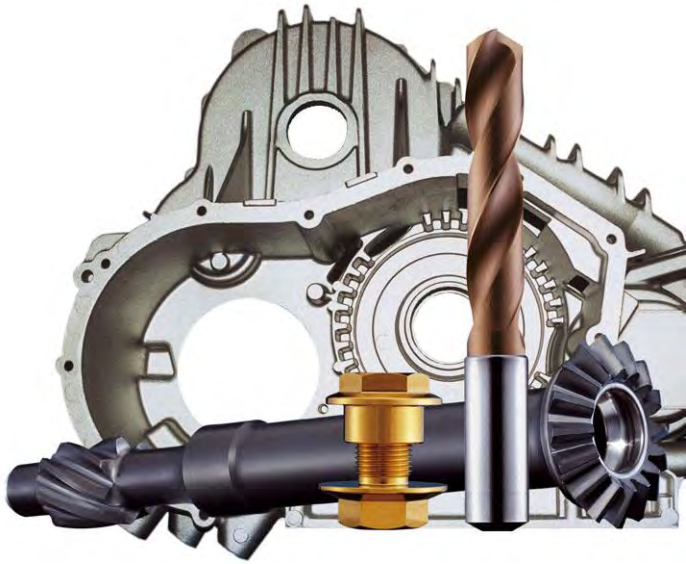
PVD Coatings: no life without !

Wim Geurts
Sales Engineer Nederland

17-04-2014 Veldhoven



What are PVD coatings ?

***P**hysical **V**apour **D**eposition*

- ***Applied in vacuum at temperatures between 200 and 480 °C***
- ***Thickness of the coating 1-16 µm***
  - ***Standard : 3±1 µm***
  - ***Thin : ±1 µm***
  - ***Special : ±16 µm***
- ***Strong adhesion of the coatings***
- ***High hardness and low frictioncoëfficiënt***

Characteristics of PVD / CVD (diamond) Coatings

Multipurpose coatings

	Composition	Microhardness (HV 0,05)	Coefficient of friction against steel (dry)	Internal Stress (Gpa)	Max. temperature of use (°C)	Colour	Coatingtemp. (°C)
BALINIT® A	TiN	2300	0,4	-2,5	600	gold-yellow	480*
BALINIT® ALCRONA PRO	AlCrN	3200	0,35	-3	1100	bright-grey	480
BALINIT® FUTURA NANO	TiAlN	3300	0,3 - 0,35	-1,3 / -1,5	900	violet-grey	480*
BALINIT® X.CEED	AlTiN	3300	0,4	-3 / -3,5	900	blue-grey	>480**

Dedicated coatings

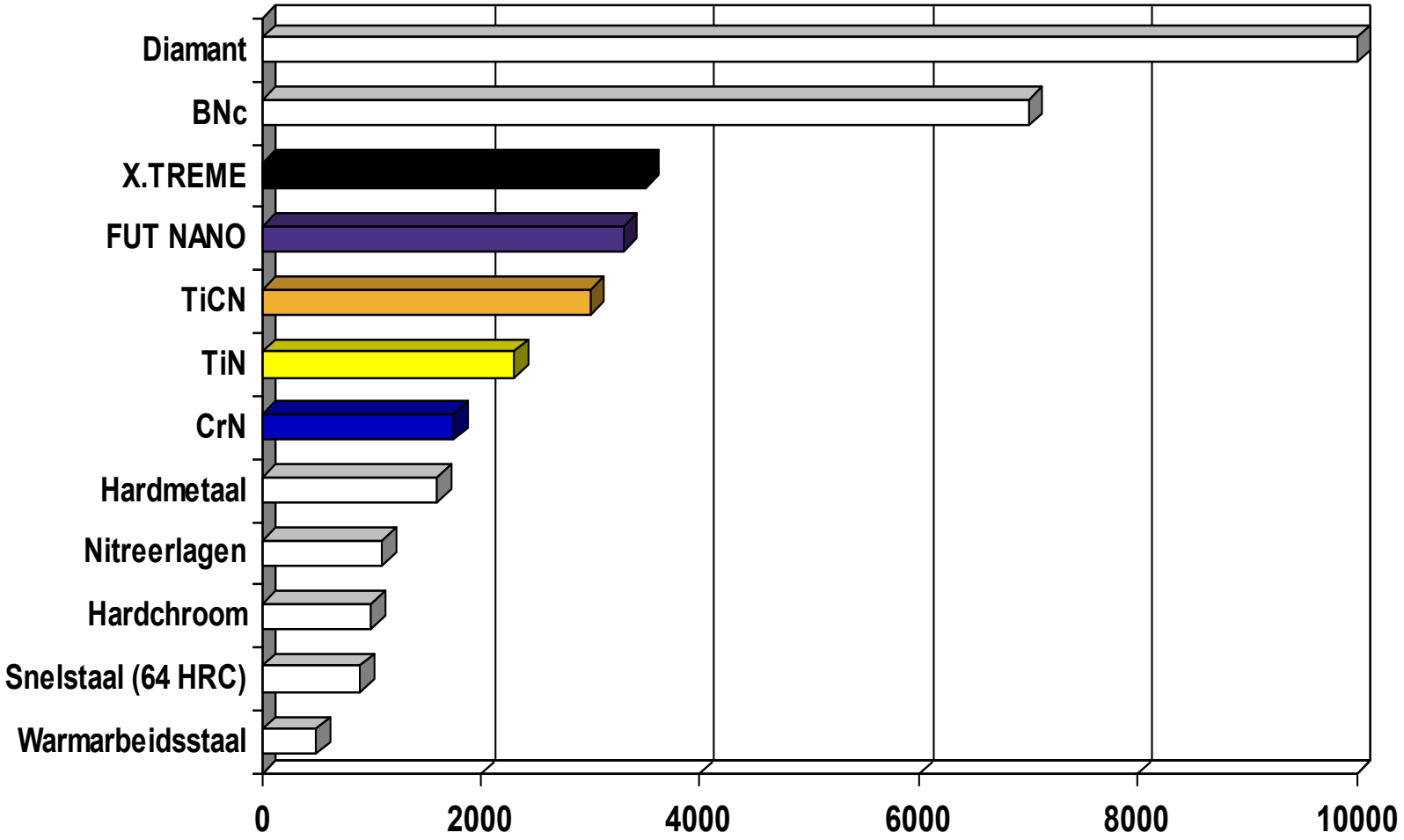
BALINIT® ALDURA	TiAlCr-based	3300	0,35 - 0,40	-3	> 1100	blue-grey	580**
BALINIT® ALNOVA	AlCrN	3200	0,3	-3	1100	bright-grey	500
BALINIT® C	WC/C (a-c:H:W)	1500	0,1 - 0,2	-1	300	black-grey	<250
BALINIT® CROVEGA	CrN	1750	0,5	-1,5 / -2	700	silver-grey	<250
BALINIT® DIAMOND CLASSIC	Crystalline Diamond	10000	0,15 - 0,20		~600	grey	800**
BALINIT® DIAMOND PLUS	Nanocrystalline Diamond	10000	0,15 - 0,20		~600	grey	800**
BALINIT® HELICA	AlCr-based	3000	0,25	-3	1100	copper	480
BALINIT® TRITON	a-C:H	> 2000	0,1 - 0,2		350	black	<250

* also available as BALINIT® ARCTIC 200°C
** only available on carbide substrates

