

MINIMIZE OXIDATION WITH MINIMOX™ COATINGS

HIGH TEMPERATURE ALLOY PROTECTION *Nanocrystalline surface treatment to enhance self-protective oxide formation*

WHY PUT IT IN THE ALLOY, WHEN YOU CAN PUT IT ON THE ALLOY?

Material Interface, Inc., is currently developing and refining a series of Minimox™ nanocrystalline coatings that:

- Impart significant high temperature protection to stainless steel and other alloys, including nickel-based super alloys and aluminum.
- Limit oxide scale growth, yielding an adherent and dense surface.
- Often provide corrosion resistance.
- Are economical and easy to apply through a simple dip, spray, or roll process.

Use lower cost alloys for elevated temperature applications

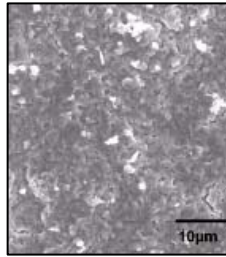


Stainless steel bolts dipped in Minimox nanocrystalline solution before being heated in air to 1000°C. The lack of peeling oxide on the coated bolts demonstrates the effectiveness of this simple-to-apply coating.

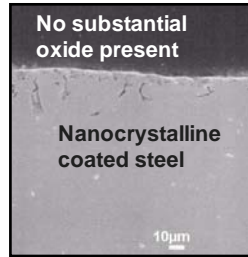
OXIDATION RESISTANCE

316L Stainless Steel, 1000°C, dry air. Spalling is reduced with Minimox™ coating, applied via dipping & air dry.

**Coated –
Thin, intact
oxide**

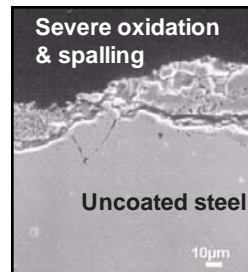
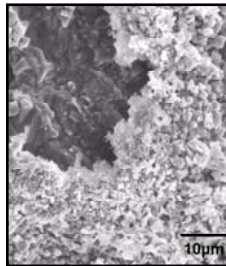


Surfaces

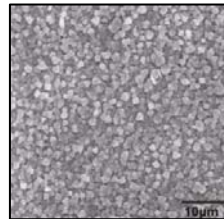
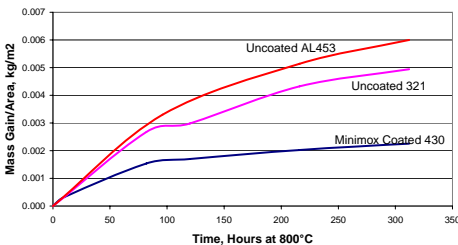


Cross sections

**Uncoated -
Thick, spalling
Oxide**



430 Stainless Steel, 800°C, dry air. Mass gains due to oxide growth are reduced with the Minimox™ process.

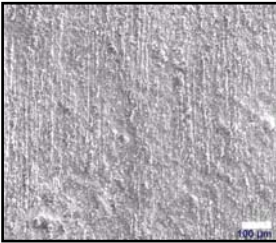


Surface of 430 SS after 300 hr, 800°C

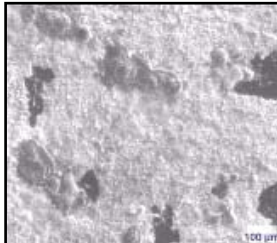
Samples of 430 stainless steel were treated with the Minimox™ coating and heated to 800°C for over 300 hours. Although a higher temperature than 430 typically sees in service, the purpose was to compare oxidation rate of a ferritic stainless to that of 321, a steel with titanium additions often selected for its oxidation resistance, and to AL453™, a specialty steel with alloy additions developed specifically for improved oxidation resistance at high temperature. *The mass gain of Minimox-coated 430 stainless steel is less than that of 321 and AL453™.*

CORROSION PROTECTION

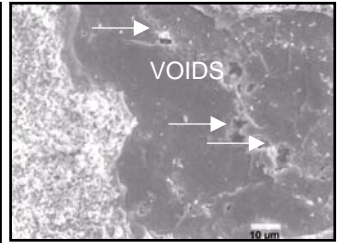
The nanocrystalline coating process alters the nucleation and growth of thermal oxides – yielding an oxide surface that is more dense, adherent, and intact. This layer improves the corrosion resistance as demonstrated with the nickel surfaces shown below.



