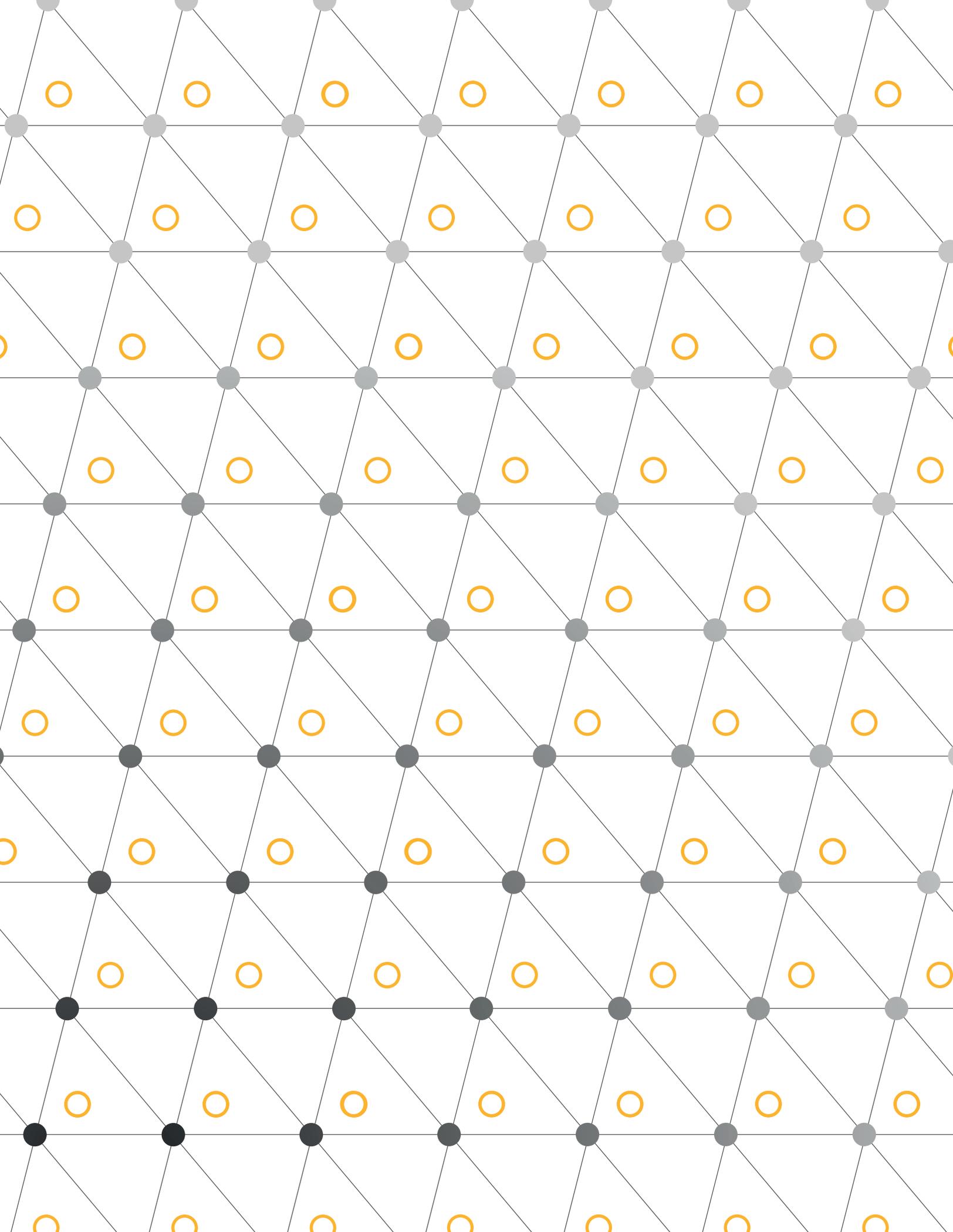


YES

**PLASMA
NITRIDING
WORKS** *for*
TITANIUM

Here's When and Why.





Yes, Plasma Nitriding Works for Titanium.

👉 Here's When and Why



LAST REVIEW: 09/02/2026

Andrés Bernal D. | José Domingo Guerra B. | María Fernanda Cadavid T.