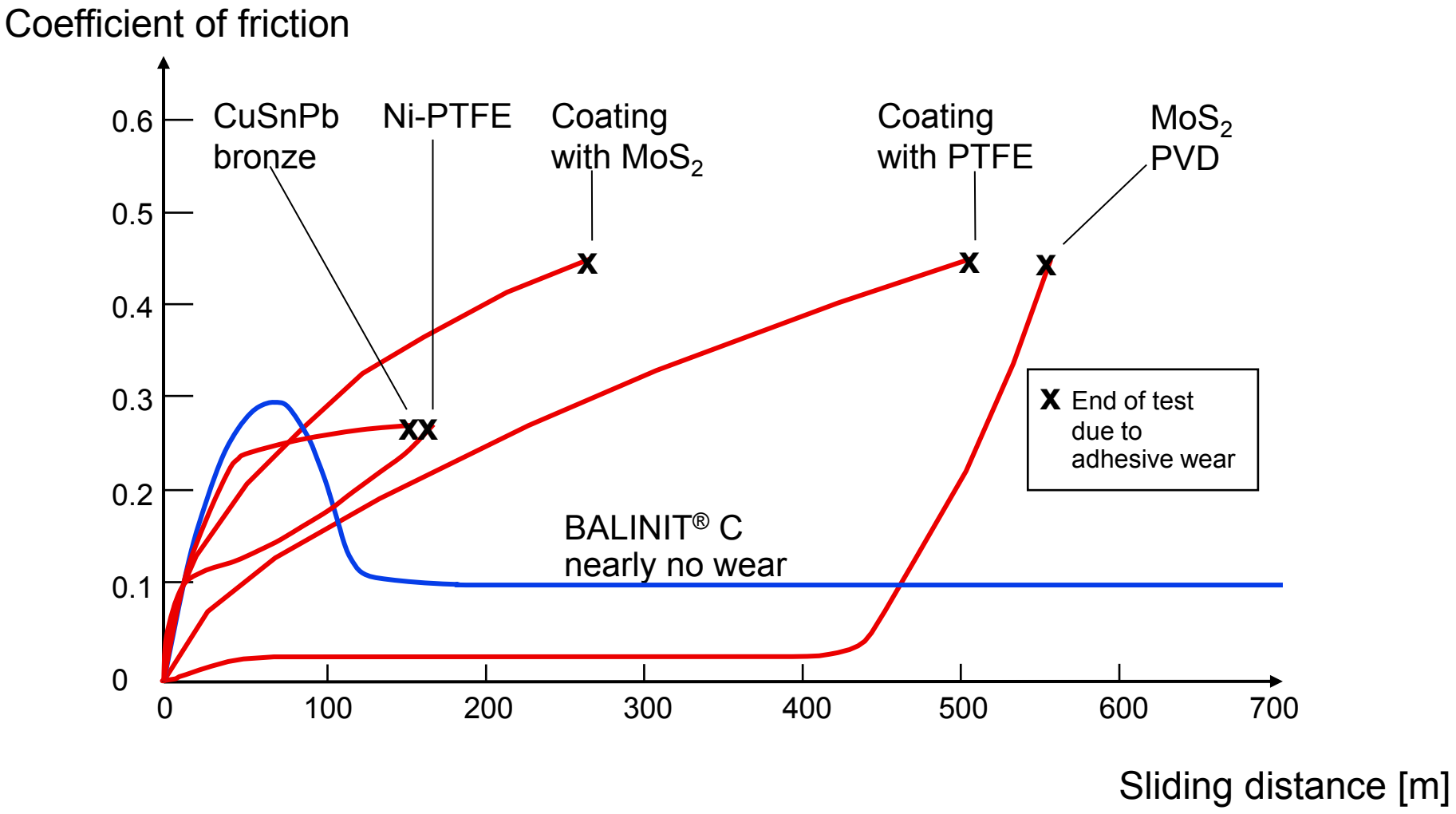
More information available on www.oerlikon.com/balzers/be. For other coatings (pre- and posttreatments) contact **your local Sales Engineer**.

BE002EN (1010)

Comparison of hardness

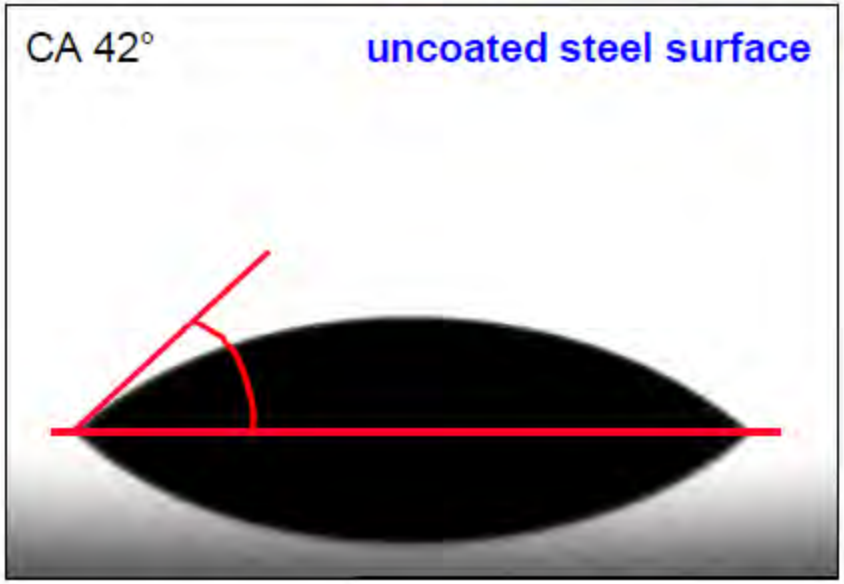


Dry running properties of sliding materials



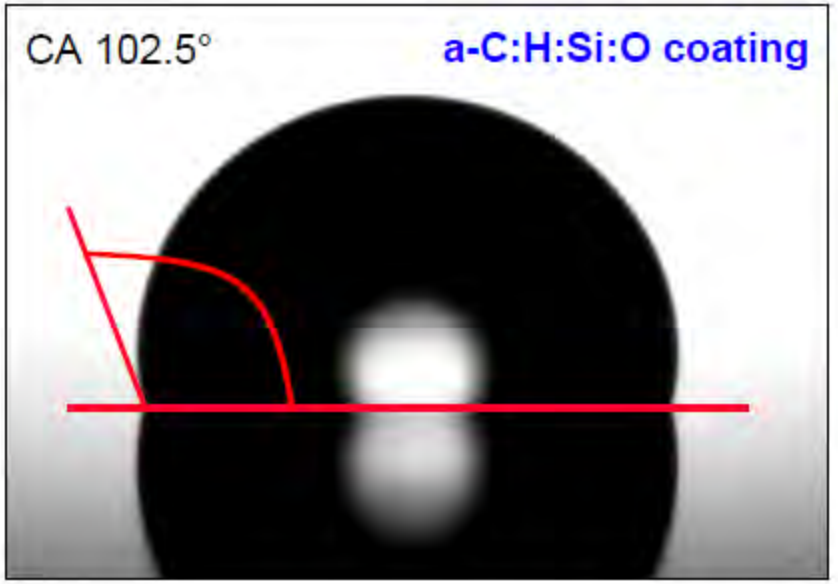
Surface energy properties.

Contact angle measurement



Hydrophilic surface

High surface energy (63 mN/m)



Hydrophobic surface

Low surface energy (22 mN/m)

Wear resistant coatings for tools.

Cutting

↓

Higher
Productivity

Punching/
forming

↓

Longer tool life
Dry running

Plastics processing

↓

Mould protection
Shorter cycle times

Die casting

↓

Longer tool life

Wear protection / reduction of friction for precision components.

Rocker arm

Injection system

ARCTIC coating series

Wear protection coatings for tools

Punching / Forming

Plastics processing

General engineering

Low tempered steels are used

Coating temperature of 200°C is requested

What does ARCTIC mean ?

