EXPANITE
SURFACE HARDENING OF STAINLESS STEEL

Fighting wear, corrosion, galling and fatigue on stainless steel and titanium alloys

Agenda 10.10.19

- Expanite Introduction
  - From Research to business
  - Facts & Figures
  - Strategy
  - Key pointers
- Expanite processes. This is how we do it
- Wear and Corrosion after… Testing Expanite
- ExpaniteHard-Ti

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From research to business

- Expanite founded in 2010 by
  - Prof. Marcel Somers
  - Ph.D. Thomas L. Christiansen
  - Ph.D. Thomas Strabo Hummelshøj

  …but development goes back to 2000!
- First major customer early 2012
- Company culture driven by being a game-changer on the following parameters
  - Speed
  - Tailoring
  - Cleanliness
  - On-site

University anno 2009

Hillerød ultimo 2012

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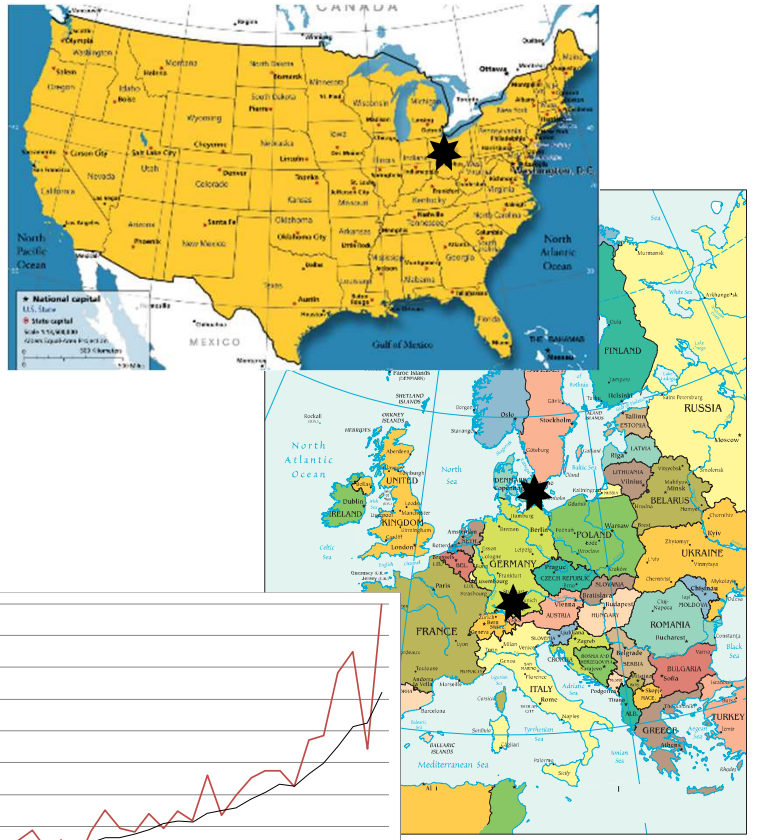
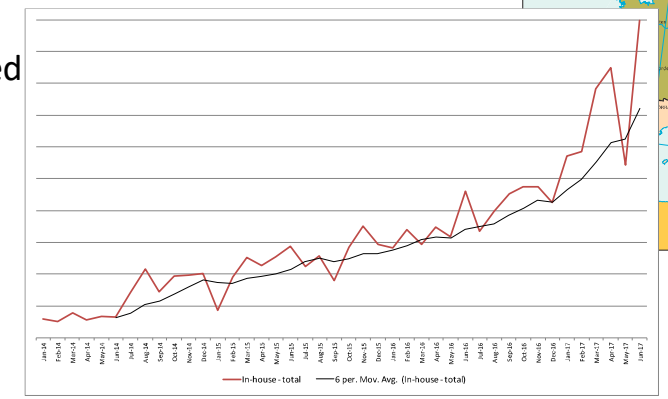
Expanite as of January 2019

- Primary facility (600m2) in Hillerød, Denmark
  - R&D facility incl. lab and experimental furnaces
  - Expanite Treatment Center for production
- US treatment facility near Cleveland, Ohio
- German treatment facility near Stuttgart
- Chinese facility near Shanghai
- All sites are ISO9001:2015 certified
- 2x yearly growth since 2013
- Approx. 26 employees





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Strategy

- Two pillars for growth
  - Expanite Treatment Centers
    - Establish a global chain of treatment centers to service small to large size customers.
    - Key benefits are lead-time and quality
  - On-site installations
    - Install (standard) furnace with Expanite license for larger customers and or those customers who sees hardening as strategically important to their business
    - Key benefits are lead-time and cost-savings due to reduced work-in-progress and logistics

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Goes beyond the surface to reduce lead time and costs

THE BEST PRODUCT

- The best in wear and corrosion resistance when it comes to surface hardening of stainless steel
- No matter choice of stainless steel, there is a solution

SHORTEST LEAD TIMES

- Processes are running day-to-day
- 2-3 working days lead time is offered
- Standard lead time 6-9 working days

TAILORED & STANDARD

- Hardening processes can be tailored matching individual requirements
- The product portfolio includes a wide-range of standard solutions

"YOUR PLACE OR MINE?"

- Treatment centers in Denmark, Germany and the US
- The possibility to install equipment on-site with customers
- Production sites are ISO9001 certified and CQI-9 compliant

TOTAL COST OPTIMISATION

- The best product gives the longest lifetime
- The shortest lead times reduces inventory and work in progress
- Competitive pricing completes the cost optimization

OPENNESS AND PARTNERING

- Considering the needs of the end user
- Understanding your process and challenges
- Focusing on knowledge sharing

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EXPANITE
3 Challenges
This is how we do it

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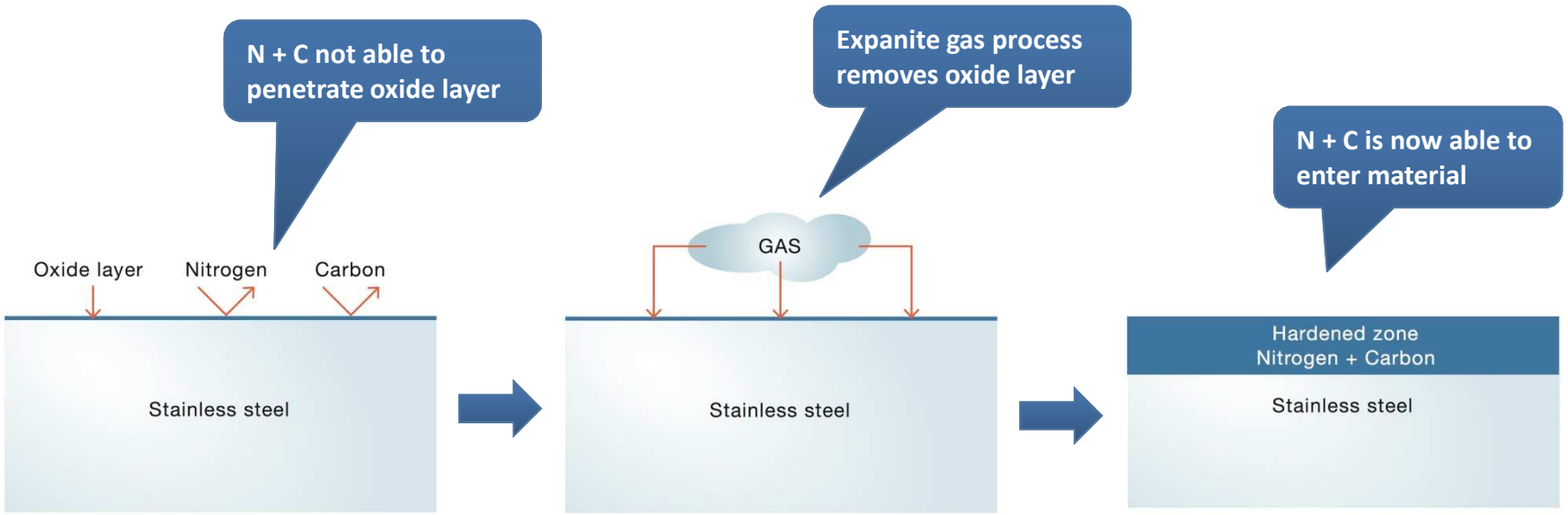
Challenge no 1 – passive oxide layer



