
</tr>
<tr>
<td>Specific gravity</td>
<td></td>
<td>4.51</td>
<td>7.93</td>
<td>8.0</td>
<td>7.9</td>
<td>8.9</td>
<td>2.7</td>
</tr>
<tr>
<td>Thermal expansion coefficient</td>
<td></td>
<td>8.4</td>
<td>17.3</td>
<td>16.0</td>
<td>12.0</td>
<td>17.0</td>
<td>23.0</td>
</tr>
<tr>
<td>Thermal conductivity</td>
<td>cal/cm/sec/°C/cm</td>
<td>0.041</td>
<td>0.039</td>
<td>0.039</td>
<td>0.150</td>
<td>0.920</td>
<td>0.490</td>
</tr>
<tr>
<td>Electric resistance</td>
<td>μΩ·cm</td>
<td>47</td>
<td>72</td>
<td>74</td>
<td>9.7</td>
<td>1.7</td>
<td>2.7</td>
</tr>
<tr>
<td>Young’s modulus</td>
<td>Kg/mm²</td>
<td>10,860</td>
<td>19,300</td>
<td>19,300</td>
<td>21,000</td>
<td>11,000</td>
<td>7,000</td>
</tr>
</tbody>
</table>

Titanium is officially approved as a non-combustible material. (Minister of Land, Infrastructure and Transport Certification No. “NM-8596)”
1. Basic characteristics of titanium building materials

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 material for service in these areas. As a typical example of corrosion 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⁻             | SO₄²⁻            |
| Springhead       | 52.5             | 1.30             | 738.6           | 5,070            |
| Public Bath      | 46.7             | 1.35             | 845.3           | 5,460            |

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

(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 the fact 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 decocation 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, Nantaya and Yakuoin 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].

(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.

9. Workability

(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, etc., 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.

NIPPON STEEL holds titanium welding training courses periodically to provide appropriate guidance on welding technology.

10. Execution and applications

Most of the execution methods for exterior materials (roofing and walling) of conventional metals can likewise be applied to titanium.

11. Economics

Titanium, when used as a roofing and exterior material, may seem rather expensive in initial cost on a base-metal basis in comparison with other materials. But, the elimination of re-painting, re-roofing and other such needs brings running costs steeply down to an extremely low level. Over a long span of 20 to 30 or more years, titanium will come out as a winner in terms of life-cycle cost.

This advantage becomes even more marked in highly corrosive environments such as coastal, industrial and urban areas.

A sample construction cost comparison between titanium and pre-painted stainless steel

<table>
<thead>
<tr>
<th>Material</th>
<th>Fabrication cost</th>
<th>Execution cost</th>
<th>Maintenance cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Titanium</td>
<td>At the time of completion</td>
<td>Fist repair</td>
<td>Second repair</td>
</tr>
<tr>
<td>Fluorocarbon resin paint-coated stainless steel</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Range of availability of our products (Cold rolled sheets)

*Please feel free to contract us to discuss manufacturing to order outside of the values and specifications stated above.
NIPPOON STEEL has an extensive menu of titanium materials consisting of various combinations of three kinds of surface finish and several tens of colors which are suitable for applications ranging from modern buildings to traditional Japanese buildings and also monuments.

**2–1. An extensive product menu (Surface finish)**

Alumina blasting finish
Alumina powder is blasted directly onto the titanium.

- Alumina blasting finish (AD03, AD06, AD09)

Roll dull finish
After vacuum annealing (VAF), titanium materials are dull-finished on a skin-pass mill.

- Roll dull finish (ND10, ND20, SD3)

- Pickling dull finish (VP20)

Pickling dull finish
A dull-finish is given by pickling and skin passing.

- Pickling dull finish

Coloring
Anodic oxidation

**Alumina blasted titanium**, which is aimed at creating the appearance of smoked tiles, is used on traditional Japanese buildings, particularly temples and shrines.