ARCTIC coating series

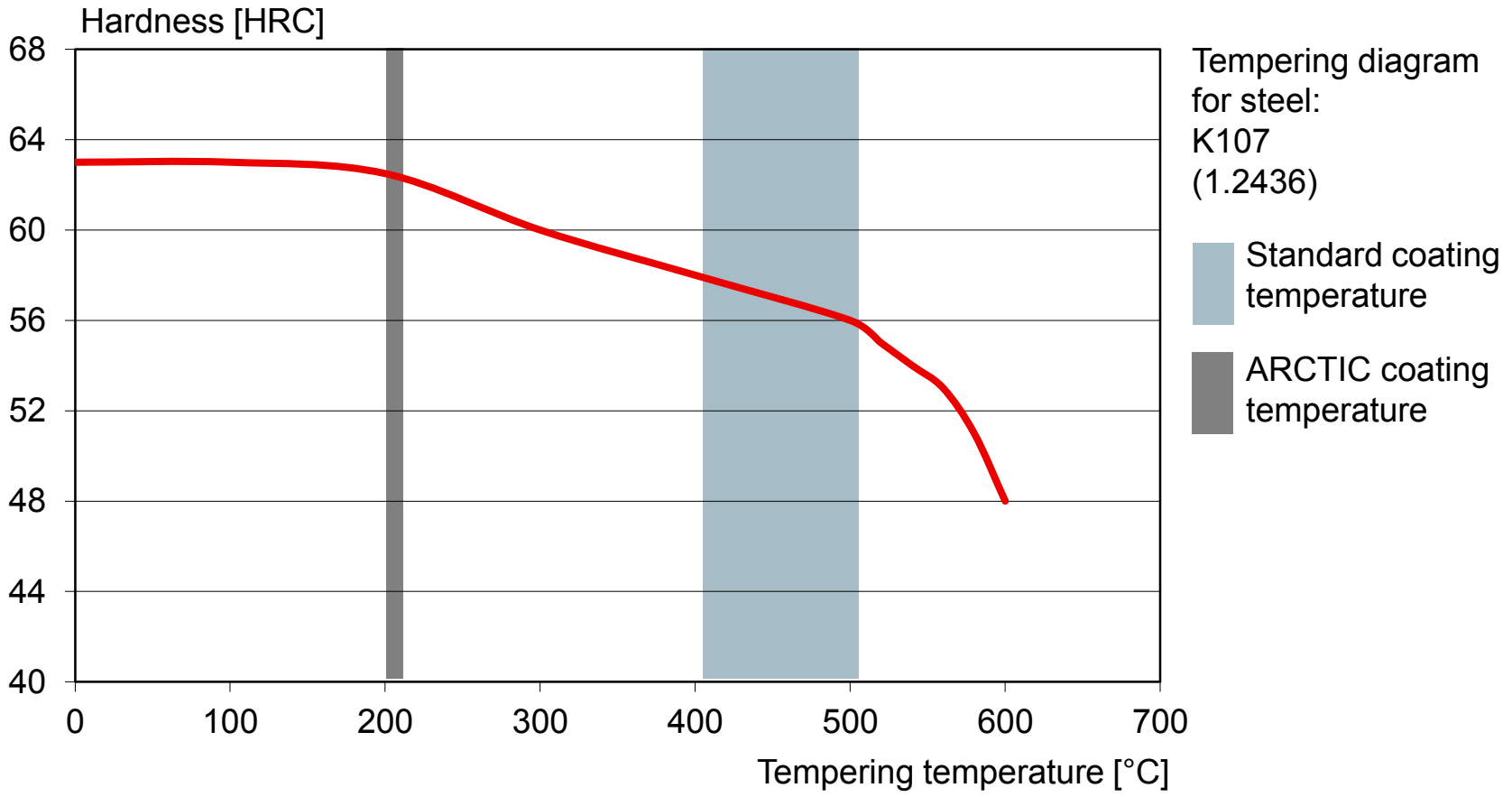
- BALINIT® A ARCTIC
- BALINIT® D ARCTIC
- BALINIT® FUTURA NANO ARCTIC

Deposited at 200°C

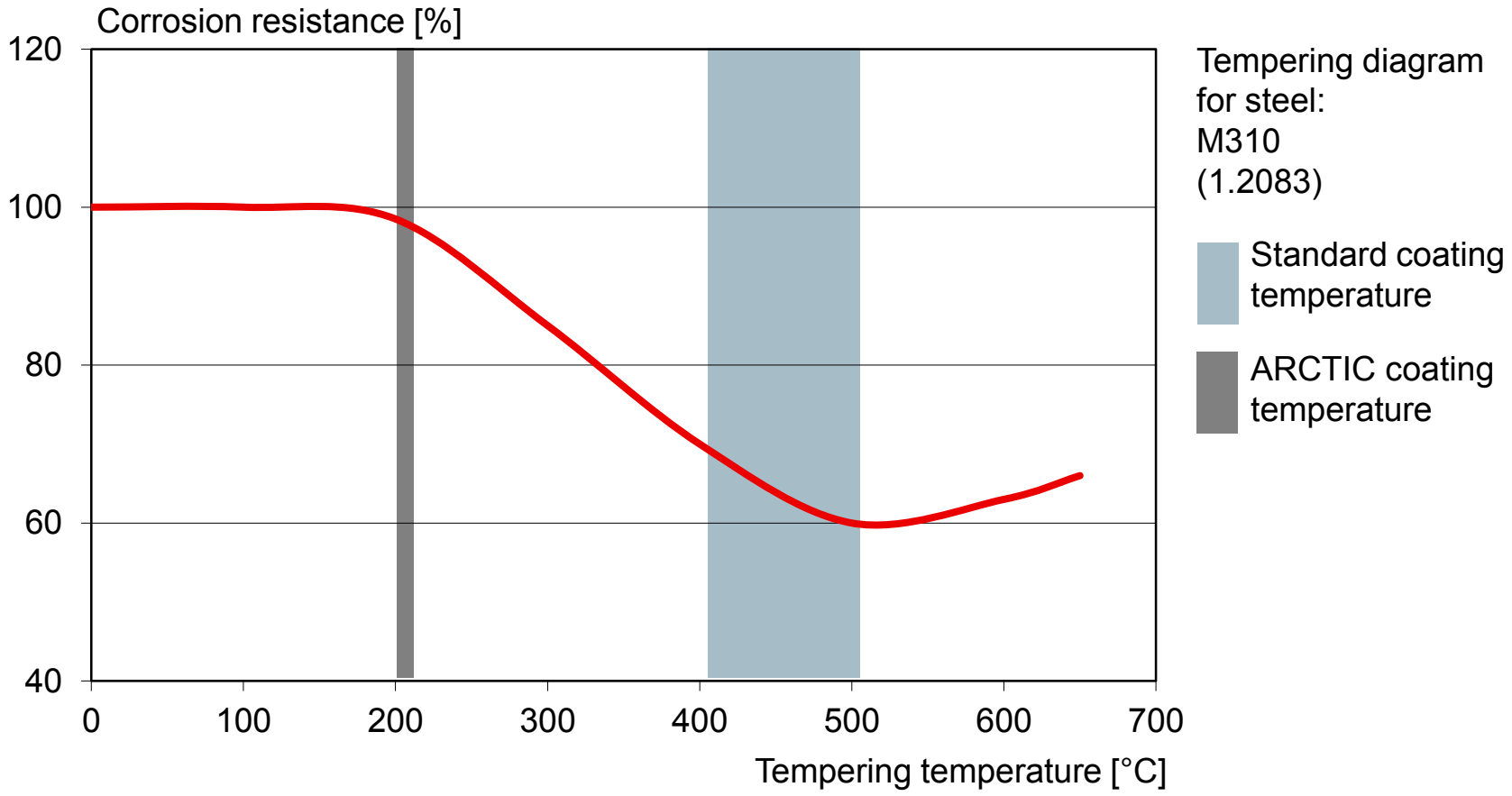
BALINIT® ARCTIC coating series

- Coating temperature at 200°C has the benefits of
  - no loss of hardness for low tempered steel grades
  - no effect on corrosion resistance
  - prevention of distortion
- BALINIT® properties and performance are unaltered
- Excellent coating adhesion

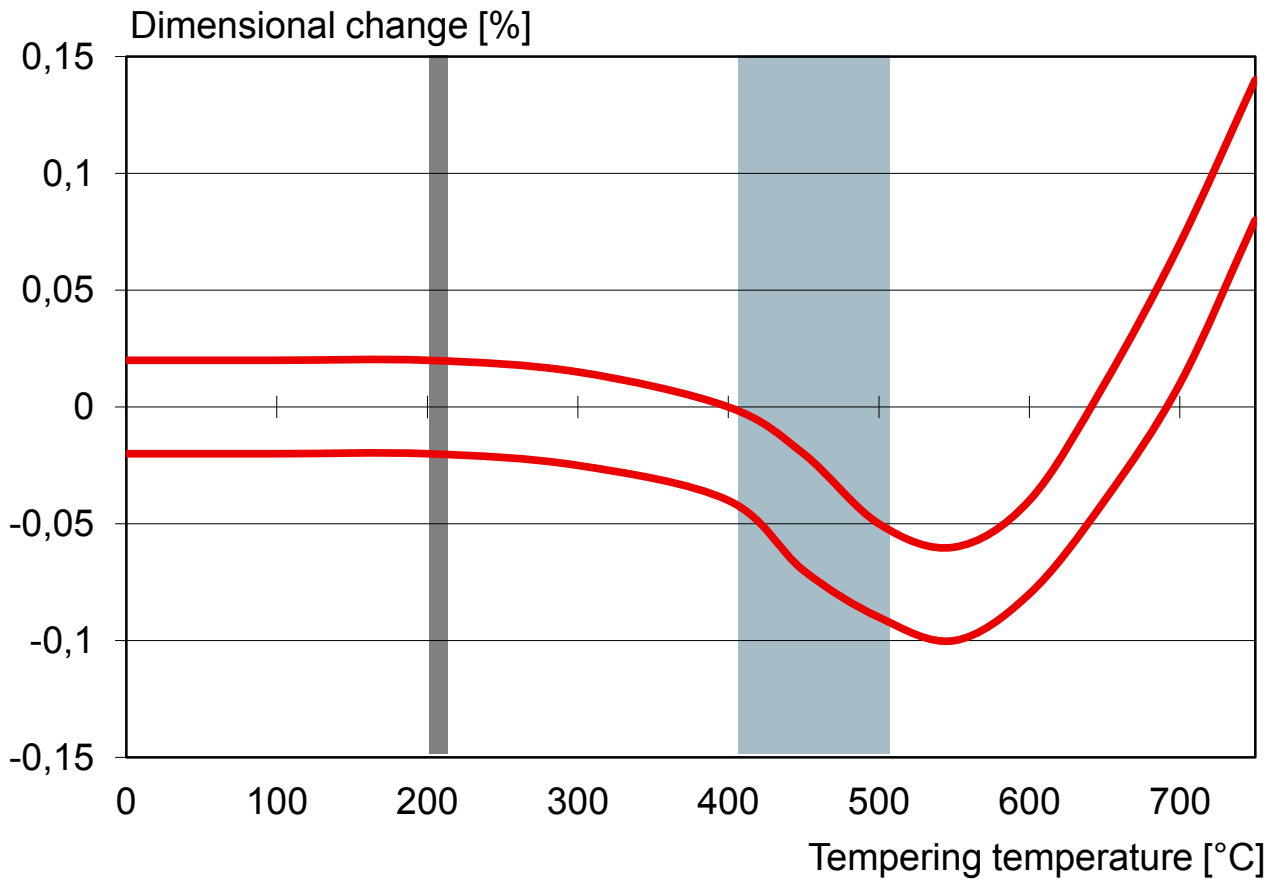
No loss of hardness for low tempered steel grades