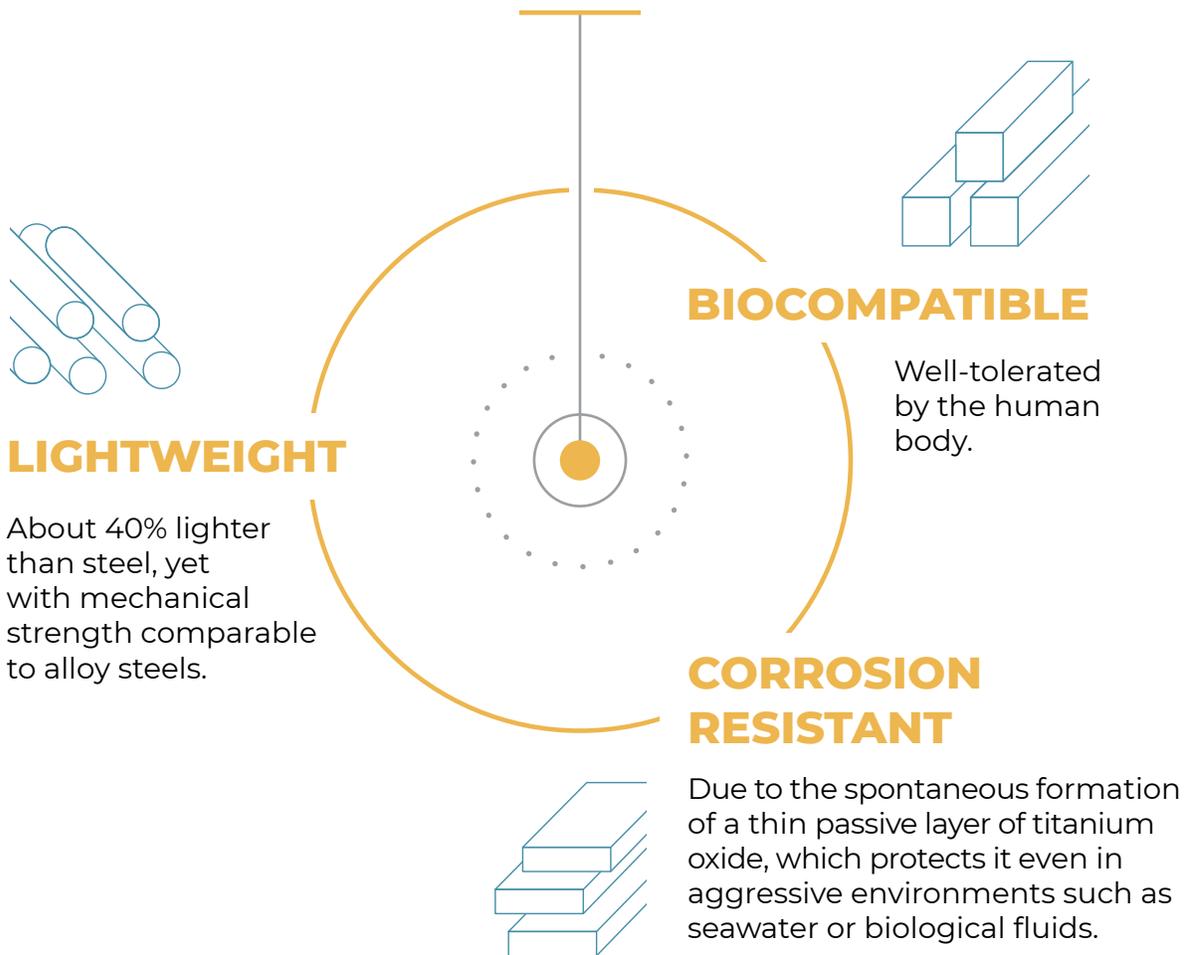
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Titanium
Yes, Plasma Nitriding Works for
Titanium. Here's When and Why.

Named after the Titans of Greek mythology, this metal has the qualities of a true warrior:



Despite its exceptional properties, titanium is **not widely used as a bulk metal** because extraction and refining are costly.

Although abundant in the Earth's crust, titanium is not found in pure form but strongly bonded to oxygen. It occurs mainly as ilmenite (FeTiO_3), which is more common, and rutile (TiO_2), which is richer in titanium. **To be industrially useful, it must be refined, purified, and alloyed.**



Titanium
Yes, Plasma Nitriding Works for
Titanium. Here's When and Why.

ALLOYS

WHY

BENEFITS

LIMITS

COMPARE

FURNACES

Plasma nitriding for titanium

OVERVIEW

LET'S START FROM THE BEGINNING



Titanium
Yes, Plasma Nitriding Works for
Titanium. Here's When and Why.



ALLOYS

CLASSI FICATION



Titanium
Yes, Plasma Nitriding Works for
Titanium. Here's When and Why.