Expanite patent

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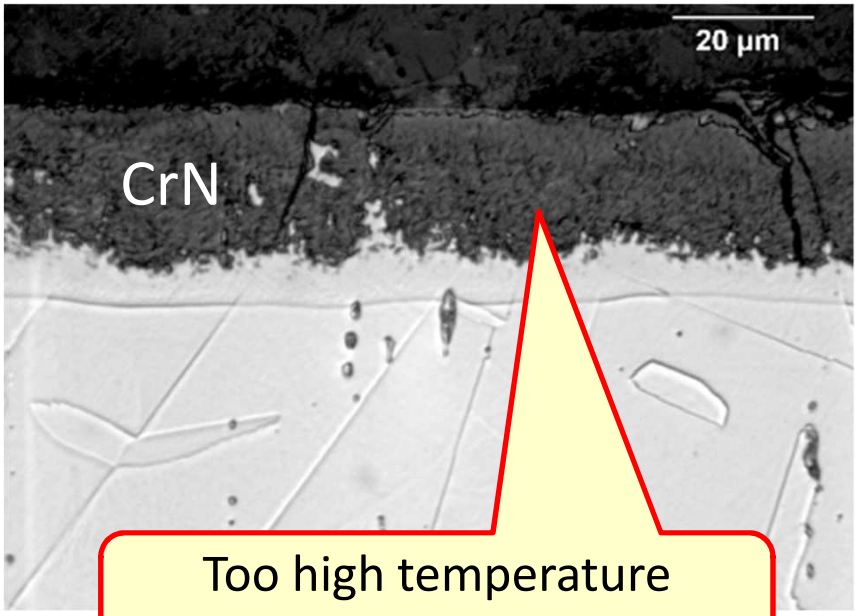
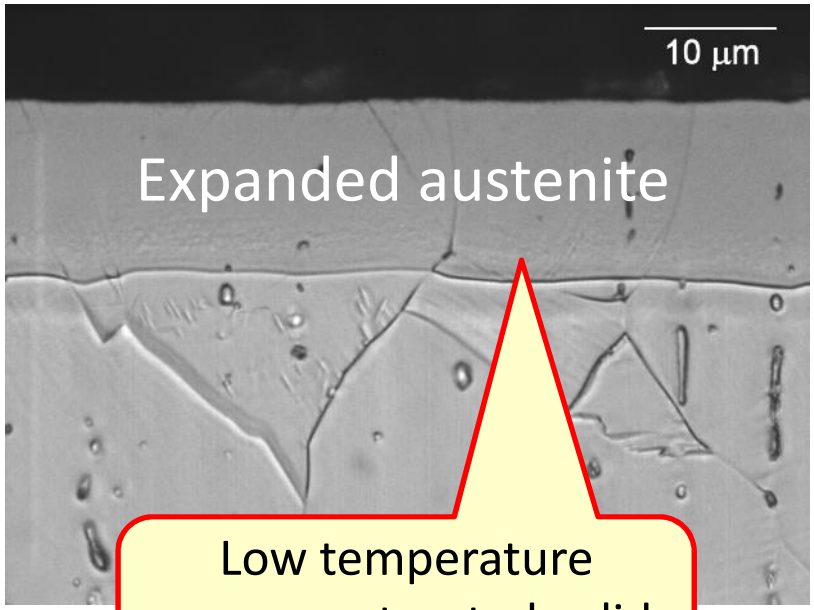
Challenge no 2 – Temperatures



Too high temperature
– corrosion resistance lost!



Low temperature
– supersaturated solid solution

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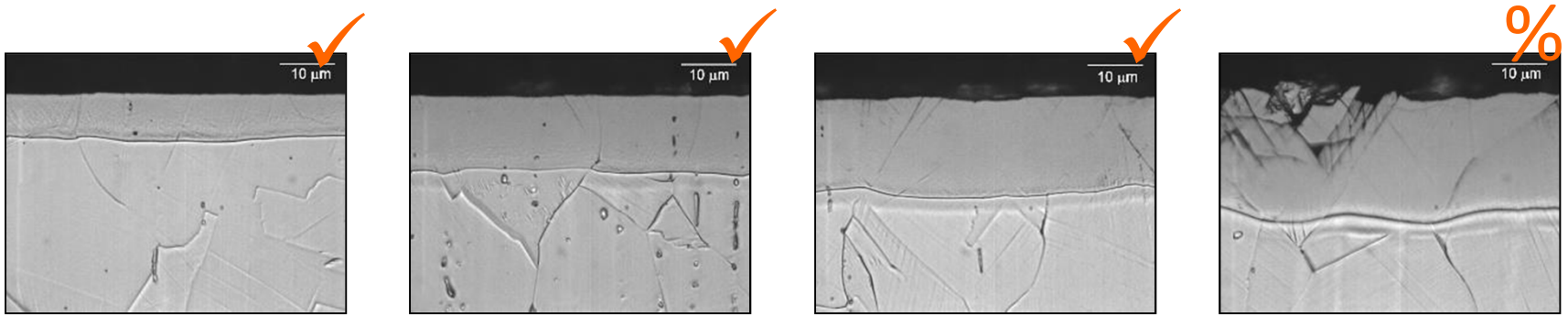
Challenge no 3 – Stabil Process = accurate control…



Changing thermodynamical parameters

Use a gaseous process !

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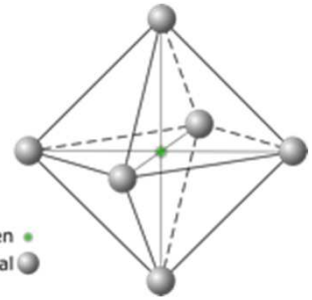
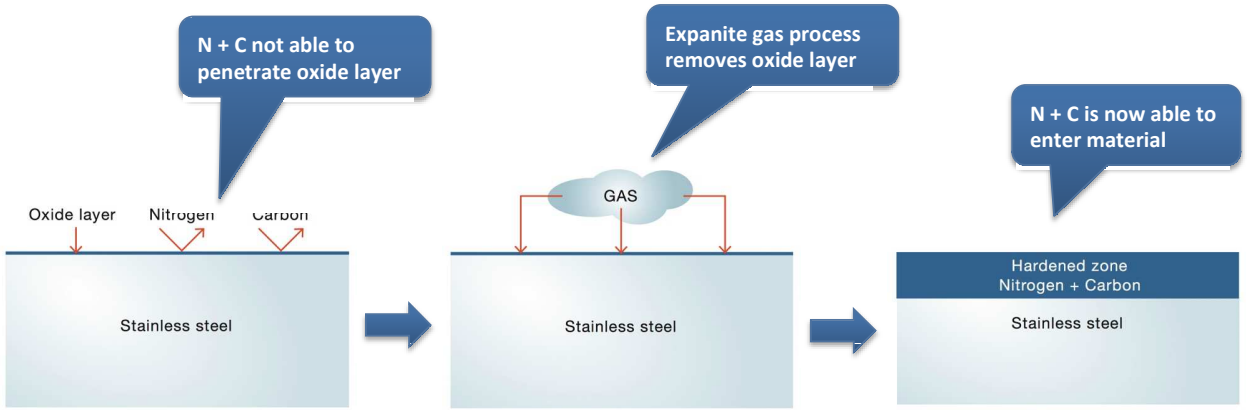
What is Expanite?

A technology
=
process/recipe
=
time + temperature + pressure + gas flow + surface physics & chemistry in a furnace
=
a gas-based diffusion process





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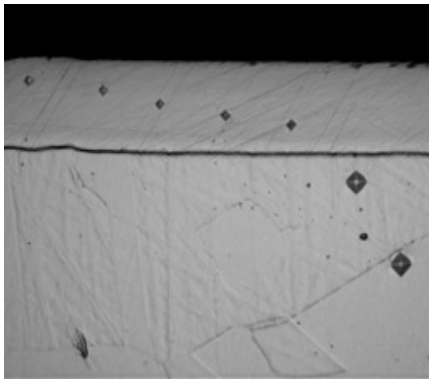
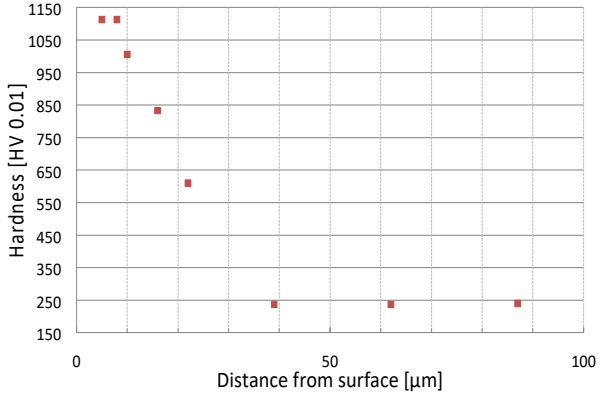
What's unique?