No effect on corrosion resistance



Prevention of distortion

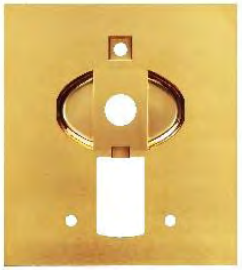
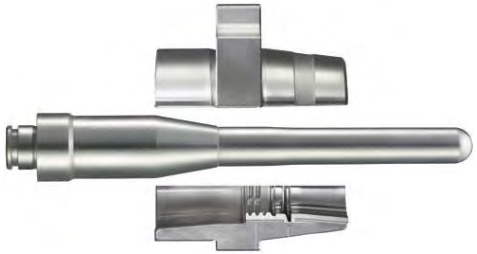


Tempering diagram for steel:
M310
(1.2083)

Standard coating temperature

ARCTIC coating temperature

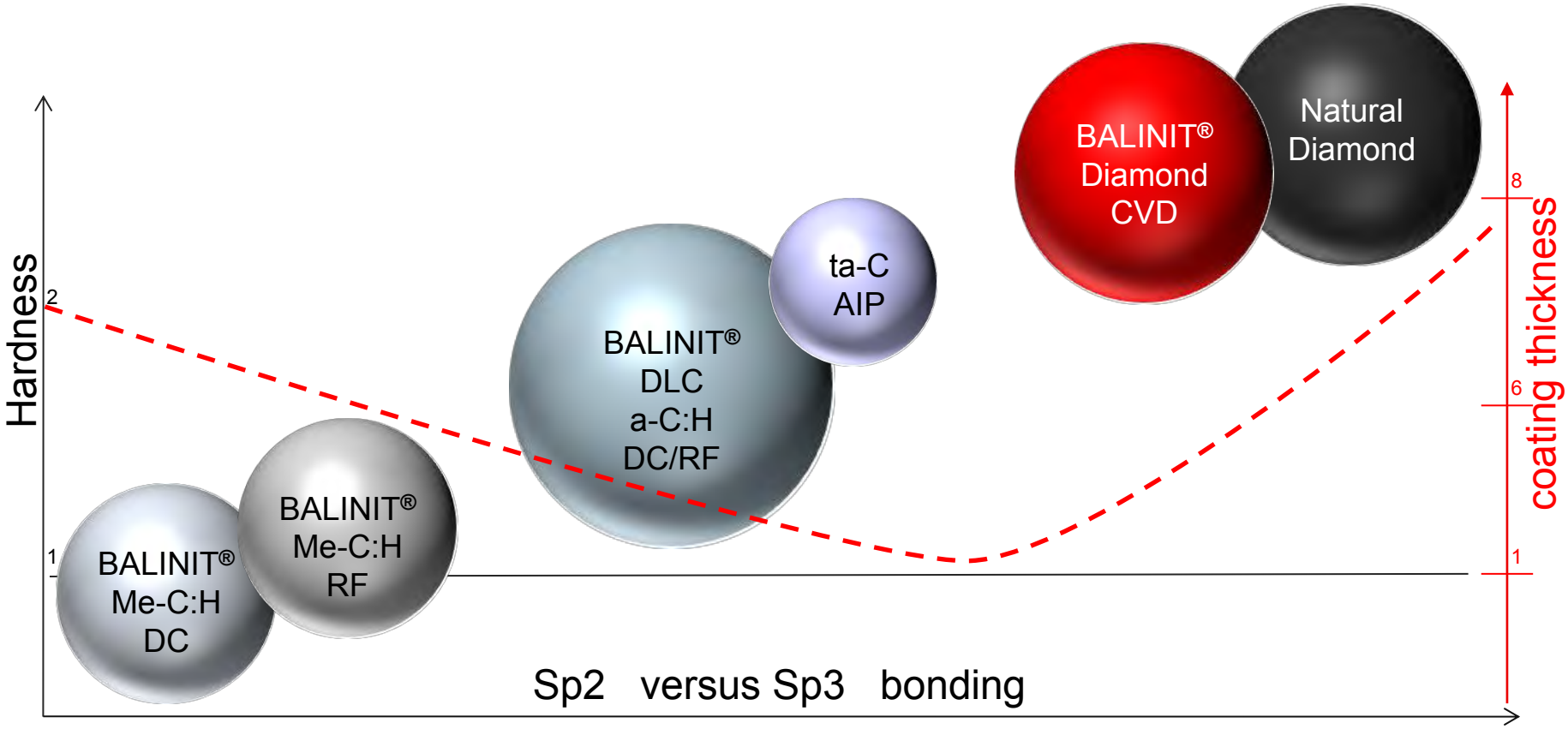
ARCTIC coating series - properties

BALINIT® A ARCTIC (TiN)	BALINIT® D ARCTIC (CrN)	BALINIT® FUTURA NANO ARCTIC (TiAlN)
		
Hardness 2300 HV - abrasive wear resistance - adhesive wear resistance	**Hardness 1750 HV** - adhesive wear resistance - corrosion resistance - oxidation resistance	**Hardness 3300 HV** - abrasive wear resistance - high thermal stability - high oxidation resistance - high chemical stability

Deposition temperature 200°C

Max. coating thickness 5-6 µm (depending on tool size)

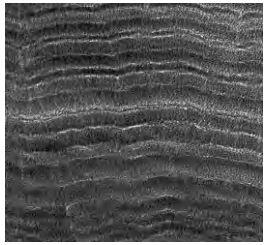
Carbon based coatings.



Carbon based coatings.

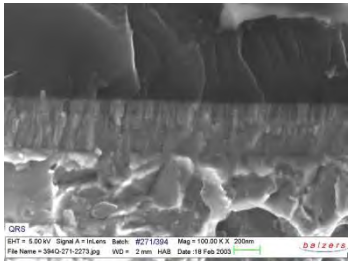
BALINIT® C (WC/C)
a-C:H:Me

- very good adhesion
- high elasticity
- moderate hardness (1’000 / 1’500 HV)



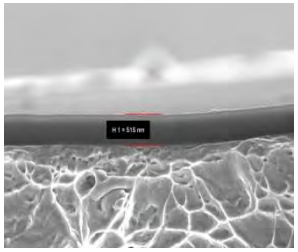
BALINIT® DLC
a-C:H

- high wear resistance
- higher hardness (>2’500 HV)
- low friction



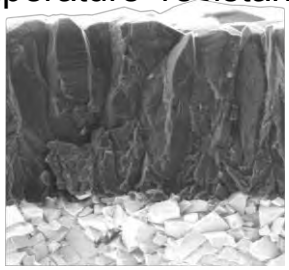
BALINIT® HARD CARBON
ta-C

- hydrogen-free
- high hardness (5’000 HV)
- Temperature resistance up to 450ºC



BALINIT® DIAMOND
PCD / NCD

- max. wear resistance
- max. hardness (10’000 HV)
- Temperature resistance up to 800ºC