ALLOYS

Industrial Classification Of Titanium

ALLOY TYPE	ASTM GRADE	ALLOYING ELEMENT(S)	KEY CHARACTERISTICS	LIMITATIONS	TYPICAL APPLICATIONS	HEAT TREATMENT NOTES
COMMERCIA-LLY PURE TITANIUM (α) / CP TITANIUM (α)	GRADE 2	Oxygen (plus traces of Fe, N, C)	Excellent oxidation resistance. Good performance at elevated temperatures.	Lower tensile and fatigue strength compared to alloys. In gas processes, commercially pure Grade 2 titanium is prone to hydride needle formation (embrittlement), whereas alloys are much less susceptible.	Cold-formed parts or components exposed to constant heat without cyclic loading. Common in molds, housings, heat exchangers, and chemical plant structures where hardening is not required.	No response is observed under quenching or aging treatments. During nitriding, two separate sublayers form: TiN at the surface and an underlying Ti ₂ N layer.
BETA (β):	GRADES 19, 20, 21, OR 38	Vanadium, Molybdenum, Chromium, Niobium	High hot-workability. Good response to hardening.	Lower corrosion resistance. Higher density. Limited availability and relatively higher cost.	Used where complex forming plus subsequent heat treatment is required: anchors, structural supports, or parts that need hardening	Heat-treatable (responds to quenching and aging).
ALPHA-BETA (α+β):	GRADE 5 (TI-6AL-4V) GRADE 23 (TI-6AL-4V ELI)	Aluminum, Vanadium, or other β-stabilizers	Balanced combination of strength, toughness, and machinability. High resistance to heavy loads and cyclic stresses. Good corrosion resistance, even in biological or marine environments.	Expensive	Versatile choice for critical components requiring machining, cyclic load resistance, and surface treatments—such as fasteners, wear parts, and nitrided components.	Age-hardenable. Responsive to surface treatments such as nitriding.

GRADES 5 AND 23:

Ti-6Al-4V alloy (alpha-beta), classified as Grade 5, accounts for more than 50% of the titanium used worldwide. It is the industry standard in aerospace, medical, and mechanical engineering applications. Its 6% aluminum content improves oxidation resistance while preserving low weight, while the 4% vanadium provides hardenability and increases mechanical strength.

It is important to note that aluminum is not soluble in titanium nitrides. As a result, during nitriding, aluminum is displaced inward, forming an aluminum-enriched intermediate layer located just below the compound zone (white layer) and above the diffusion zone.

Unlike commercially pure titanium, TiN and Ti₂N nitrides are mixed within the compound layer rather than forming separate sublayers.

Ti-6Al-4V ELI (Extra Low Interstitials) alloy—Grade 23—is a variant of Grade 5 with reduced levels of interstitial elements (such as oxygen, nitrogen, and carbon). It is widely used in medical and dental applications due to its excellent chemical stability and superior performance in long-term contact with biological tissues.



Titanium
Yes, Plasma Nitriding Works for Titanium. Here's When and Why.



W H Y

NITRIDING TITANIUM?

BECAUSE



Titanium
Yes, Plasma Nitriding Works for
Titanium. Here's When and Why.



IMPROVING

WEAR RESISTANCE



Plasma nitriding is not a conventional heat treatment, as it neither modifies the material's bulk structure nor relies on volumetric phase changes (such as steel quenching). Instead, it is a thermochemical surface treatment where nitrogen atoms, activated by plasma, diffuse into the titanium surface **to form high-hardness titanium nitrides, such as TiN and Ti₂N.**

This is especially important for titanium, whose most recognized limitation is its poor surface wear resistance.

While titanium has excellent corrosion resistance and high tensile strength, its surface deteriorates rapidly in applications involving sliding contact, continuous friction, or moderate abrasion.

This premature wear can shorten component life, cause loss of dimensional accuracy, or interfere with the function of moving or precision parts.

By producing a hard nitride layer on the surface through plasma nitriding, **wear resistance is greatly increased without affecting the core properties of the material.** The result is a more stable, longer-lasting surface that performs well under prolonged mechanical contact.



Titanium
Yes, Plasma Nitriding Works for Titanium. Here's When and Why.

PRESERVING

CORROSION RESISTANCE

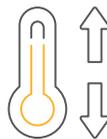


One of titanium's most important properties is its **excellent corrosion resistance**, even in aggressive environments such as saline solutions, marine atmospheres, or biological systems. This performance comes from the spontaneous formation of an ultrathin, stable, and self-healing passive layer of titanium oxide (TiO_2).

Conventional heat treatments can compromise this layer, especially when carried out:



In atmospheres containing free oxygen.



At high temperatures for long durations.



Without precise control of the process gases.

Under these conditions, the oxide layer can grow excessively and become porous, brittle, or discontinuous, losing its protective function and weakening the surface's chemical resistance.