**NIPPON STEEL**

- Pat. No. 3688762, No. 3408726, No. 3397377, No. 3177816, No. 5435257, and No. 3655432

**Pat. No. 3688762, No. 3408726, No. 3397377, No. 3177816, No. 5435257, and No. 3655432**

**Spherical observation deck at Fuji Television’s headquarters**
Surface: Roll dull (ND10)
Area: 2,800 m²
Weight: 14 tons
Completed: 1996

**Hotel Lakeside International & Convention Center**
Surface: Roll dull (ND20)
Area: 12,000 m²
Weight: 21 tons
Completed: 2011

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

**Shimane Art Museum**
Surface: Pickling dull (VP20)
Area: 10,000 m²
Weight: 60 tons
Completed: 1998

**Showa Hall**
Surface: Alumina blasting (AD09)
Area: 4,200 m²
Weight: 56 tons
Completed: 1998

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

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

**When titanium is pickled, it appears whitish. This is a representative example which shows that color-tone from one lot to another over a large area can be reduced.**

**Alumina powder** is blasted directly onto the titanium.

**Roll dull finish**
Roll dull, which is our main product, is used on a great many buildings.

**Please contact us if you would like to request acid pickling with a dull finish.**
2-2. An extensive product menu (Surface finish)

**A Roll dull + color finish**

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

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

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

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

- **Ryukotokuji Temple**
  - Surface: Alumina Blasting (AD09), Verdigris coloring
  - Area: 2,500 m²
  - Weight: 5.9 tons
  - Completed: 2009

**B Alumina blasting + color finish**

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

**Colored titanium**

**Coloring of titanium**

We have constructed a quality control setup that enables us to stably provide colored titanium construction material.
- Uniform color
- Technology for ensuring adhesion of the film
- Development of new products
- Development of color forming protective film, and so on

**Principal of coloring of titanium**

**Coloring (Anodic oxidation)**

When a thin oxide film (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 coloring of titanium**

**Coloring of titanium**

When using colored titanium, please understand the following points.

1. The oxide film 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 film 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.

   For this reason, in addition to checking the color using color samples, we 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 film may grow depending upon the weather atmospheric conditions, causing the color to change.

   With our titanium products, there have been cases in which the oxide film grew, causing the color to change from yellow (1) whose film thickness is thin, to purple over a period of about 10 years. The main factors contributing to this phenomenon are the extreme thinness and the narrow range of the oxide film required to produce the initial yellow color.

   For a customer who wants yellow, we recommend yellow (2) because the oxide film needed to develop the color is relatively thicker and the oxide film range of that color is comparatively less narrow. Customers should note, however, that the color of any colored titanium may change gradually with time depending upon the environmental conditions.

   The hue changes in the sequence gray, yellow, purple, olive green, yellow, purple, and green, as the thickness of the oxide film increases.

4. Titanium becomes dirty like other metals. Finger marks get on it. Depending upon the type of contamination, the titanium surface may appear blackened, but the contamination can be removed with detergent. Note, however, that if the contamination is allowed to remain, it may become difficult to remove.

   We recommend that you use a neutral detergent or our recommended detergent to clean titanium. If you use a detergent that contains a strong acid, the oxide film on the surface may dissolve, preventing the original color from being restored. (See Page 15.)

**Relationship between film thickness and interference color (Theoretically calculated values)**

- **Film thickness (μm)**
  - 0
  - 0.05
  - 0.1
  - 0.15

- **Interference color**
  - Green
  - Purple
  - Yellow
  - Olive green
  - Blue

**When a thin oxide film (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 coloring of titanium**

When using colored titanium, please understand the following points.

1. The oxide film 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 film 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.

   For this reason, in addition to checking the color using color samples, we 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 film may grow depending upon the weather atmospheric conditions, causing the color to change.

   With our titanium products, there have been cases in which the oxide film grew, causing the color to change from yellow (1) whose film thickness is thin, to purple over a period of about 10 years. The main factors contributing to this phenomenon are the extreme thinness and the narrow range of the oxide film required to produce the initial yellow color.

   For a customer who wants yellow, we recommend yellow (2) because the oxide film needed to develop the color is relatively thicker and the oxide film range of that color is comparatively less narrow. Customers should note, however, that the color of any colored titanium may change gradually with time depending upon the environmental conditions.

   The hue changes in the sequence gray, yellow, purple, olive green, yellow, purple, and green, as the thickness of the oxide film increases.

4. Titanium becomes dirty like other metals. Finger marks get on it. Depending upon the type of contamination, the titanium surface may appear blackened, but the contamination can be removed with detergent. Note, however, that if the contamination is allowed to remain, it may become difficult to remove.

