BLÖSCH

A Company of BCI

PLATIT

Advanced Coating Systems

SWISS QUALITY

QuadCoatings4®, a New Generation of PVD Coatings for High-Performance Cutting Applications

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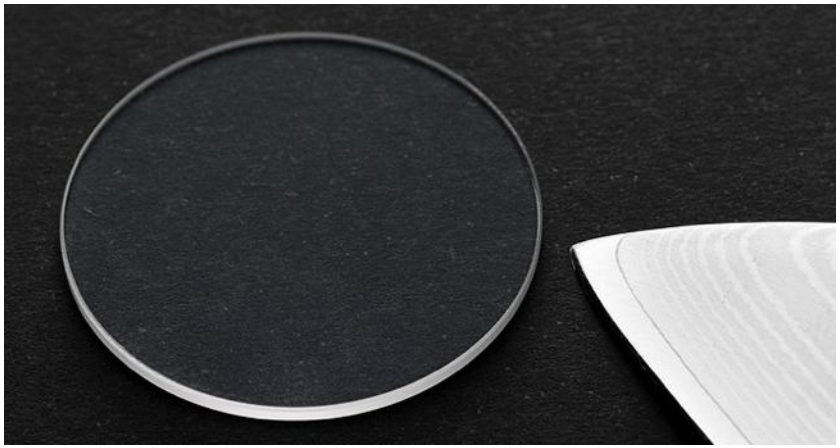
B AUTHENTIC

Outline

- BCI Blösch Group
- Platit AG
- Optimization of high performance tools
  - Substrate and treatments
  - Macro geometry
  - Micro geometry
  - Coatings
- QuadCoatings4®

Dr. Patrick Blösch

- Education
  - MSc ETH EEIT (2008)
  - Dr. sc. ETH Zürich (2012)
  - Executive MBA, focus on innovation management (not yet completed)



- Position
  - Business unit manager for hard and scratch-resistant antireflective coatings
  - Project manager (e.g. R&D)

The BCI Blösch Group

- Family owned incorporated company
- Founded in 1947
- Independent
- Technology leader
- International business
- 350 employees worldwide

Headquarter in Grenchen, Switzerland

Organization Structure

BCI

BLÖSCH	LISS	PLATITE Advanced Coating Systems SWISS QUALITY	PLANAR Technologie
Switzerland	Czech Republic	Switzerland Czech Republic U.S.A. Scandinavia Korea China Japan …	Switzerland

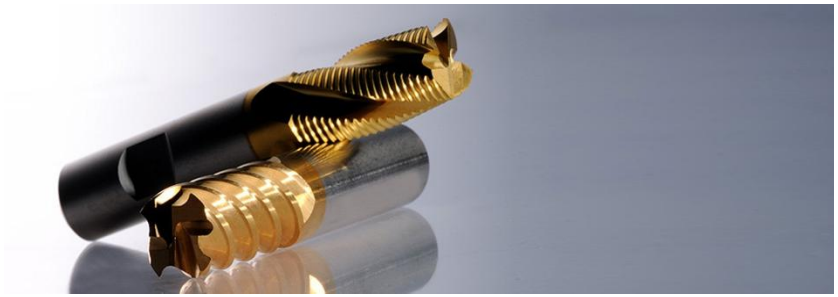
Research and Development Activities

- Vacuum coating technologies (PVD/CVD)
- Microsystem components by laser structuring
- Plasma treatments
- PVD plant engineering (hardware and software)

We participate in several research projects in collaboration with international universities

Markets

- Swiss watch industry
- Telecommunication
- Optics
- Medical
- **Cutting tool industry**
- Aerospace
- Precise components



Example – Technologies for watch industry

Hard and colorless antireflection coatings on sapphire watch glass

Hard coatings on stainless steel watchcases

Colored coatings for dial plates

Special phases of the moon

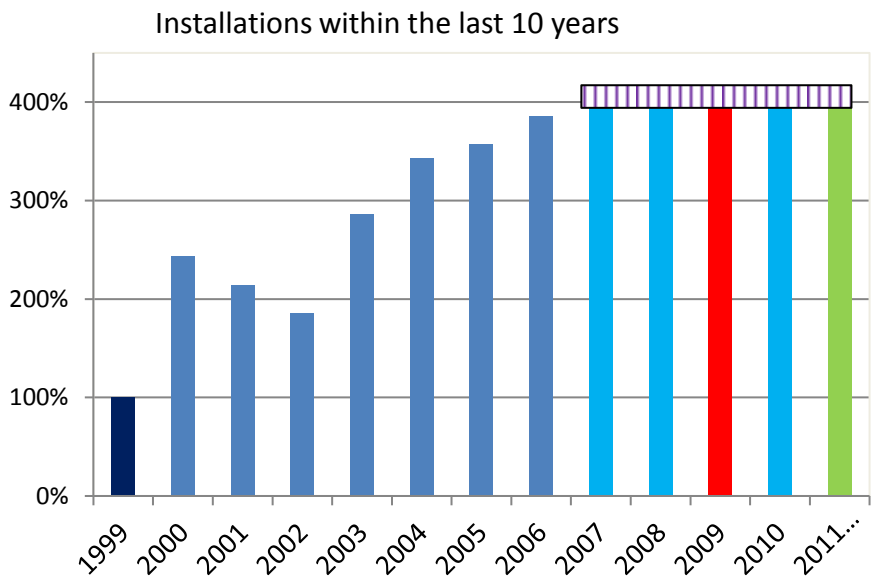
Black Diamond-Like-Carbon (DLC) coatings for bracelets

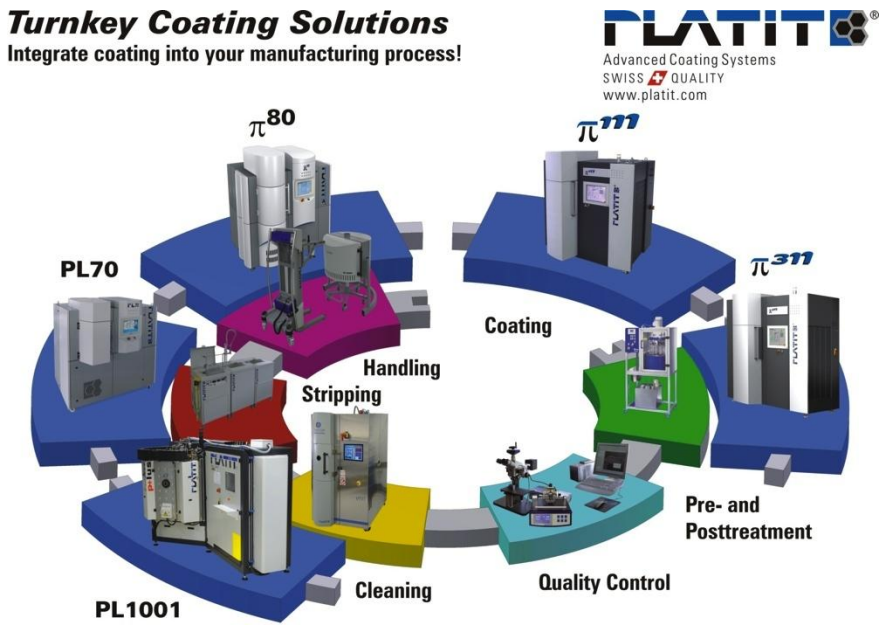
Development and production of PVD coating units

PLATIT AG

PLATIT AG in a few Words…

- Development and production of **PVD coating units**
- Design of **dedicated PVD coatings**
- 87 employees
- No job coating!
- **340 Installations** in 37 Countries (Feb. 2013)





The PLATIT Team

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PLATIT

← Grenchen, CH

Selzach, CH →

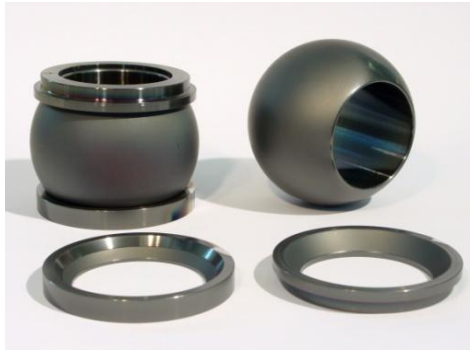
PIVOT

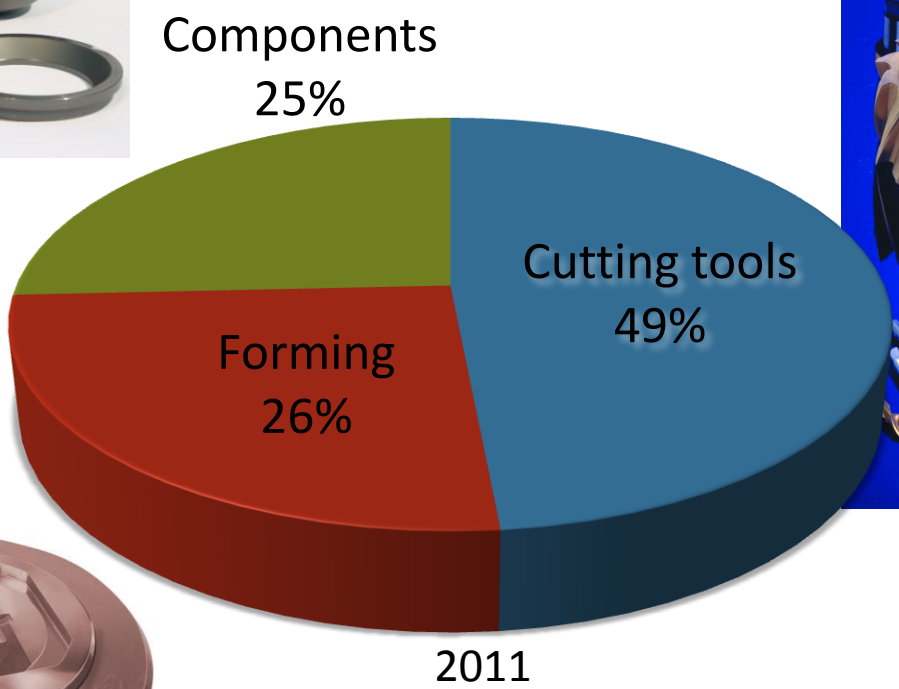
Sumperk, CZ

PLANAR Technologie

Riaz, CH

Typical Applications of PLATIT Coatings





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SWISS QUALITY

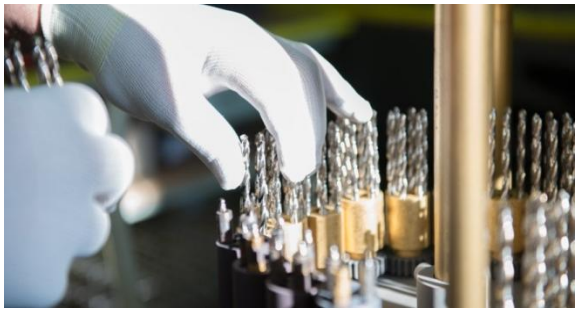
BLÖSCH

The LISS

- owned by BCI 100%
- Founded in 1991, coating centre 1997
- Surface technology and innovation
- International business
- 95 employee
- New R&D and production centre 3500 m^2

Jozef Sondor

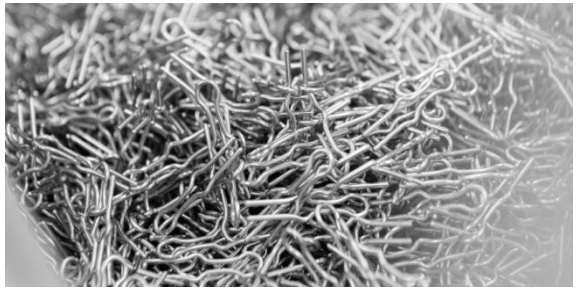
- Materials science and Engineering



- Position

Manager of BU hard and soft coating

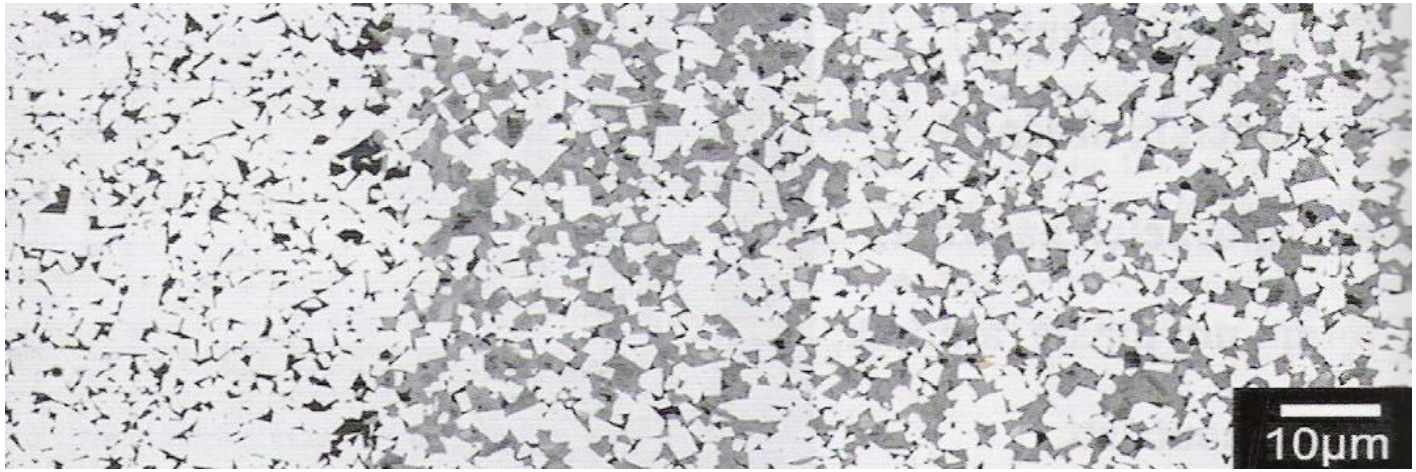
R&D department, responsible for vacuum projects



Tools material – why is important?

Carbide

Grain size, % Co, toughness , hardness

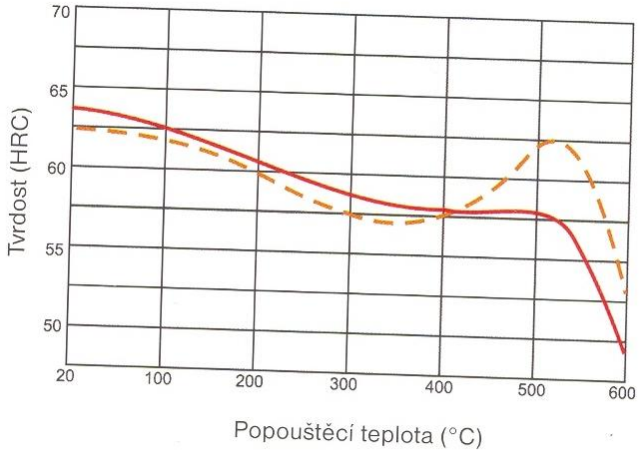


Tool steel

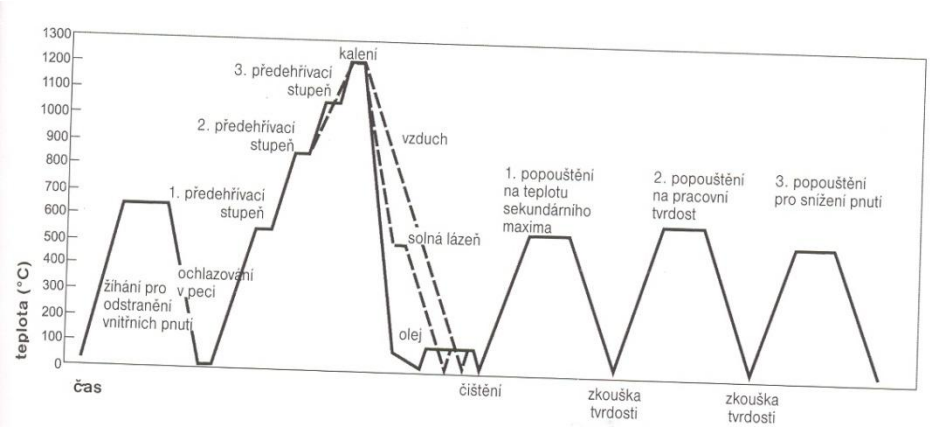
Chemical composition, hardness, heat treatment

Tools material – why is important?

