

ABC

stainless STEELS

And why **plasma nitriding** is the right way
to treat them without damaging
their anti-corrosion shield



ABC stainless STEELS

And why **plasma nitriding** is the right way
to treat them without damaging
their anti-corrosion shield

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

© 2025 | ION HEAT S.A.S

This material is intended for educational purposes only and may not be used for economic or commercial purposes. ION HEAT owns and retains all copyrights and other intellectual property rights; therefore, it may not be reproduced, modified, copied, or disclosed without the Company's written consent.



ABC of stainless steels
And why plasma nitriding is the best
way to harden them without
damaging their corrosion resistance



We present a clear and technical guide on how stainless steels work and **why plasma nitriding is the most effective treatment** to harden their surface without losing corrosion resistance.

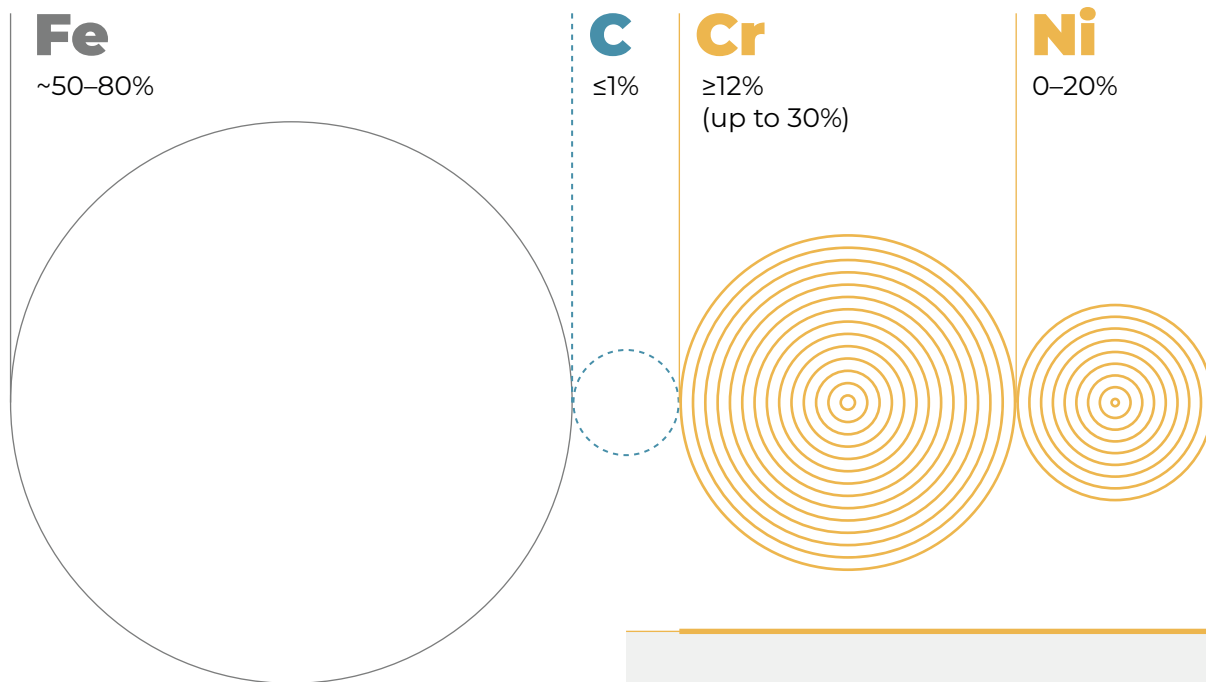
LET'S START FROM THE BEGINNING



ABC of stainless steels
And why plasma nitriding is the best way to harden them without damaging their corrosion resistance

What are stainless steels?

They are alloys of iron and carbon, like all steels, that also contain chromium and, in many cases, nickel.



Chromium, when exposed to oxygen in the environment, forms a chromium oxide layer (Cr_2O_3) on the metal surface, acting as a protective barrier against aggressive agents.

Nickel, on the other hand, does not directly participate in this layer, but it adds chemical stability and supports the steel's structure.

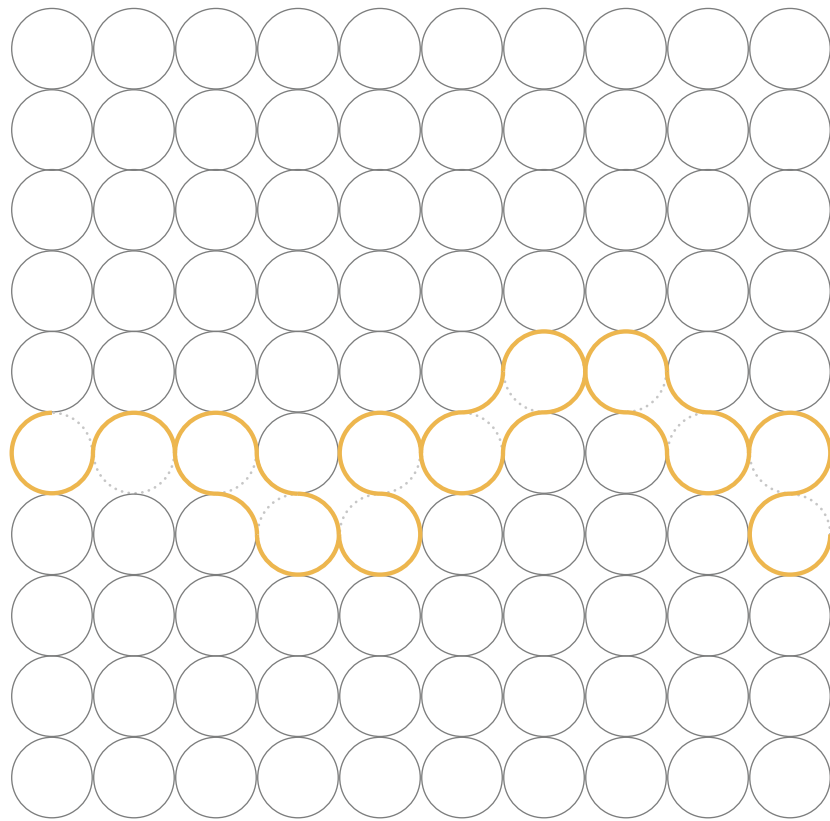
These two elements provide excellent corrosion resistance, meaning protection against oxidation when in contact with air, water, or salt.



ABC of stainless steels
And why plasma nitriding is the best
way to harden them without
damaging their corrosion resistance

Important:

For the oxide layer to form, the steel must contain at least **12% chromium by weight.**



Most stainless steels are based on Fe-Cr-C and Fe-Cr-Ni-C systems, although they may also include other alloying elements such as molybdenum (Mo), manganese (Mn), nitrogen (N), silicon (Si), titanium (Ti), and niobium (Nb).



ABC of stainless steels
And why plasma nitriding is the best way to harden them without damaging their corrosion resistance

Paradox

Stainless steel does not rust because it is already 'oxidized'