   We recommend that you use a neutral detergent or our recommended detergent to clean titanium. If you use a detergent that contains a strong acid, the oxide film on the surface may dissolve, preventing the original color from being restored. (See Page 15.)
3-1. Development of titanium that does not readily become discolored

We developed titanium for building use that does not readily become discolored, and at present we use it for all building material products (surface finishes) including colored materials. As a result of exposing titanium for four years in Okinawa, only a very small amount of discoloration occurred in titanium for building use that does not readily become discolored.

Exposure test for titanium building material that does not readily become discolored

- The pH value of acid rain in Okinawa is roughly the mean value (pH 4.8, in 2003), but because of the high temperature and humidity this is one of the regions in the Japan where discoloration occurs most rapidly.
- The mean pH value of acid rain throughout Japan is pH 4.7, (2003 data). Notes: pH 5.6 or less is acid rain; Neutral is 7.0.

We established an accelerated test method that reproduced the discoloration.

Application to coloring of titanium for building use that does not readily become discolored

- The graph below shows the results of exposure of titanium of the color corresponding to a thin film at which the discoloration occurs most easily (gold or yellow), in Okinawa. Even after three years’ exposure, the change in color difference of the material, which does not readily become discolored, is very small.
- The Zamami Pier (made of material that does not readily become discolored) retains its gold color two and a half years after it was constructed in Okinawa.

Points to note concerning titanium building material that does not readily become discolored

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

Change in color difference of gold colored titanium in Okinawa in the case where conventional material and also material that does not readily become discolored are used as base materials

When titanium for building use that does not readily become discolored is colored, the discoloration resistance improves remarkably.

Application to coloring of titanium for building use that does not readily become discolored

- The graph below shows the results of exposure of titanium of the color corresponding to a thin film at which the discoloration occurs most easily (gold or yellow), in Okinawa. Even after three years’ exposure, the change in color difference of the material, which does not readily become discolored, is very small.
- The Zamami Pier (made of material that does not readily become discolored) retains its gold color two and a half years after it was constructed in Okinawa.
3-2. Development of titanium that does not readily become discolored

Discoloration phenomenon
At the beginning of the 1990s, some of the titanium roofs that had been installed prior to that time changed color from silver to brown. The surface of titanium has a chemically stable oxide film (passive film). The protective action of this film provides excellent resistance to corrosion. If the oxide film on the surface of the titanium (thickness approx. 0.01 μm) grows to between 0.03 and 0.05 μm, the original silver surface will appear brown as a result of interference light. This phenomenon is called discoloration of titanium. It does not adversely affect the corrosion resistance.

Mechanism of discoloration
As a result of investigating the discolored areas, a minute amount of carbide and fluorides was found remaining in the oxide film and on the surface of the titanium base metal. Various tests were carried out, and as a result it was found that these substances react with acid rain, causing the film to grow. The higher the atmospheric temperature, the more pronounced is this trend.

Mechanism of discoloration of titanium (pattern diagram)

Examples of discoloration
(The test piece is conventional vacuum-annealed material (VA).)

Before exposure to atmosphere

After 7 years’ exposure in Oita City

Development of titanium building materials that does not readily become discolored
It is known that carbon, the cause of discoloration, which is included in rolling mill lubricant used for cold rolling during the manufacture of titanium, remains on the surface of titanium, and also fluorides, which are included in the acid solution used for pickling subsequent to cold rolling, remain on the surface of titanium. Accordingly, we established manufacturing technology to remove most of the carbon and fluorides from the surface of the titanium.

Method of manufacturing titanium cold-rolled sheets
(Points concerning the improvement of resistance to discoloration)

In order to evaluate the performance with respect to the discoloration of the manufactured titanium, an exposure test was carried out in Okinawa and also a discoloration accelerated test method based on the mechanism of discoloration was developed. As a result, the effectiveness of this method of manufacturing titanium was verified. (See Page 10.)

4. 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. 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.
5. A wealth of application technology

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

Development of a material that has little distortion during forming

● 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

We have succeeded in significantly reducing pocket waves by carrying out the following subsequent to vacuum annealing. Sometimes during rolling, pocket waves occur on titanium. We have developed technology to reduce this phenomenon. By performing skin pass rolling by using dull rolling, and applying waves in advance to the edges of the titanium sheet, we have succeeded in significantly reducing pocket waves.