PVD coatings usually made **at 480°C**.
For Tools is important – last temperature of tempering

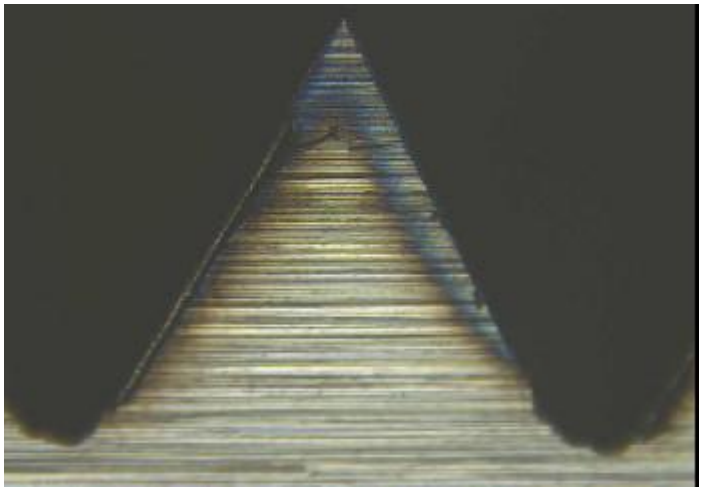


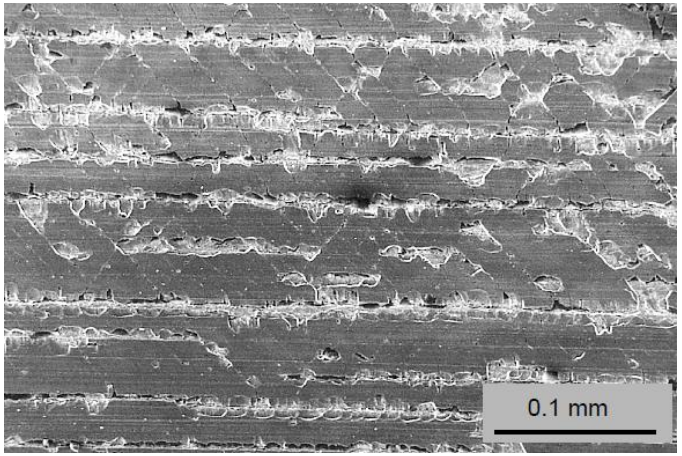
Tools steel with high carbon contents – high amount of Austenite = 4 times tempering

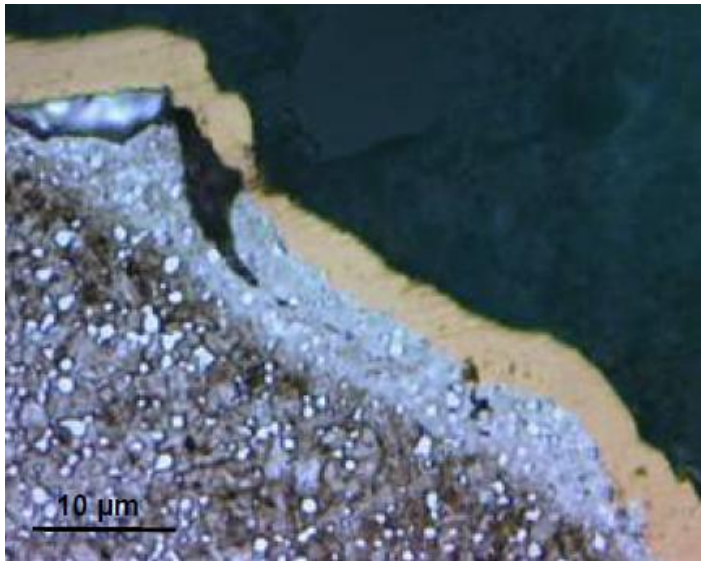


Tools material – what else is important?

1. Oxidation burns
2. Overtempering
3. Residual stress
4. Rehardening burns

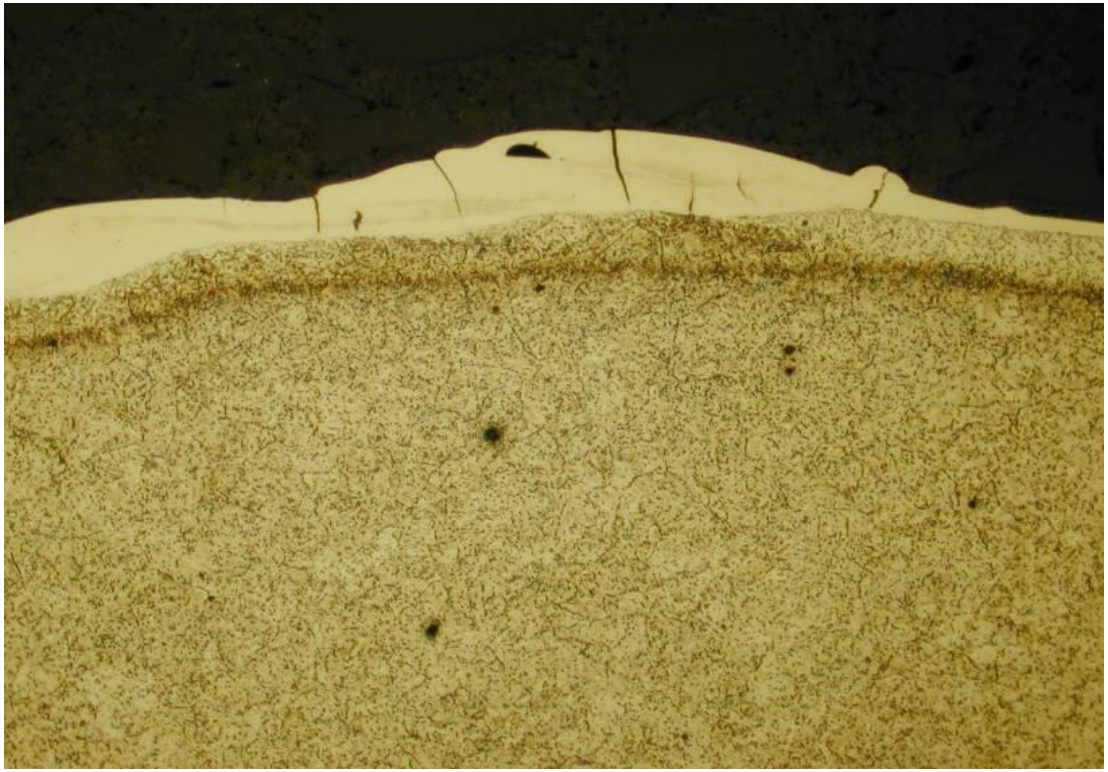




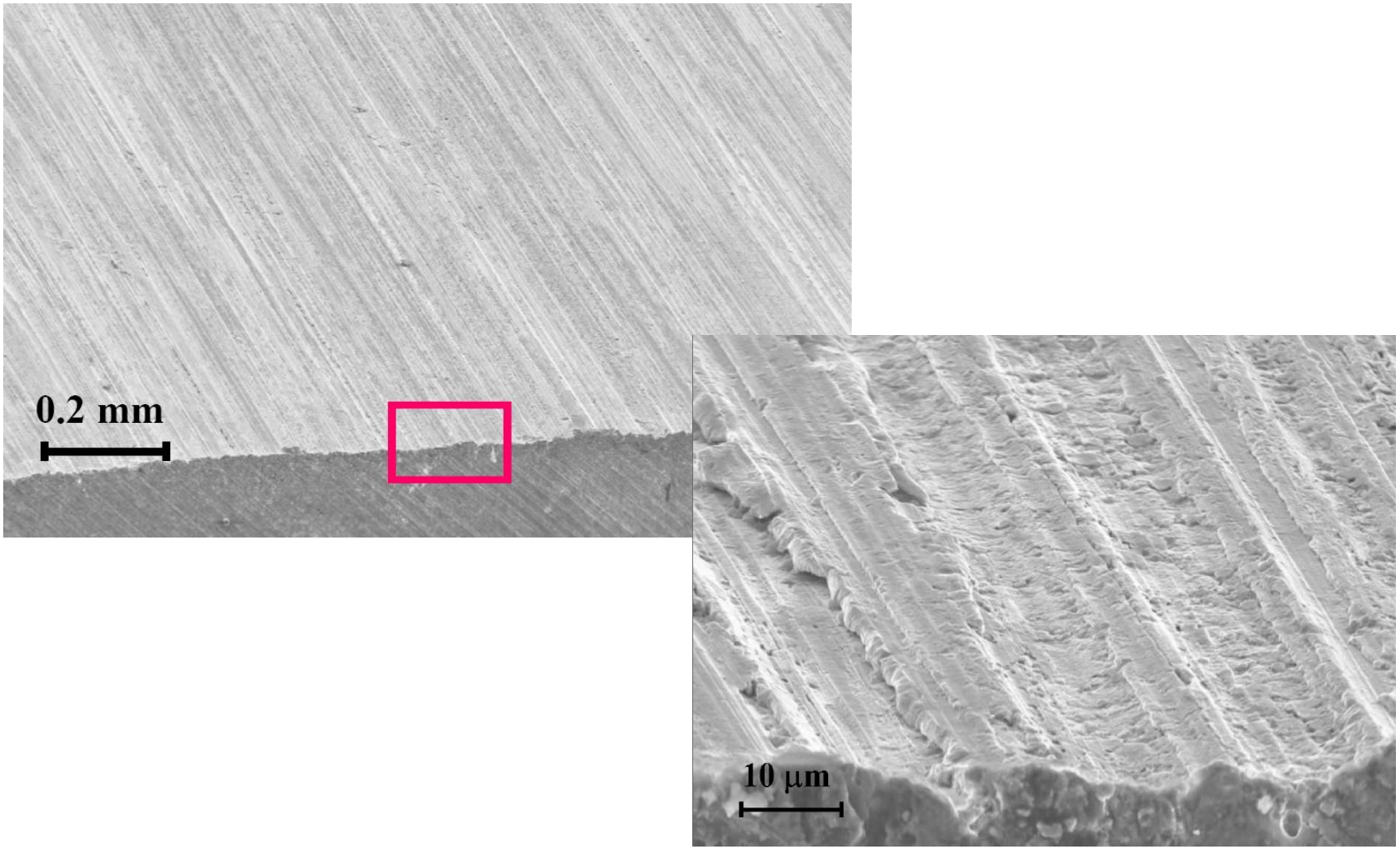


Tools material – EDM Process

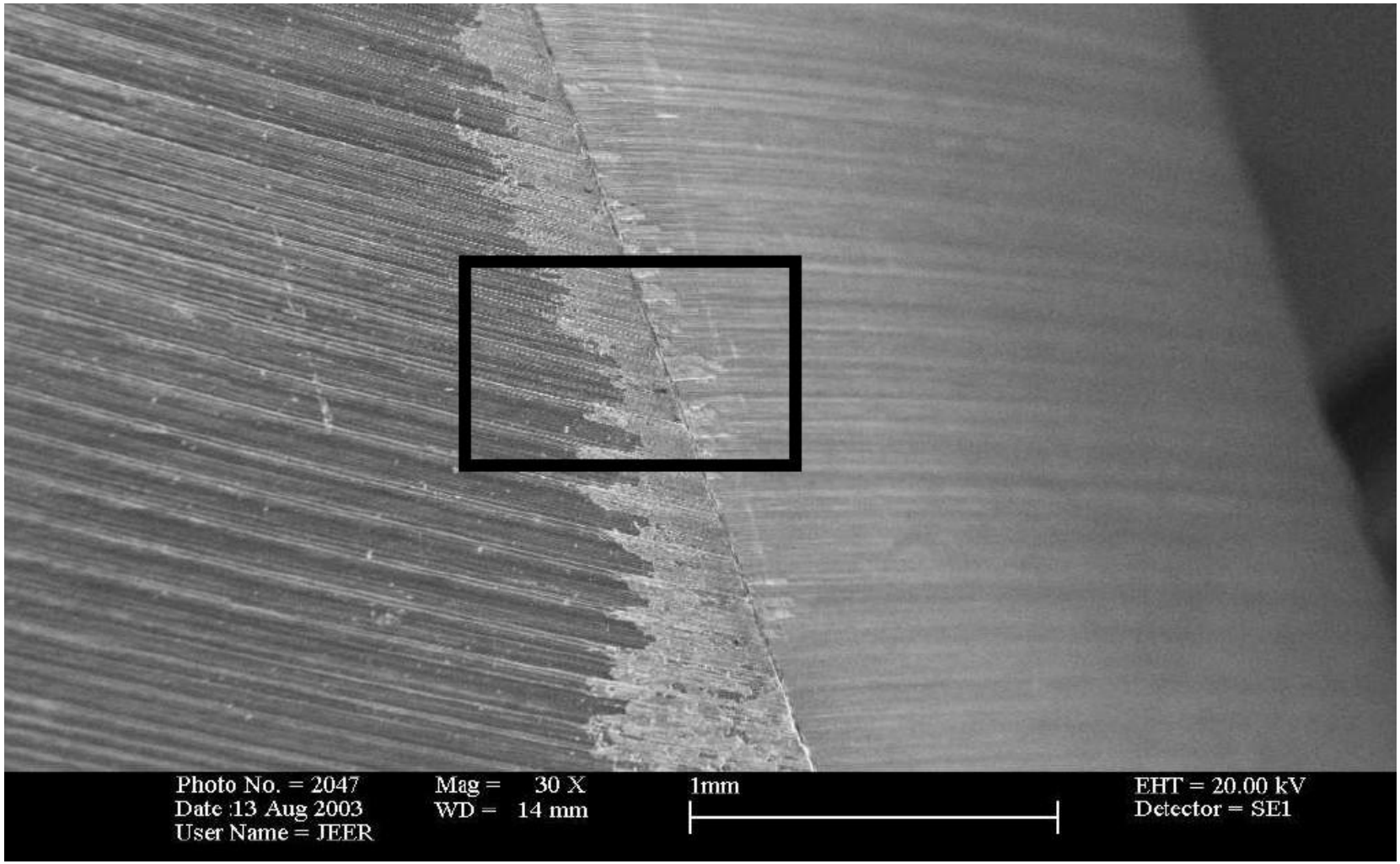
- White layer
- Easy to break out with/without coating
- Change cutting parameter
- USE POST TREATMENT



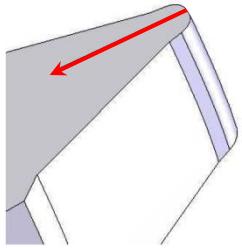
Tools material – surface roughness



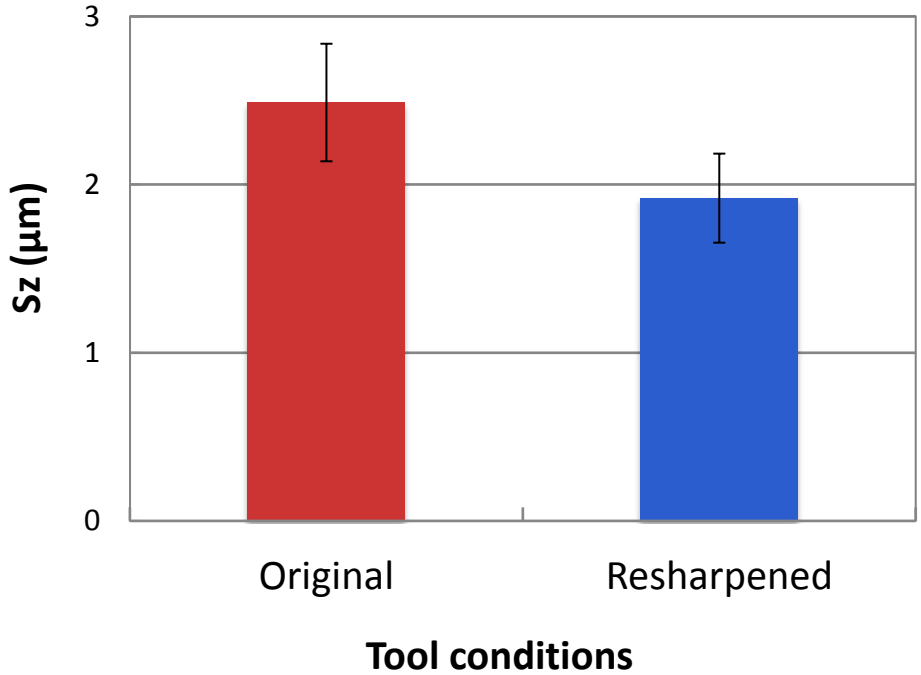
Tools material – surface roughness



Tools material – surface roughness



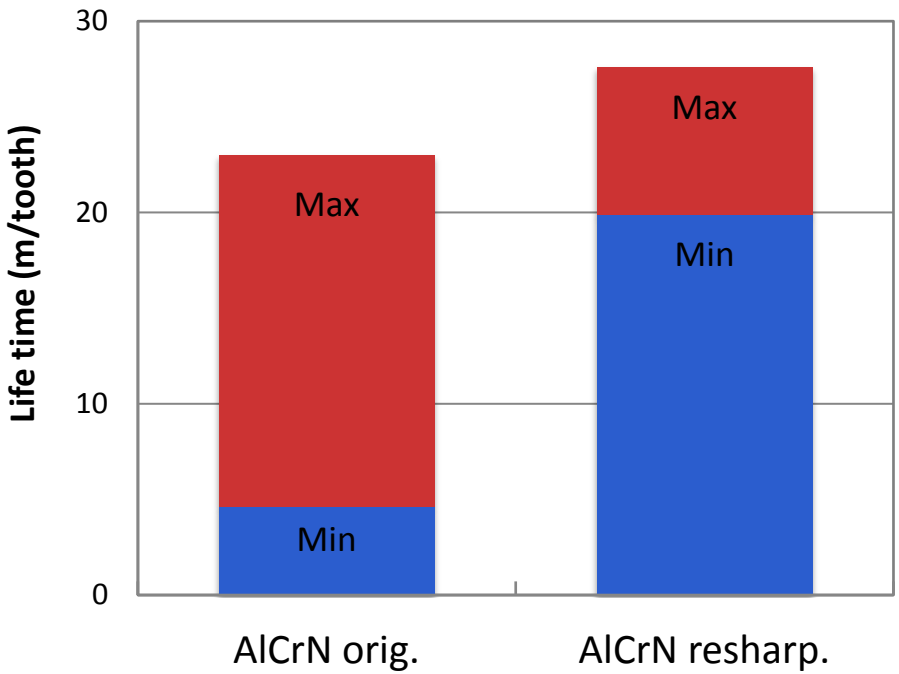
- Sz measured on cutting faces with *Form Talysurf 120*
- Brandnew (=original) vs. resharpened hob
- Lower Sz for the resharpened hob



Tools material – surface roughness

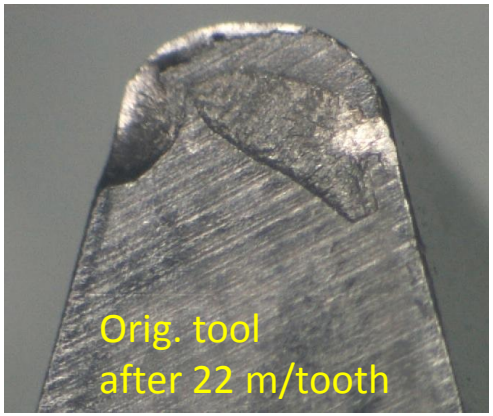
Resharpened:

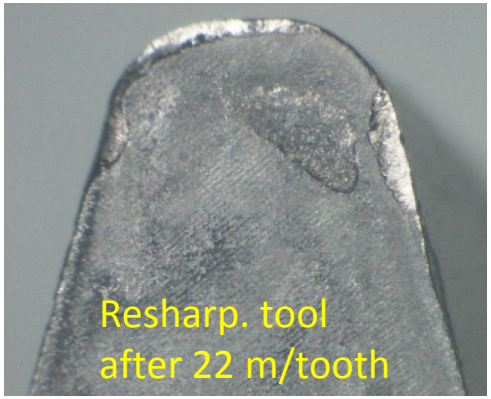
- Increased tool life
- Less fluctuation of the tool life time
- No grinding traces
- Improved chip removal → less crater wear



HSS hob (fly cutter), m = 2.5, v_c = 150 m/min, f_a = 1.69 mm/rev, dry

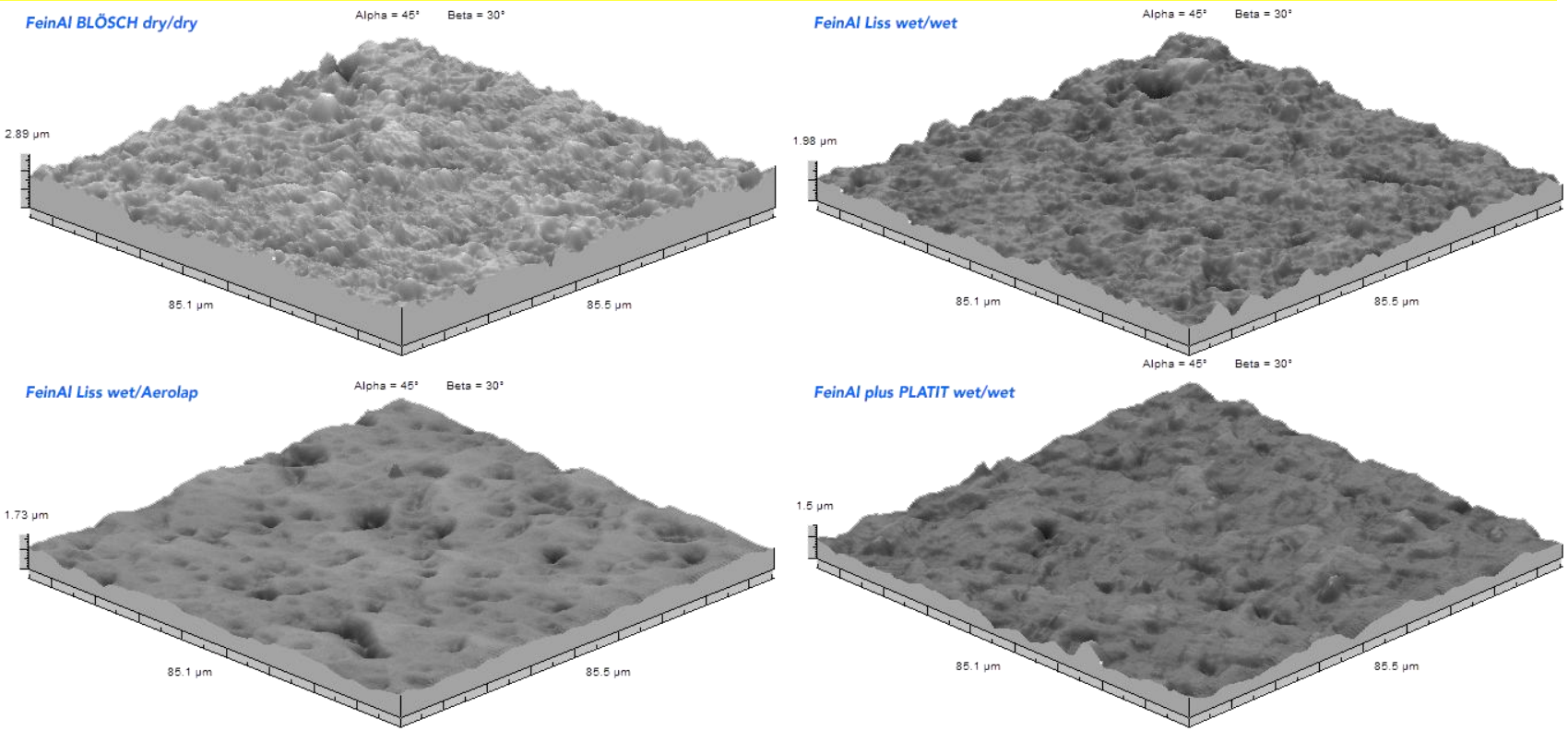
Crater wear on Cutting face:





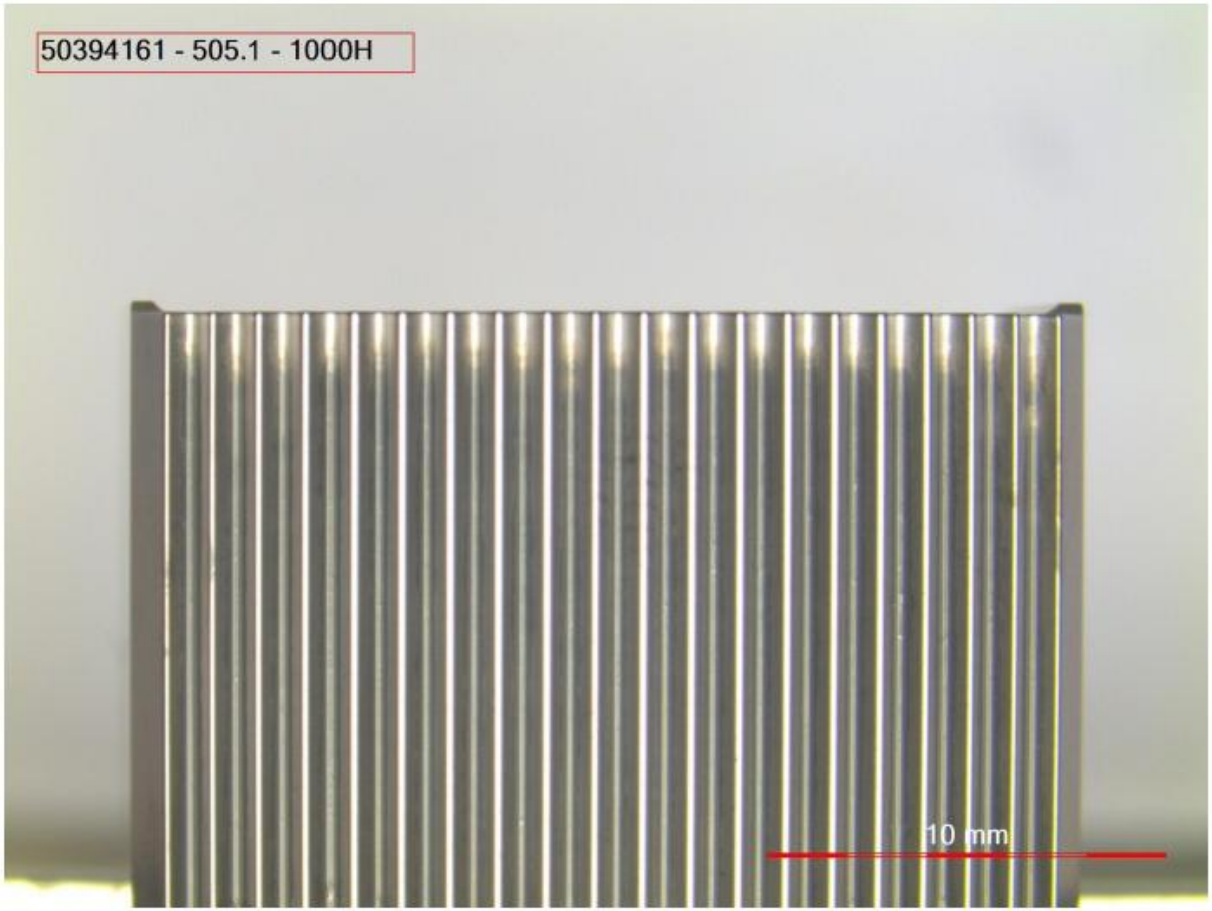
Surface roughness – post-treatment

Surface roughness – post-treatment



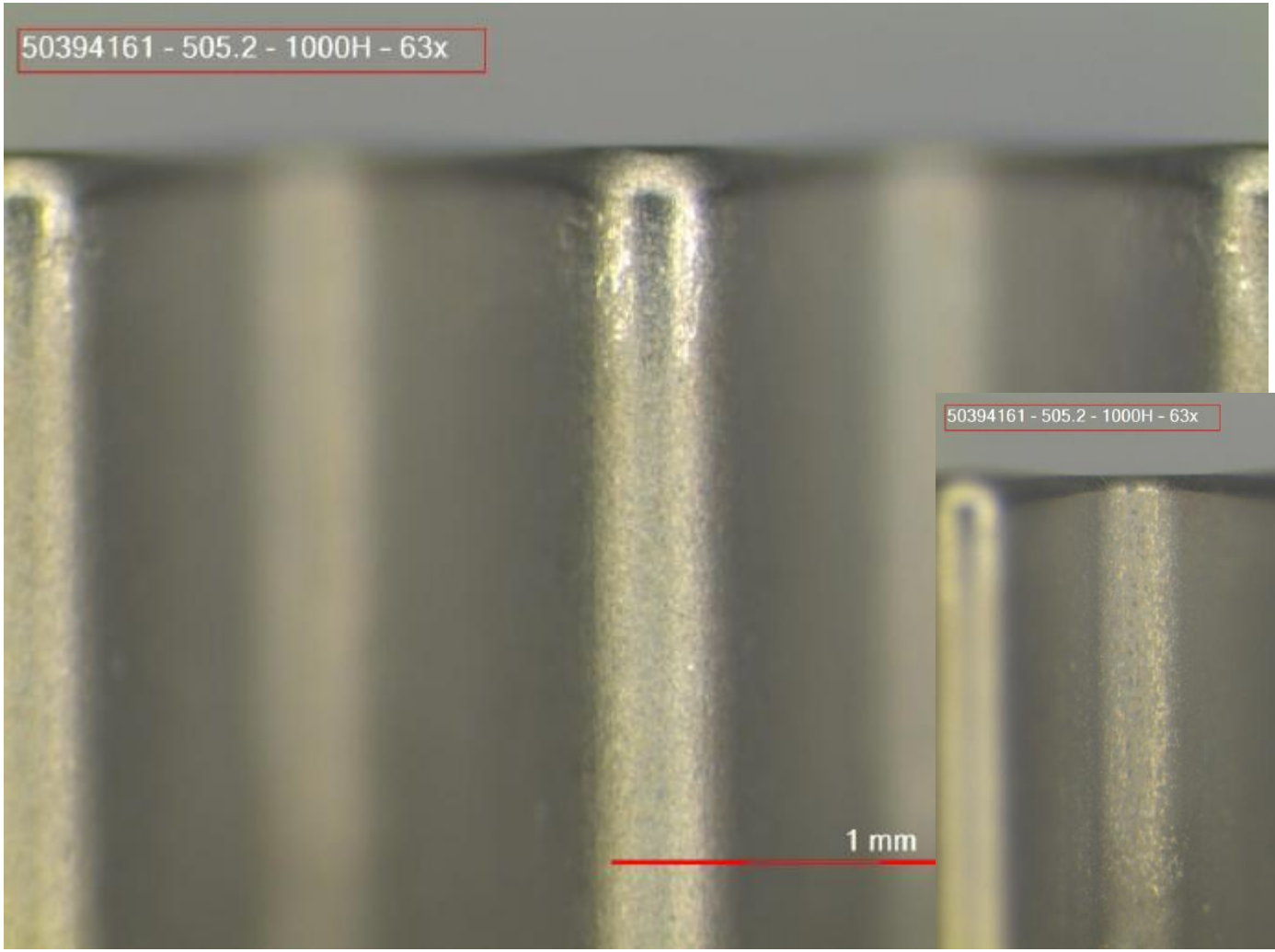
Werkzeug	Behandlung vor/nach	R_a	ΔR_a	R_z	ΔR_z
63-1 FeinAl Liss	*nassstrahlen/AeroLap*	**0.107**	± 0.010	**1.24**	± 0.08
63-2 FeinAlplus Platit	*nassstrahlen/nassstrahlen*	**0.124**	± 0.011	**1.38**	± 0.11
61-1 FeinAl Liss	*nassstrahlen/nassstrahlen*	**0.150**	± 0.004	**1.69**	± 0.07
61-2 FeinAl Blösch	*trockenstrahlen/trockenstrahlen*	**0.175**	± 0.007	**1.83**	± 0.20