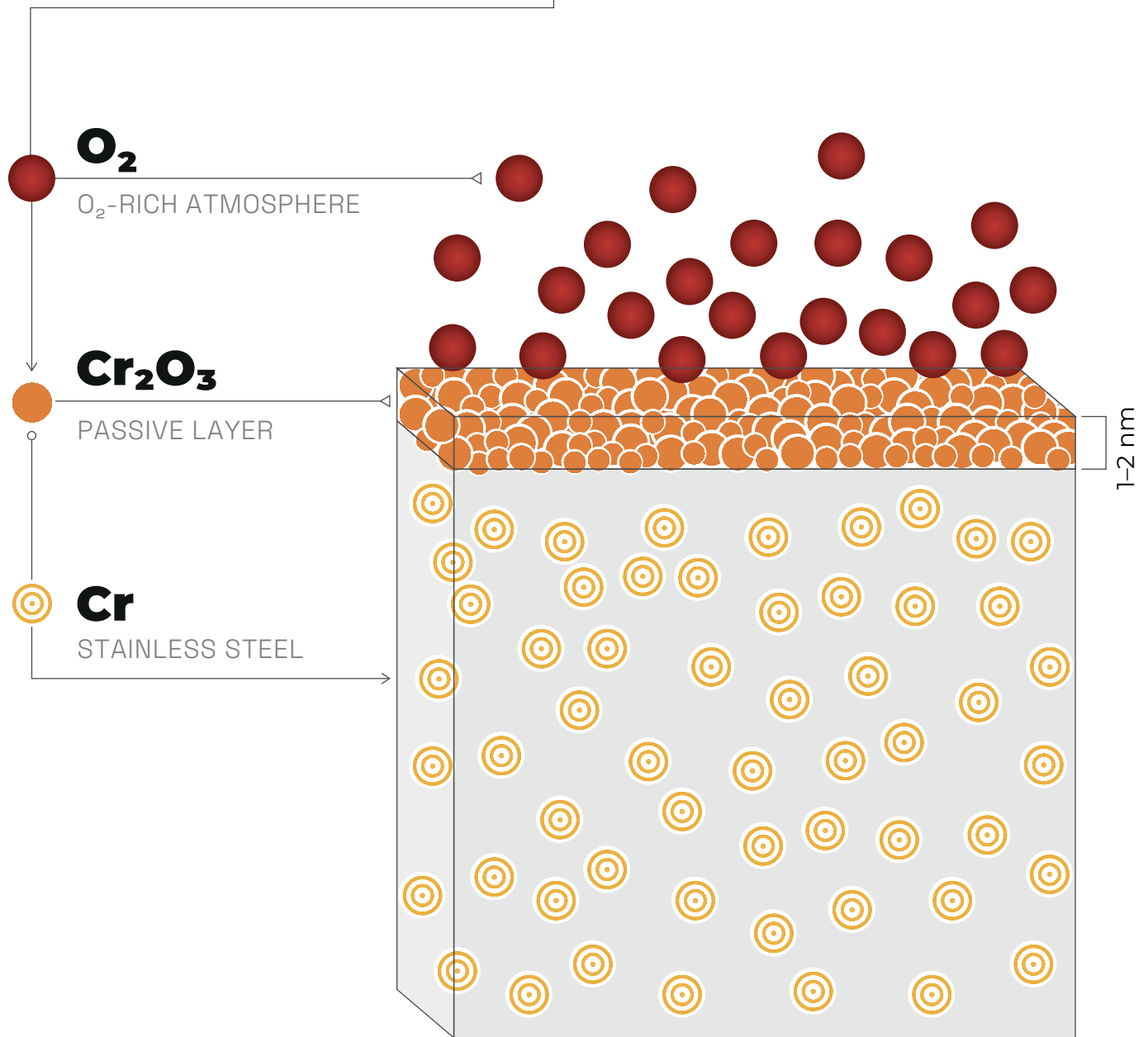
The protective layer on stainless steels is chromium oxide (Cr_2O_3), a 'good' oxide that 'seals' the material and prevents it from continuing to react with air, water, or salt.

That is why it is called
Passive Layer

00



ABC of stainless steels
And why plasma nitriding is the best way to harden them without damaging their corrosion resistance



GRAPHIC | Chemical reaction of chromium oxide



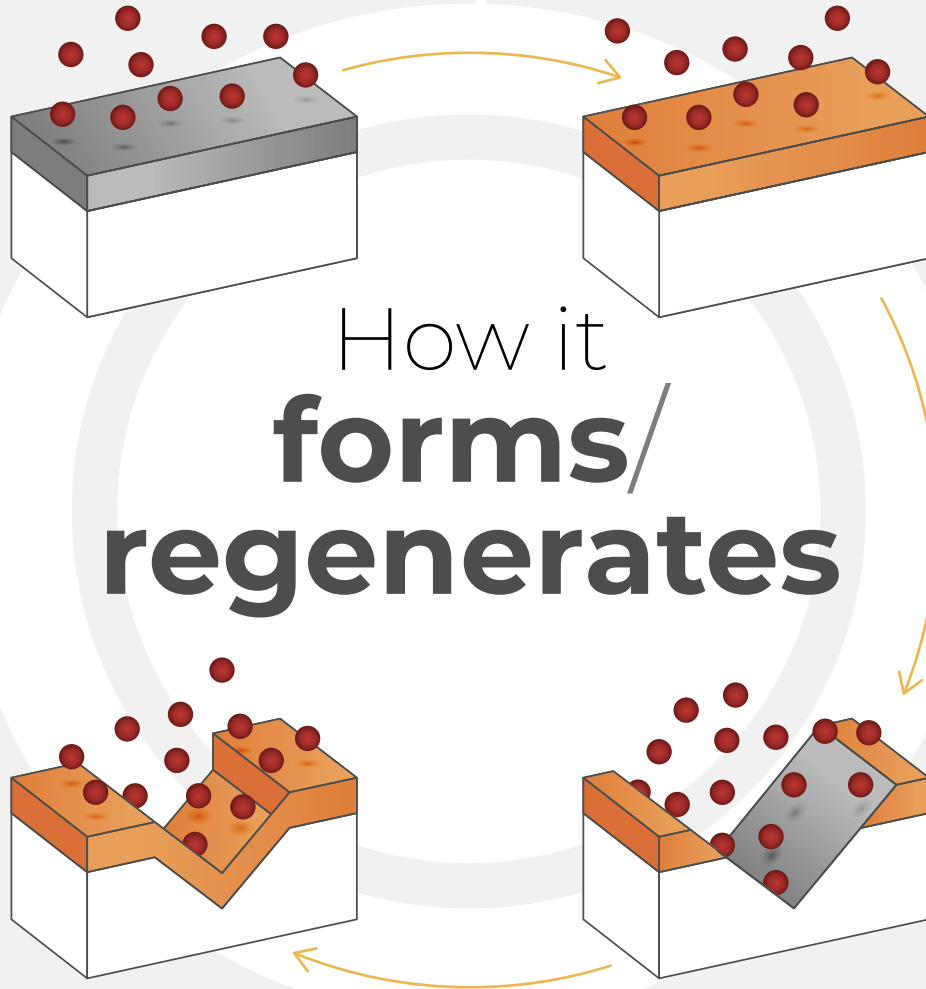
A fast and self-sustaining reaction:
chromium oxidizes first and forms a barrier that stops corrosion before it even begins.



ABC of stainless steels
And why plasma nitriding is the best way to harden them without damaging their corrosion resistance

The chromium present on the steel surface reacts with oxygen in the air and **spontaneously forms an ultrathin chromium oxide layer** (Cr_2O_3).

This layer, only 1–2 nanometers thick, fully covers the surface and acts as a barrier that **prevents oxygen from penetrating and corroding the metal**.



That is why stainless steel **maintains its corrosion resistance** over time.

If the layer is damaged (by machining, impact, or scratching), it **reforms automatically** as long as oxygen is available.



ABC of stainless steels
And why plasma nitriding is the best way to harden them without damaging their corrosion resistance

Some Applications

Stainless steels are everywhere (and not by chance). They are chosen when durability, cleanliness, and good appearance must come together, without the material failing over time.

Food and beverage | They are used in components of food-processing equipment because they do not contaminate, do not rust, and are easy to clean. Tanks, valves, contact surfaces: everything must be stainless, literally.



Medical and pharmaceutical

In operating rooms and laboratories, instruments cannot rust or retain residues. That is why stainless steel is synonymous with hygiene and sterility.



Chemical and oil industry

In these environments, acids, pressure, and heat dominate. Therefore, a material that does not corrode in hostile conditions is required: piping, reactors, and valves.



Power generation

In power plants, turbines, and boilers, a steel that can withstand heat, steam, and years of service without cracking or rusting is essential.



Automotive and transportation

From trims, exhausts, and structures to engine parts in cars and aircraft: stainless steel delivers strength with aesthetics, without the need for replacements from corrosion.



Construction and urban furniture

Railings, façades, exposed bolts. It is a material that endures the elements without losing its shape or shine.



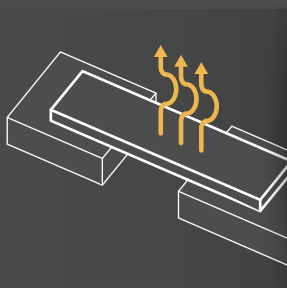
Consumer goods

From a spoon to a coffee maker, stainless steel is present because it looks good, lasts long, and does not retain odors or flavors.