- Improving hardness and in the same time improving/restoring corrosion resistance beyond what the market previously has seen

ISO9227 168hr salt spray

Micrographs & hardness profile of part in AISI316





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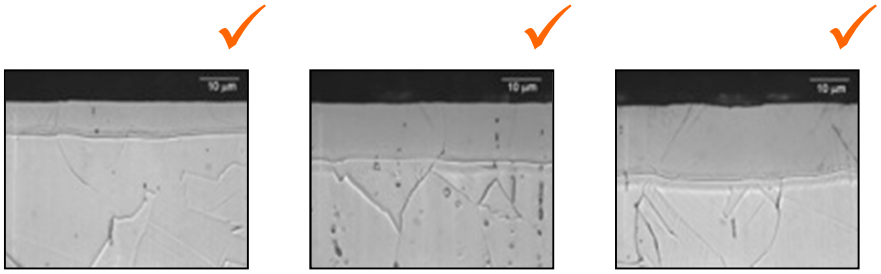
What's unique?

Accurate control

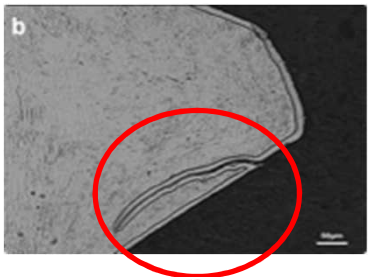
- Tailoring
- Scalable
- Clean
- Fast & Cost effective



Identical temperature and time – only increasing gas potential

Bulk-ware treatment

- Homogenous hardening
- No post cleaning
- Bulk treatment



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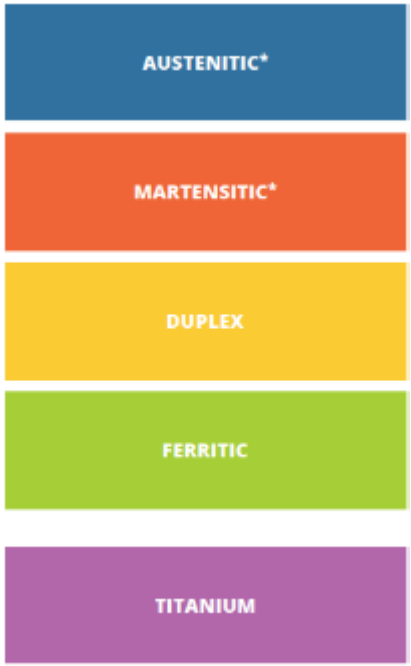
Product portfolio

- Tailoring of four core processes
  - ExpaniteHigh-T
  - ExpaniteLow-T
  - SuperExpanite = ExpaniteHigh-T + ExpaniteLow-T
  - ExpaniteHard-Ti
- Other services include
  - Material recommendation/selection
  - Implementation & quality control of Expanite

Whatever your stainless steel alloy, there is always an Expanite solution



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The processes

ALLOY	PROCESS
AUSTENITIC*	SuperExpanite ExpaniteHigh-T
DUPLEX	SuperExpanite ExpaniteHigh-T
FERRITIC	SuperExpanite ExpaniteHigh-T ExpaniteLow-T
MARTENSITIC*	SuperExpanite ExpaniteHigh-T

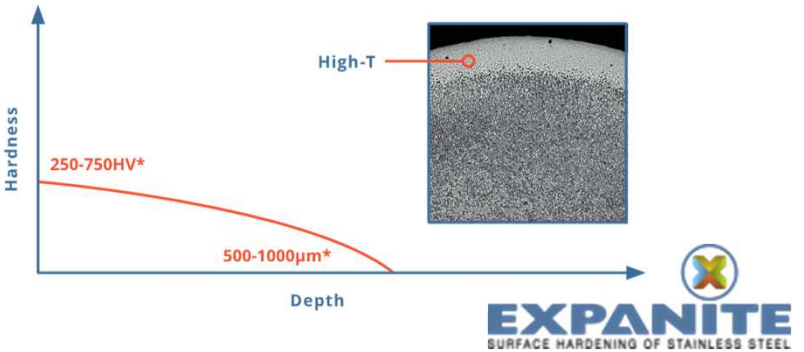
* Including precipitation hardenable steels

Temperature in vacuum: 1000-1200C
Fast gas quench
Adds nitrogen
DK: 400x400x600
DE: 400x400x1000

ExpaniteHigh-T

A high-temperature solution-nitriding process pushing nitrogen deep into the bulk material. This re-establishes the core hardness of the material, which creates a unique load-bearing capacity and secures corrosion resistance second-to-none.

Benefit:
Get all the best things of annealing while maintaining core hardness and increasing corrosion resistance.



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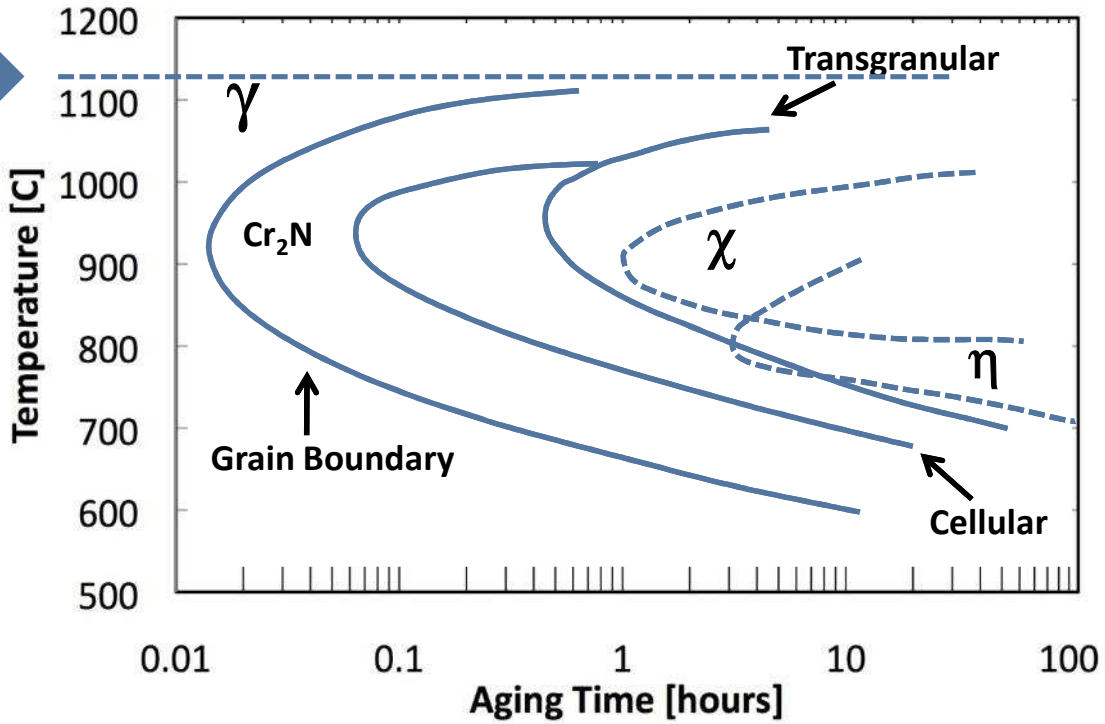
ExpaniteHigh-T

Nitrogen in solid solution



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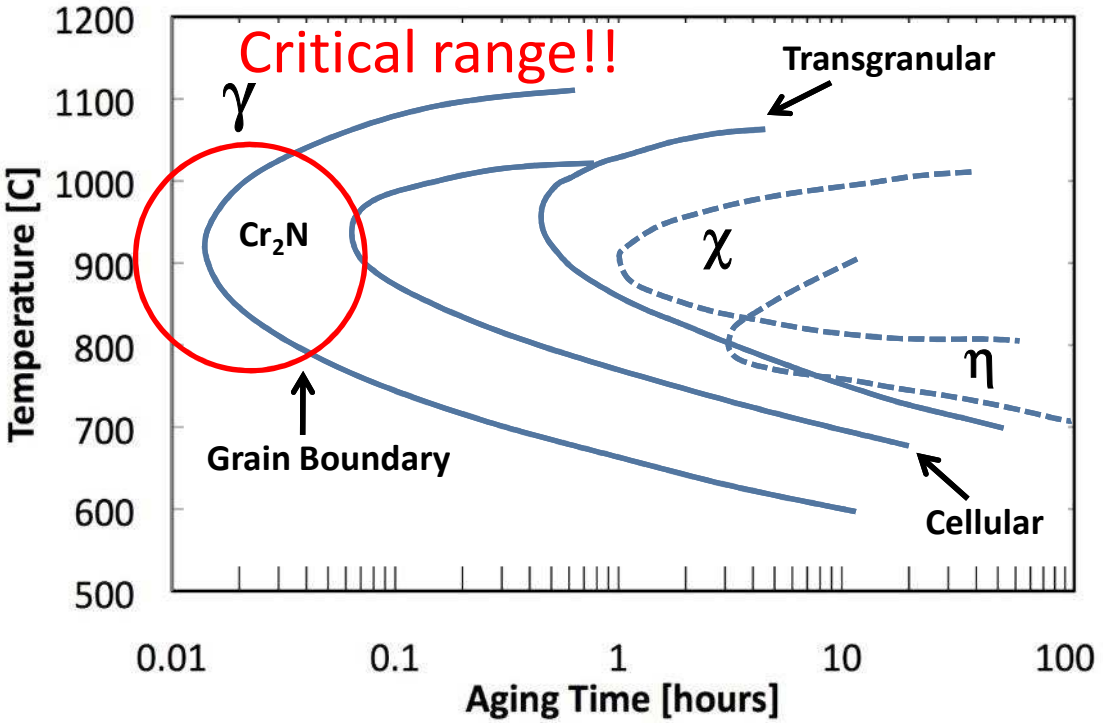
ExpaniteHigh-T

ExpaniteHigh-T applies special gas quench for high interstitial contents

High pressure N_2 quench can impair the corrosion resistance!!