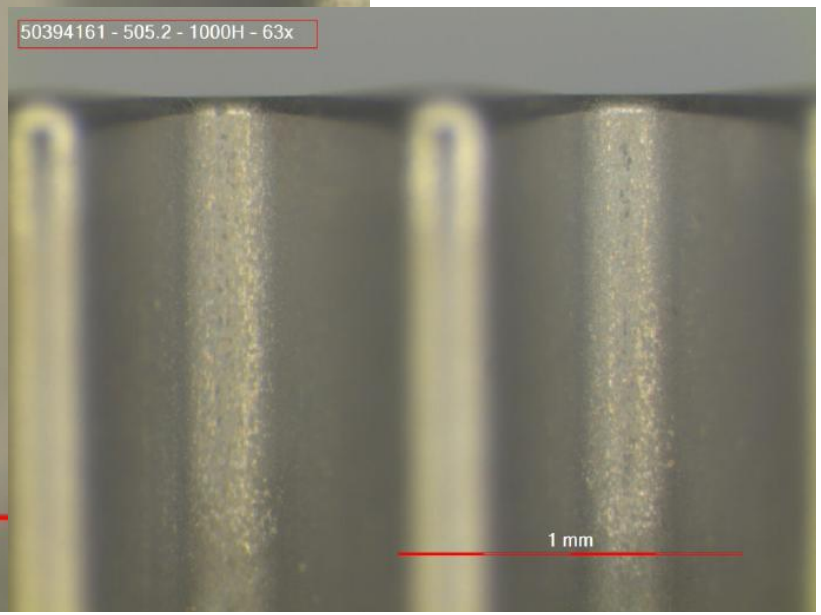
Surface roughness – post-treatment



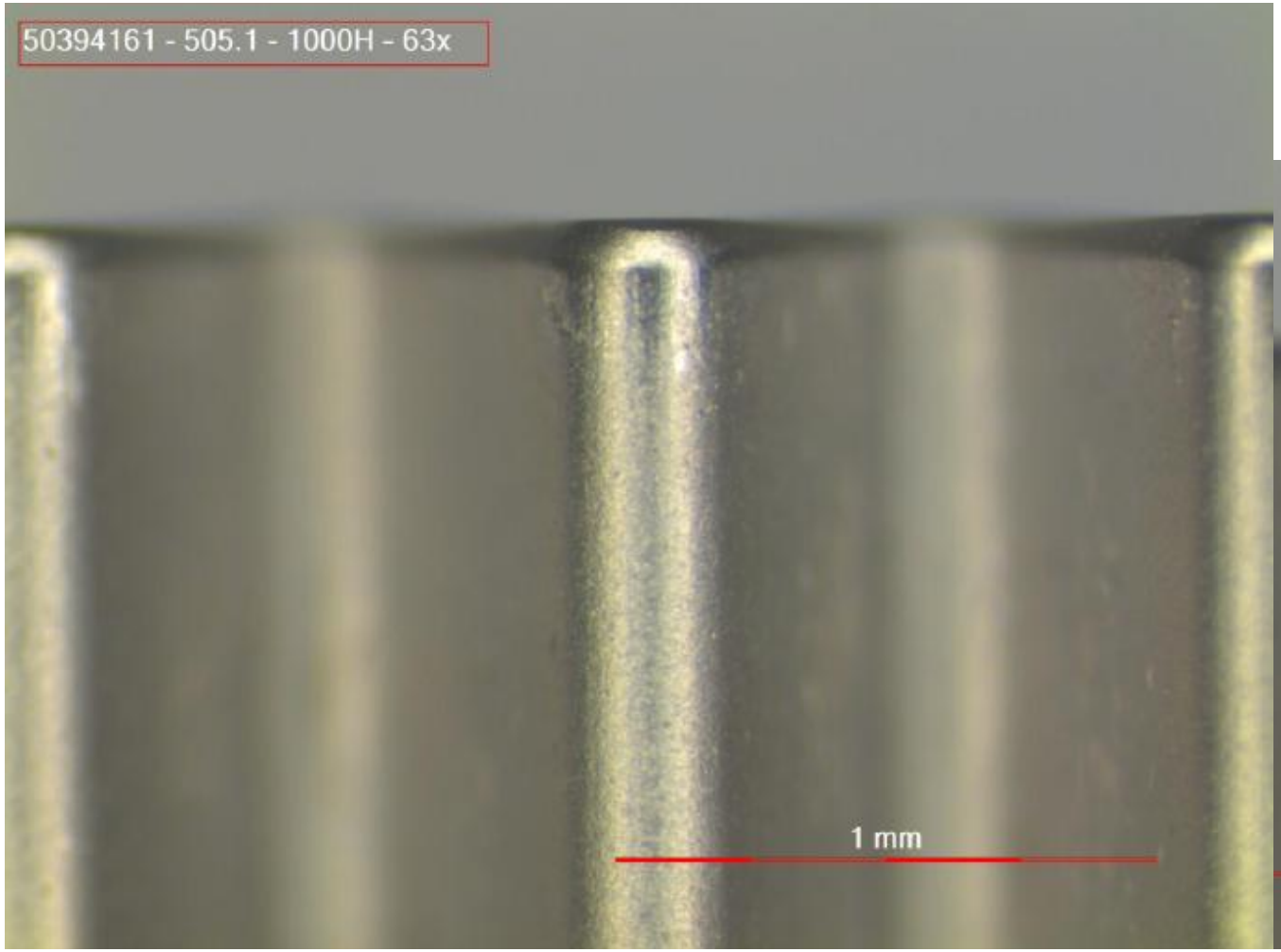
Stamping, Feintool

Dry blasting

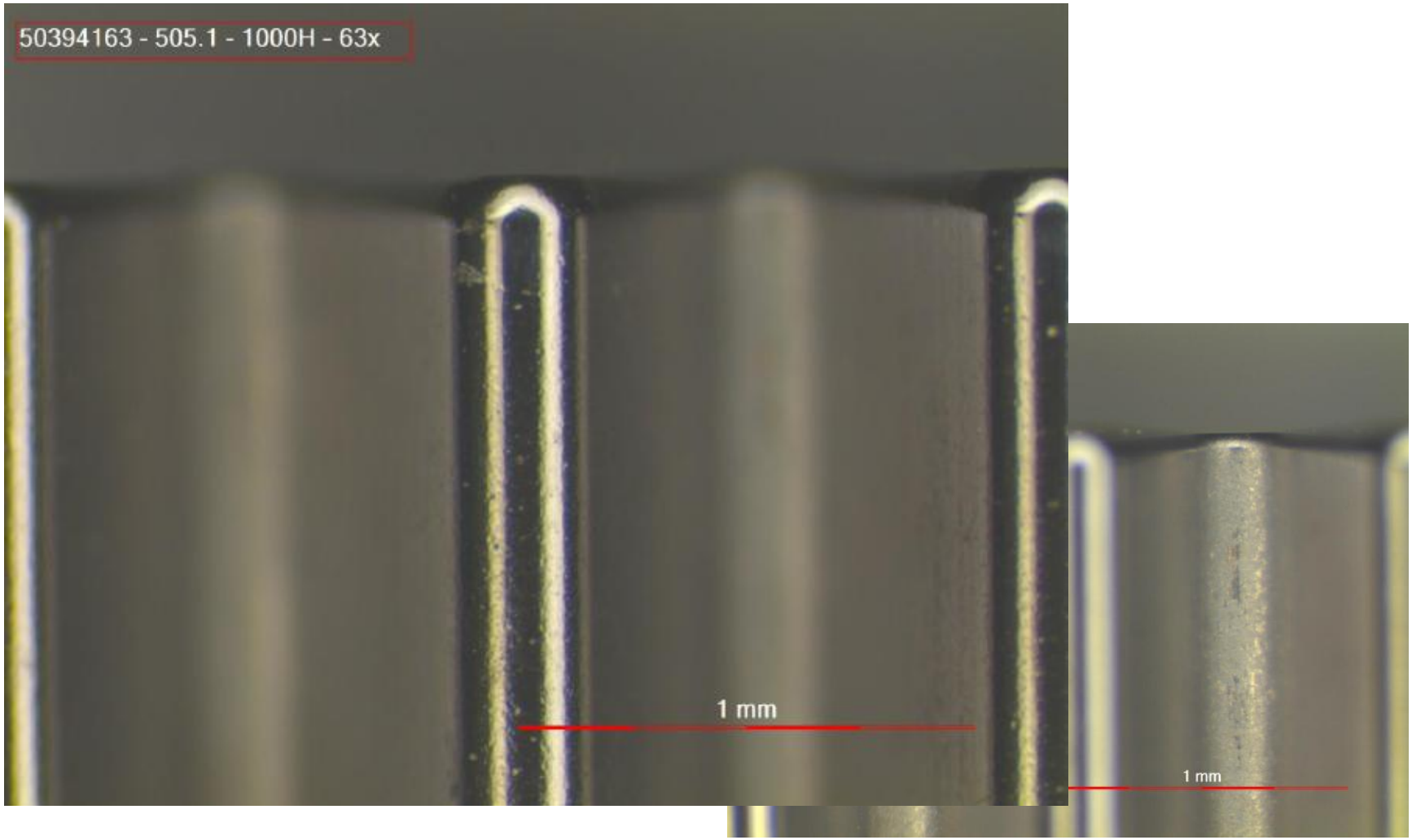




Wet blasting

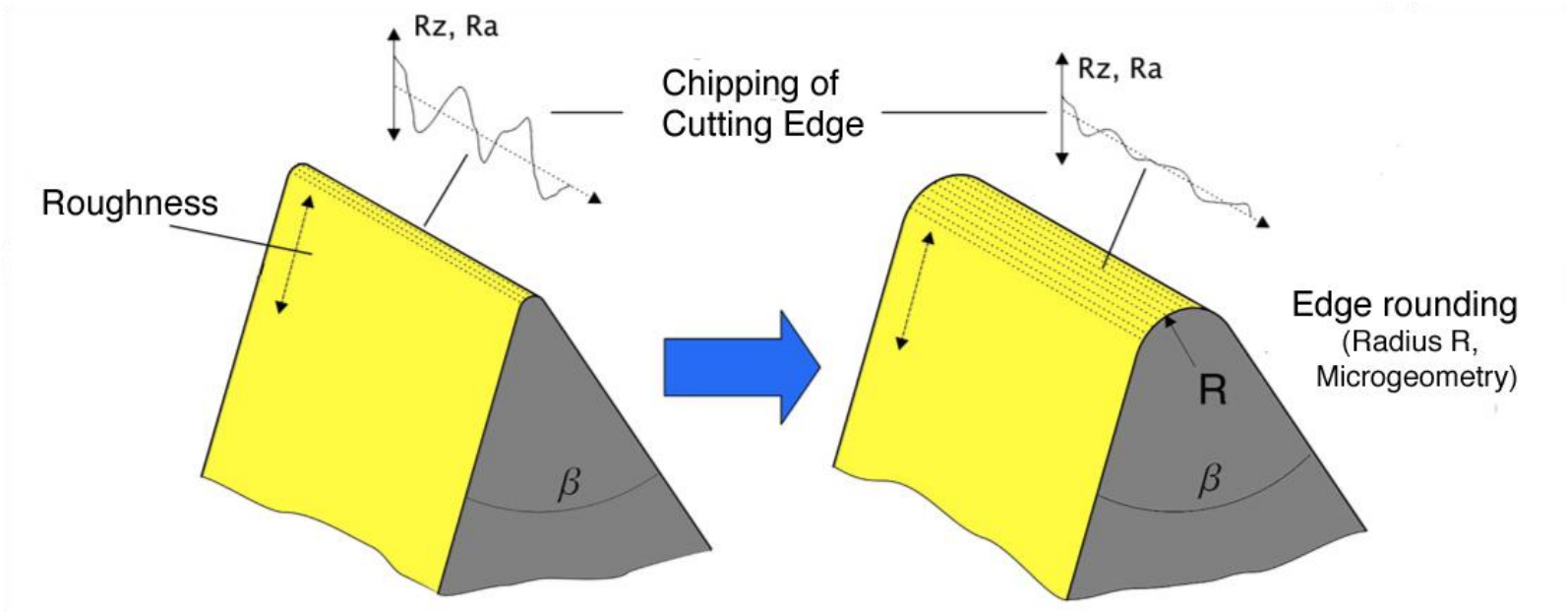


mikroLAP by LISS



MICRO GEOMETRY

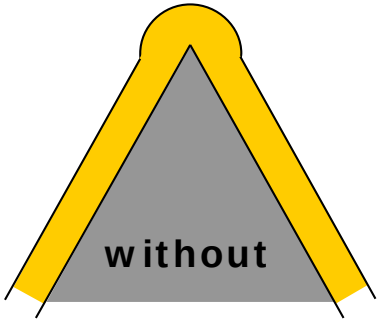
Edge preparation

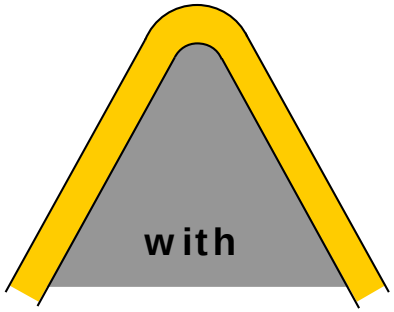


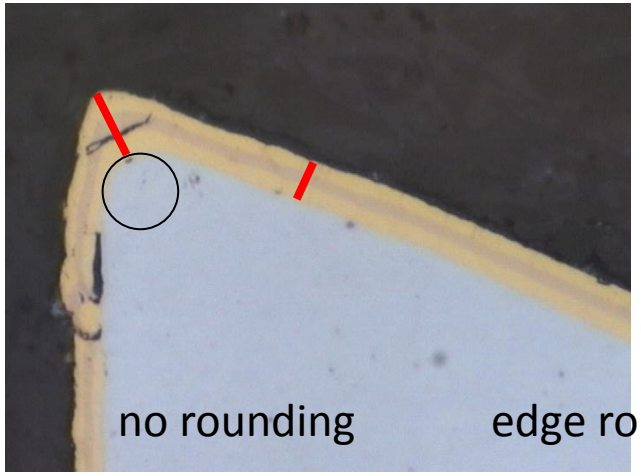
- Stabilizing and smoothing out the cutting edge
- Improved chip removal
- Optimized micro geometry (dep. on the application)
- **Increased Tool life!**

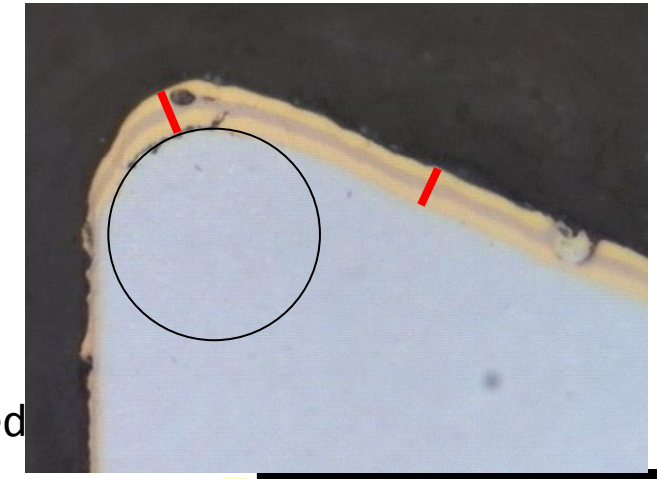
Edge preparation

- Edge rounding compensates so called Antenna effect for PVD Coatings
- Compressive stress reduced, improved coating adhesion

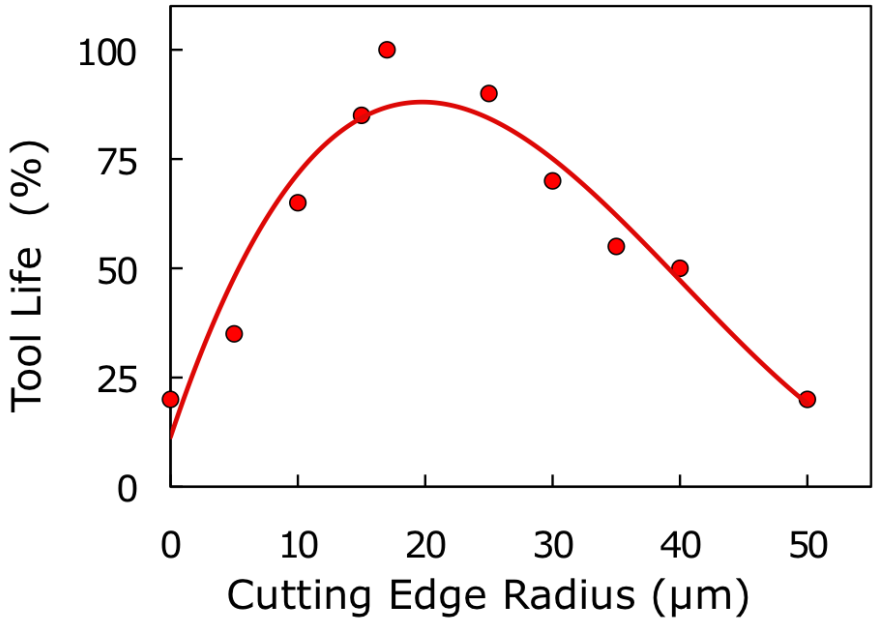


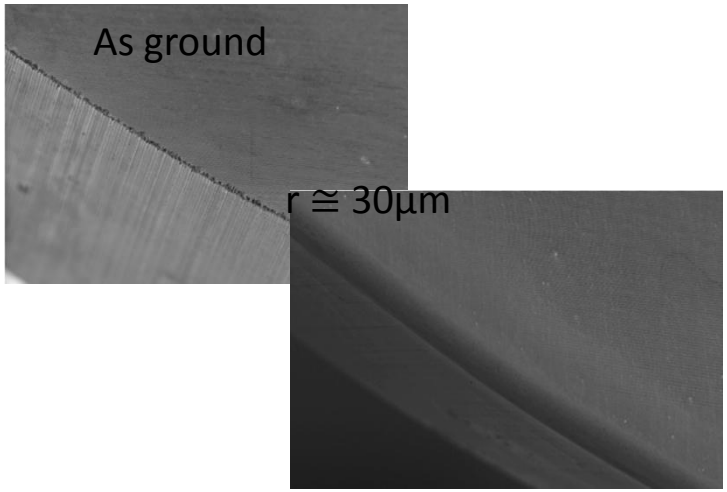






Edge preparation – only HP tools?





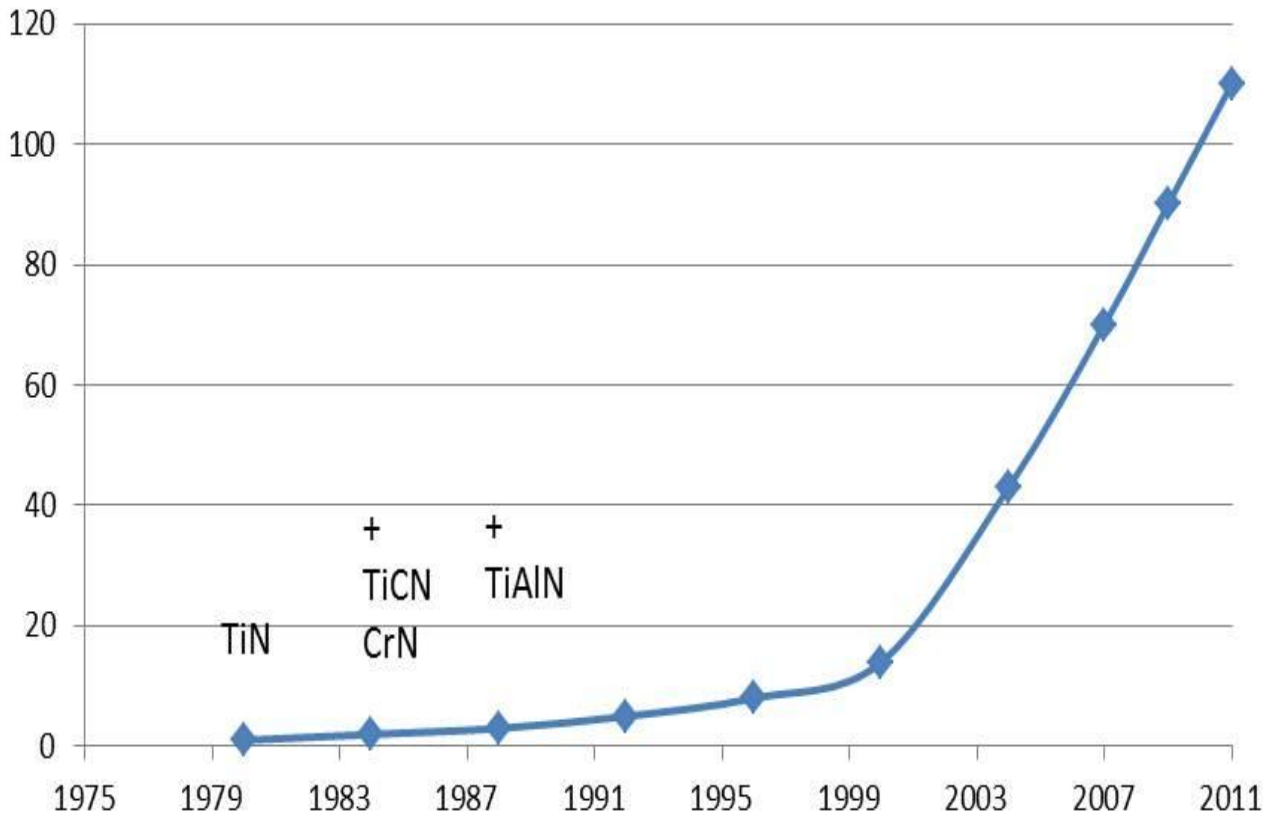
Source: GFE, Schmalkalden

- Edge rounding by brushing
- Optimum rounding for this type of tool and this application: Tip 17–20 µm

Material: 1.2379 - X155CrVMo12-1, Tool: End mill, nACRo coated,
Ø=10mm, z=4, ae=0.25 x d – ap=1.5 x d – vc=150 m/min – fz=0.05 mm/z

COATINGS

Available Coatings on the Market



2011:
mehr als
100;

Ti-basiert	Monolayer
C basiert	Multilayer
Cr-basiert	Gradient
Zr-basiert	Nanolayer
W-basiert	Nanocomposite
V-basiert	TripleCoatings
Mo-basiert	
Al-basiert	
Si-basiert	
.....	