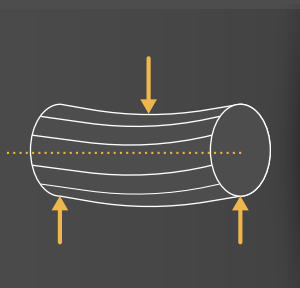
ABC of stainless steels
And why plasma nitriding is the best way to harden them without damaging their corrosion resistance

Main Drawbacks



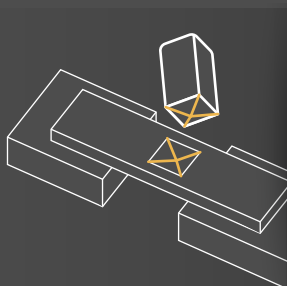
Low load-bearing capacity:

In general, their structural strength is lower than that of other alloy steels.



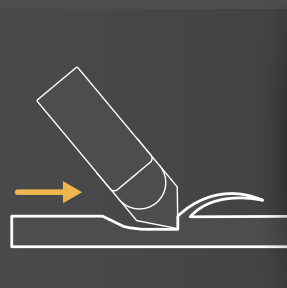
Relatively low yield strength:

They deform more easily under constant stress.



Limited hardness:

Especially in austenitic grades, which cannot be hardened by heat treatment.



Low wear resistance:

They are not ideal for applications with constant friction or abrasion, unless the surface is modified (for example, with nitriding).



ABC of stainless steels
And why plasma nitriding is the best way to harden them without damaging their corrosion resistance

Types of stainless steels

MOST USED AISI/UNS	TYPICAL COMPOSITION	KEY MECHANICAL PROPERTY	TYPICAL APPLICATIONS	HEAT TREATMENT
Martensitic				
- AISI 410 - AISI 420 - AISI 431 - AISI 440	Cr CHROMIUM Typically between 10,5 y 18% C CARBON 0,1 - 0,4%	• High mechanical strength and hardness. • Low toughness and ductility.	- Cutting tools. - Valves. - Turbines. - Shafts.	Hardened by heat treatment (quenching and tempering). The only stainless steels hardenable by martensite.
Ferritic				
- AISI 409 - AISI 430 - AISI 439 - AISI 446	Cr CHROMIUM 10,5 - 30 % Low carbon. No nickel.	• Medium strength. • Good performance in moderately corrosive environments.	- Exhaust systems. - Home appliances. - Heat exchangers.	Not hardenable by quenching. Used in annealed or cold-worked condition.
Austenitic				
- AISI 304 - AISI 316 - AISI 321 - AISI 310	Cr CHROMIUM 16 - 26 % Ni NICKEL 8 - 22 % C CARBON Low carbon, especially in L grades	• Excellent corrosion resistance. • High ductility and toughness.	- Food industry. - Medical equipment. - Marine environments.	Not hardenable by quenching. Strength can be increased by cold working, especially in non-stabilized grades.



ABC of stainless steels
And why plasma nitriding is the best way to harden them without damaging their corrosion resistance

MOST USED AISI/UNS	TYPICAL COMPOSITION	KEY MECHANICAL PROPERTY	TYPICAL APPLICATIONS	HEAT TREATMENT
Duplex				
UNS S32205 S31803 S32750	Cr CHROMIUM 18 - 26 % Ni NICKEL 4,5 - 6,5 % Mo N Included	• High mechanical strength. • High resistance to pitting and cracking.	Chemical industry. Subsea pipelines. Desalination plants (especially super duplex grades).	Not hardenable by quenching. Supplied in solution-annealed condition, which balances both phases.
Precipitation-hardening (PH)				
AISI 630 (17-4 PH) UNS S17400	Cr CHROMIUM ~15 - 17 % Ni NICKEL ~3 - 5 % Cu Al Nb Copper, aluminum, or niobium as hardening elements.	• High mechanical strength. • Good toughness and corrosion resistance. • Dimensional stability.	Aerospace. Injection molds. Shafts, gears, and precision structural components.	Hardened by age hardening (precipitation). Supplied in annealed condition (Condition A) and aged according to required properties.
Sintered metals / Powder metallurgy stainless steel				
No conventional AISI designation. Produced under proprietary specifications, often based on 316L or other standard compositions adapted to sintering.	Equivalent to commercial grades (such as 316L), but with possible adjustments in carbon, nickel, or additives depending on application and required density.	• Good corrosion resistance. • Lower mechanical strength and structural density compared to forged steels. • Sensitive to porosity.	Metal filters. Medical implants. Precision surgical tools. Low structural impact components. Complex-shaped parts difficult to machine.	Can be annealed or subjected to mild heat treatments to improve cohesion and microstructure. Plasma nitriding is especially useful to harden the surface without embrittling the porous material.



ABC of stainless steels
 And why plasma nitriding is the best way to harden them without damaging their corrosion resistance

Insights from the table

When analyzing the different types of stainless steel, clear patterns emerge that provide key insights:

Alloying elements

define how stainless steel performs under mechanical loads, heat treatments, and corrosive environments.

C

CARBON

Present in all steels, it determines hardness and response to heat treatment.

In martensitic grades, a moderate to high content allows the formation of martensite, a hard and brittle structure.

In austenitic grades, it must be kept low to avoid chromium carbide precipitation, which reduces corrosion resistance.

Cr

CHROMIUM

The key element that turns a regular steel into stainless. Starting at 12% by weight, chromium enables the spontaneous formation of a thin chromium oxide layer (Cr_2O_3) on the surface.

This passive layer acts as a protective barrier against corrosion.



ABC of stainless steels
And why plasma nitriding is the best way to harden them without damaging their corrosion resistance

Ni

NICKEL

Stabilizes the austenitic (FCC) structure, improving ductility, toughness, and fracture resistance, even at low temperatures.

It also provides chemical stability in aggressive environments. It is essential in austenitic stainless steels.

Mo

MOLYBDENUM

Strengthens resistance to localized corrosion, especially against chlorides.

Reduces susceptibility to pitting and cracking. Common in steels for marine, chemical, or pharmaceutical environments (such as AISI 316).

N

NITROGEN

Improves mechanical strength by acting as a solid-solution hardener and increases resistance to localized corrosion.

It also stabilizes the austenitic phase. Found in some duplex and high-performance austenitic steels.

Nb

NIOBIUM

Not present in all stainless steels, but essential in precipitation-hardening (PH) grades.

They enable the formation of fine, hard phases through age hardening, improving mechanical strength without sacrificing chemical integrity or corrosion resistance.

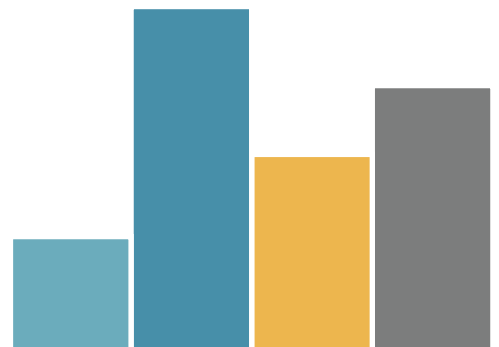
Al

ALUMINUM



ABC of stainless steels

And why plasma nitriding is the best way to harden them without damaging their corrosion resistance



Behavior under heat treatment

TYPES OF STAINLESS STEEL

MARTENSITIC

FERRITIC + AUSTENITIC + DUPLEX

PH (PRECIPITATION HARDENING)

ALL TYPES

HEAT TREATMENTS

● QUENCHING

The only stainless steels that can be quenched. Their hardness is adjusted with the corresponding tempering.

● COLD WORKING

Not hardenable by quenching. Used in annealed condition.

● AGE HARDENING

After initial annealing, they are hardened through precipitation treatments.

● PLASMA NITRIDING

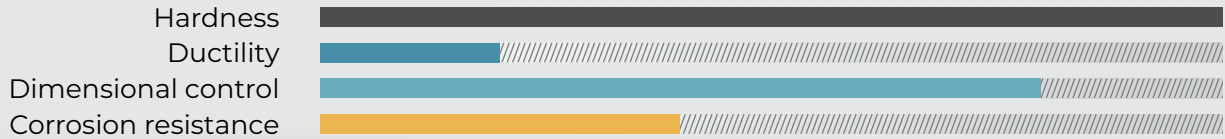
Case-dependent. Low-temperature surface treatment. Especially useful for parts manufactured by powder metallurgy and 3D printing, where altering the core or the base microstructure is not desired.