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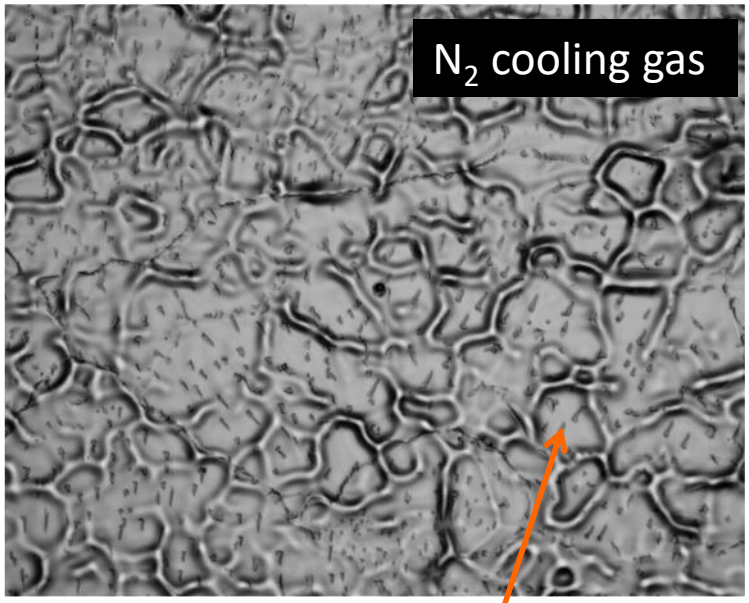
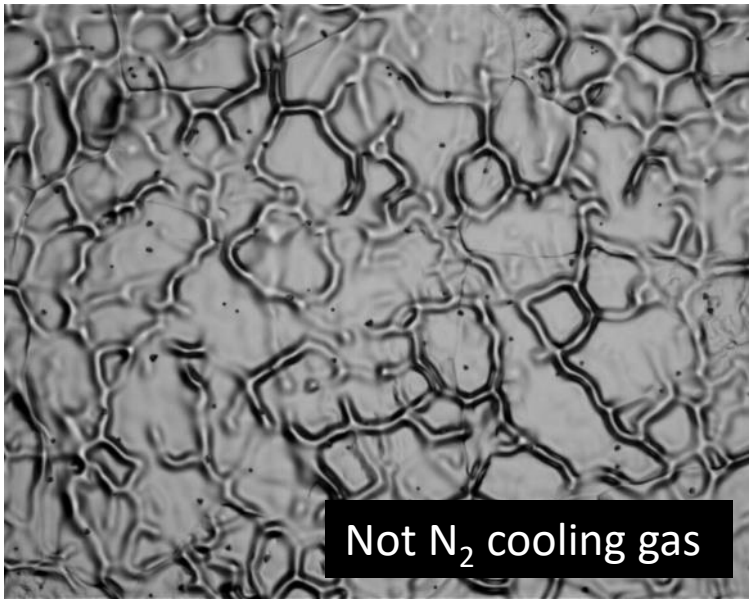
Conventional Solution Nitriding

N_2 cooling compromise corrosion resistance



Surface decorated with
fine surface nitrides



Expanite patent

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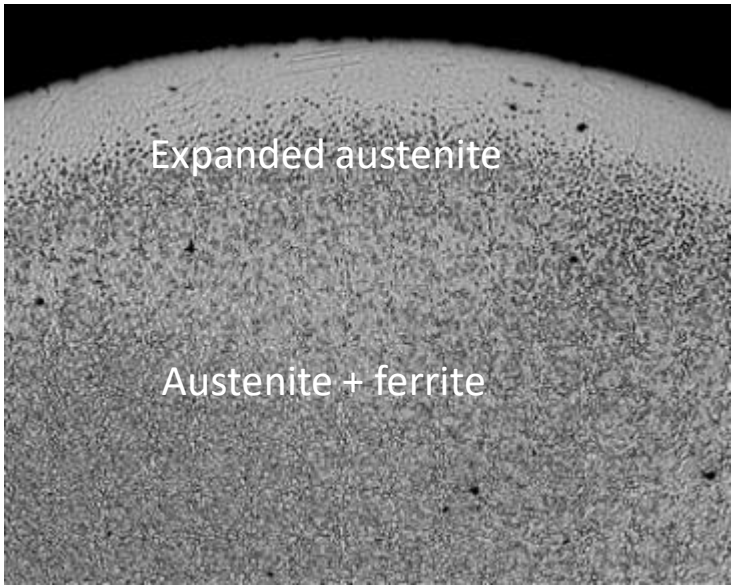
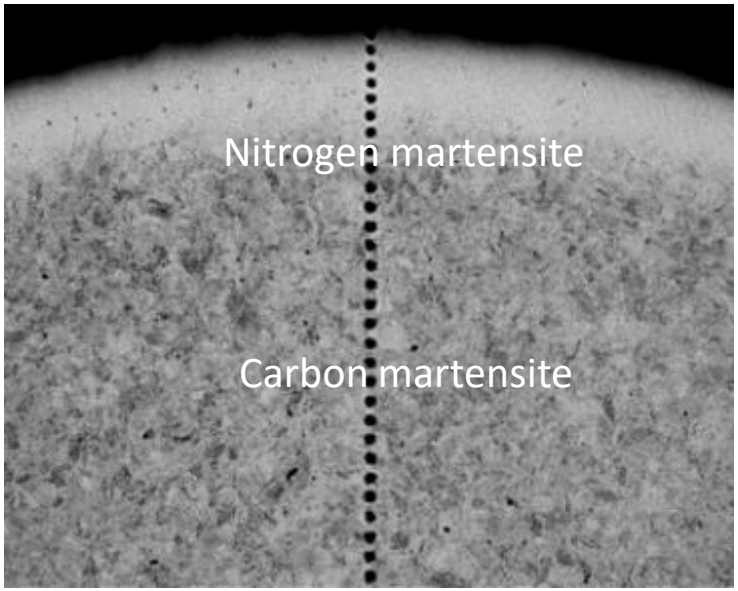
ExpaniteHigh-T

Hardness and corrosion resistance increase!





Duplex stainless steel

Martensitic stainless steel

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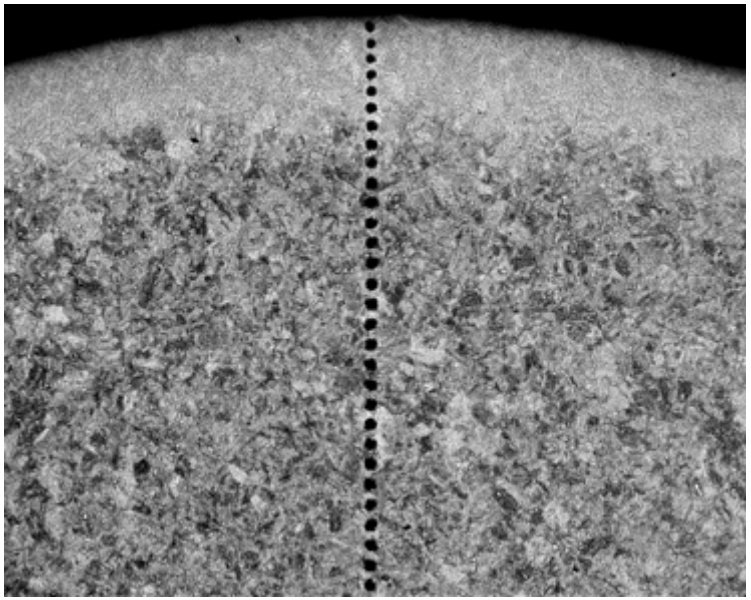
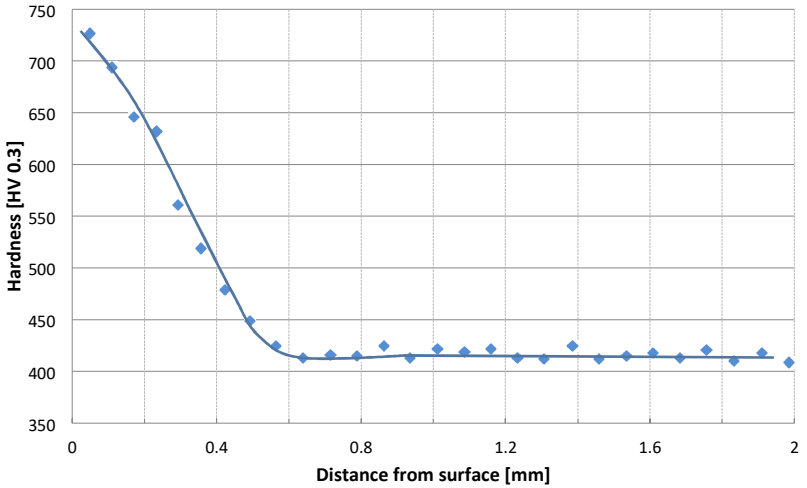
Martensitic stainless steel