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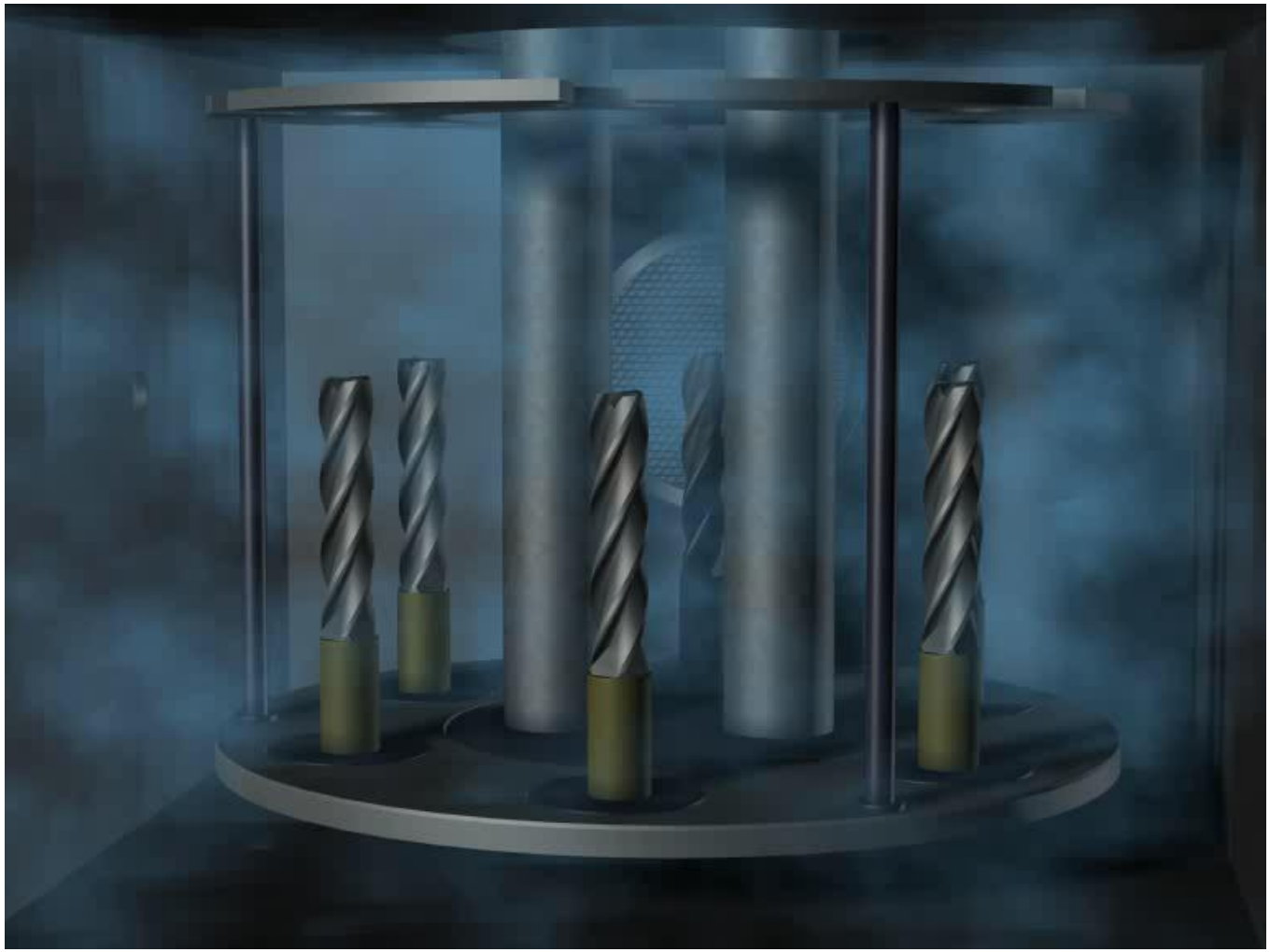
ARC coating deposition process



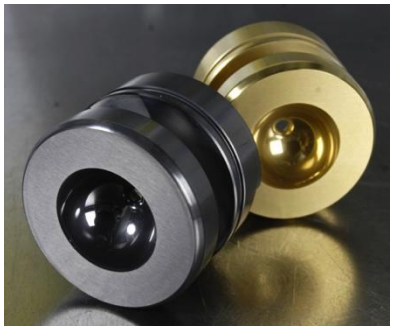
Demands on PVD Coatings

- High hardness and wear resistance
- High toughness and excellent adhesion
- Good chemical, oxidative und structural stability
- Thermal barrier
- Low friction coefficient
- „Separator“ between tool and cutting material

…at the temperature of the application!

Components

Cutting/Forming



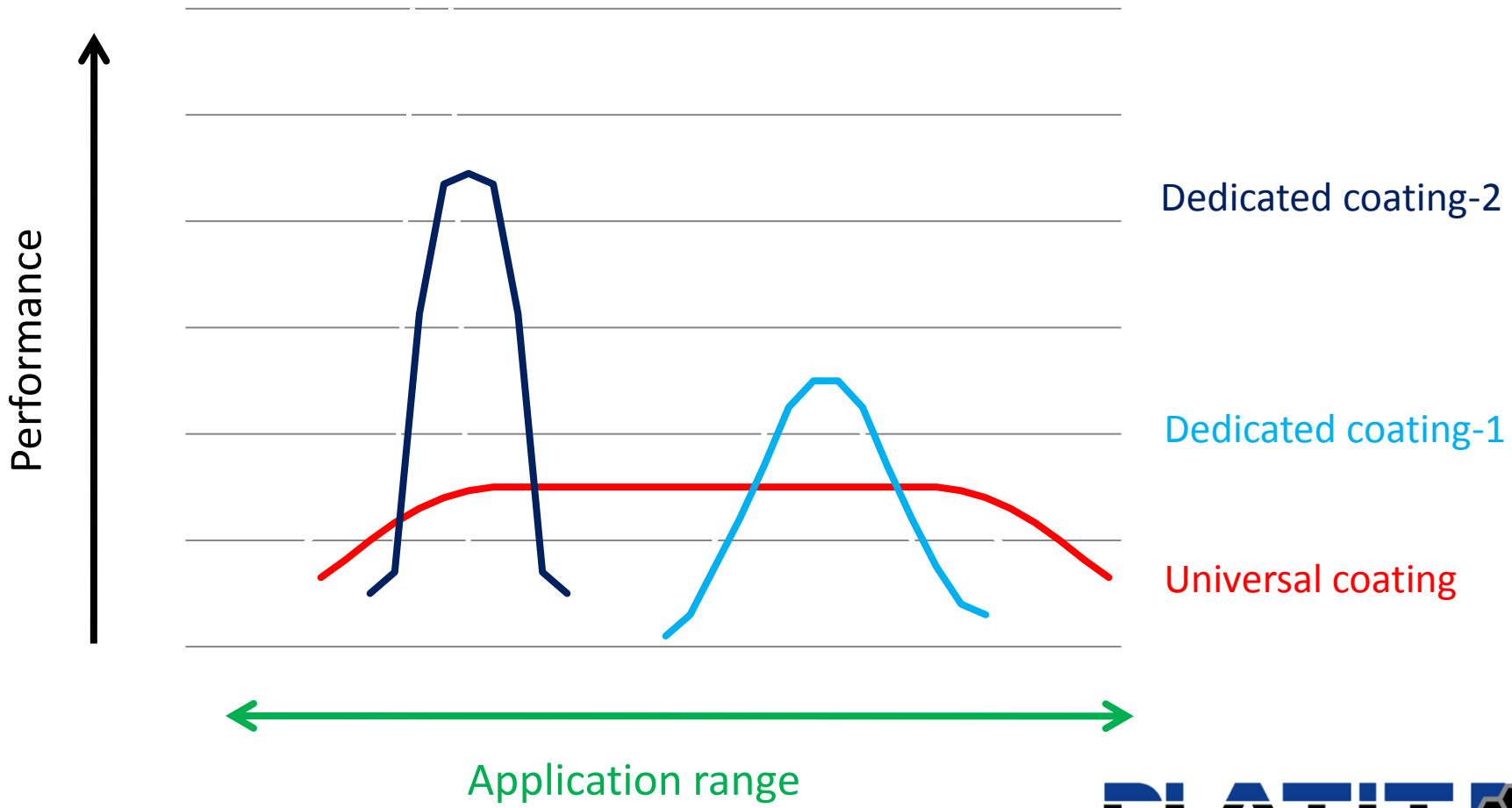
Injection Molding

Dry Cutting

0 200 400 600 800 1000

Application temperature [°C]

Dedicated Coatings for Special Applications



Advanced Coating Systems
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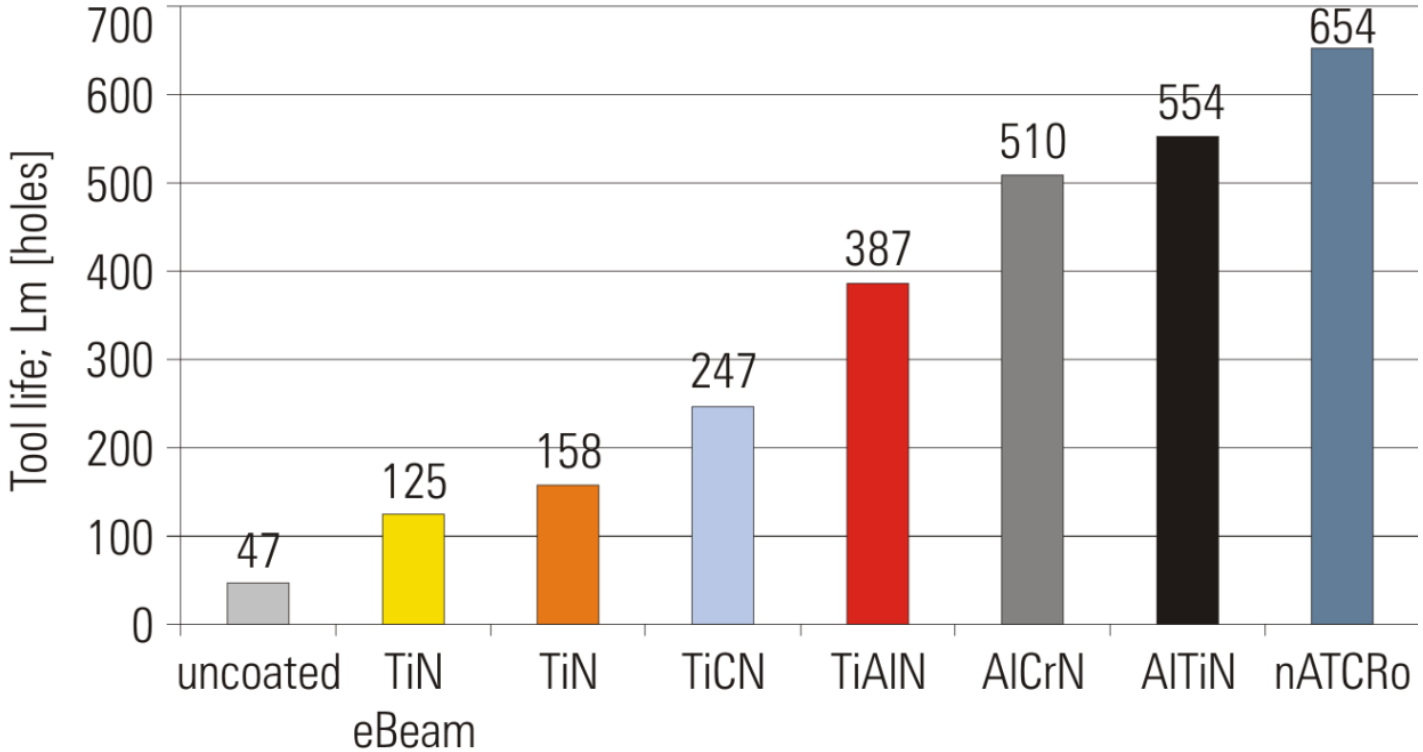
Tool Life Comparison for Different Coatings

Example: HSS-Drills:



Mat.: Tool steel - X155CrVMo12-1 - 1.2379 - HB290 - ap=18mm - blind holes
Tools: HSS-drills - Type N - DIN 338 - d=6mm - vc=22 m/min - f=0.1 mm/rev - emulsion 7%

Coating

1. Chemical composition (stoichiometry)
2. Microstructure
3. Coating design
4. Post treatment

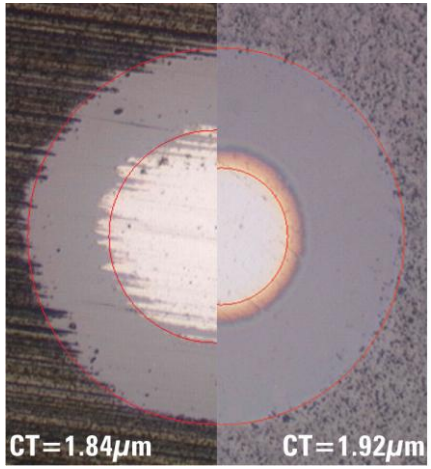
1. Chemical Composition

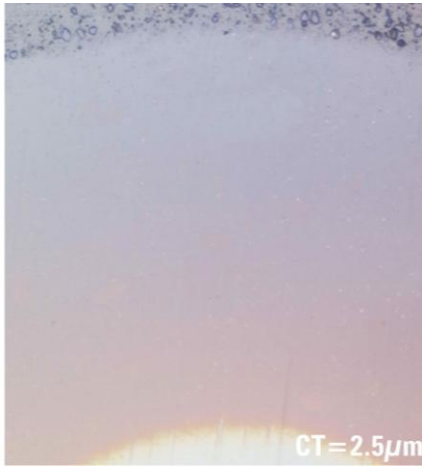
Element	Hardness	Friction	Structural stability vs. T	Oxidation resistance	Wear resistancse RT	Wear resistance 600°C
Titan (TiN)	Base	Base	Base	Base	Base	Base
Chrom (CrN)	Ø	(+)	–	Ø	++	+
+ Carbon	++	++	–	– –	++	– –
+ Al	+	–	+	+	Ø	++
+ Si	++	Ø	+(+)	+	+	+(+)
+ Oxygen	–	– / +	++	++	(–)	+

- General trends for the influence of different components on the properties of the PVD coatings
- Choice of the coating system depends on the application

2. Microstructure

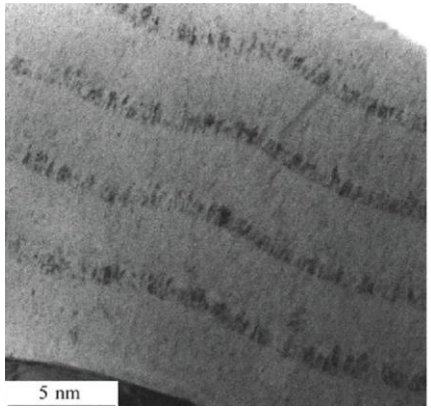
Monobloc

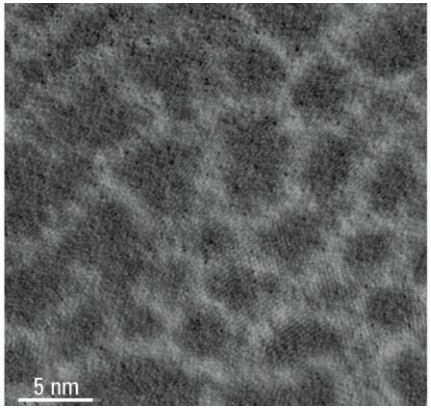




Gradient

Laminates

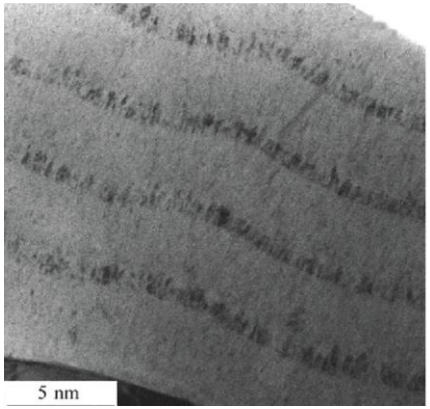


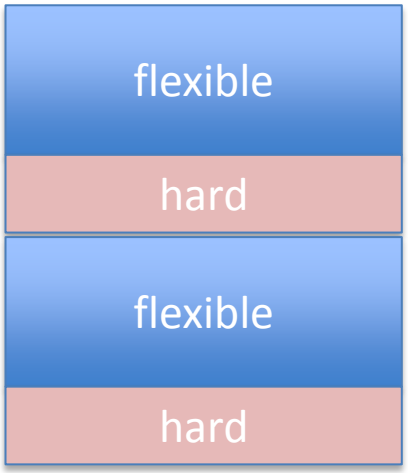


Nanocomposite

Laminates

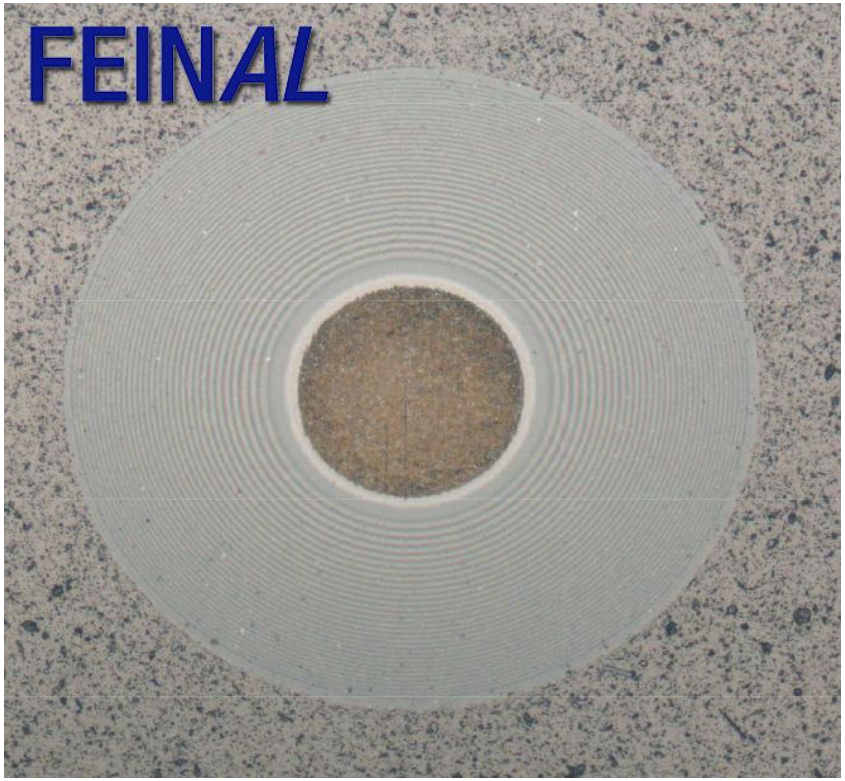
- Two repeating materials with defined thickness in nanometer scale
- Each material has its unique function, e.g.
  - Hardness
  - Flexibility (toughness)
  - Chemical stability
  - Wear resistance
  - Friction
- Combination of these materials in the nanolaminate configuration yield to new properties