Classification of carbon coatings; VDI 2840

	Amorphe Kohlenstoffschichten **Amorphous carbon films** DLC coatings							Kristalline C-Schichten **Crystalline carbon films**	
								diamond coatings	
doping, additives	without hydrogen		metal	with hydrogen		metal	others	undoped	doped
bonding	sp^2	sp^3	sp^2	sp^2 / sp^3	sp^3	sp^2		sp^3	
abbreviation	**a-C**	**ta-C**	**a-C:Me**	**a-C:H**	**ta-C:H**	**a-C:H:Me** (Me = W, Ti, ...)	**a-C:H:X** (X = Si, O, N, F, B)	**-**	**-**
common names	DLC, graphitic carbon	DLC, amorphic diamond		DLC, hard carbon		DLC Me-DLC Me-C:H MeC:H	DLC X-DLC Si-DLC	CVD diamond	
deposition process	PVD	PVD	PVD	PA-CVD	PVD PA-CVD	PVD PA-CVD	PVD PA-CVD	CVD	

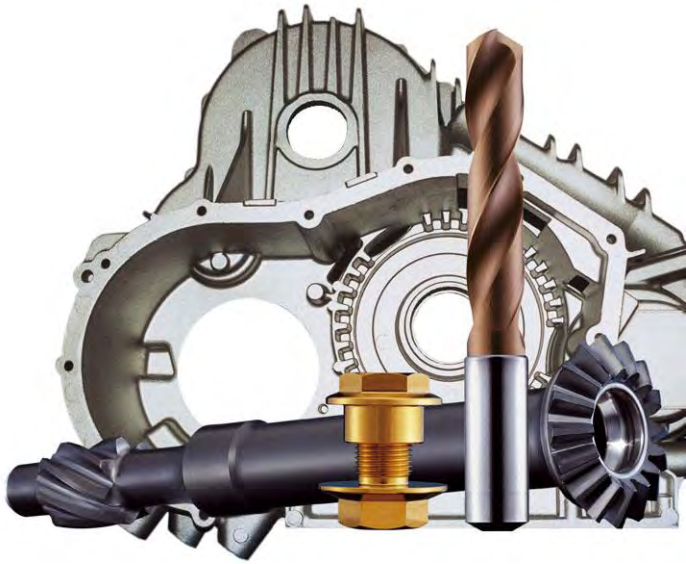
Product info t-aC

Coating material	Tetrahedral amorphous carbon (t-aC)
Microhardness (H_v 0.01)	4000 - 5000
Coefficient of friction against steel (pin-on-disc, dry)	< 0.15 (w/o post-treatment)
Max.application temperature	500°C
Coating colour	depending on thickness: rainbow, black, grey
Coating type	monolayer
Coating thickness (depends on tool geometry)	0.3 to 3 µm
Coating temperature (C°)	< 150°C

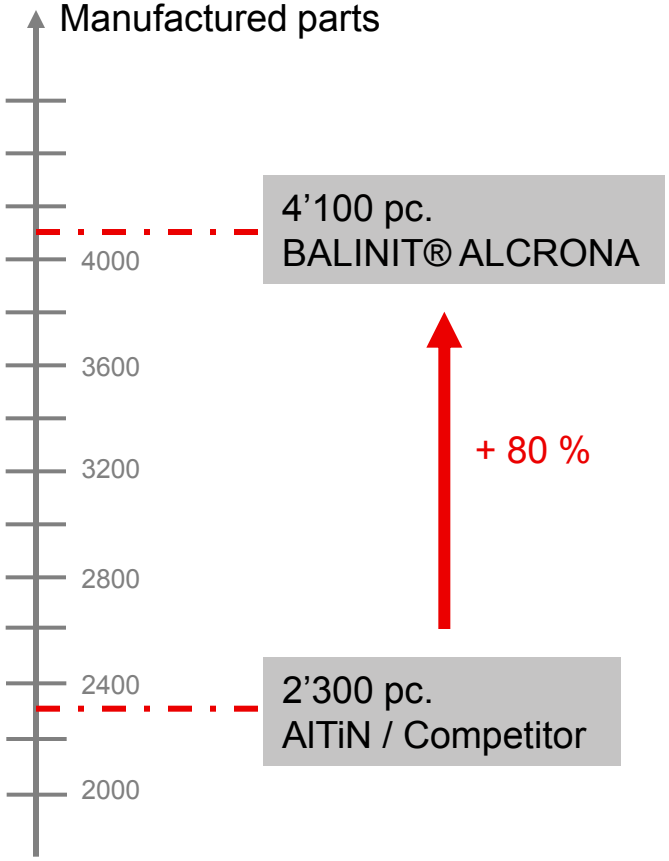
Coatable materials

Warmwerk-staal	Koudwerk-staal	Veredelings-staal	Roestvast-staal	Snelstaal	Brons	Diversen
1.2323	1.2083	1.1151	1.4002	1.3202	Ampco 8	Ferro Titanit
1.2343	1.2316	1.1181	1.4006	1.3207	Ampco 18	
1.2344	1.2362	1.1191	1.4021	1.3243	Ampco 45	Durotherm 600
1.2360	1.2363	1.1221	1.4028	1.3245	Ampco 83 (300°C)	
1.2365	1.2369	1.2307	1.4034	1.3247	Ampco 88 (450°C)	Hastelloy
1.2367	1.2376	1.2311	1.4057	1.3255	Ampco 95 (450°C)	
1.2567	1.2378	1.2312	1.4110	1.3333	Ampco M4	TiAl6V4
1.2581	1.2379	1.2738	1.4112	1.3341	Ampco 940 (420°C)	
1.2603	1.2380	1.6582	1.4116	1.3342	Ampco 944 (450°C)	Hardmetalen
1.2606	1.2436	1.7225	1.4120	1.3343	Ampco 972 (500°C)	
1.2662	1.2601		1.4122	1.3344		
1.2678	1.2609		1.4125	1.3348	Hovadur K220 (420°C)	
1.2709	1.2631		1.4528	1.3355	Hovadur K265 (450°C)	
1.2744	1.2851		1.4542		Hovadur K350 (300°C)	
1.2777	1.3551			CPM Rex M4		
1.2799			Elmax	CPM Rex T15	Moldmax LH (375°C)	
1.2885	CPM 9V		M 390 PM	ASP 23/ 30/ 60	Moldmax HH (315°C)	
1.2889	CPM 10V			S 390 PM		
1.6358	T440V			S 690 PM		
	Vanadis 4					
	K190 PM					
	SMV 5					

Some examples….



Considerably higher service life.
Hobbing of gears



Tool:
PM-HSS hob

Workpiece:
Steel, DIN 1.7131 (~ AISI 5115)

Cutting parameters:
v_c = 200 m/min
VB ~ 0.3 mm
Dry

Source:
Automotive manufacturer

Productivity boosts by 20%
Threaded cores for bottle caps

Description
Production process: injection moulding
Particularity: lubricants and mould release agents cannot be used for pharmaceutical or food packaging.

Threaded cores uncoated
Production downtime: 1 day per week

Threaded cores BALINIT®-coated
- Trouble-free production during several months
- 10% shorter cycle times
- Yield productivity gains of up to 20%

Punching; wear comparison after 1.5 Mio strokes

Application:
Punching

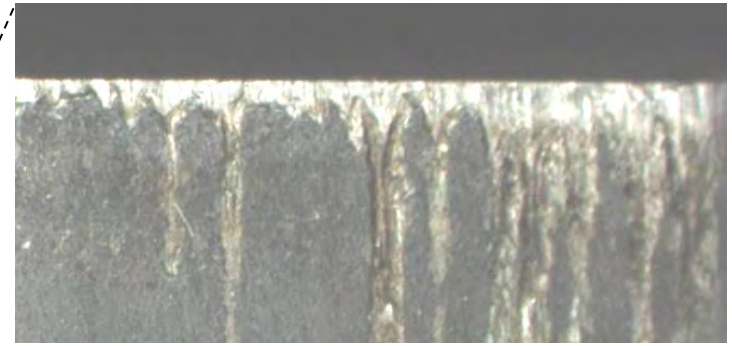
Tool:
Punch
DIN 1.2379 (~AISI D2), 60-62HRC
Size: 40x60x80 mm