Performing skin pass rolling by using dull rolling.

(regrowth of the oxide film)

Discolored area

Cleaning

Example of cleaning

If there are places in the roof and other areas where rainwater is liable to form pools, titanium becomes contaminated like any other metal. Contamination, if left unattended, may sometimes become hard to remove. Contamination due to drips of caulk material also becomes hard to remove with time. It is recommended that all these points be taken into consideration in the early design stages.

Contamination, if left unattended, may sometimes become hard to remove. Contamination due to drips of caulk material also becomes hard to remove with time. It is recommended that all these points be taken into consideration in the early design stages.

Cleaning method

① Removing adhesive remaining on the protective film
Wipe off adhesive using a sponge or cloth moistened with alcohol, benzene, or thinner, or a mixed solution consisting of alcohol and toluene or benzene. In sequence from the weakest acting liquid. It is important to view 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 soap. Water. If you are unable to do so, use an organic solvent (alcohol, benzene, etc.) In this case, you must observe the aforementioned 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.

Precautions for cleaning

① There are various causes of contamination and discoloration of titanium building material, 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, the nylon, and so on, 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, marred the appearance of the titanium.

③ Even in the case of only 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 also 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, marred the appearance of the titanium.

⑤ When cleaning building tiles, marble, aluminum, and so on, 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 use.

(Source: Japan Titanium Society)
Examples of use of titanium for building applications

Roll dull (ND20) was used in the T.C.M. (Titanium Composite Material) of Mitsubishi Chemical.

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

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

The Taipei Arena is the first instance of full-fledged use of titanium in Taiwan.

Taipei Arena (Taiwan)
- Surface: Roll dull (ND20)
- Area: 20,000 m²
- Weight: 50 tons
- Completed: 2005

We offer particularly lustrous colored products for Frank O. Gehry’s projects.

Hotel Marques de Riscal (Spain)
- Surface: Roll dull (SD3)
- Area: 2,400 m²
- Weight: 12 tons
- Completed: 2004
Examples of use of titanium for building applications

The Kyushu Oil Dome is the first example of the use of titanium that does not readily become discolored. Roll dull (ND20) was used.

<table>
<thead>
<tr>
<th>Location</th>
<th>Surface</th>
<th>Area</th>
<th>Weight</th>
<th>Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kyushu Oil Dome</td>
<td>Roll dull (ND20)</td>
<td>32,000 m²</td>
<td>80 tons</td>
<td>2001</td>
</tr>
</tbody>
</table>

JR Hakodate Station is the first structure where titanium building materials were adopted for exterior panels on a full scale, as a result of their feature of being resistant to changes in color.

<table>
<thead>
<tr>
<th>Location</th>
<th>Surface</th>
<th>Area</th>
<th>Weight</th>
<th>Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>JR Hakodate Station</td>
<td>Roll dull (ND20)</td>
<td>1,000 m²</td>
<td>7 tons</td>
<td>2003</td>
</tr>
</tbody>
</table>

The teahouse of the Kinkakuji Temple, which is a World Heritage site, uses alumina blasting.

<table>
<thead>
<tr>
<th>Location</th>
<th>Surface</th>
<th>Area</th>
<th>Weight</th>
<th>Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teahouse (Josokutei)</td>
<td>Alumina blasting (AD03)</td>
<td>100 m²</td>
<td>0.5 tons</td>
<td>2003</td>
</tr>
</tbody>
</table>

The roof of the Hozomon of Sensoji Temple was the first instance of using titanium Japanese tiles. Also, our highly workable material, Super-Pure Flex, has been used for the ridge-end tiles.

<table>
<thead>
<tr>
<th>Location</th>
<th>Surface</th>
<th>Area</th>
<th>Weight</th>
<th>Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hozomon of Sensoji Temple</td>
<td>Alumina blasting (AD03, AD06)</td>
<td>1,000 m²</td>
<td>8 tons</td>
<td>2007</td>
</tr>
</tbody>
</table>

- Awarded the Fiscal 2006 Otani Art Museum Award
- "Titanium stepped Japanese tile roof and ridge-end tiles"
Examples of use of titanium for building applications

Titanium roofing with an alumina blasting finish adopted for the teahouse of the Raku Kichizaemon-Kan, newly opened on the premises of the “Sagawa Art Museum” in Moriyama City, Shiga Prefecture.