Laminates – Application FEIN*AL*

Dedicated multifunctional coating for fine blanking:



Light microscope image of a calotte-grinded sample with FEIN*AL to demonstrate the multilayered coating structure*

Structure:

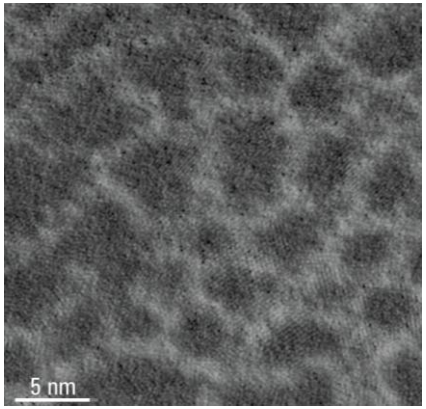
- Aluminum-chromium-nitride (AlCrN)-based multilayered nanostructures
- Combines high hardness with toughness
- Optimized multilayer architecture with Al-rich layers for high thermal insulation and Cr-rich layers for high hardness and wear resistance

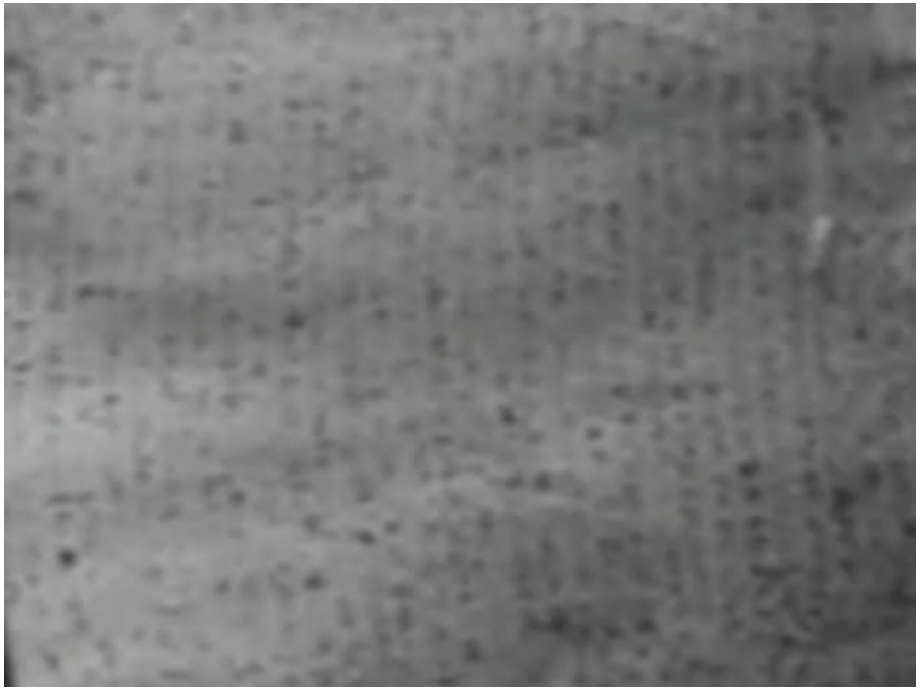
Result in application:

- The fine nanolayered structure leads to high film elasticity that prevents crack propagation
- Extremely high abrasive wear resistance in combination with film oxidation resistance

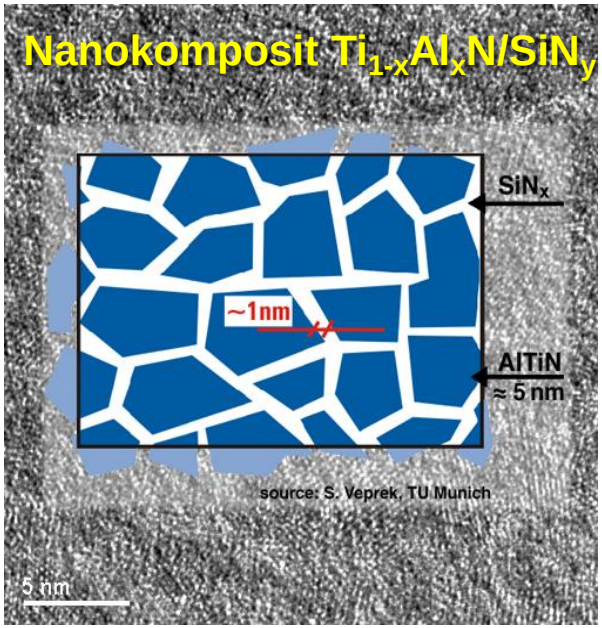
Nanocomposites

- Two materials with one crystalline and one amorphous phase
- Special properties (high hardness and high heat resistance)

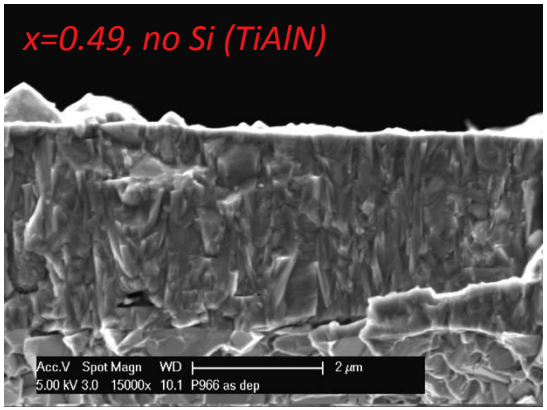


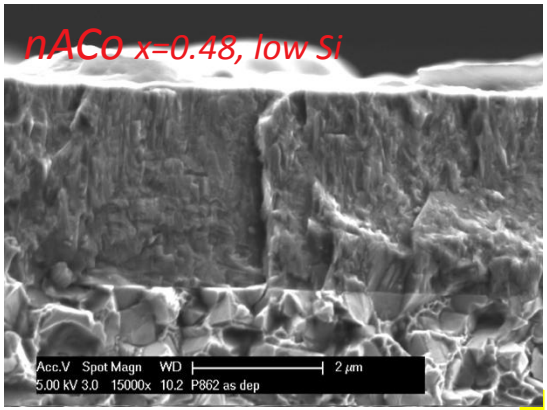


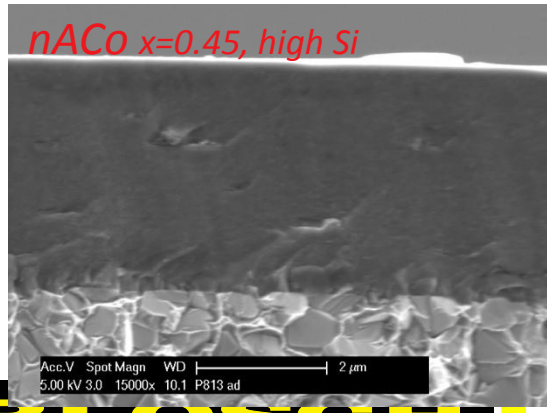
Si Containing Superhard Nanocomposites



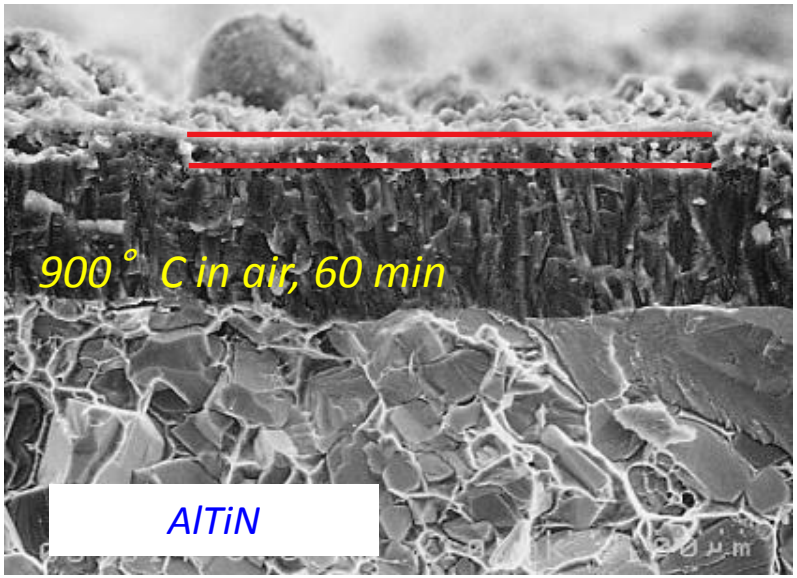
- **Si addition** changes microstructure from columnar to isotropic glassy structure
- **Hall-Patch relation**: Nanocristallites result in highest hardness
- **Nanocomposite** structure with so called "super hardness" (≥ 40 – 50 GPa)
- TiN/Si_xN Nanocomposite
- $Ti_{1-x}Al_xN/Si_yN$ Nanocomposite ➔ **nACo**

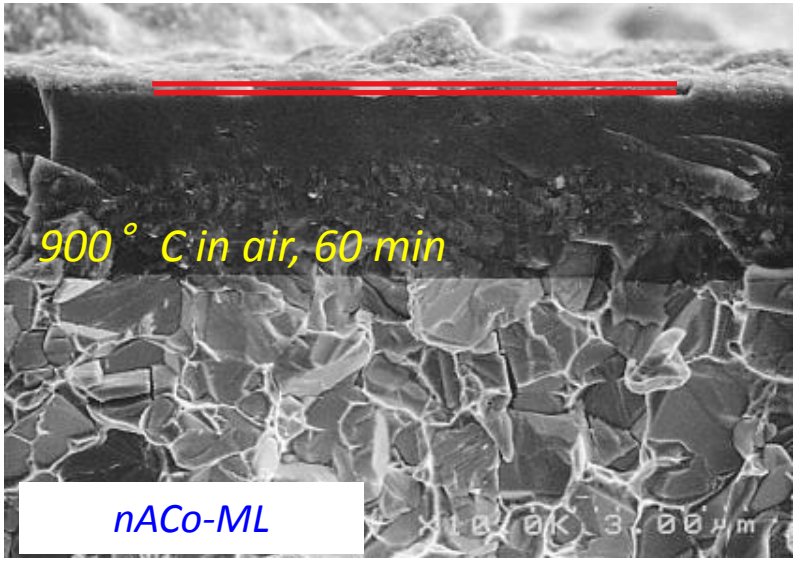


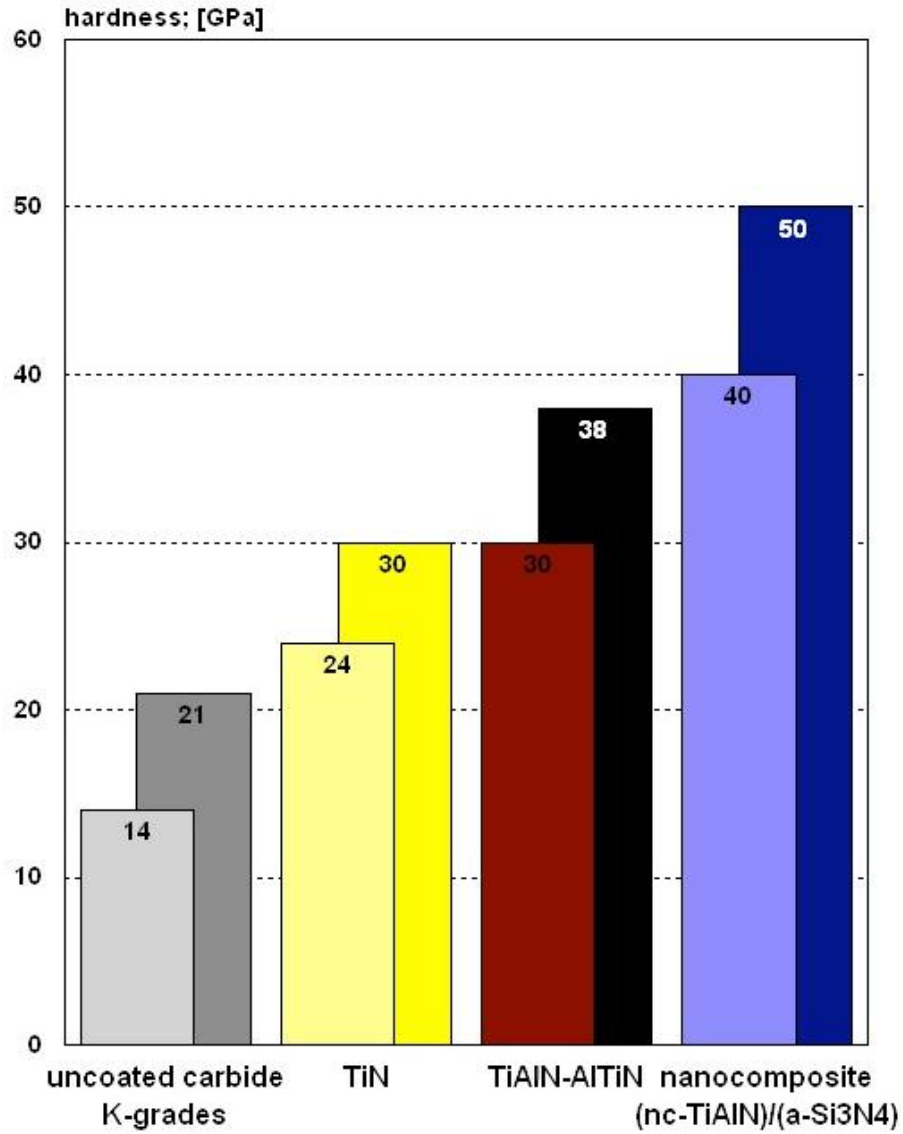




Oxydation Resistance (AlTiN <> nACo)