12.5Cr-**0.12C**-(1.5Mn+1.0Si max)



Treatment: ExpaniteHigh-T
Case Depth High-T: 0.55 mm
Surface hardness: 950 HV0.3



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SURFACE HARDENING OF STAINLESS STEEL

The processes

Temperature in atmospheric environment: 380-470C
Adds nitrogen and carbon in solid solution
DK: 600x600x1000
DE: 800x800x1000

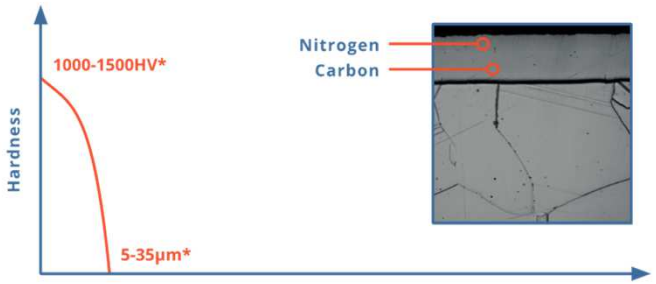
ALLOY	PROCESS
AUSTENITIC*	SuperExpanite ExpaniteHigh-T
DUPLEX	SuperExpanite ExpaniteHigh-T
FERRITIC	SuperExpanite ExpaniteHigh-T ExpaniteLow-T
MARTENSITIC*	SuperExpanite ExpaniteHigh-T

* Including precipitation hardenable steels

ExpaniteLow-T

A low-temperature nitrocarburizing process, by which a double hardened zone containing nitrogen and carbon is established. Nitrogen adds increased surface hardness while carbon bridges the gap to the softer core. A smooth hardness profile is tailored!

Benefit:
Controlled surface hardness between 1000-1500HV.



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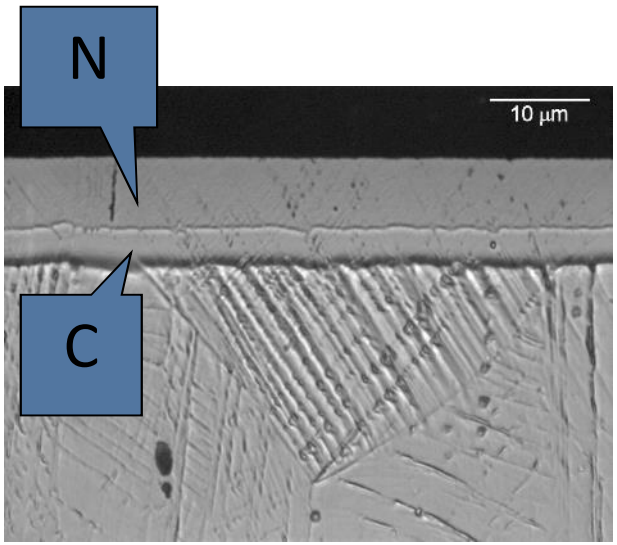
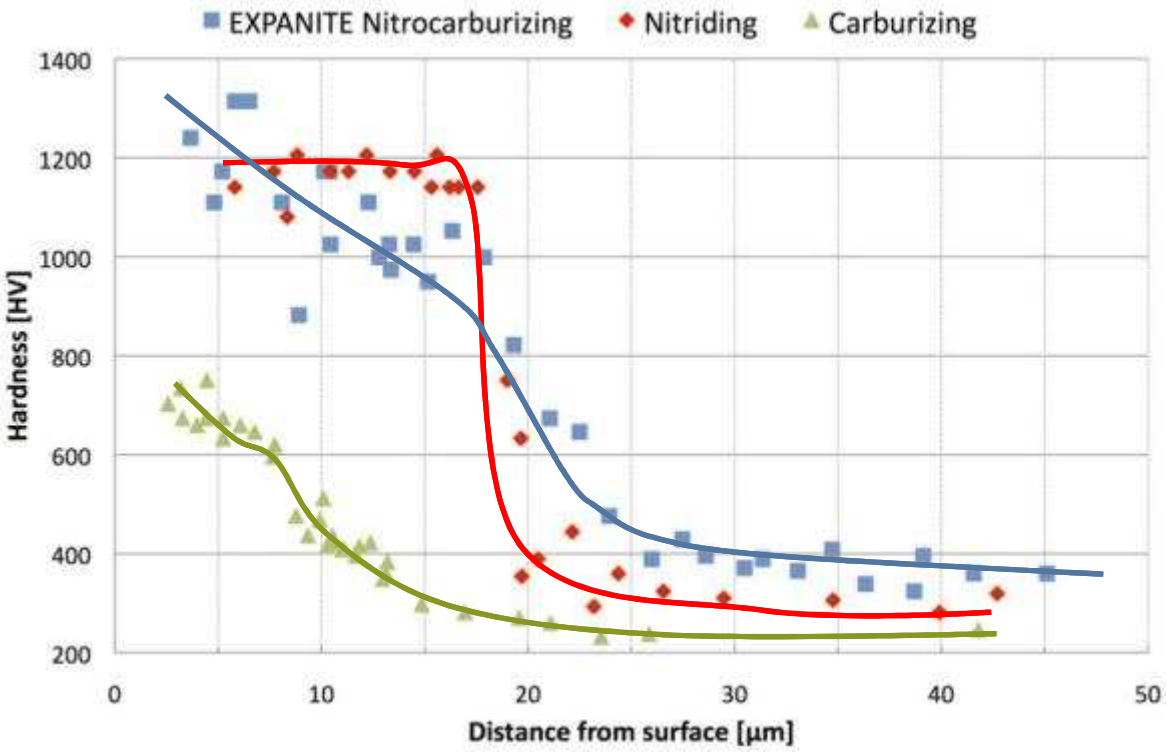
Carbon *and* nitrogen – a smooth profile





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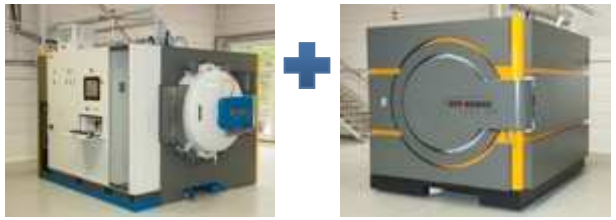
The processes



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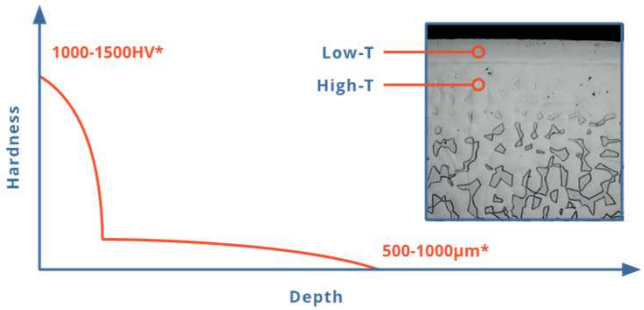
MARTENSITIC*	SuperExpanite ExpaniteHigh-T

* Including precipitation hardenable steels

SuperExpanite

By combining the ExpaniteHigh-T and ExpaniteLow-T processes you get a previously unseen surface hardness founded on top of a bulk material, which has very strong loadbearing capacity. Superior corrosion, wear and fatigue properties is the outcome – SuperExpanite is simply setting new standards for what can be achieved by surface-hardening stainless steel.

Benefit:
Superior corrosion, wear, scratch and fatigue properties.



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Wear and Corrosion after…..