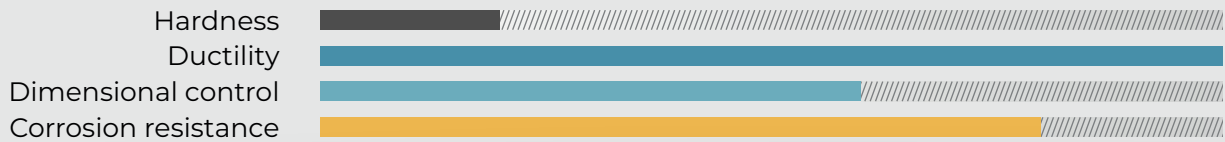
ABC of stainless steels
And why plasma nitriding is the best way to harden them without damaging their corrosion resistance

Interplay of mechanical properties

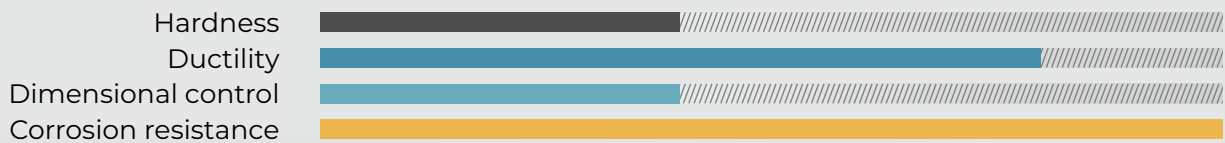
MARTENSITIC



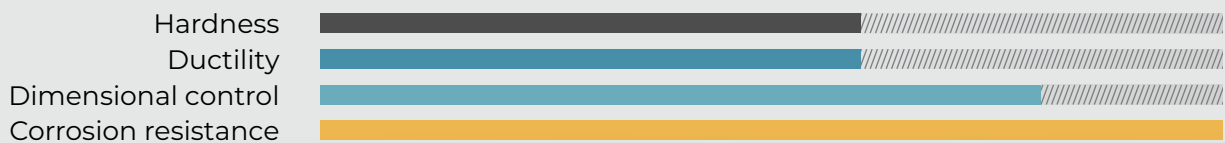
FERRITIC



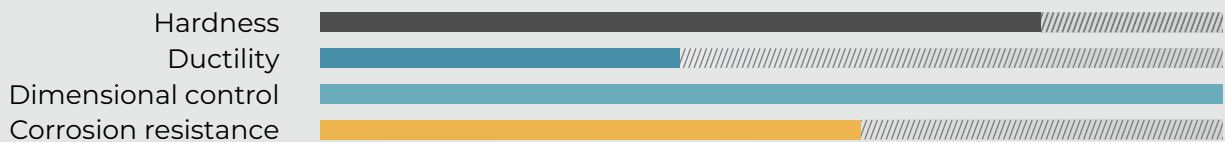
AUSTENITIC



DUPLEX

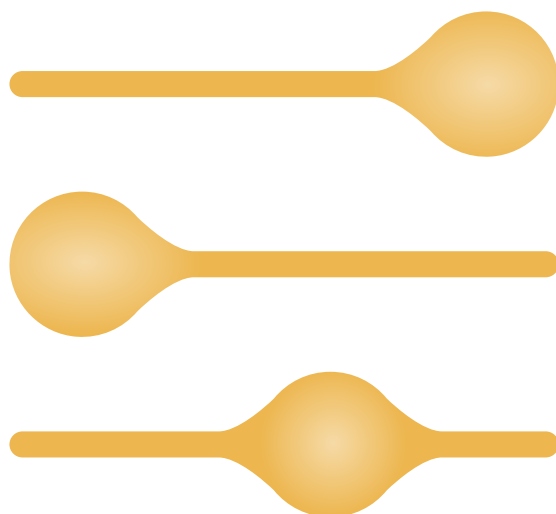


PRECIPITATION-HARDENING (PH)



ABC of stainless steels
And why plasma nitriding is the best way to harden them without damaging their corrosion resistance

How to treat **stainless steel?**



ABC of stainless steels

And why plasma nitriding is the best way to harden them without damaging their corrosion resistance

Heat treatments are applied to modify the mechanical properties of steel, especially its wear resistance.

However, **not all types of stainless steel respond the same way** to these treatments.



What types of treatments exist?

Harden and adjust toughness

Exclusive to martensitic stainless steels.

QUENCHING & TEMPERING

Form hard phases

By alloying elements such as niobium or aluminum in PH steels.

AGE HARDENING
(precipitation)

Soften the material and relieve internal stresses

Especially in ferritic, austenitic, and duplex grades.

ANNEALING

Improves mechanical strength through plastic deformation without altering the crystal structure.

Particularly useful in austenitic grades.

COLD WORKING

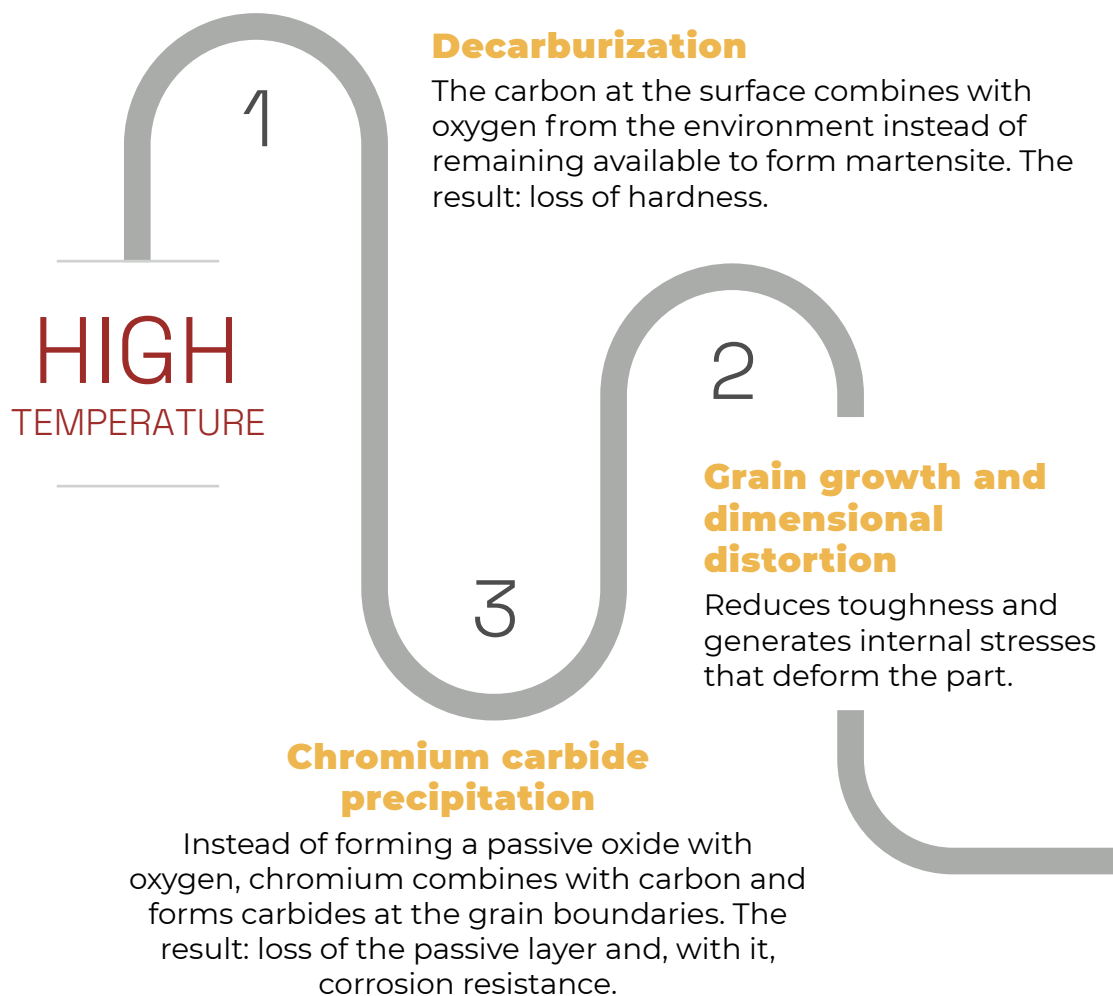
And what about NITRIDING?