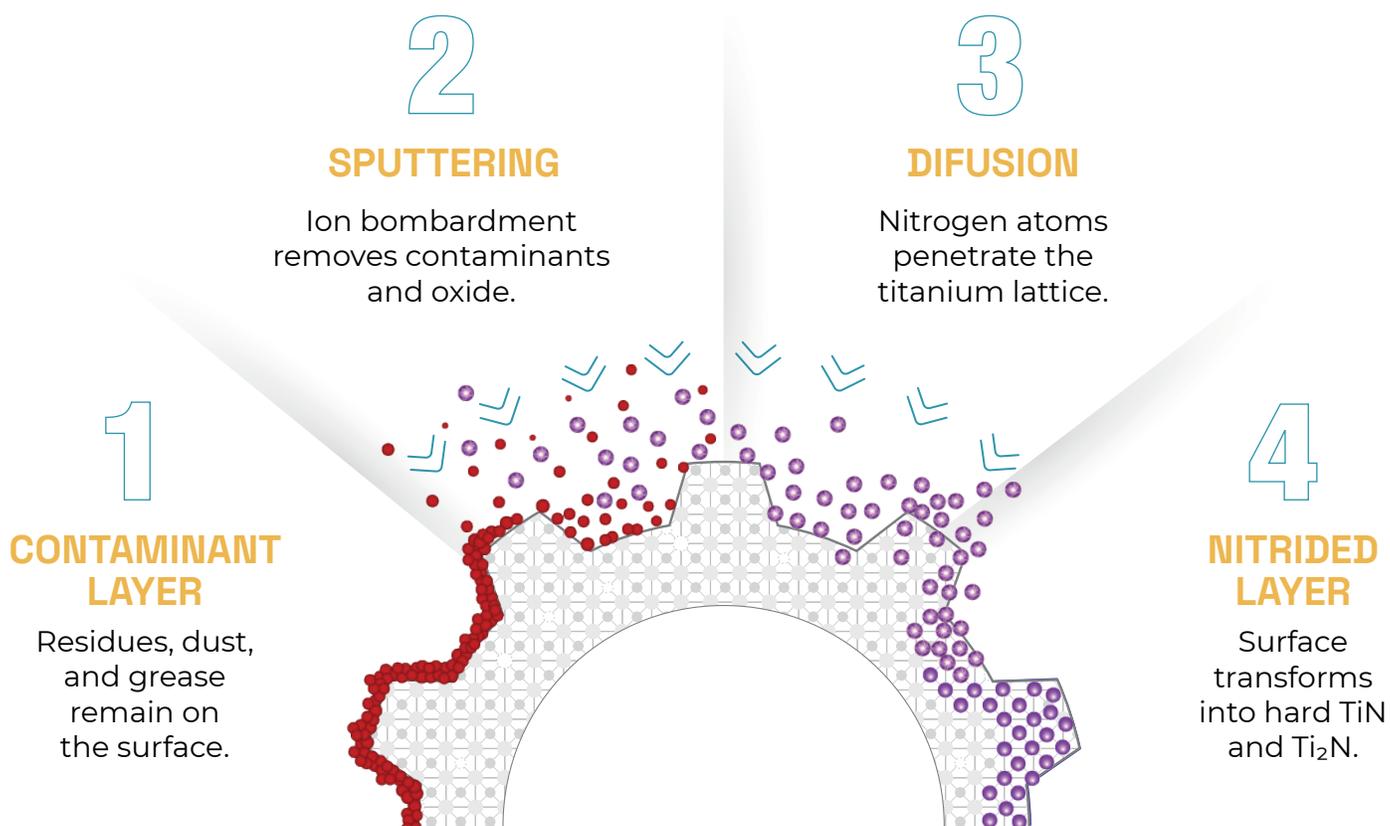
Plasma nitriding, on the other hand, is performed under vacuum in tightly controlled atmospheres, using a plasma ignition system that activates the surface through a **process known as sputtering**.



Titanium
Yes, Plasma Nitriding Works for Titanium. Here's When and Why.

During sputtering, plasma ions bombard the surface, **removing impurities, contaminants, and the existing passive film**. Rather than being a drawback, this step is critical: it leaves the surface clean, active, and ready to form a new protective layer.

Instead of the original TiO_2 film, the surface develops titanium nitrides (TiN and Ti_2N), which are chemically stable, highly corrosion resistant, and far harder than the native oxide.



In short, plasma nitriding removes the initial passive layer but replaces it with a more effective protective barrier, **preserving—and even enhancing**—the chemical resistance of titanium in aggressive environments.



Titanium
Yes, Plasma Nitriding Works for Titanium. Here's When and Why.