Testing Expanite

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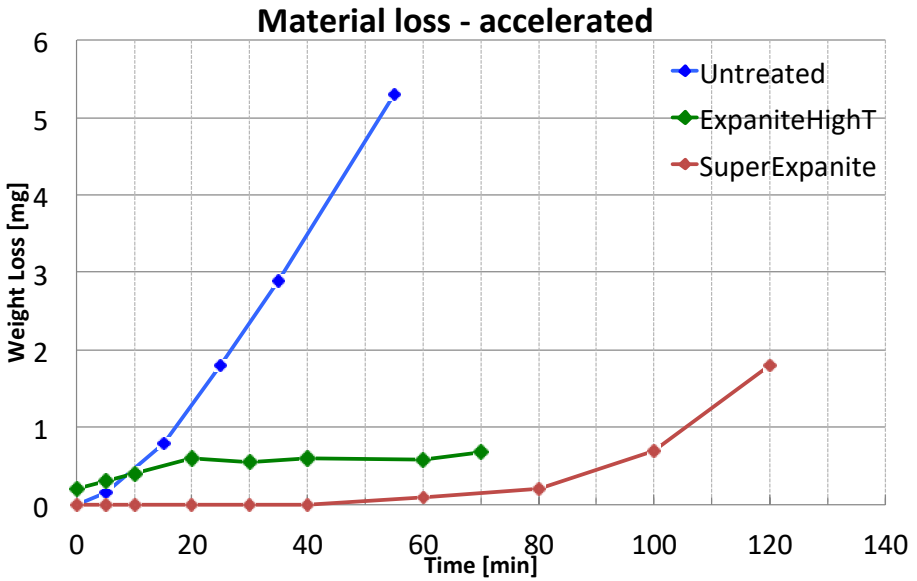
The pain…and the solution!



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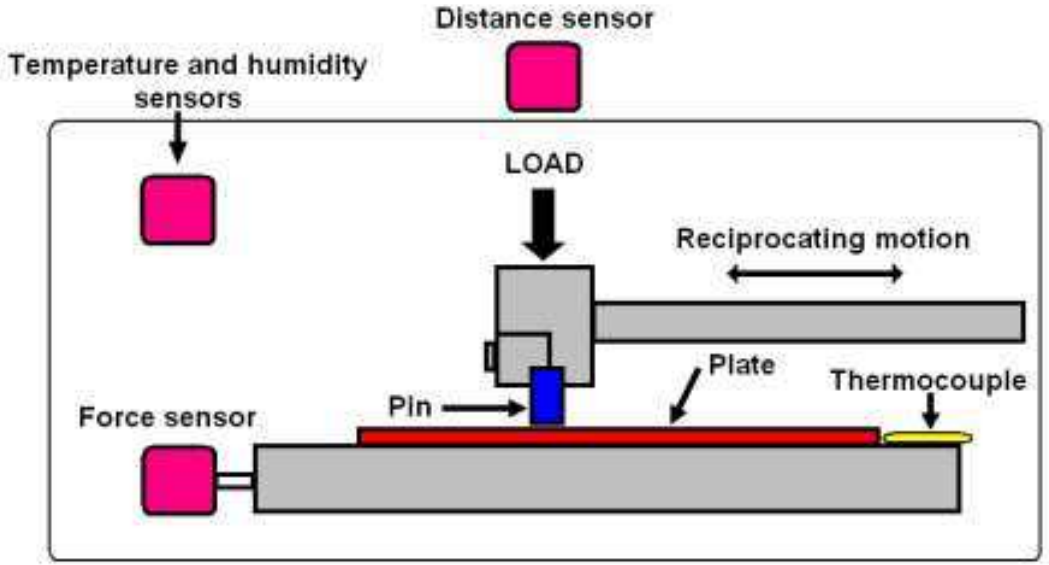
ASTM G133 wear test performed on AISI 316 stainless steel with and without “SuperExpanite” surface hardening treatment



Lubrication: none
Ceramic silicon nitride ball
Force: 25N
Total sliding distance: 100m

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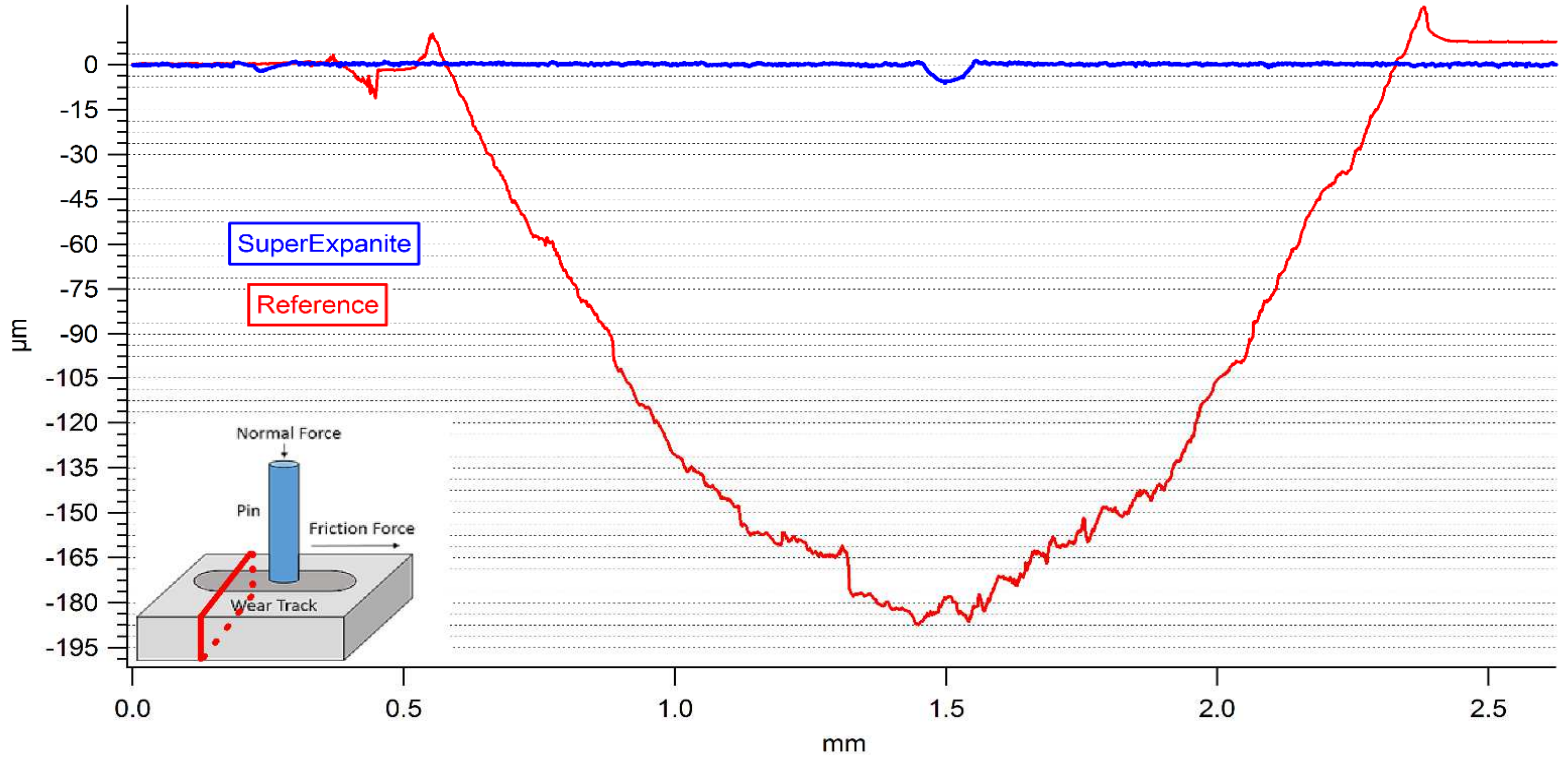
SURFACE HARDENING OF STAINLESS STEEL