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

Gold titanium used in the construction of the roof of the Miyajidake Shrine.

Miyajidake Shrine
Surface: Roll Dull (ND20), Gold coloring
Area: 220 m²
Completed: 2010

Reference materials

Table 1. Orders of stabilization of metals

<table>
<thead>
<tr>
<th>Order</th>
<th>Element</th>
<th>Existing ratio (%)</th>
<th>Accumulated total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Oxygen</td>
<td>49.50</td>
<td>49.5</td>
</tr>
<tr>
<td>2</td>
<td>Silicon</td>
<td>26.80</td>
<td>76.3</td>
</tr>
<tr>
<td>3</td>
<td>Aluminum</td>
<td>7.56</td>
<td>83.8</td>
</tr>
<tr>
<td>4</td>
<td>Phosphorus</td>
<td>0.08</td>
<td>91.6</td>
</tr>
<tr>
<td>5</td>
<td>Sulfur</td>
<td>0.06</td>
<td>97.7</td>
</tr>
<tr>
<td>6</td>
<td>Nitrogen</td>
<td>0.03</td>
<td>98.8</td>
</tr>
<tr>
<td>7</td>
<td>Fluorine</td>
<td>0.03</td>
<td>99.0</td>
</tr>
<tr>
<td>8</td>
<td>Rubidium</td>
<td>0.03</td>
<td>99.3</td>
</tr>
<tr>
<td>9</td>
<td>Barium</td>
<td>0.02</td>
<td>99.5</td>
</tr>
<tr>
<td>10</td>
<td>Zirconium</td>
<td>0.02</td>
<td>99.7</td>
</tr>
<tr>
<td>11</td>
<td>Chromium</td>
<td>0.19</td>
<td>99.9</td>
</tr>
<tr>
<td>12</td>
<td>Nickel</td>
<td>0.09</td>
<td>99.9</td>
</tr>
<tr>
<td>13</td>
<td>Phosphorus</td>
<td>0.08</td>
<td>99.9</td>
</tr>
<tr>
<td>14</td>
<td>Carbon</td>
<td>0.08</td>
<td>99.7</td>
</tr>
<tr>
<td>15</td>
<td>Sulfur</td>
<td>0.06</td>
<td>97.7</td>
</tr>
<tr>
<td>16</td>
<td>Nitrogen</td>
<td>0.03</td>
<td>98.8</td>
</tr>
<tr>
<td>17</td>
<td>Fluorine</td>
<td>0.03</td>
<td>99.0</td>
</tr>
<tr>
<td>18</td>
<td>Rubidium</td>
<td>0.03</td>
<td>99.3</td>
</tr>
<tr>
<td>19</td>
<td>Barium</td>
<td>0.02</td>
<td>99.5</td>
</tr>
<tr>
<td>20</td>
<td>Zirconium</td>
<td>0.02</td>
<td>99.7</td>
</tr>
<tr>
<td>21</td>
<td>Chromium</td>
<td>0.19</td>
<td>99.9</td>
</tr>
<tr>
<td>22</td>
<td>Strontium</td>
<td>0.02</td>
<td>99.9</td>
</tr>
<tr>
<td>23</td>
<td>Vanadium</td>
<td>0.015</td>
<td>99.9</td>
</tr>
<tr>
<td>24</td>
<td>Nickel</td>
<td>0.010</td>
<td>99.9</td>
</tr>
<tr>
<td>25</td>
<td>Copper</td>
<td>0.010</td>
<td>99.9</td>
</tr>
<tr>
<td>26</td>
<td>Tungsten</td>
<td>0.006</td>
<td>99.9</td>
</tr>
<tr>
<td>27</td>
<td>Lithium</td>
<td>0.006</td>
<td>99.9</td>
</tr>
<tr>
<td>28</td>
<td>Cerium</td>
<td>0.005</td>
<td>99.9</td>
</tr>
<tr>
<td>29</td>
<td>Cobalt</td>
<td>0.004</td>
<td>99.9</td>
</tr>
<tr>
<td>30</td>
<td>Tin</td>
<td>0.004</td>
<td>99.9</td>
</tr>
</tbody>
</table>