ABC of stainless steels
And why plasma nitriding is the best way to harden them without damaging their corrosion resistance

BUT...

Why can high-temperature heat treatments ruin stainless steel?



ABC of stainless steels
And why plasma nitriding is the best way to harden them without damaging their corrosion resistance

Cold working, applied to austenitic, ferritic, and duplex steels, and precipitation hardening, used in PH steels, make it possible to increase tensile strength and hardness throughout the section without compromising corrosion resistance. They work within the structural limits of each alloy and are effective when the goal is to reinforce the bulk material without altering its surface.

But when the objective is to increase hardness without losing passive protection, the 'classic alternative' is to use martensitic stainless steels and apply quenching and tempering.

However, this process involves heating above 950 °C and rapidly cooling to induce martensite. The risk: sensitization, meaning the formation of chromium carbides at the grain boundaries, which deteriorates the passive layer and reduces corrosion resistance.

¿ANOTHER ALTERNATIVE TO HARDEN STAINLESS STEELS?

If the goal is to strengthen the surface without compromising the ductility of the core or the corrosion-resistant properties of the material,

**it is worth considering
thermochemical treatments,
especially nitriding.**



ABC of stainless steels
And why plasma nitriding is the best way to harden them without damaging their corrosion resistance

Nitriding

of stainless steels

Nitriding is a thermochemical treatment that hardens the steel surface by introducing nitrogen atoms into its outer layer.

Unlike heat treatments, which rely on phase changes through controlled heating and cooling, nitriding is a thermochemical process that introduces nitrogen atoms into the steel surface to increase hardness and wear resistance. It does not involve a complete transformation of the crystal structure, but rather a surface enrichment with nitrogen that modifies its properties.

In industry, there are three main methods to carry out nitriding:

SALT BATH

GAS NITRIDING

PLASMA

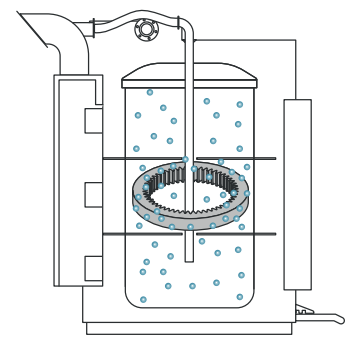
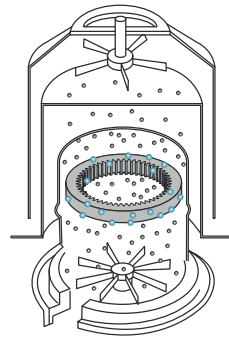
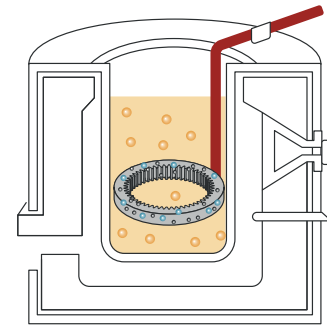
Let's see them side by side:



ABC of stainless steels
And why plasma nitriding is the best way to harden them without damaging their corrosion resistance

Comparison

of nitriding methods for stainless steels



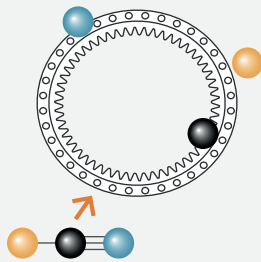
NITRIDING METHOD	SALT BATH NITRIDING	GAS NITRIDING	PLASMA NITRIDING
ATMOSPHERE	Molten cyanide salts.	Gaseous atmosphere (typically dissociated ammonia).	Glow discharge in controlled atmosphere.
PROCESS DESCRIPTION	Parts are immersed in a cyanide-based salt bath. This bath contains compounds such as sodium cyanate (NaCNO) and sodium cyanide (NaCN), which thermally dissociate. Cyanide acts as the nitrogen source (and also some carbon), which diffuses into the steel surface.	Gas nitriding is carried out by placing the parts in a furnace with an ammonia-rich atmosphere (NH ₃). Ammonia partially dissociates into hydrogen and atomic nitrogen, and this nitrogen diffuses through the steel surface.	Inside a vacuum chamber, a high-voltage electric field is created between the parts (cathode) and the furnace walls (anode). The atmosphere, composed of nitrogen (N) and hydrogen (H) gases, is ionized by the current and forms an active plasma. The ions accelerated by the electric field bombard the surface of the parts, and nitrogen penetrates by diffusion.



ABC of stainless steels
And why plasma nitriding is the best way to harden them without damaging their corrosion resistance

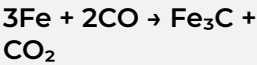
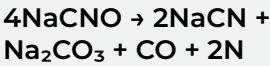
PRINCIPLE

SALT BATH
NITRIDING



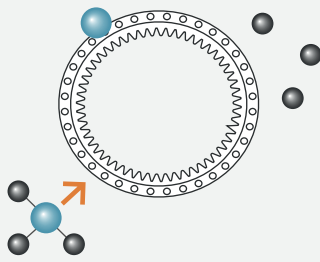
NaCN
Cyanide salt
diffusion

The thermal reaction dissociates the salts and releases active nitrogen species:



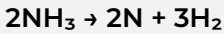
These species enable the formation of a nitrided layer, with high nitride and cementite (Fe_3C) content, particularly in carbon steels.

GAS
NITRIDING



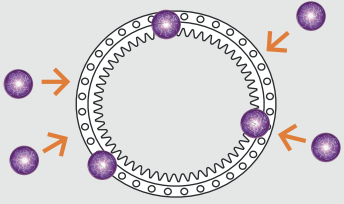
NH₃
Ammonia
diffusion

Ammonia decomposes upon contact with the hot steel surface:



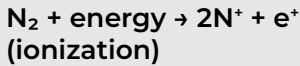
Atomic nitrogen adheres and diffuses into the surface layer of the material, generating compounds such as iron nitrides (Fe_{2-3}N), responsible for increased hardness.

PLASMA
NITRIDING



N⁺
Nitrogen
ion bombardment
Electrically charged gas

At low pressure (1–10 hPa) and with a potential difference of 300–1000 V, the gas transforms into plasma:



→ Ions accelerate toward the cathode (the parts), producing sputtering cleaning, surface activation, and nitrogen entry in an atomic, highly reactive state.

TEMPERATURE

TYPICAL RANGES FOR CARBON STEELS:

570 - 620 °C
1058 - 1148°F

520 - 600 °C
968 - 1112°F

350 - 600 °C
662 - 1112°F

PASSIVE LAYER DEGRADATION LIMIT IN STAINLESS STEELS:
450 - 470 °C = 842 - 878°F



ABC of stainless steels
And why plasma nitriding is the best way to harden them without damaging their corrosion resistance

APPLICATION IN STAINLESS STEELS

SALT BATH NITRIDING



Not advisable

Not ideal. Although it can form a hard layer, the process severely damages the natural passivation of stainless steel.

Salts interfere with the chromium oxide layer, causing localized attack (pitting) that compromises corrosion resistance.

In addition, the carbon that diffuses along with nitrogen may form chromium carbides, further reducing the material's corrosion resistance.

GAS NITRIDING



High-risk without tight control

The process must be handled with extreme care. If the temperature exceeds a certain threshold or the atmosphere is not properly controlled, chromium nitrides may form at the grain boundaries, reducing the free chromium content and compromising corrosion resistance.

Also, no well-defined compound zone is formed, and the hardness achieved may be lower than with other, more controllable methods.

In most cases, an additional step is required: post-oxidation. This regenerates the chromium oxide layer and improves corrosion resistance, although it rarely restores it completely.

PLASMA NITRIDING



Best option

This is the ideal treatment. Thanks to the low temperature at which it can be performed (~400 - 450 °C) and the precise control of the environment, chromium nitrides do not form and the passive layer is preserved.

Plasma nitriding hardens the surface without affecting corrosion resistance, maintaining the base structure of stainless steel.

Furthermore, since no carbon is used in the atmosphere, the risk of grain sensitization is completely avoided.