Main conclusion: 125 times less wear on SuperExpanite treated plane surface

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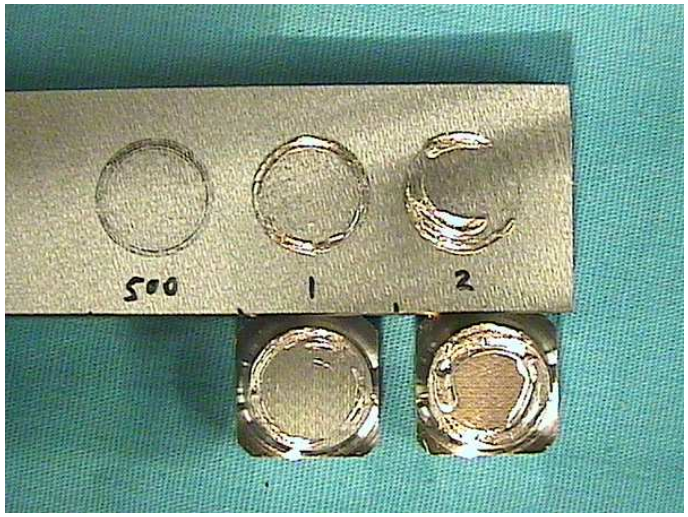
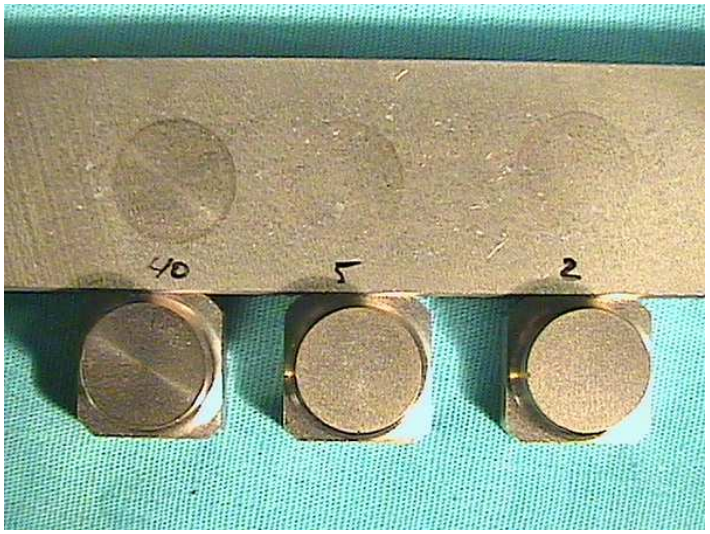
SURFACE HARDENING OF STAINLESS STEEL

ASTM G98 galling resistance test on EN 1.4401/AISI 316

Non-treated 316 vs. 316 reference



SuperExpanite vs. SuperExpanite



	Non-treated	Expanite-treated
0.5 ksi	+	no
1 ksi	+	no
2 ksi	+	no
5 ksi	+	no
…	…	…
40 ksi	+	no

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Don’t just take our words for it

“I haven’t seen such a solution to galling on 316 in my 15+ years of tribology testing”

–Steven Budinski Owner/ Bud Labs

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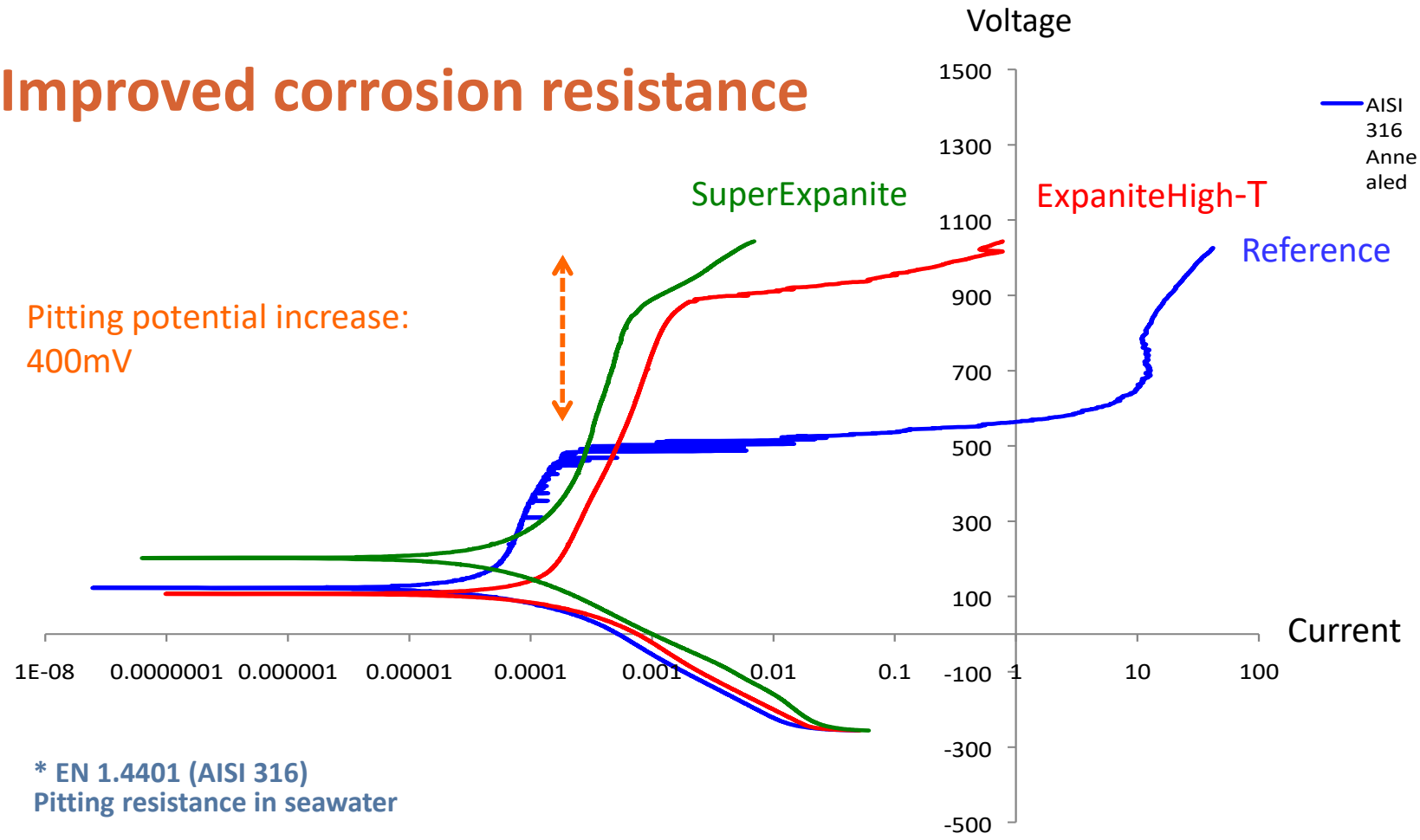
Improved corrosion resistance



*** EN 1.4401 (AISI 316)**
Pitting resistance in seawater

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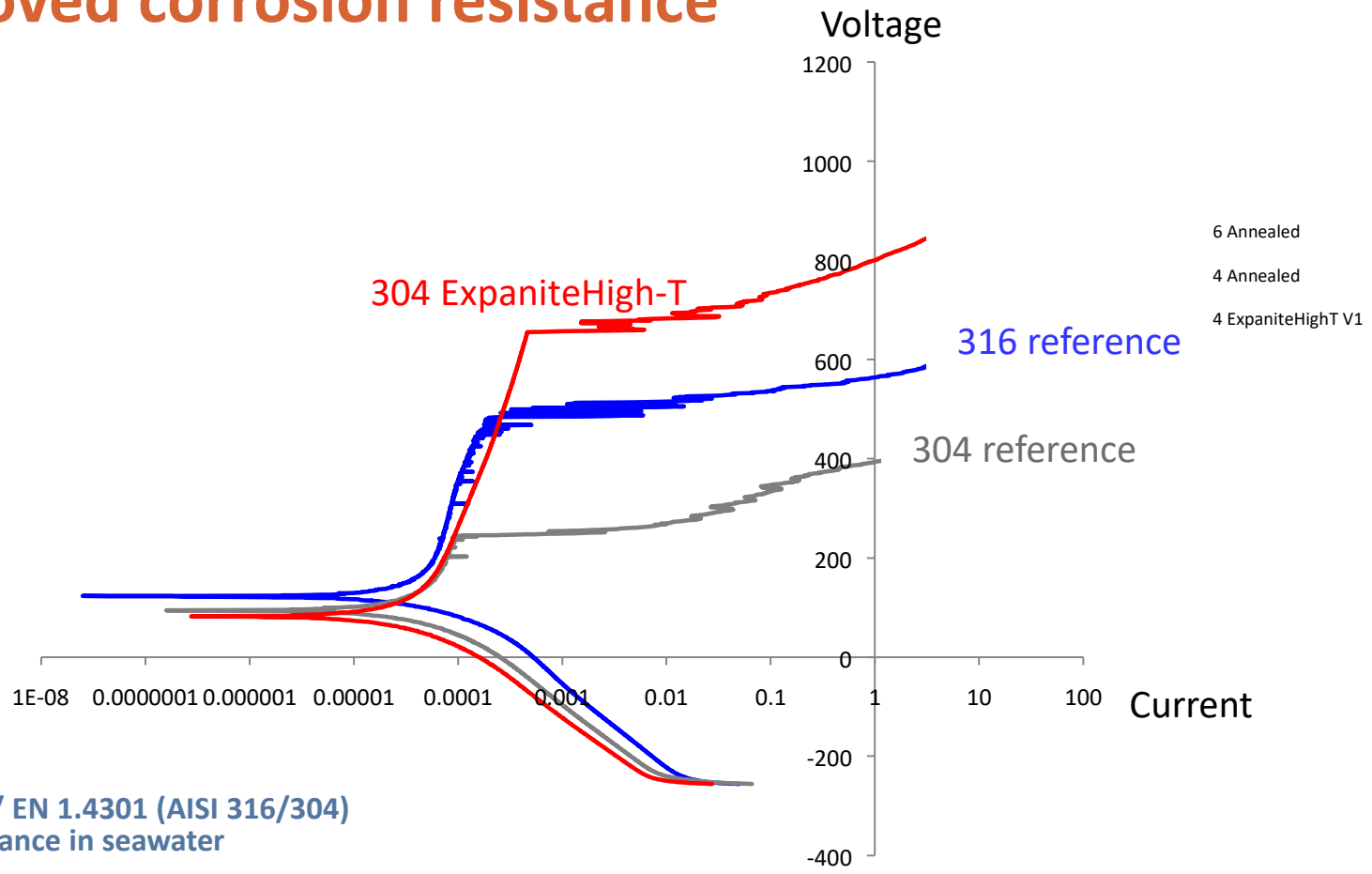
Improved corrosion resistance