PRESERVING

BIOCOMPATIBILITY

3

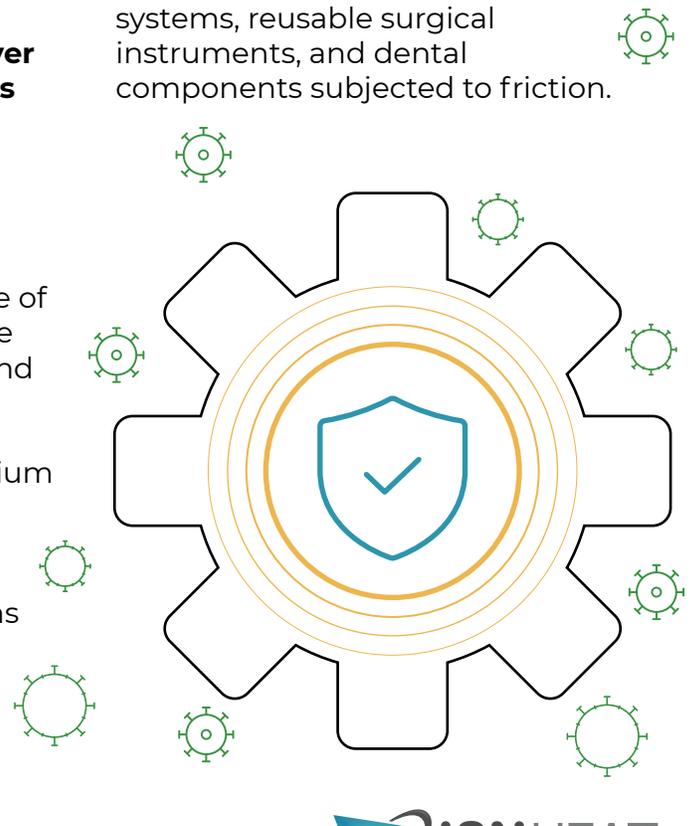
Titanium's biocompatibility is due to the chemical stability of its surface, which prevents the release of metallic ions into the surrounding environment and avoids inflammatory, toxic, or immunological reactions when in contact with human tissues.

Specifically, **the passive titanium oxide layer (TiO₂) does not dissolve in biological fluids** and acts as an electrochemical barrier between the metal and the physiological environment.

For this reason, titanium—especially in high-purity grades such as Grade 23—is one of the few metals that can be implanted in the human body without additional coatings and without risk of rejection.

Now, the new surface layer formed by titanium nitrides (TiN and Ti₂N) **during plasma nitriding preserves the material's biocompatibility** and is widely used in approved medical applications, as it remains bioinert (does not trigger an immune response) and chemically stable.

In addition, a polished nitrided surface exhibits low chemical reactivity, which hinders the adhesion of organic substances. This makes it well suited for orthopedic implants, bone screws and fixation systems, reusable surgical instruments, and dental components subjected to friction.



Titanium
Yes, Plasma Nitriding Works for
Titanium. Here's When and Why.

CERTIFYING

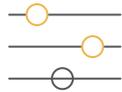
CRITICAL PARTS WITHOUT MARGIN FOR ERROR

4

Industrial, surgical, aerospace—some applications leave no room for mistakes or variation. When a part must perform flawlessly for years—whether inside the human body or in flight—surface treatment cannot be experimental. It has to be repeatable, traceable, and certifiable.

That is exactly what plasma nitriding delivers.

Because it is performed in a controlled vacuum environment, free from unpredictable chemical atmospheres, plasma nitriding ensures that every cycle:



Uses the exact same parameters (temperature, voltage, pressure, time, and gas composition).



Produces consistent, verifiable results.



Is digitally recorded, with integrated process reports, ideal for certified quality systems.

This is especially critical in sectors such as **aerospace**, where a failure can be catastrophic, and in **biomedicine**, where every screw or implantable component must be biocompatible, functional, and suitable for sterilization.



Titanium
Yes, Plasma Nitriding Works for
Titanium. Here's When and Why.

BENE -
FITS

ADVANTAGES *of* PLASMA NITRIDING



Titanium
Yes, Plasma Nitriding Works for
Titanium. Here's When and Why.

Enhanced Properties



Plasma nitriding significantly modifies the surface of titanium, enhancing its mechanical properties while leaving the bulk structure unchanged.

SURFACES HARDNESS

Outer layer (TiN): Reaches hardness values above **1,500–2,000 HV**, responsible for abrasive wear resistance and the characteristic gold color.

Diffusion zone (α -Ti(N)): Provides a supporting hardness of **700–900 HV**, critical to prevent the hard layer from collapsing or cracking under load (the “eggshell effect”).

CASE DEPTH

Compound layer (TiN + Ti₂N): Typically thin and tightly controlled (**3–10 μ m**) to avoid brittleness.

Diffusion zone: Deep (**20–50 μ m**), integrated into the material core.

COMPRESSIVE STRESSES

Nitriding generates **compressive residual stresses** (approximately 1 GPa) at the surface. This acts as an “invisible shield” that suppresses crack initiation, dramatically improving fatigue resistance.



Titanium
Yes, Plasma Nitriding Works for Titanium. Here's When and Why.



Precise Temperature Control

At room temperature, titanium has a hexagonal crystal structure (alpha phase). When the transition temperature is exceeded (approximately 882 °C in pure titanium or about 995 °C in alloys such as Ti-6Al-4V), the structure transforms to cubic (beta phase).

Unlike steel, where phase transformation is used for hardening (quenching), in titanium this transformation is applied in other upstream metallurgical processes to:



Improve the diffusivity of alloying elements.



Facilitate hot forming or forging (the beta phase is more ductile).