Workpiece:
Furniture fittings
Workpiece material DC1 sheet material

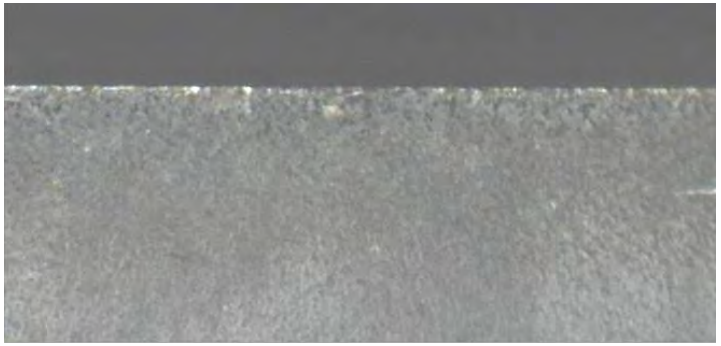
Customer problem:
Low tool lifetime

Coating:
BALINIT® ALCRONA ADVANCED

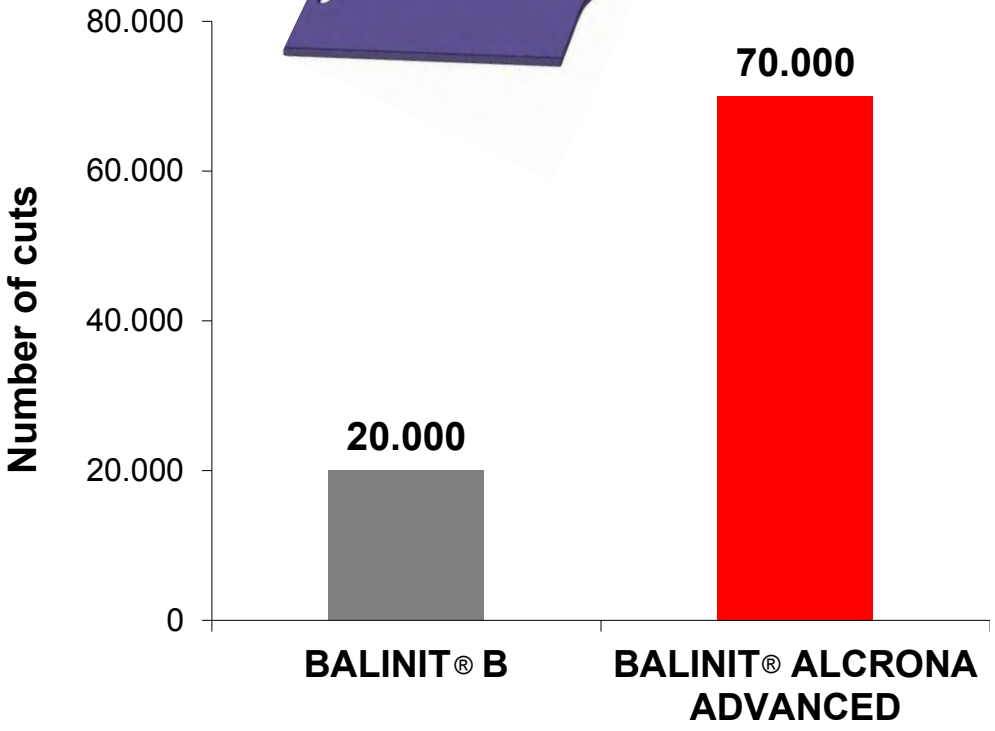
BALINIT® ALCRONA



BALINIT® ALCRONA ADVANCED



Trimming knife.



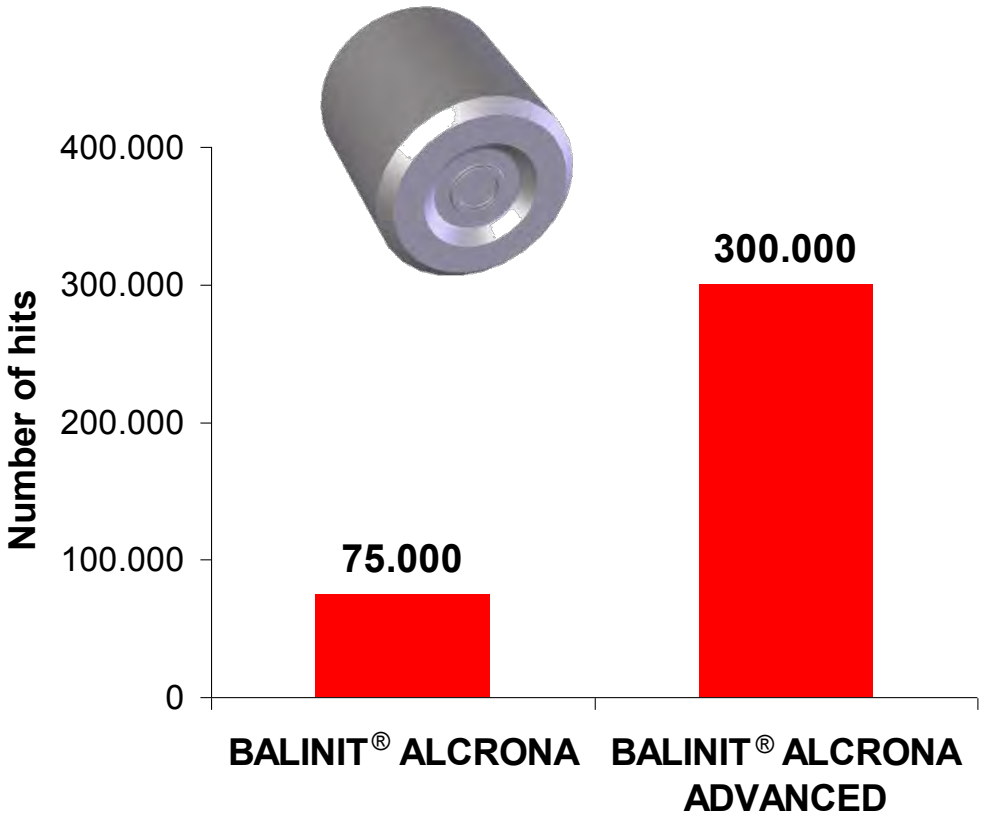
Application:
Trimming

Tool:
Straight knife
ASP 2023 / DIN 1.3344
62 HRC

Workpiece:
Steel tubes

Benefit:
Increased tool lifetime
Less machine downtime

Forming Punch.



Application:
Forming of bolt head

Tool:
Forming punch
CPM1V (PM Steel)
BALINIT® ALCRONA ADVANCED

Problem
Low tool liftime

Benefit:
Increased tool lifetime
Less machine downtime
Less scrap

PVD coatings on vehicle components

- Markedly higher injection pressure in diesel and gasoline engines
- Reduced friction on cam shafts, tappets, piston rings, gears, etc.
- Lower vehicle weight due to smaller components
- Less fuel consumption
- Reduced emission

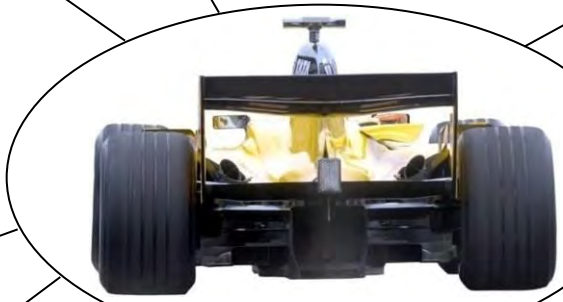
PVD coatings for highly demanding components

Being part of all successful formula 1 racing cars

Cam follower
(rocker arm and shaft, tappets)

Suspension parts

Wrist pins



Valves

Camshafts

Con rods

Pistons

Gear wheels

Crank shaft

Performance increase.

Diesel injector with piezo technology

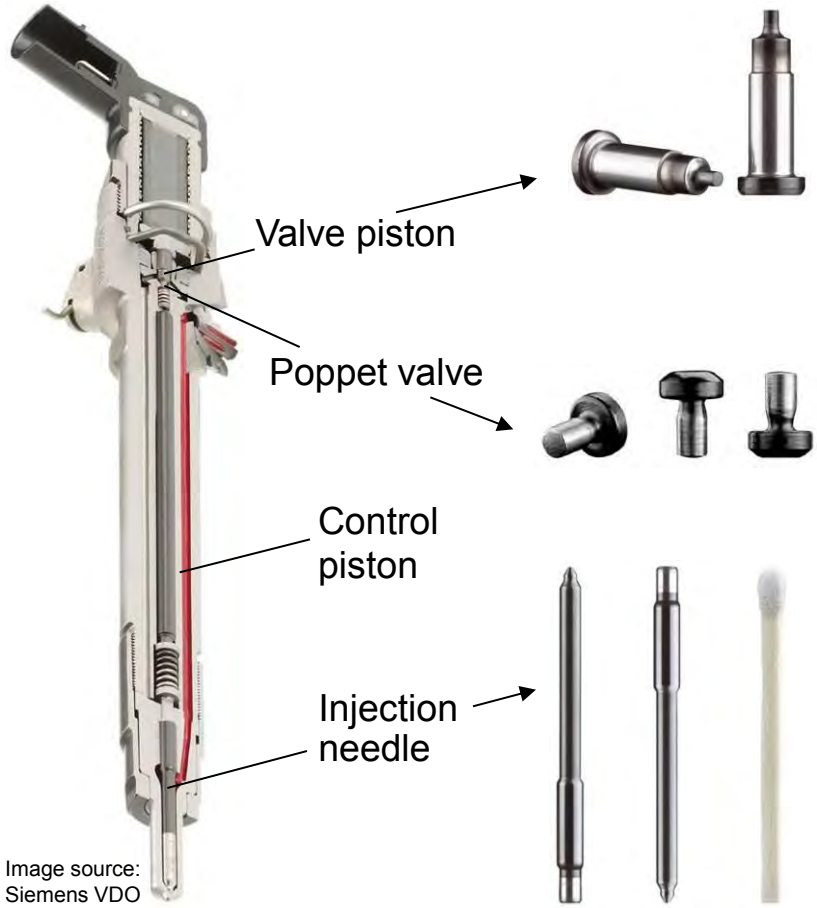


Image source:
Siemens VDO

Components of the injector out of a Common-Rail diesel injection system are coated with performance increasing carbon coatings in mass-production.