*EN 1.4401 / EN 1.4301 (AISI 316/304)
Pitting resistance in seawater

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ExpaniteHard-Ti

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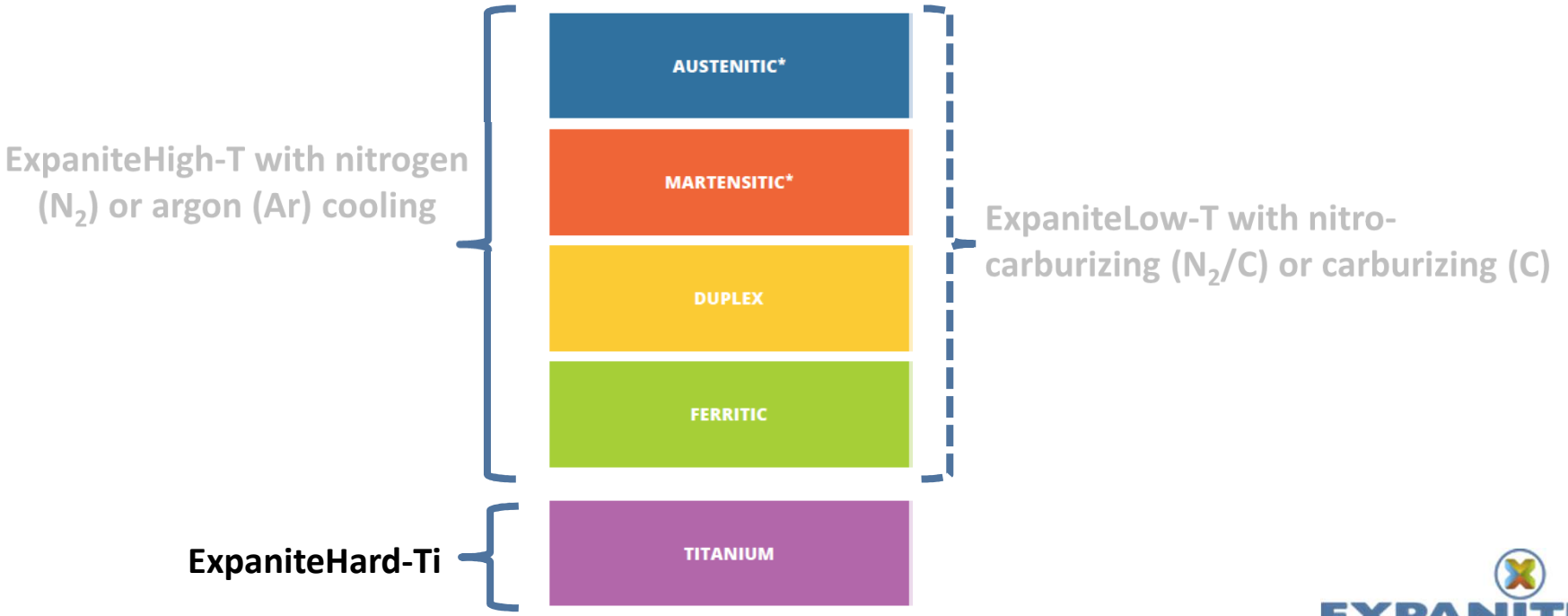
Product portfolio – a closer look at ExpaniteHard-Ti



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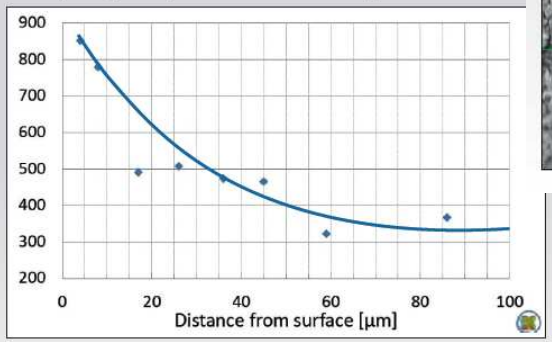
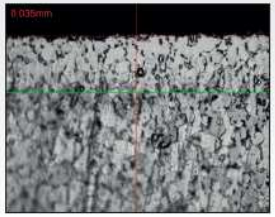
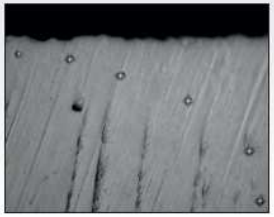
ExpaniteHard-Ti

- Gas process <800C
- Adds oxygen; no titanium-nitrides
- Can be used for:
  - Alloyed titanium e.g. grade 5
  - Pure titanium e.g. grade 2
- Surface hardness: approx. 1000HV
- Case depth: **10-50µm**

Hardness profile
Case depth of approx. 30µm and surface hardness of approx. 930HV0.05

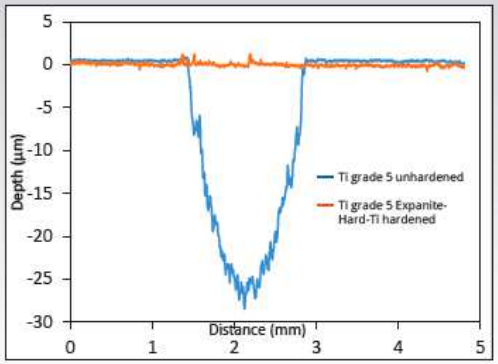






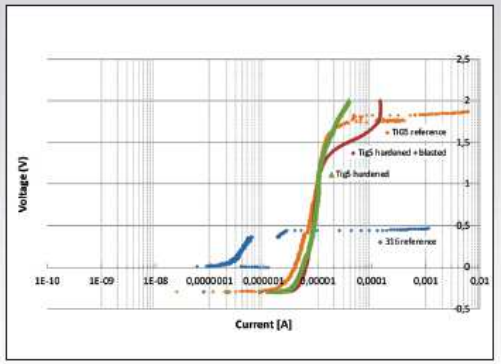
Superior wear resistance

The widely accepted ASTM G133 linear wear test performed titanium grade 5 with and without ExpaniteHard-Ti shows clearly the effect of the hardening. Where the unhardened reference part – standard "off the shelf" titanium grade 5 – shows severe wear, the part with ExpaniteHard-Ti is completely unaffected.



Exceptional corrosion resistance maintained

Not surprisingly, standard unhardened titanium shows very strong results in a cyclic polarization pitting corrosion test, and significantly better than standard AISI316L stainless steel. Much more surprisingly, the ExpaniteHard-Ti hardened titanium sample matches if not improves the pitting corrosion performance of the unhardened reference.



Applications: Watch in titanium

- **What**: all exterior parts (case, bezel, bracelet, back, buckle) from Swiss watch brand Horage
- Part are made in titanium grade 5 and then hardened by Expanite (ExpaniteHard-Ti); 30µm and approx. 1000HV.
- **Benefits:**
  - **Unique product with virtually unscratchable surface!**

EXPANITE
SURFACE HARDENING OF STAINLESS STEEL

Titanium Grade 5 - Galling Test

with and without ExpaniteHard-Ti hardening

Titanium Block and Pin:
Not ExpaniteHard-Ti hardened
Time: > 3 Sec.

Test 1

Titanium Block:
ExpaniteHard-Ti hardened
Titanium Pin:
Not ExpaniteHard-Ti hardened
Time: > 9 Sec.

Titanium Block and Pin:
ExpaniteHard-Ti hardened
Time: > 155 Sec.

EXPANITE
SURFACE HARDENING OF STAINLESS STEEL

A little summery :

- Short process time
- Cleaner
- Bulk wear
- **Cost effective**
- Improving hardness and in the same time Improving/restoring corrosion resistance
- Improving wear, galling or corrosion

That’s why The future is gas-based diffusion

EXPANITE
SURFACE HARDENING OF STAINLESS STEEL