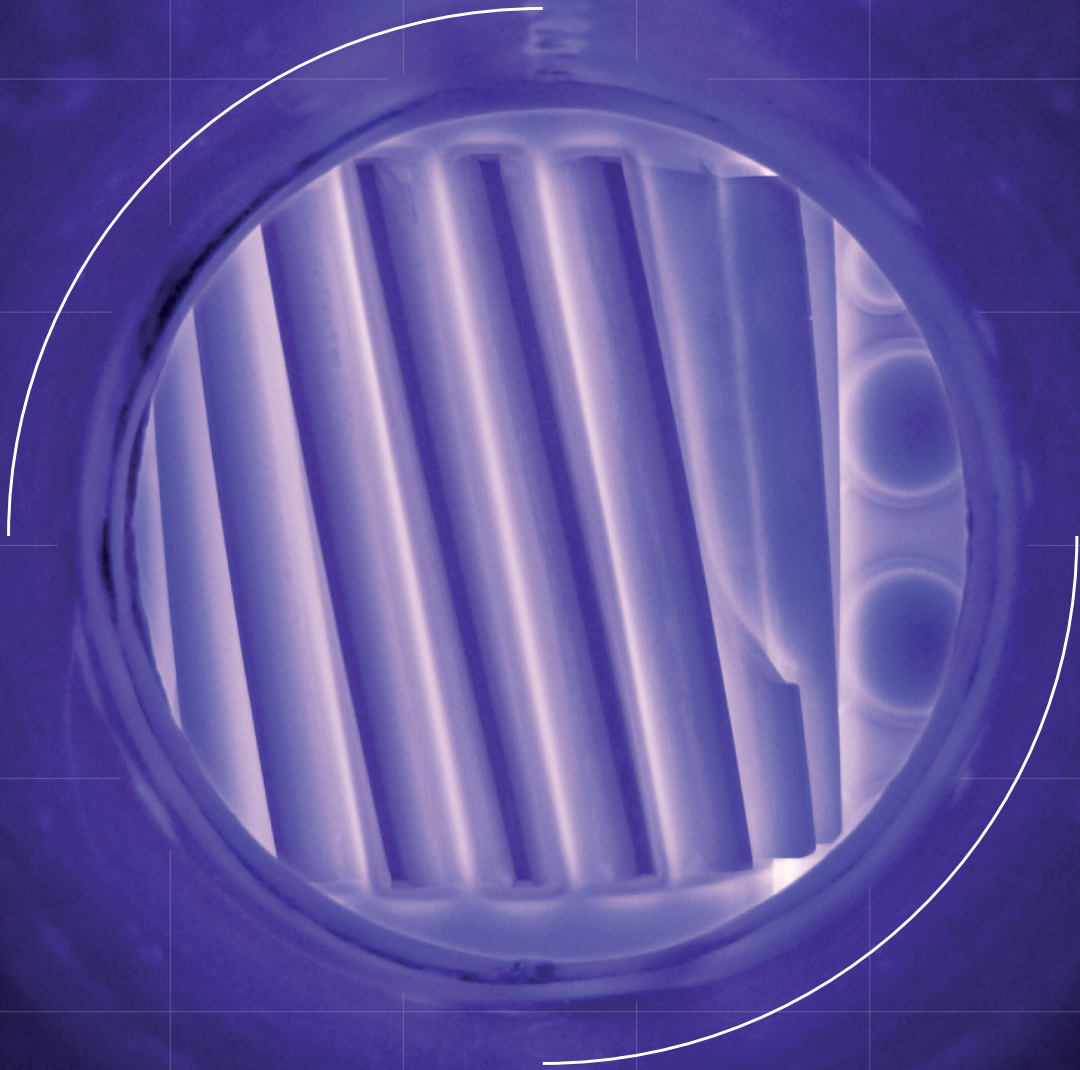
The result is a hardened zone by expanded austenite (S-phase), clean, uniform, and suitable for demanding environments such as pharmaceutical, medical, food, or marine.

**No post-oxidation
required.**



ABC of stainless steels

And why plasma nitriding is the best way to harden them without damaging their corrosion resistance



Why is plasma nitriding
the best way
to harden stainless steels
without damaging their
corrosion resistance?

plasma

NITRIDING

Most heat treatments present a dilemma when applied to stainless steels: yes, they can increase hardness, but at the expense of their most valuable property—corrosion resistance.

Plasma nitriding breaks that logic. Not only does it harden the surface without altering the core of the material, but **it also protects and even enhances passivation**—something other methods simply cannot guarantee.

⦿ **Its strength: precise process control under unique plasma conditions.**



ABC of stainless steels
And why plasma nitriding is the best way to harden them without damaging their corrosion resistance



Plasma nitriding

what truly
sets it apart?



ABC of stainless steels
And why plasma nitriding is the best
way to harden them without
damaging their corrosion resistance

Temperature control

Plasma nitriding can operate at low temperatures (**≈350 - 450 °C in austenitic stainless steels**), which prevents unwanted phase transformations and keeps chromium stable in solid solution.

This controlled temperature minimizes the risk of distortion, preserves the original geometry of the part, and reduces the need for post-machining.

**The secret isn't the heat
— it's the ion bombardment.**

KEY POINT

The process takes place in a vacuum chamber with gases such as hydrogen and nitrogen. A high-voltage electric field ionizes these gases and directs the ions toward the surface of the parts, activating the surface and enabling nitrogen diffusion.



ABC of stainless steels
And why plasma nitriding is the best way to harden them without damaging their corrosion resistance

Optimized sputtering with argon

Hydrogen ions, due to their small size, do not penetrate the crystal lattice: they rebound, cleaning the surface of impurities, oils, and residues. This impact cleaning is known as sputtering.

For stainless steels, argon is added—a noble gas with heavier atoms. These argon ions can also remove the passive chromium oxide layer, which might seem like a problem... but it is not.

By temporarily removing that surface barrier, nitrogen can diffuse more effectively. The result is a hardened, nitrogen-enriched layer, composed of the material's original microstructure plus nitrogen atoms embedded in it—without forming chromium nitrides—that improves hardness and corrosion resistance.

Technically, this layer is called expanded austenite or S-phase (when formed on austenite), and it corresponds to a nitrogen supersaturated solid solution in the crystal lattice. Unlike precipitated nitrides, this phase hardens the surface without compromising corrosion resistance or altering the steel's internal structure.

NITRO BOOST

Plasma nitriding hardens without affecting the core of the part, combining low friction with high wear resistance—an unbeatable combination.

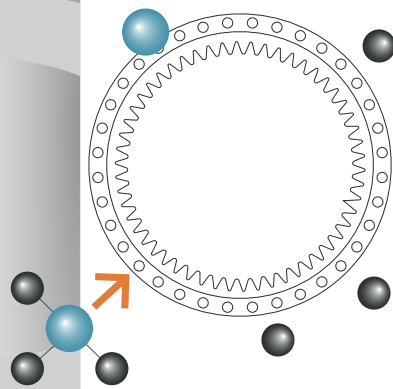
And there is no need to worry about the passive layer: once the process ends, the free chromium at the surface reacts with oxygen in the air and spontaneously regenerates a new protective layer.



ABC of stainless steels
And why plasma nitriding is the best way to harden them without damaging their corrosion resistance

Oxygen-free process

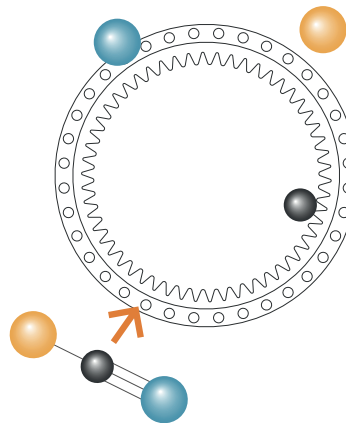
Another major advantage of plasma nitriding is that it is carried out in an oxygen-free environment. This makes a real difference compared to other methods:



GAS NITRIDING

Although hydrogen acts as a reducing gas, chromium oxide removal is partial and uneven.

If oxides remain on the surface, nitrogen does not diffuse properly, and the nitrided layer loses consistency.



SALT BATH NITRIDING

In the presence of oxygen, the active compounds regenerate chromium oxides, which act as a passive barrier during treatment.