DLC-coated injection needles are dimensionally stable even in long-term usage, thus ensuring the leak tightness of the system. The good sliding properties guarantee a precise flow of the diesel fuel.

WC/C-coated valve pistons virtually show no wear even at extreme pressures.

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One crown for life.

BALINIT® coatings for safe dental applications.

Medical

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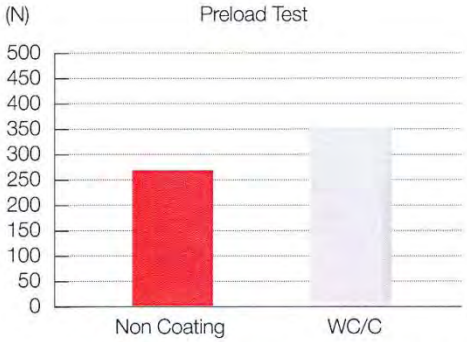
Biocompatible BALINIT® coatings reduce implant problems.

The shock for anyone with crowns: the crown begins to wobble and loosen slowly but surely from the implant. A new operation with risks must be carried out. Implant parts can break and the whole implant needs to be replaced. With BALINIT® C you are on the safe side, screw torque is reduced and simultaneously the coated implant screws have 30% improved fastening torque.

Your advantages with BALINIT® coated abutment screws.

- Improved screw adjustability
- Reduction of torque at the application of the screws
- Implant screws can be removed without any risk of breaking or seizure
- Cost savings due to easier and faster exchange of the abutment screws and implants

With BALINIT® C crowns remain firm.



Preload Test: Torque 30 Ncm, Material: Ti6AlV4, 30% load increase with BALINIT® C coating.

We recommend: BALINIT® coatings for safe implants.

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Flowing smoothly.

BALINIT® DLC coating increases the performance and reliability of ceramic sealing disks for high quality sanitary fittings.

General Engineering

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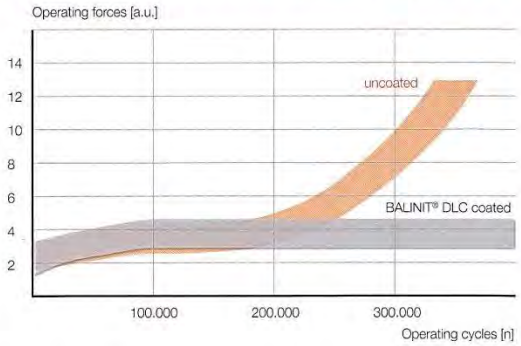
BALINIT® DLC for long life and smooth operation.

Ceramic sealing disks, made predominantly from aluminium oxide (Al2O3), have been an industrial standard in sanitary fittings for decades. However, during service the silicone-based lubrication, grease is constantly consumed until finally the ceramic disks rub against each other giving rise to premature wear. Consequently, lime and rust deposit easily on worn, lubricant free surfaces and can thereby lead to leaking fittings or in extreme cases to jamming components. BALINIT® DLC coated ceramic sealing disks reduce all this problems to a minimum and substantially increase the lifetime with a range of unique advantages.

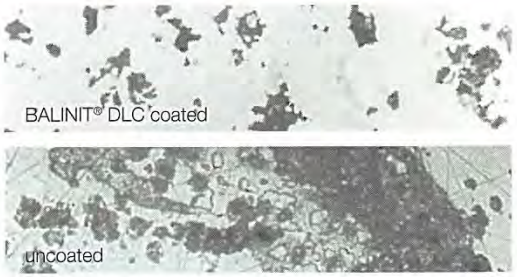
Your advantages with BALINIT® DLC coated ceramic sealing disks.

- Excellent sliding behaviour against Al2O3 without the need for lubricating grease
- Outstanding resistance against premature wear
- Improved resistance against lime & rust deposition
- Constant low actuation forces over the whole, extended lifetime of the component
- Significant contribution to water saving due to reduced risk of leaking fittings

Constantly low actuation forces and resistance against premature wear.



Effect of BALINIT® DLC coating on the operating forces of sanitary fittings – coated versus uncoated ceramic sealing disks.



Contact surface of coated and uncoated ceramic disks after 100 000 operating cycles. Run-in surface with no wear scars. Ceramic pores are visible as the coating replicates the original surface. Significant signs of premature wear for uncoated sealing disk.

We recommend: BALINIT® DLC for long life sanitary fittings.

BALINIT® DLC				
Coating material	**Micro-hardness (HV)**	**Typical thickness**	**Coefficient of friction μ against steel (dry)**	**Colour**
DLC	>2000	1-3 μm	0.1 - 0.2	Black

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The perfect cut.

BALINIT® DLC coating for a outstanding shaving and grooming performance.

General Engineering

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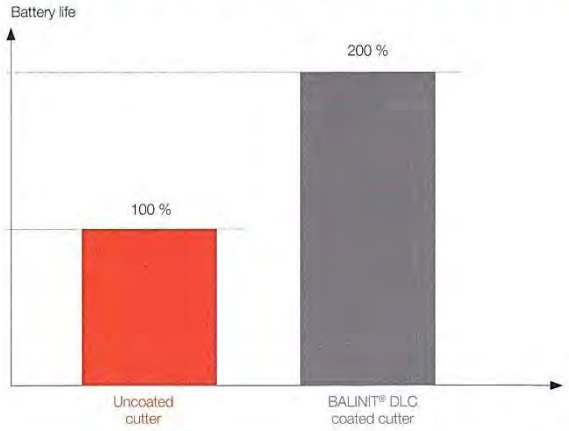
BALINIT® DLC coatings give you cutting edges.

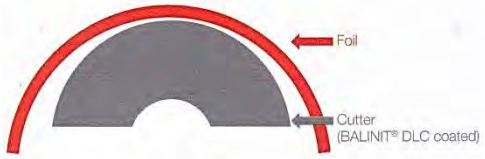
The perfect cut demands for a sharp and durable cutting edge. BALINIT® DLC coated blades combine excellent edge-holding property together with a low friction coefficient - and thereby contribute to a comfortable cutting experience. Less friction induced heat also improves system efficiency and results in longer battery life. If friction is not an issue then BALINIT® coatings like golden TiN offer a wide range of attractive colours combined with excellent scratch resistance.

Your advantages with BALINIT® DLC coated blades.

- Stable cutting edges for excellent long-term shaving performance
- Low friction between cutter and foil (or guard) for reducing heat generation and improving battery life
- Attractive colours combined with scratch resistance
- Easy cleaning due to reduced deposition of limestone

Batteries live longer with low friction coatings.





We recommend: BALINIT® coatings for shaving and grooming applications.

Coating	Coating material	Micro hardness (HK 0.01)	Typical thickness	Coefficient of friction μ against steel (dry)	Colour
BALINIT® DLC	a-c:H	2500	1-4 μm	0.1-0.2	Black
BALINIT® A Arctic	TiN	2300	1-4 μm	0.4	Gold

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Hard work needs hard coatings.

BALINIT® DLC coating for superior reliability and high wear resistance of mechanical seals.

General Engineering

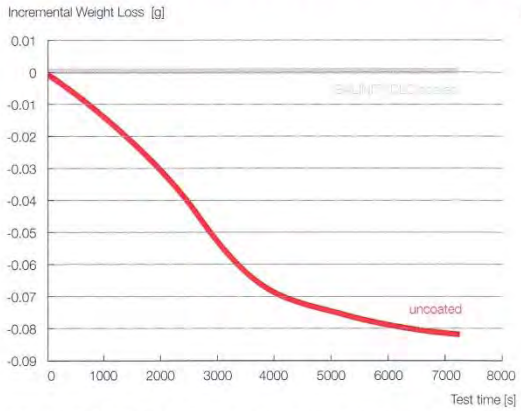
BALINIT® DLC: for safe oil exploration.