Adjust the α/β phase balance to optimize toughness and strength.

However, during nitriding, the objective is typically to remain below this phase transformation to avoid excessive grain growth, which would embrittle the component.

This is where plasma nitriding performed in **hot-wall furnaces makes a critical difference:** by separating the heat source from plasma generation, they allow precise and independent temperature control. This ensures uniform heating cycles, eliminates the risk of edge overheating (edge effect), and **preserves microstructural integrity**—even in batches of parts with complex geometries.



Titanium
Yes, Plasma Nitriding Works for Titanium. Here's When and Why.

C Controlled Atmosphere

Above 600 °C, titanium becomes highly reactive to elements such as oxygen, nitrogen, carbon, and hydrogen, increasing the risk of forming brittle or undesirable surface layers.

One of the key advantages of plasma nitriding is that it is carried out in a controlled vacuum atmosphere, minimizing unwanted reactions.

This helps avoid:



Oxidation, which degrades the protective passive layer.



Hydrogenation. Unlike gas nitriding (which uses ammonia, NH_3 , and inevitably releases hydrogen), plasma nitriding can operate with pure nitrogen or nitrogen/argon mixtures. This eliminates the hydrogen source, preventing hydride embrittlement that severely degrades the toughness of titanium.



Carburization, which produces brittle carbides (TiC) that reduce surface ductility.



The formation of irregular or unstable nitrides that compromise mechanical strength.

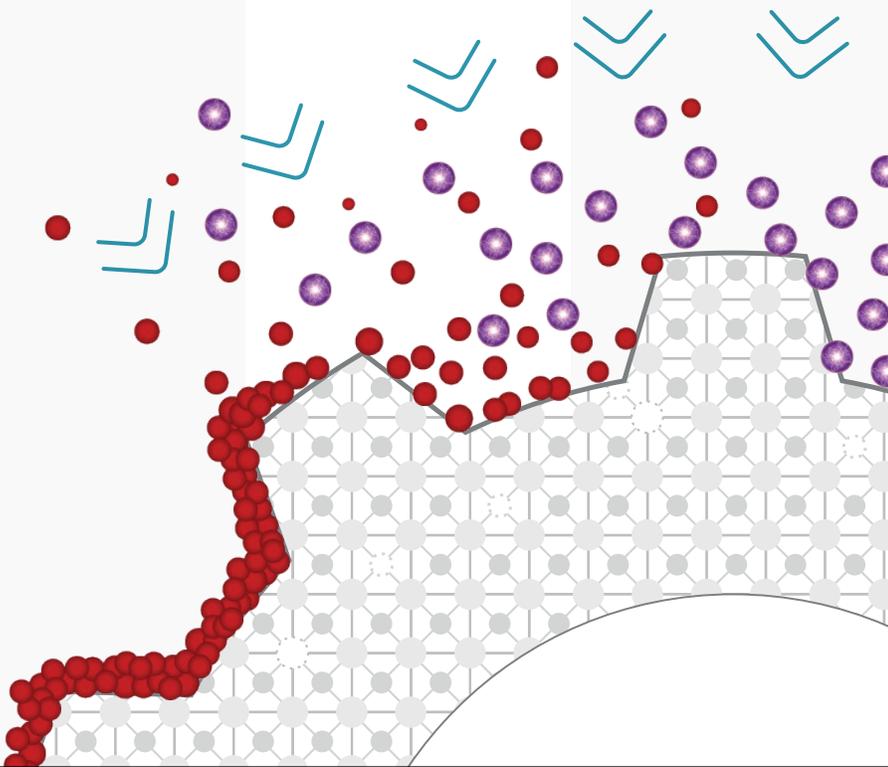
This tightly regulated environment preserves surface integrity and ensures the foundation for a high-precision treatment.



Titanium
Yes, Plasma Nitriding Works for Titanium. Here's When and Why.



Sputtering



As an inherent part of the process, ion bombardment—known as sputtering (cathodic sputtering)—occurs, actively **cleaning the surface of the parts before diffusion begins.**

This effect removes microscopic residues, dust, and organic contaminants, but **its most critical role in titanium is depassivation.**

Titanium spontaneously forms a highly stable oxide layer (TiO_2) that acts as a barrier, blocking nitrogen ingress. Unlike conventional gas nitriding, which often requires aggressive chemical pretreatments to break this 'shield,' **plasma ions physically bombard and disrupt the oxide layer.**

This leaves the metal lattice chemically clean and active, allowing nitrogen diffusion to start immediately, uniformly, and at more tightly controlled temperatures.



Titanium
Yes, Plasma Nitriding Works for
Titanium. Here's When and Why.