This prevents a deep and uniform nitriding effect.



ABC of stainless steels
And why plasma nitriding is the best way to harden them without damaging their corrosion resistance

Double-Duty Layer

During plasma nitriding, the stainless steel surface undergoes thorough cleaning: the process begins by removing natural oxides to clear the way for nitrogen. Once the surface is open, nitrogen diffuses easily into the material.

What happens next depends mainly on the treatment temperature. At higher temperatures, nitrogen can form hard, well-defined metallic nitrides, ideal for wear protection. At lower temperatures—especially in austenitic steels, which are more sensitive to corrosion—nitrogen does not form separate compounds; instead, it dissolves into the crystal lattice and creates a special structure known as expanded austenite or S-phase.

This S-phase is a true metallurgical achievement: **it combines high hardness with excellent corrosion resistance.** It does not break the protective chromium oxide layer; on the contrary, it preserves it. Thus, we achieve what once seemed impossible: hardening the surface without destroying its ability to withstand aggressive environments.

AND THE FINAL RESULT? A PERFORMANCE SANDWICH:

- At the center, the original steel, retaining its mechanical properties.
- Around it, a hardened layer produced by nitrogen.
- On the surface, a new passive chromium oxide layer acting as a shield against corrosion.

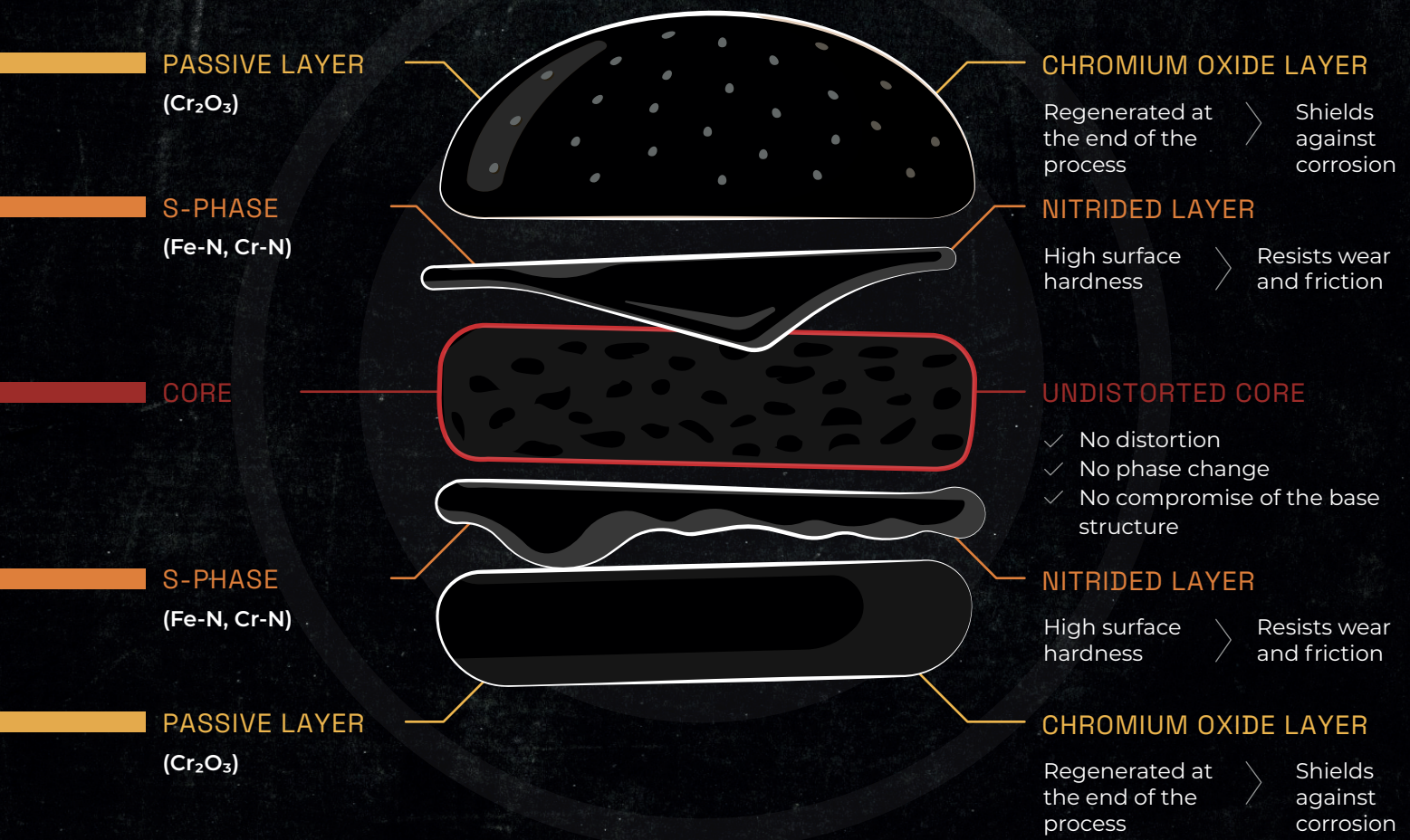
Hardness or corrosion resistance? With plasma nitriding, you don't have to pick—have both in one 'stack'.



ABC of stainless steels
And why plasma nitriding is the best way to harden them without damaging their corrosion resistance

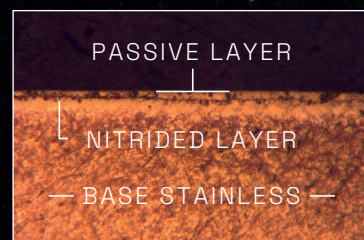
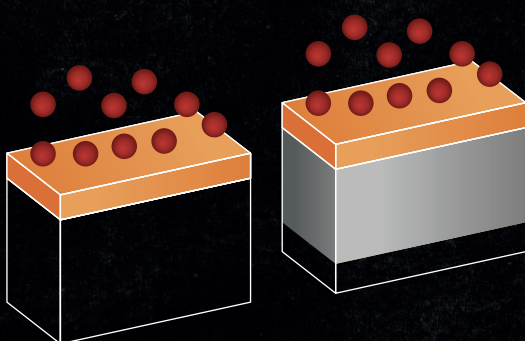
Plasma nitriding gives stainless steel a double-layer upgrade.

Like a functional sandwich, it forms a dual layer that has it all: surface hardness from the S-phase and corrosion resistance thanks to the chromium oxide layer.



BEFORE

AFTER



MICROGRAPH

STAVAX stainless steel
200X | 50 μm

When is plasma nitriding recommended for stainless steel parts?



SUITABLE APPLICATIONS

- Alternative to hard chromium plating or certain external coatings, depending on technical requirements. *
- High-friction conditions with risk of wear.
- Moving parts in sliding contact (shafts, guides, seals).
- Corrosive environments combined with surface hardness requirements.
- Parts requiring dimensional precision without distortion.
- Porous materials not fully sintered or with unsealed cavities.



UNSUITABLE APPLICATIONS

- Repeated impact or shock loads.
- Parts that will be machined after treatment.
- Applications where toughness is more critical than surface hardness.



KEY BENEFITS IN STAINLESS STEELS

- Surface hardening without loss of corrosion resistance, provided temperature is controlled according to the stainless steel grade.
- Low friction and longer service life in sliding surfaces.
- Minimal thermal distortion and no contaminating residues.
- Clean, stable process in vacuum.
- Compatible with precision parts or complex geometries.



TECHNICAL FACTORS TO CONSIDER

- Requires parameter adjustment according to steel grade and application.
- Not a universal solution: must be tailored to each part.
- Not a coating: no external layer is applied.**
- Achieved hardness must not compromise functional integrity.
- Does not replace mechanical or structural treatments.

* Hard chromium plating has historically been used to improve surface hardness and wear resistance, but its electrodeposition process carries environmental and health risks due to the use of hexavalent chromium compounds (Cr^{6+}).

** Plasma nitriding can be a viable alternative when a hardened, clean surface without toxic residues is required, especially if no external layer with specific additional properties (such as optical, dielectric, or thermal barrier properties) is needed.