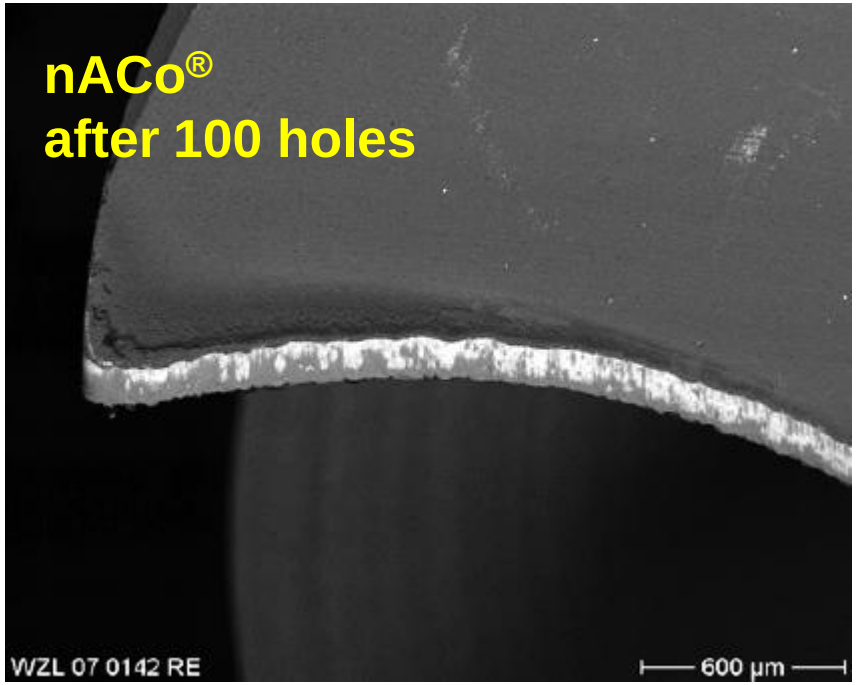


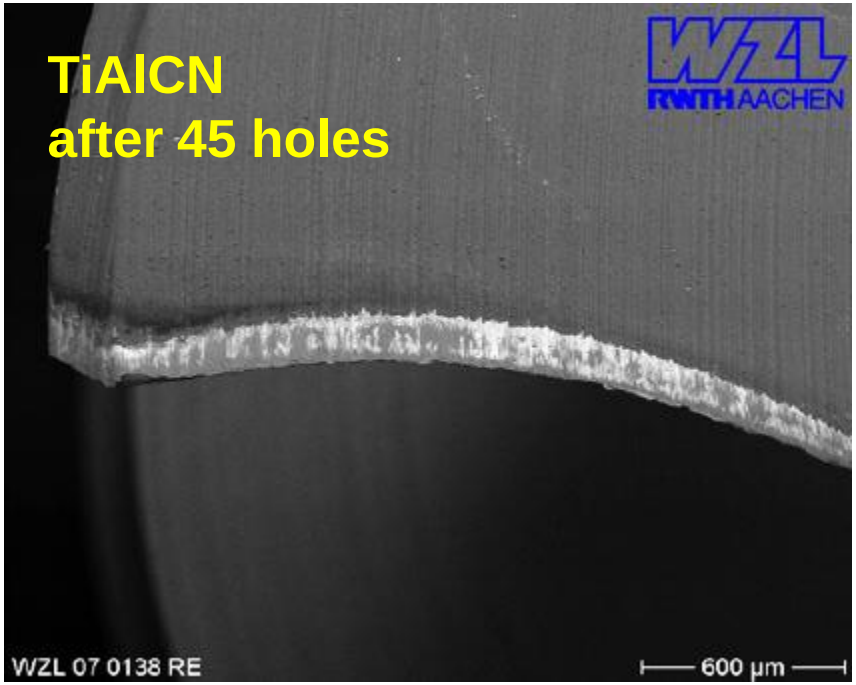




Nanocomposites – Application nACo

Drilling of Inconel 718 with **nACo**

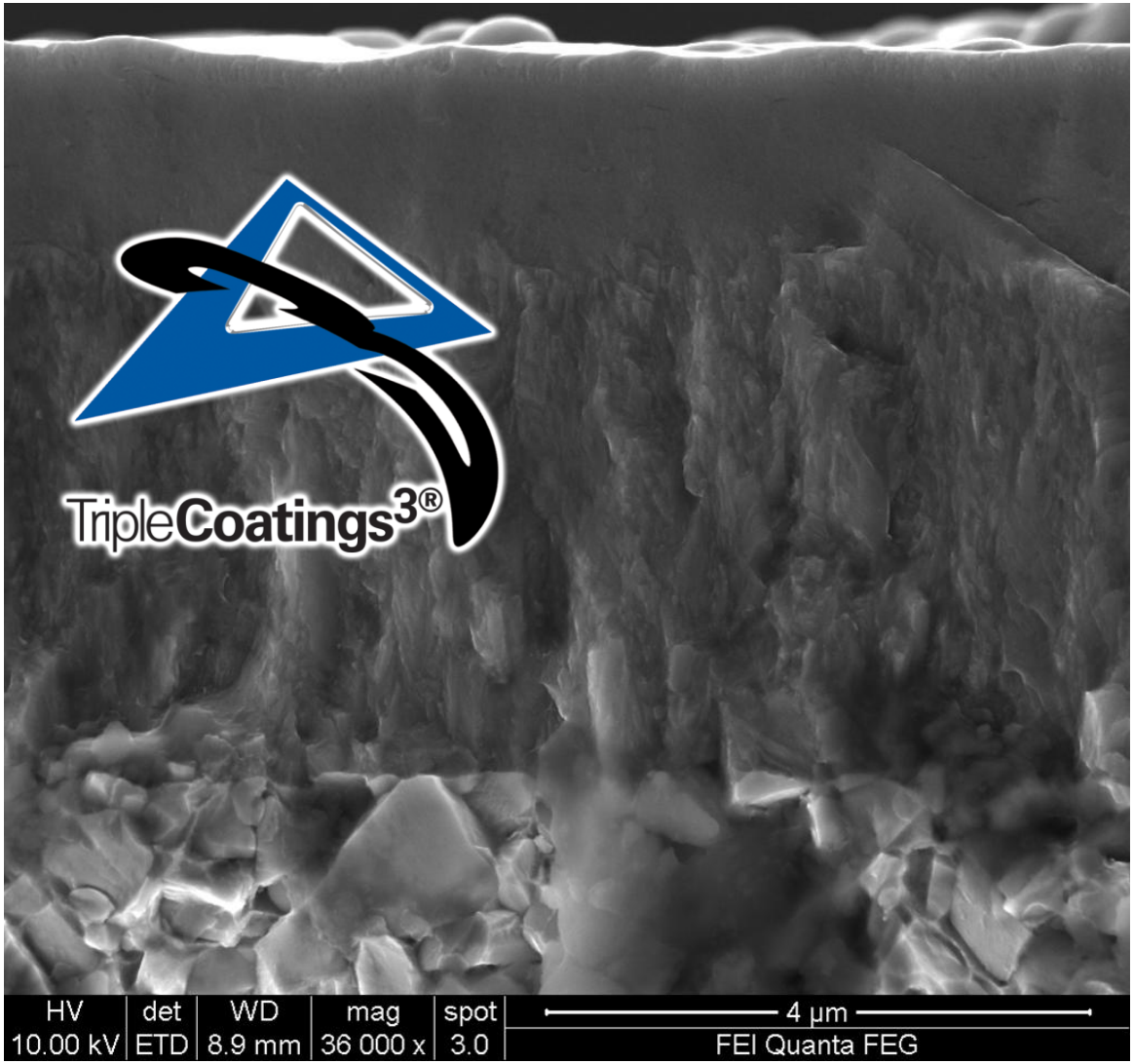




Material	Strength	Tool	ap	vc	n	fz	f	vf	Lubrication	t/ hole
NiCr19Fe18Nb5Mg	[N/mm²]	carbide with IC	[mm]	[m/min]	[1/min]	[mm/z]	[mm/U]	[mm/min]		[s]
Inconel 718	≈1280	Ø 6.8 mm, z=2	20	25	1170	0.045	0.09	105	Emulsion	11.4

Source: MACHERENA 6th FP EU-Projekt, WZL Aachen, D. Lung, I Essel, C. Essig

3. Coating Design



e.g.: nACRo³

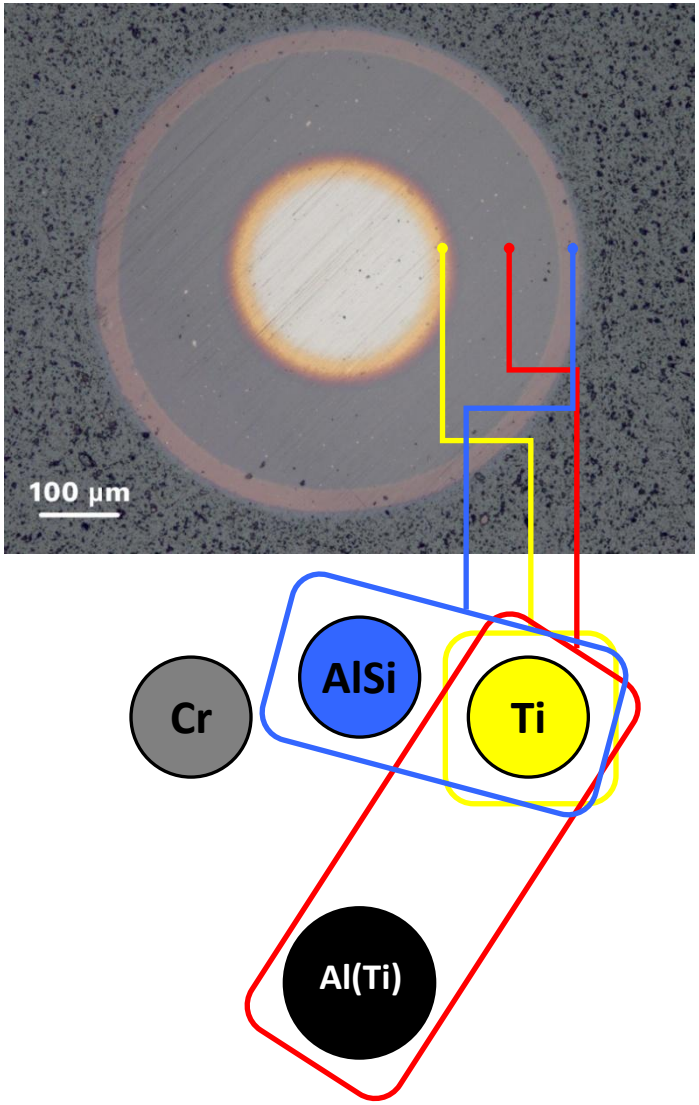
⇐ Top layer:
nACRo®
Cr-based nanocrystalline

⇐ Core layer:
AlTiCrN
microcrystalline

⇐ Base layer:
CrN adh. Layer

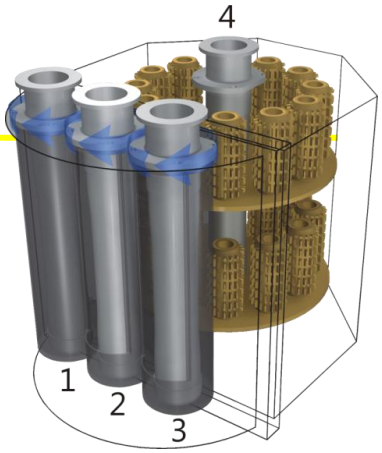
⇐ Cemented carbide
substrate

TripleCoating nACo3®



Applications:

- Universal milling (to replace TiAlN)
- Expert for drilling and turning



TiN

Adhesion layer

- E modulus: smooth transition Substrate → Coating

AlTiN

Core layer

- Low internal stress, tough
- Thermal barrier

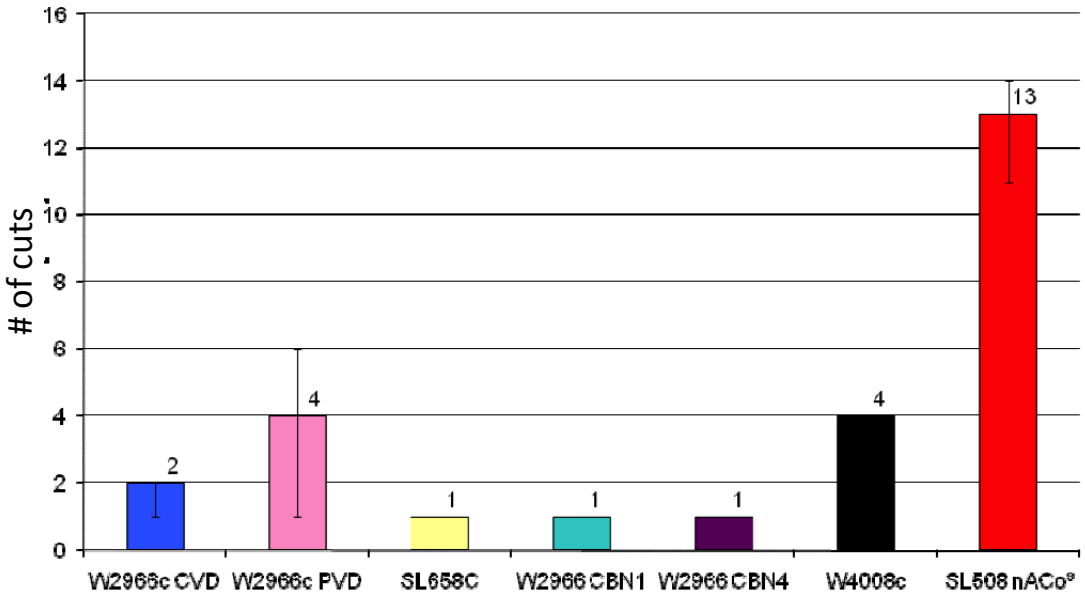
AlTiN/SiN

Hard Top layer

- High warm hardness
- Wear resistant: abrasive, oxidative

nACo3®: Also for "Exotic" Cutting Material

Turning of ADI 900 with Coated Ceramic



Maschine:	MONFORTS VNC 600
Work Piece:	Tube D=198mm, d=142mm
Material:	ADI 900, ≈325 HBWT2,5/187,5
Operation:	Turning interrupted cut
Insert:	CNGX 120716 Ceramic var. CVD, PVD-Coatings
Parameter:	v_c=270 m/min, f=0.4mm a_p=2mm, dry

- **A**ustempered **D**uctile cast **I**ron: high strength, high ductility and high toughness, but:
- Hard to machine, often grinding preferred
- **≥ 10 cuts only with nACo³**

QUAD-COATINGS

QuadCoatings4®

Combine different coating properties in one coating system

TripleCoatings$^{3®}$

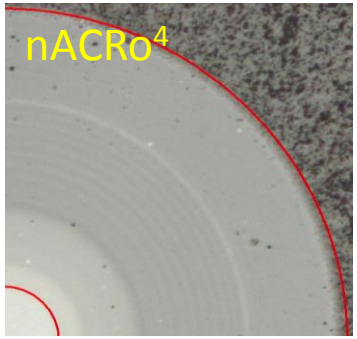
1. Adhesion layer (CrN, TiN)
2. Tough base layer (e.g. AlTiCrN-ML)
3. Hard top layer (Nanocomposite)

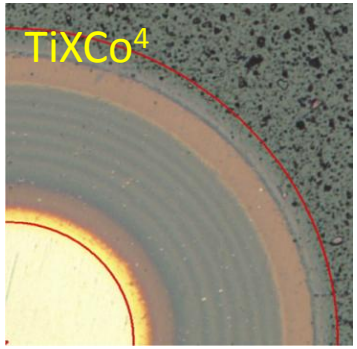
QuadCoatings$^{4®}$:

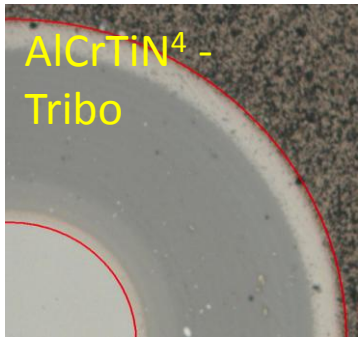
Triple Structure + 4th coating zone:

e.g.:

+ Transition layer / **2nd base layer**
+ top layer for **self lubrication**
+ **Oxidation resistant** top layer



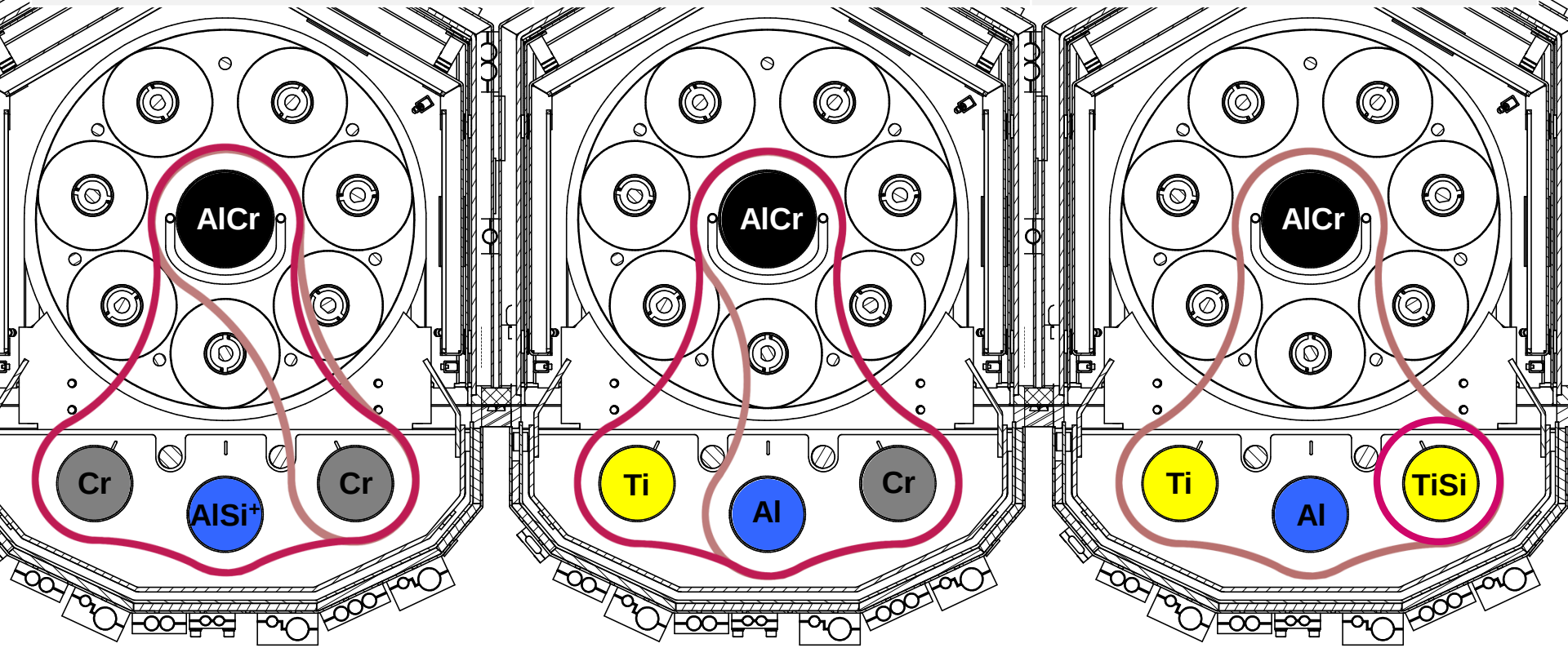




Cathode Use for Quad Coatings in the ⍰411

New Power Cathode Configurations: Fast Cycle Times

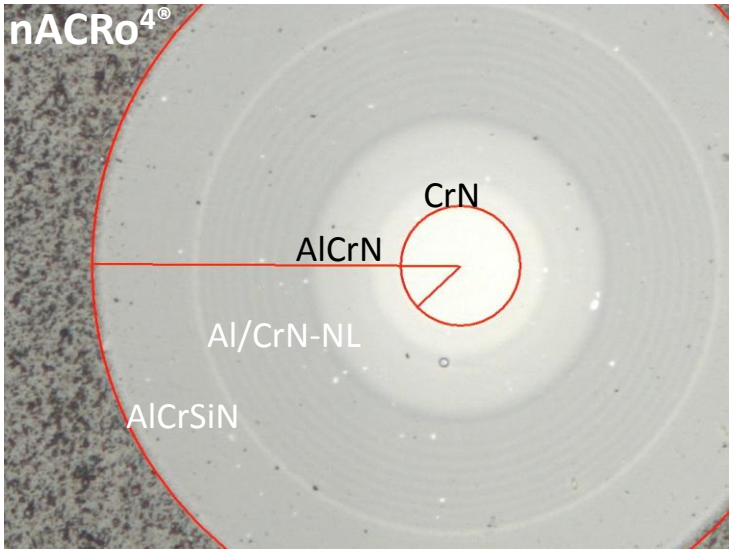
nACRo[4]		AlCrTiN[4]		TiXCo[4]	
Base:	AlCrN	Base:	AlCrN	Base:	AlCrTiSiN
Top:	AlCrSiN	Top:	AlCrTiN	Top:	TiN/Si_xN



Properties of PLATIT's nACRo4

Application: Hobbing

- **AlCrN-based Multi- / Nanolayer** structure leads to high film elasticity
  ➔ prevents crack propagation
- Very good abrasive **wear resistance** and **thermal insulation**
- **Si doped top layer** inhibites crater wear on HSS hobs