Mechanical seals are used in the rotating equipment such as drilling bits, compressors, pumps etc. and typically subjected to high loads and abrasive environments. BALINIT® DLC coated mechanical seal faces provide outstanding abrasive and adhesive wear resistance due to high hardness and low friction of coating. BALINIT® DLC on dry gas seal components provides increased life and improved performance without additional lubrication. BALINIT® DLC is used for various mechanical seal applications and also can be considered as a replacement for solid ceramic, silicon carbide or thermal sprayed materials. It offers an effective replacement for Cr plating with a lower cost solution.

Your advantages with BALINIT® DLC coated mechanical seals.

- Low friction reduces seal damage caused by start up and / or coast down conditions
- Less danger of leakage thus protection of the entire system and the environment
- Increased life and less maintenance
- Significant reduction in downtime
- Cost savings as a result

Trust in constantly low friction and wear resistance.



Effect of BALINIT® DLC coating on the weight loss of a thrust washer test – coated verse uncoated washers (bottom washer coated, total wear of both washers).
Test conditions: 1603 RPM, 600 N, 2 hours, 600P mineral oil, 10 N/mm^2.
The pV (pressure / velocity) test with two DLC coated washers results in nearly no wear.
A test with both washers uncoated results in high wear.

We recommend: BALINIT® DLC for safe sealing

BALINIT® DLC and DLC STAR			
Coating material	**Micro-hardness (HV)**	**Typical thickness**	**Colour**
a-C:H/CrN	> 2000	2-4 µm	Black

Let your business take off.

BALINIT® coatings for high-performance aerospace components and cutting tools.

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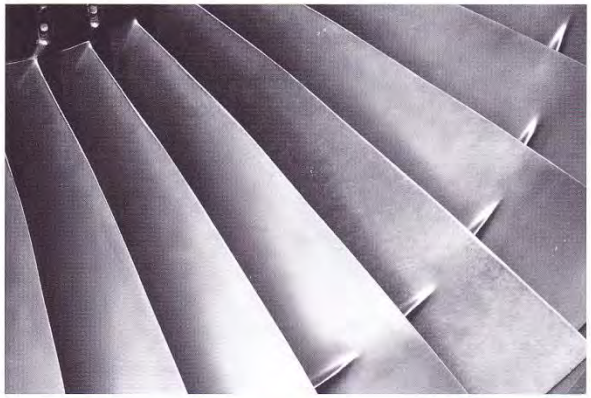
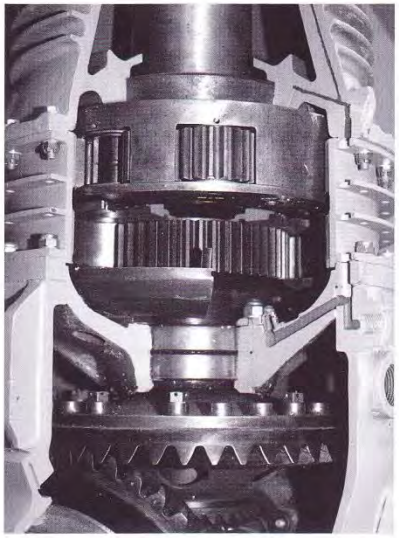
A trusted Innovation Partner.

Oerlikon Balzers has numerous innovation activities focused on aerospace applications. Just two examples are anti erosion solutions for turbine compressor blades and emergency run coatings for helicopters axles. Come and innovate with Oerlikon Balzers!



Special coatings for compressor blades
Balzers develops next generation thick multilayer coatings to protect compressor blades against erosion.



Coatings for helicopter gears
Balzers develops advanced BALINIT® C coatings for helicopter gears to provide emergency run behaviour in case of oil loss in the gear box.

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Quieter, smoother and safer ride control.

BALINIT® DLC coating is made for wear resistant and low friction suspension products.

General Engineering

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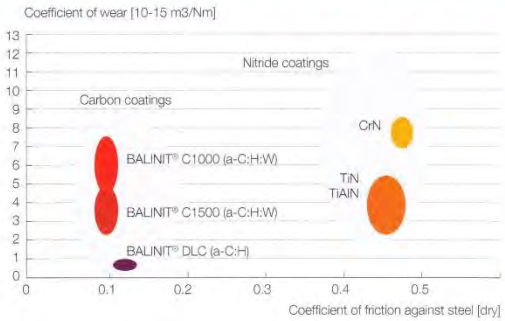
BALINIT® DLC for low friction surface.

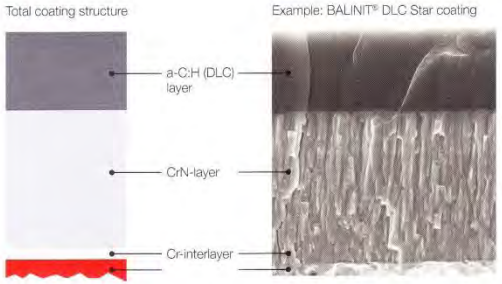
Suspension tubes and damper shafts historically have been plated with chrome for many years. Motorcycle fork tubes are under extreme conditions on the road and on track. Often the chrome plating can wear thin and can easily be damaged from foreign bodies impacting the surface which leads to wear on the oil seals and eventually leaks. Therefore trust in BALINIT® DLC. It's a very wear resistant PA-CVD coating which reduces friction and improves feel by a surface 5 times harder than steel, 2 times harder than chrome plating and by a coefficient of friction 8 times lower than steel and 2 times lower than hard chrome.

Your advantages with BALINIT® DLC coated suspension products.

- Hard impact resistant coating to prevent damage of the inner tubes
- Excellent sliding behaviour against bushes and oil seals
- Decorative colours to enhance the astetic appearance
- Prevents sliding and abrasive wear of the seal faces
- Low friction even under marginal lubrication

Your benefit: low wear and low friction.





The abrasive wear resistance was measured by the ball crater method where a 20 mm ball rotates on the surface with continuous addition of diamond suspension. The friction is measured in a pin disk arrangement under dry condition against steel. Especially BALINIT® DLC and DLC STAR show a unique combination of low wear and low friction.

We recommend: BALINIT® coatings for low friction suspensions.

Coating	Coating material	Micro-hardness (HV)	Typical thickness	Colour
BALINIT® DLC or DLC STAR	DLC/CrN	>2000	2-4 µm	Black
BALINIT® A	TiN	2300	2-4 µm	Gold
BALINIT® FUTURA NANO	TiAlN	3300	2-4 µm	Anthrazite
Chrome electroplated (Ref)	Cr	1000	5-50 µm	Metallic

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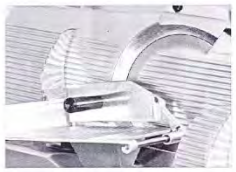
Good taste.

BALINIT® coatings for food processing and packaging.



General Engineering

Approved for packaging for the food industry.

UNITED STATES DEPARTMENT OF AGRICULTURE
MARKETING AND REGULATORY PROGRAMS
AGRICULTURAL MARKETING SERVICE

EQUIPMENT ACCEPTANCE CERTIFICATE

Firm: Oerlikon Balzers Coating USA Inc.
1475 Woodfield Road #201
Schaumberg, Illinois 60173

Model Designation: Coatings
Balinit CNI and Balinlt D

October 15, 2013
Date of Issuance

October 14, 2018
Date of Expiration

U.S. Department of Agriculture
Marketing and Regulatory Programs
Agricultural Marketing Service
Dairy Grading Branch
1400 Independence Ave., SW
Washington, DC 20250-0230

The issuance of this form is based on U.S. Department of Agriculture, Dairy Grading Branch, Equipment Design Review Section, evaluation of the equipment listed above for compliance with:

USDA Dairy Equipment Guidelines

This form does not limit USDA's responsibility to take appropriate action in cases in which evidence of non-compliance, improper maintenance, or non-sanitary conditions have been observed.

USDA United States Department of Agriculture

DA-161 (08-04) Destroy previous editions.

Certificate

for

BALINIT® D
BALINIT® CNI
BALINIT® CROVEGA
(Chromium Nitride)

A Product of

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9496 Balzers / Liechtenstein

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Global Registration and Strategic Consulting
4452 Itingen
Switzerland
Phone +41 (0)61 975 11 11
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The BALINIT® CNI coating has been approved by the FDA and USDA for the production of packaging for the food industry.

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Thank you very much for your attention!