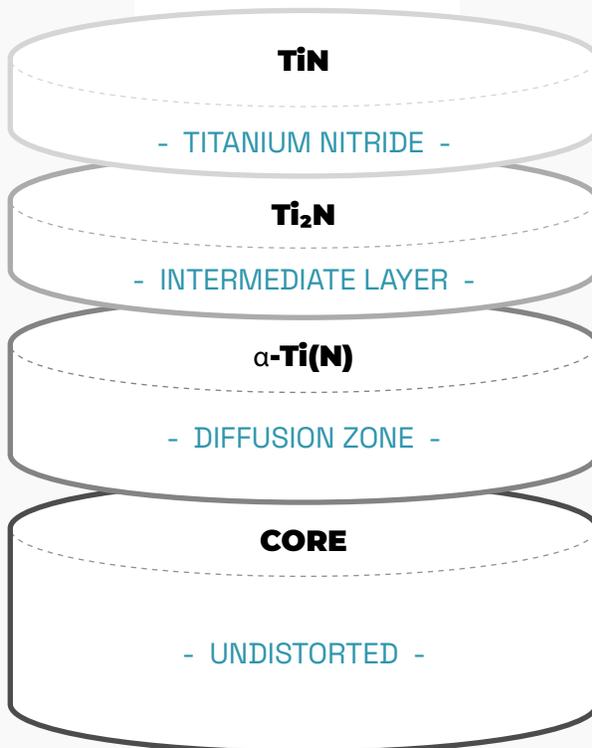
Nitrided Layer

Unlike processes such as anodizing, PVD, or other coating techniques, plasma nitriding does not deposit an external layer on the part. Instead, it alters the atomic composition of the titanium surface by diffusing nitrogen into the crystal lattice.

This distinction is crucial:

- No added coating.
- No risk of delamination.
- No dimensional issues or interference in precision fits.

The modified layer form within the base metal itself and typically consists of three well-defined zones:



▶ A very hard, ceramic-like, golden surface layer.

▶ With high hardness and excellent adhesion.

▶ Nitrogen dissolved in the titanium lattice, more ductile and gradual in structure, acting as an anchor to prevent crack propagation.

This stepped structure creates a hard outer surface with a tough inner support, improving wear resistance, maintaining exceptional dimensional stability, and withstanding thermal cycling and dynamic loads without spalling.



Titanium
Yes, Plasma Nitriding Works for Titanium. Here's When and Why.



LIMITS

**WHEN
PLASMA NITRIDING TITANIUM
is NOT
RECOMMENDED**



Titanium
Yes, Plasma Nitriding Works for
Titanium. Here's When and Why.

While plasma nitriding offers significant benefits, it is not a universal solution. There are cases where it may be unnecessary—or even counterproductive:

A

WHEN THERE IS NO SIGNIFICANT FRICTION OR WEAR

If the surface of the part is not subject to sliding contact, abrasion, or surface fatigue, hardening it by plasma nitriding may not be needed. In such cases, the cost of treatment is not justified by the functional gain.

B

WHEN A SPECIALIZED POST-TREATMENT COATING IS APPLIED

In certain medical applications, some implants receive bioactive coatings (such as hydroxyapatite) designed to bond to titanium's natural oxide layer. **Pre-nitriding the surface changes its chemistry to a golden ceramic (TiN)**, which may affect coating adhesion or interfere with osteointegration processes that have not been validated on nitrides.

**NOT
RECOMMENDED**

C

WHEN THE DESIGN INCLUDES 'SHADOWED AREAS' OR CRITICAL CAVITIES

Plasma nitriding relies on direct ion bombardment. In geometries with very narrow slots or deep blind holes, two opposite phenomena may occur: **Lack of treatment / Hollow cathode effect.**



Titanium
Yes, Plasma Nitriding Works for Titanium. Here's When and Why.

COMPARE

ADVANTAGES OF PLASMA NITRIDING *over* GAS NITRIDING

BENEFITS



Titanium
Yes, Plasma Nitriding Works for
Titanium. Here's When and Why.



Advantages of Plasma Nitriding Compared to Gas Nitriding:

01 PROCESS CONTROL

Plasma nitriding allows millimetric-level adjustment of independent variables: voltage, pressure, temperature, atmosphere composition, and time. This results in consistent, auditable outcomes. In gas nitriding, control depends on gas flow rates and chemical dissociation kinetics (KN), which are difficult to stabilize from batch to batch.

In gas nitriding, the high nitrogen potential of ammonia tends to produce excessively thick and porous compound layers (a microscopic 'Swiss cheese' effect) that compromise adhesion.

Plasma nitriding, operating under vacuum with controlled gas mixtures, **enables the formation of compact, dense, and porosity-free layers.**

02 AVOIDS BRITTLE AND POROUS LAYERS

03 TEMPERATURE INDEPENDENT OF CHEMISTRY

This is a fundamental difference: in gas nitriding, heat is required to 'crack' ammonia and release nitrogen. In plasma nitriding, electricity dissociates the gas. As a result, the generation of active nitrogen does not depend on temperature.