Table 2. Clarke number (%w/w)

<table>
<thead>
<tr>
<th>Order</th>
<th>Element</th>
<th>Existing ratio (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Oxygen</td>
<td>49.50</td>
</tr>
<tr>
<td>2</td>
<td>Silicon</td>
<td>26.80</td>
</tr>
<tr>
<td>3</td>
<td>Aluminum</td>
<td>7.56</td>
</tr>
<tr>
<td>4</td>
<td>Phosphorus</td>
<td>0.08</td>
</tr>
<tr>
<td>5</td>
<td>Sulfur</td>
<td>0.06</td>
</tr>
<tr>
<td>6</td>
<td>Nitrogen</td>
<td>0.03</td>
</tr>
<tr>
<td>7</td>
<td>Fluorine</td>
<td>0.03</td>
</tr>
<tr>
<td>8</td>
<td>Rubidium</td>
<td>0.03</td>
</tr>
<tr>
<td>9</td>
<td>Barium</td>
<td>0.02</td>
</tr>
<tr>
<td>10</td>
<td>Zirconium</td>
<td>0.02</td>
</tr>
<tr>
<td>11</td>
<td>Chromium</td>
<td>0.19</td>
</tr>
<tr>
<td>12</td>
<td>Nickel</td>
<td>0.09</td>
</tr>
<tr>
<td>13</td>
<td>Phosphorus</td>
<td>0.08</td>
</tr>
<tr>
<td>14</td>
<td>Carbon</td>
<td>0.08</td>
</tr>
<tr>
<td>15</td>
<td>Sulfur</td>
<td>0.06</td>
</tr>
<tr>
<td>16</td>
<td>Nitrogen</td>
<td>0.03</td>
</tr>
<tr>
<td>17</td>
<td>Fluorine</td>
<td>0.03</td>
</tr>
<tr>
<td>18</td>
<td>Rubidium</td>
<td>0.03</td>
</tr>
<tr>
<td>19</td>
<td>Barium</td>
<td>0.02</td>
</tr>
<tr>
<td>20</td>
<td>Zirconium</td>
<td>0.02</td>
</tr>
<tr>
<td>21</td>
<td>Chromium</td>
<td>0.19</td>
</tr>
<tr>
<td>22</td>
<td>Strontium</td>
<td>0.02</td>
</tr>
<tr>
<td>23</td>
<td>Vanadium</td>
<td>0.015</td>
</tr>
<tr>
<td>24</td>
<td>Nickel</td>
<td>0.010</td>
</tr>
<tr>
<td>25</td>
<td>Copper</td>
<td>0.010</td>
</tr>
<tr>
<td>26</td>
<td>Tungsten</td>
<td>0.006</td>
</tr>
<tr>
<td>27</td>
<td>Lithium</td>
<td>0.006</td>
</tr>
<tr>
<td>28</td>
<td>Cerium</td>
<td>0.005</td>
</tr>
<tr>
<td>29</td>
<td>Cobalt</td>
<td>0.004</td>
</tr>
<tr>
<td>30</td>
<td>Tin</td>
<td>0.004</td>
</tr>
</tbody>
</table>

Table 3. Corrosion potential in seawater (Flow)

<table>
<thead>
<tr>
<th>Metal</th>
<th>Potential (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stainless steel (SUS 304)</td>
<td>+0.2</td>
</tr>
<tr>
<td>Nickel</td>
<td>+0.6</td>
</tr>
<tr>
<td>70/30 Copper-Nickel</td>
<td>+0.45</td>
</tr>
<tr>
<td>Lead</td>
<td>+0.25</td>
</tr>
<tr>
<td>96/14 Copper-Nickel</td>
<td>+0.2</td>
</tr>
<tr>
<td>11% Nickel steel</td>
<td>+0.15</td>
</tr>
<tr>
<td>3 Chromium Molybdenum steel</td>
<td>+0.05</td>
</tr>
<tr>
<td>3% Nickel steel</td>
<td>+0.05</td>
</tr>
<tr>
<td>Aluminum</td>
<td>-0.2</td>
</tr>
<tr>
<td>Zinc</td>
<td>-0.35</td>
</tr>
</tbody>
</table>

Sea water-aerated atmospheric conditions (25°C)