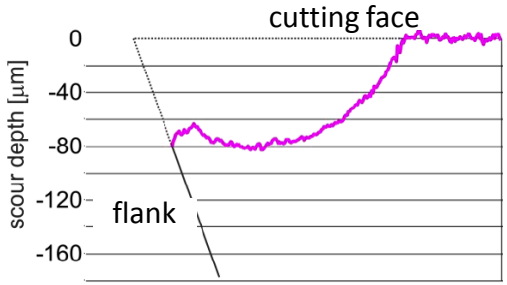


Properties of nACRo^4	
Micro hardness [$HV_{0.025}$]	3'500
Friction coefficient μ against steel (dry)	≈ 0.60
Coating thickness range [µm]	2 – 6
Max. operation temperature [° C]	1000
Color	grey

Image Source: C. Maurer, FEINTOOL

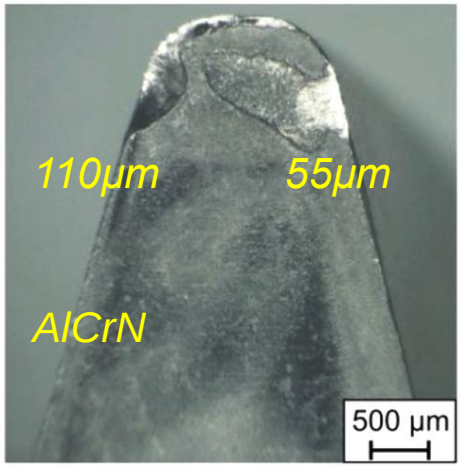
Wear Pictures of Cutting Faces

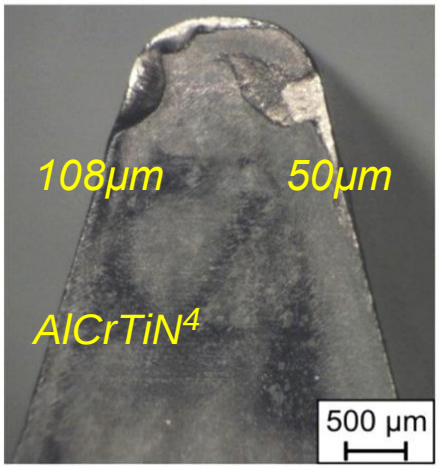
Principle of measurement:

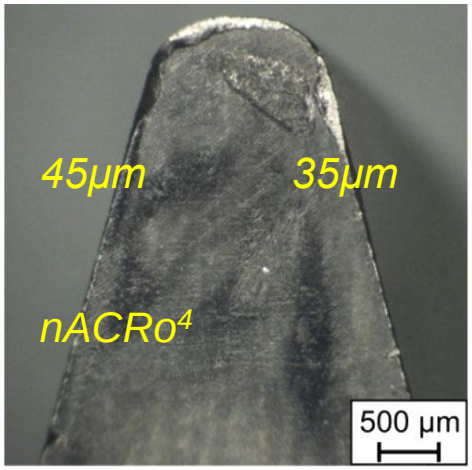


- Optically measurement of the crater wear
- Crater Wear at 27 m/tooth
- Same wear behavior for AlCrN and AlCrTiN^4
- nACRo^4: Si doped AlCrSiN top layer

  → crater wear reduced by 50%





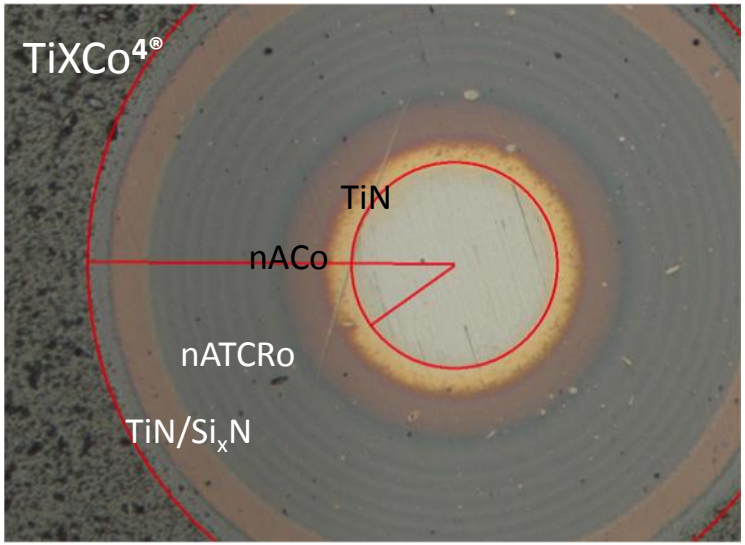


HSS hob (fly cutter), m = 2.5, v_c = 150 m/min, f_a = 1.69 mm/rev, dry

Properties of PLATIT's TiXCo4

Applications: Hard Cutting / Drilling

- Combination of three **nanocomposites**
- **Optimized Si content** for each layer
- Micro-/nanolayer structure
- Superhard **Ti/Si$_x$N** layer on top



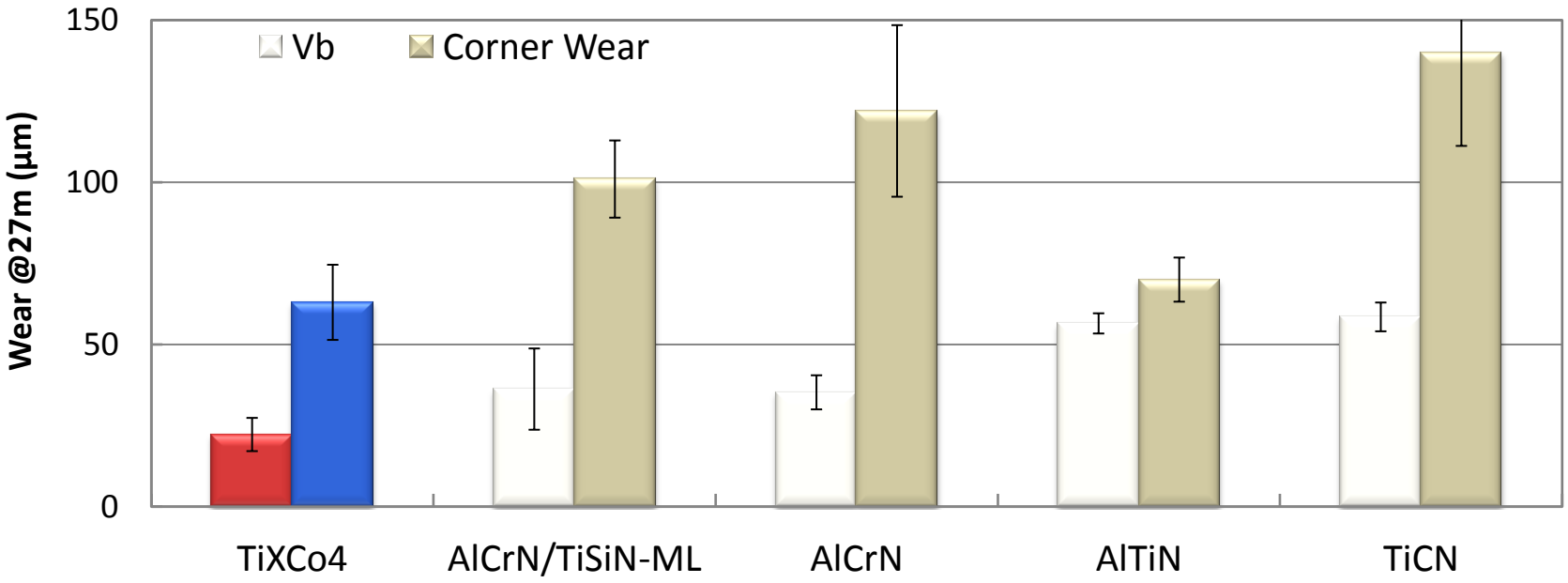
Properties of TiXCo$^{4®}$	
Micro hardness [HV$_{0.025}$]	4'000
Friction coefficient μ against steel (dry)	≈ 0.60
Coating thickness range [µm]	1 – 4
Max. operation temperature [° C]	900
Color	grey /copper

Image Source: C. Maurer, FEINTOOL

Milling in Hot Working Steel, 54HRC

Field Test at Customer Place in China

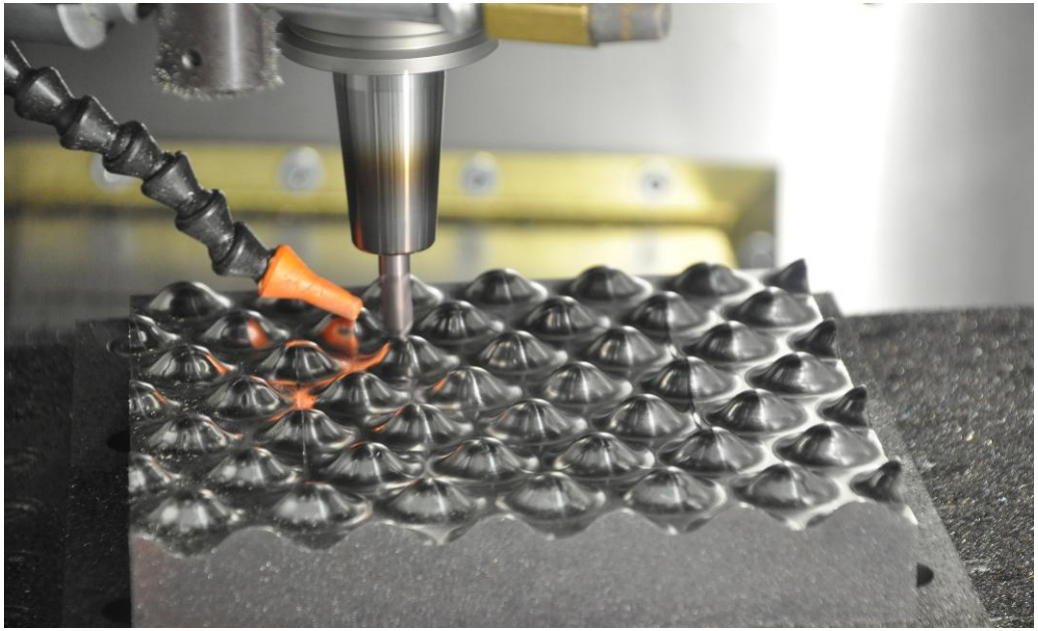
- Solid carbide endmill, **No edge preparation**, coated as ground
- Coating thickness: **d = 2µm**
- **Lowest wear** for **TiXCo^4** with TiN/Si_xN toplayer



Tool: Solid carbide endmill, d= 8mm, v_c= 100m/min, a_p= 4mm, a_e= 0.03mm, **emulsion**,
Cutting length: 27m, Work piece material: Hot working steel, 1.2344 / SKD61, 54 HRC

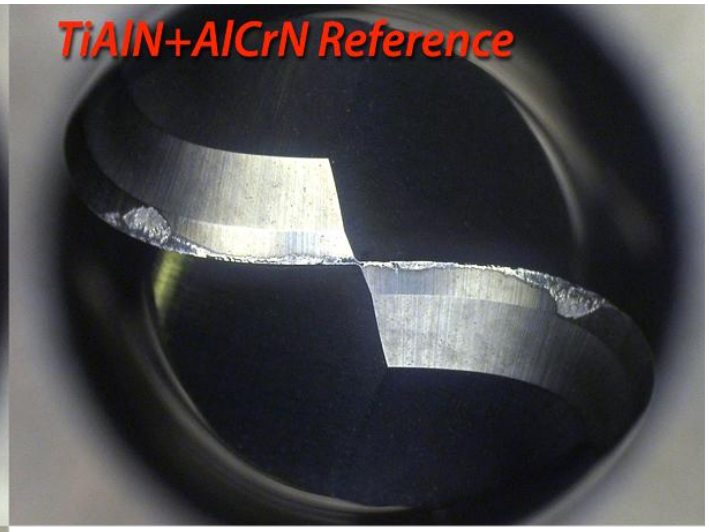
3D Milling in Super Hardened Steel

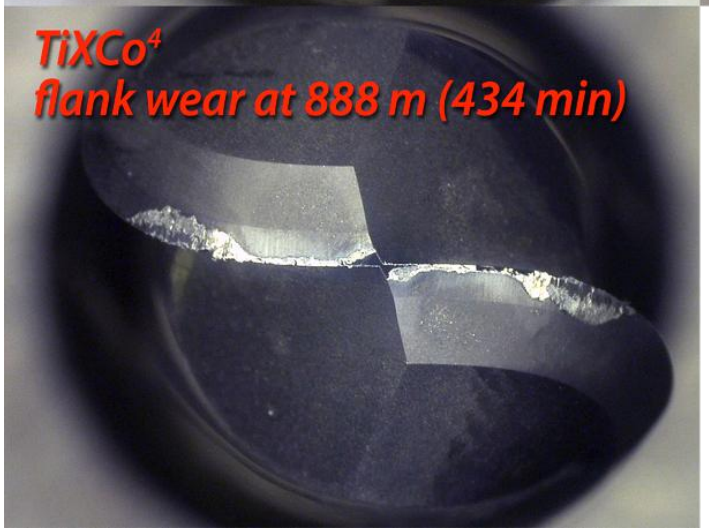
- Dry milling of abrasive and hard steel, **≥ 60 HRC**
- Ball nose end millls, Ø = 10mm
- Edge prep by tool supplier: **r ≈ 8 – 10 µm**
- European market references: TiAlN+AlCrN
- Testing: **TiXCo^4**



Hardened cold-working steel 1.2080 - X210Cr12, 61 HRC, dry
Ball-nose end mill Ø10 mm, z = 2, v_c=280 m/min, n =10445 min^{-1},
ap = 0.14 mm, ae = 0.1 mm, fz = 0.1 mm

Milling in Super Hardened Steel, ≥60 HRC





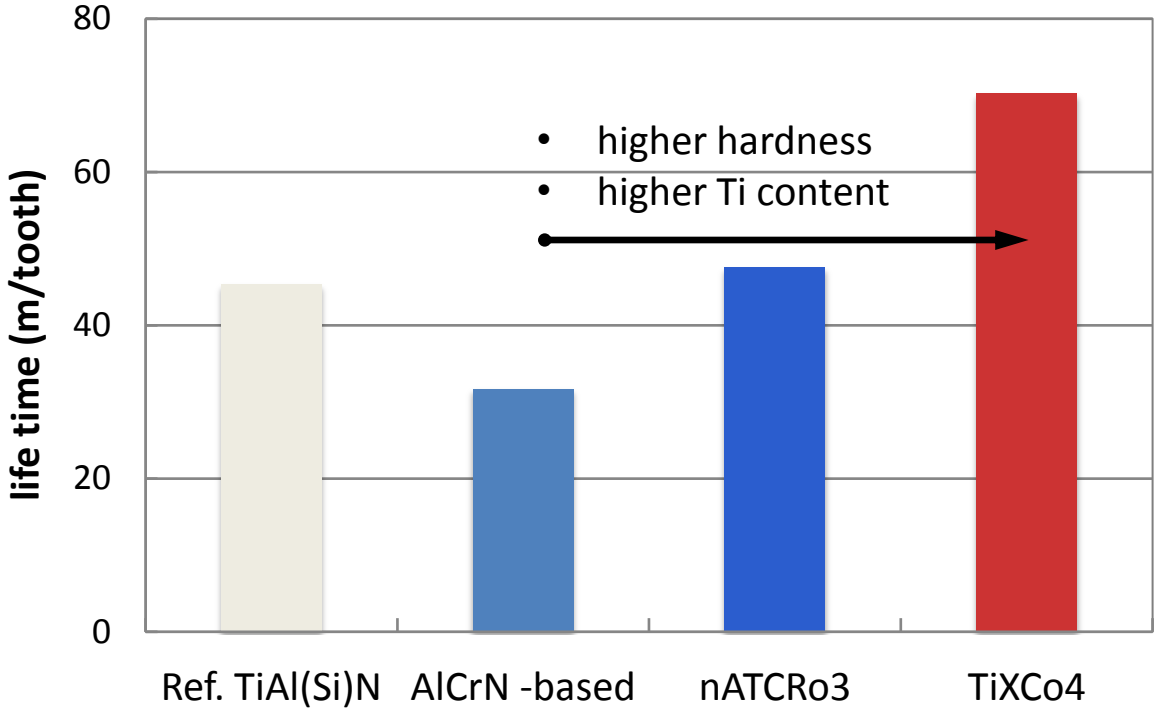
- Ref. TiAlN+AlCrN:
  stopped at 444m, VB_{max} reached
- TiXCo^4: Cutting length: +100%

Hardened cold-working steel 1.2080 - X210Cr12, 61 HRC, dry
Ball-nose end mill Ø10 mm, z = 2, v_c=280 m/min, n =10445 min^{-1},
ap = 0.14 mm, ae = 0.1 mm, fz = 0.1 mm

Project with GFE, Schmalkalden, Germany

Drilling in High Strength Steel

- Solid carbide drill, Ø = 6.8mm, rounded by brushing: $r_{tip} \approx 50\mu m$
- Coating thickness: d = 3µm
- Highest life time for TiXCo4 with superhard TiN/Si_xN toplayer



Work material X155CrVMo12-1/1.2379 – Rm=1150 N/mm2 – Coolant outer **emulsion**
Solid carbide drill; Ø 6.8 mm; - vc=70 m/min – f=0.16mm/rev - ap=15 mm

Project with GFE, Schmalkalden, Germany

Conclusions

- Performance does not only depend on coating, but strongly on substrate material, geometry and surface condition
- Customized coatings for specific applications are more and more replacing universal coatings
- The coating is defined by its design, chemical composition, microstructure and surface quality
- QuadCoatings4® technology provides new perspectives to develop dedicated coatings designs for high performance applications

Questions?

THANK YOU FOR YOUR ATTENTION

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j.sondor@liss.cz