Hot-wall furnaces (such as those from ION HEAT) leverage this by decoupling heat input from ionization, allowing **complex titanium alloys to be treated with precise thermal profiles**, independent of gas chemistry.

While conventional gas nitriding uses large volumes of toxic ammonia and generates waste, plasma nitriding uses simple gases (nitrogen, hydrogen, argon) in minimal quantities.

It does not contaminate the parts, **leaves no hazardous residues, and is safe for both the operator and the environment.**

04 CLEAN AND SAFE TECHNOLOGY

05 AUTOMATIC DEPASSIVATION (SPUTTERING)

Titanium has a natural oxide 'skin' that blocks nitrogen ingress. Conventional gas nitriding cannot break it easily without chemical aids. **Plasma nitriding integrates ionic cleaning (sputtering) that bombards and removes this oxide barrier before treatment begins**, leaving the surface metallurgically active and ready to absorb nitrogen uniformly.

Plasma nitriding forms a tougher metallurgical interface. By avoiding the thick, brittle white layers typical of gas nitriding, plasma processing creates a **gradual hardness transition that better supports fatigue and prevents spalling (delamination) under load.**

06 SUPERIOR COATING ADHESION



Titanium
Yes, Plasma Nitriding Works for Titanium. Here's When and Why.



IN SUMMARY

For the surface treatment of titanium components, plasma nitriding offers clear advantages over gas or salt-based techniques: it provides thermal control independent of chemistry, ensures ionic cleaning (depassivation) that cannot be achieved by other methods, and produces high-purity, oxide-free layers—critical for biomedical and aerospace applications.

What about **SALT BATHS?**

Although salt bath nitriding is common for steels, it is not suitable for titanium for three critical reasons:



Chemical Incompatibility

Salt baths contain oxygen-bearing compounds. Because titanium strongly attracts oxygen, this leads to oxidation or brittle, contaminated layers instead of pure nitrides.



Temperature Limitation

Salt baths degrade above ~590 °C, restricting the process to a narrow thermal window that is insufficient for many deep diffusion cycles in titanium.



Environmental impact

The process generates toxic waste (cyanides/salts) and requires complex post-cleaning steps that can compromise the surface integrity of parts with intricate or porous geometries.



Titanium
Yes, Plasma Nitriding Works for Titanium. Here's When and Why.

FURNACES

CAN *all* PLASMA NITRIDING FURNACES TREAT TITANIUM?

Not necessarily. Most standard nitriding furnaces are designed to operate on steels, typically in the 400–600 °C range. Titanium, however, behaves differently. To obtain nitrided layers with real load-bearing capability and industrially relevant depth (beyond 10–20 microns), titanium diffusion kinetics require higher temperatures, typically between 700 °C and 900 °C.

The technical challenge: Treating titanium (even commercially pure or alpha alloys) at steel-level temperatures results in extremely slow processes or diffusion layers that are too thin for severe wear applications.



Titanium
Yes, Plasma Nitriding Works for
Titanium. Here's When and Why.

The advanced solution: Treating key alloys such as Ti-6Al-4V requires furnaces capable of precisely reaching and holding temperatures near 300 °C. This enables the development of deep layers with excellent tribological properties, provided temperature control is absolute to avoid exceeding the grain growth limit (beta transus).

HIGH-TEMPERATURE ADD-ON

Nitriding titanium up to 900 °C —without losing control—

**If real wear resistance is required, “doing plasma” is not enough—the equipment must deliver precise high-temperature capability.
ION HEAT GlowTech models:**



Breaking the thermal barrier

Enables treatment temperatures between 700 °C and 900 °C, essential for deep diffusion in alloys such as Ti-6Al-4V.



Hot-wall stability

Our hot-wall technology decouples heating from the plasma, enabling constant temperature control while preventing arcing and edge overheating (edge effect).



Aerospace-grade results

Ensures thick, tough diffusion layers free from the brittleness associated with unstable processes.

This capability is not a luxury—it is a technical necessity.
When severe wear resistance is required in critical components.



Titanium
Yes, Plasma Nitriding Works for Titanium. Here's When and Why.



GLOWTECH MODEL: PLASMA NITRIDING FURNACE BY IONHEAT



Titanium
Yes, Plasma Nitriding Works for
Titanium. Here's When and Why.



INVESTING IN A PLASMA NITRIDING FURNACE IS A *major* DECISION

At ION HEAT, we understand that investing in a plasma nitriding furnace is a strategic decision. That is why our technical consulting is not about 'selling,' but about validation: we assess real feasibility based on your parts, materials, and industry.

If you are considering plasma nitriding for titanium components, let's talk. We support your decision with solid technical arguments, proven experience, and reliable data.



Titanium
Yes, Plasma Nitriding Works for
Titanium. Here's When and Why.

Partnering for Precision



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