ABC of stainless steels
And why plasma nitriding is the best way to harden them without damaging their corrosion resistance

>>>> PLUS

Plasma nitriding, a game-changer for **additive manufacturing**



ABC of stainless steels
And why plasma nitriding is the best
way to harden them without
damaging their corrosion resistance

Metal additive manufacturing makes it possible to build complex components layer by layer from metallic powders.



Processes such as selective laser melting (SLM), electron beam melting (EBM), and binder jetting are based on established powder metallurgy principles and have transformed how parts are designed for aerospace, medical, and energy sectors.

It is well known that after printing, and depending on the process, some parts must undergo a post-sintering heat treatment to densify the structure and remove residual porosity. Depending on the stainless steel grade, this may include stress-relief annealing, thermal densification, or solution annealing.

Beyond consolidating the microstructure, these parts also need surface strengthening, enhanced mechanical performance, and the ability to withstand demanding wear, friction, and fatigue conditions. In that scenario, **plasma nitriding offers a high-precision solution** fully aligned with the requirements of metal AM components.

Parts produced by these methods often show surface roughness, residual porosity, microcracks, and layer-to-layer variability in mechanical properties.

Plasma nitriding addresses these challenges without compromising material integrity.

It develops a hard surface layer of iron, chromium, and alloy nitrides at higher temperatures, or expanded austenite (S-phase) at lower temperatures; induces beneficial compressive stresses that improve fatigue resistance; enhances load-bearing capacity without altering geometry; and achieves all this without blocking porosity or leaving liquid residues, as may occur with salt bath or gas processes.



ABC of stainless steels
And why plasma nitriding is the best way to harden them without damaging their corrosion resistance

It also brings **unique advantages**: operating in a controlled vacuum, free of oxygen; cleaning the surface through sputtering without affecting internal porosity; and enabling precise, repeatable control of case depth, temperature, and nitrogen penetration. Under these conditions, plasma nitriding integrates seamlessly with the consolidated microstructure of AM parts, without causing distortion or creating heat-affected zones (HAZ).

In short, plasma nitriding is not just a compatible treatment. It is a technology that naturally fits the logic of additive manufacturing, respecting its specific characteristics while boosting final performance.

Plasma nitriding does not induce aggressive hardening: it reinforces and seals each layer of the process with precision.

Plasma nitriding does not apply an external coating: it modifies the material's own surface by nitrogen diffusion in its ionic state. Unlike coatings such as hard chromium plating, PVD, or DLC, **there is no risk of delamination or contamination** from metallic debris.

This makes it an effective alternative to replace coatings in applications where dimensional integrity, cleanliness, and repeatability are critical.

Plasma nitriding is a **viable option when a hardened, clean surface without toxic residues is required**, especially if no external layer with additional properties (such as optical, dielectric, or thermal barrier properties) is needed.



ABC of stainless steels
And why plasma nitriding is the best way to harden them without damaging their corrosion resistance



ABC of stainless steels
And why plasma nitriding is the best
way to harden them without
damaging their corrosion resistance

As a closing note...

The advantages of plasma nitriding for stainless steels are neither marketing hype nor inflated claims. They are the proven outcome of a precise physical process, developed over decades and validated in laboratories, workshops, and production lines around the world.

When parts must preserve their shape, hardness, and corrosion resistance even in harsh environments, there are no shortcuts—and no room for heat treatments that compromise what the material was designed to deliver. Plasma nitriding is not an emerging alternative; **it is a mature technology, built on solid fundamentals, with repeatable results and measurable benefits.**

At ION HEAT, we don't manufacture expectations. We manufacture furnaces.

We are among the leading developers of plasma nitriding technology. Our goal is not to persuade anyone of its merits—anyone who has read this far already knows them.

Our role is to partner with each customer in building a system that fits their processes, adapts to their scale, and delivers exactly what is needed, part after part.

In this ebook we have shared the fundamentals, the comparisons, and the technical advantages of applying this process to stainless steels. The next step is not a matter of belief—**it is a matter of engineering.**

**THAT IS OUR
ROLE.**



ABC of stainless steels
And why plasma nitriding is the best way to harden them without damaging their corrosion resistance

Technical glossary



ABC of stainless steels
And why plasma nitriding is the best
way to harden them without
damaging their corrosion resistance

Hard chrome replacement

Shift toward surface treatments that provide properties similar to hard chrome (high hardness, wear and friction resistance), but without coatings, hazardous residues, or poor repeatability.

Plasma nitriding produces a functionally equivalent surface with no risk of delamination or environmental contamination.

Removal of chromium oxide passive layer

During sputtering, argon ions also remove the original chromium oxide passive layer (Cr_2O_3). While this layer protects against corrosion, it acts as a barrier to nitrogen diffusion.

Its temporary removal clears the surface for more effective nitriding.

Argon sputtering

First step in the plasma nitriding process. A surface cleaning by ion bombardment: argon ions strike the steel surface and remove impurities, oils, residues, and oxides.

This cleaning prepares the material for uniform and effective nitrogen diffusion.

Oxygen-free controlled vacuum

Plasma nitriding is performed in a vacuum chamber with a controlled oxygen-free atmosphere.

This condition prevents the formation of unwanted oxides, reduces the risk of surface contamination, and ensures a chemically stable environment for clean diffusion.



ABC of stainless steels
And why plasma nitriding is the best way to harden them without damaging their corrosion resistance

Controlled nitrogen diffusion

Nitrogen ions activated by the plasma penetrate the steel surface by diffusion, without altering the internal structure or forming undesired phases.

The process is highly controllable in depth, uniformity, and metallurgical profile.

Compound layer free of chromium carbides

Plasma nitriding avoids the formation of chromium carbides, typical in treatments involving carbon.

By working only with nitrogen, chromium remains free, preserving the corrosion resistance of the steel.

Dual-function layer

Characteristic outcome of plasma nitriding in stainless steels. The treated surface shows a hardened zone by expanded austenite (S-phase) plus a passive layer of chromium oxide.

One protects against wear, the other against corrosion.

Chromium nitrides

Hard compounds formed when nitrogen reacts with chromium in the steel.

These nitrides increase surface hardness but consume chromium needed for passivation, potentially reducing corrosion resistance.

Uniform surface hardness distribution

Thanks to the controlled atmosphere, the ion discharge spreads evenly across the exposed surface, even in complex geometries.

This provides uniform hardness without soft spots or unwanted variations.



ABC of stainless steels
And why plasma nitriding is the best way to harden them without damaging their corrosion resistance

Regenerated passive layer

Once the process is completed and the part is exposed to air, the free chromium at the surface spontaneously forms a new chromium oxide passive layer (Cr_2O_3), restoring the corrosion resistance typical of stainless steel.

Avoidance of grain boundary sensitization

Plasma nitriding is performed at temperatures low enough to avoid chromium carbide precipitation at grain boundaries. This prevents sensitization, a phenomenon that degrades corrosion resistance in heat-treated stainless steels.

Expanded austenite / S-phase

Surface layer formed when nitrogen dissolves into the crystal lattice of stainless steel at low temperature, without generating precipitated nitrides. It appears mainly in austenitic steels and is responsible for hardening without loss of corrosion resistance.

3D printing of stainless steel

Technology that produces parts layer by layer from metallic powders. Plasma nitriding is especially well suited for these parts, as it does not block porosity, does not generate liquid residues, and improves mechanical properties without altering geometry or compromising material integrity.



ABC of stainless steels
And why plasma nitriding is the best way to harden them without damaging their corrosion resistance

© 2025 ION HEAT

This document is the property of **ION HEAT S.A.S.** The photographs, illustrations, and renders are part of the Company's image bank or have been sourced from Freepik under a Premium license (unlimited use without attribution). All content is protected under Colombian copyright law.

This material is intended for educational purposes only and may not be used for economic or commercial purposes. **ION HEAT S.A.S.** owns and retains all copyrights and other intellectual property rights of this eBook; therefore, it may not be reproduced, modified, copied, or disclosed without the Company's written consent.

ION HEAT S.A.S. certifies that it has made every reasonable effort to ensure the information is accurate, complete, and reliable. However, it assumes no liability for potential errors resulting from acts or omissions based on all or part of the information provided.



Contact

COLOMBIA

Zona Franca Rionegro - 209 | Postal Code: 054047
+57 310 426 4843
ionheat@ionheat.com

UNITED STATES

+1 267 800 0446

www.ionheat.com