Nanocrystalline coated Ni 600 alloy; heated in air to 1000°C for over 500 hours. The oxide is dense, thin, and adherent. (original 100X)



Uncoated Ni 600 alloy; heated in air to 1000°C for over 500 hours. Oxide scale is blistered, flaked, and porous and has multiple protrusions.



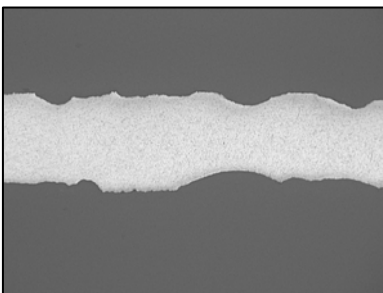
Microvoids under blistered oxide of uncoated Ni 600 alloy are ideal sites for corrosion. These corrosion nucleation sites are absent in the nanocrystalline-coated material. (original 1000X)

Aluminum Alloy *Cyclic corrosion test: hot, acidic conditions*

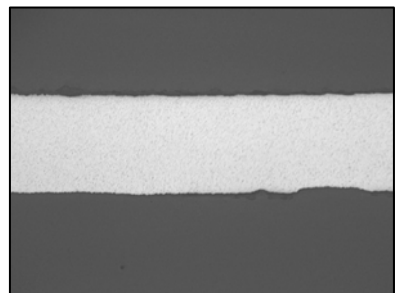
Demonstrated corrosion resistance in industrial applications.

The Minimox nanocrystalline coating has demonstrated corrosion resistance in aluminum alloys during customer testing under hot, acidic conditions. The Minimox-coated area shown above was chosen as the worst-case corrosion site by an outside lab.

Corrosion resistance has also been demonstrated in **hot salt** and **stress corrosion cracking**. Development is continuing in these applications.



Untreated Al Alloy



Minimox-coated Al Alloy

The Minimox™ Coating Process

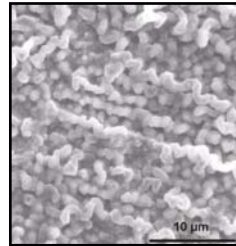
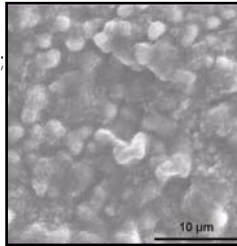
Alloys designed for high-temperature applications contain certain additions. Research has shown if those addition elements are instead applied as a *superficial nanocrystalline coating* to the surface of a more basic alloy, the same high-temperature surface oxidation properties can be achieved.

WHY PUT IT IN THE ALLOY, WHEN YOU CAN PUT IT ON THE ALLOY?

The nanoparticles are in liquid suspension. Minimox™ nanocrystalline coating provides well-dispersed, extremely small particles required for a superior coating with astonishing protection. After nanocrystalline coating, alloys heated in air exhibit a thin, adherent, intact oxide layer, rather than a thick, flaking oxide scale. The coating is applied through a dip process and air dry. Brushing and spraying has also been successful.

The nanocrystalline coating process alters the nucleation and growth of thermal oxides. This is demonstrated on the nickel samples shown below.

Untreated 600 Ni alloy;
Heated in air to 800°C
for 268 hours.
Oxide scale is thick
& friable in texture.
(original = 3000X)



600 Ni alloy coated
with Minimox;
heated in air to 800°C
for 268 hours.
The thermal oxide is
radically different.
The oxide is dense,
thin, and intact.

Development is in progress for many applications and alloys. Contact us with your requirements. This research was funded by the U.S. Department of Energy.

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