Next generation PVD coatings for tools and components

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Dr. auf dem Brinke | June 2010

Our tools
Classification of Key Surface Treatments

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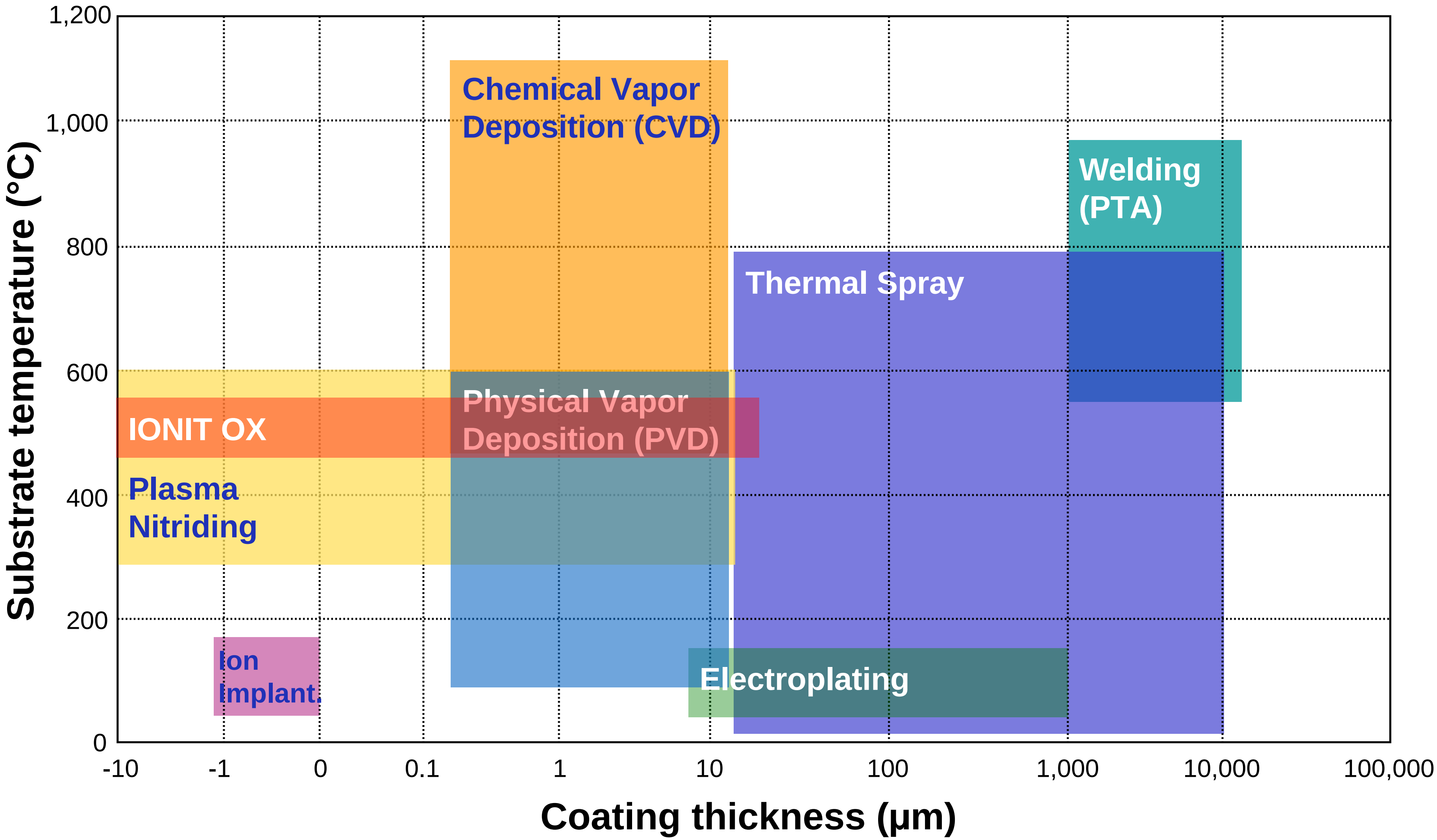
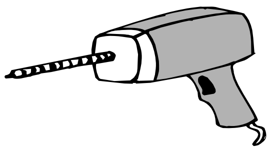


Graph for illustration purposes only, not scientifically exhaustive

Effective mass: MAXIT® coatings

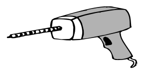
Without coating

We need for
100. 000 holes
1.000 drills -
equals 60 kg



With coating

We need for
100. 000 holes
250 drills -
equals 15 kg + 7,5 g



PVD-hard coating: 7,5 g TiN

Driving high technology
Introduction

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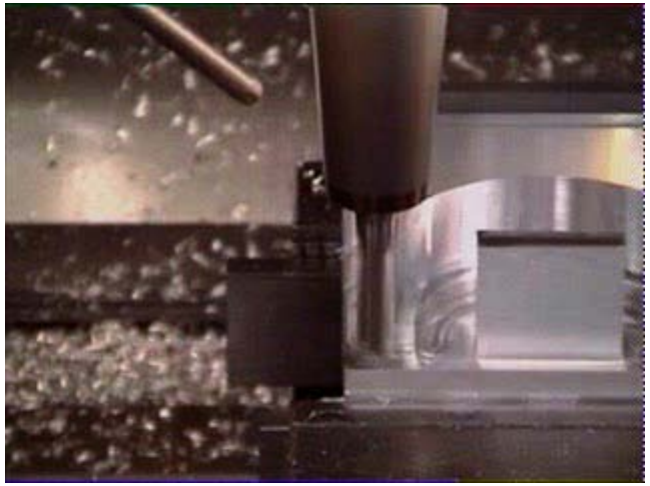
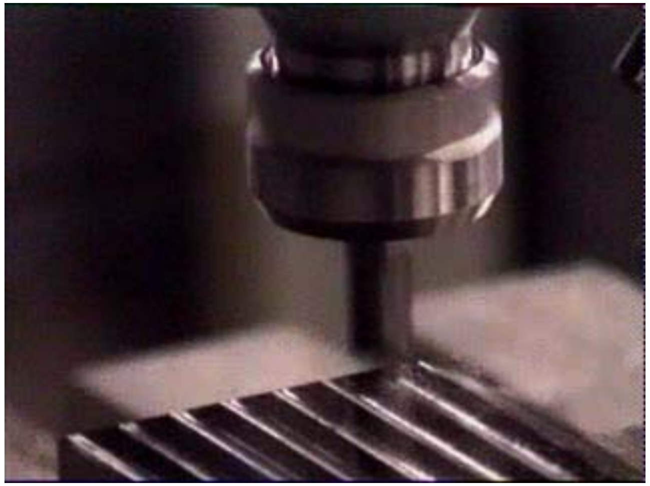


Dry cutting



High speed cutting

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Engine – Surface Treatments

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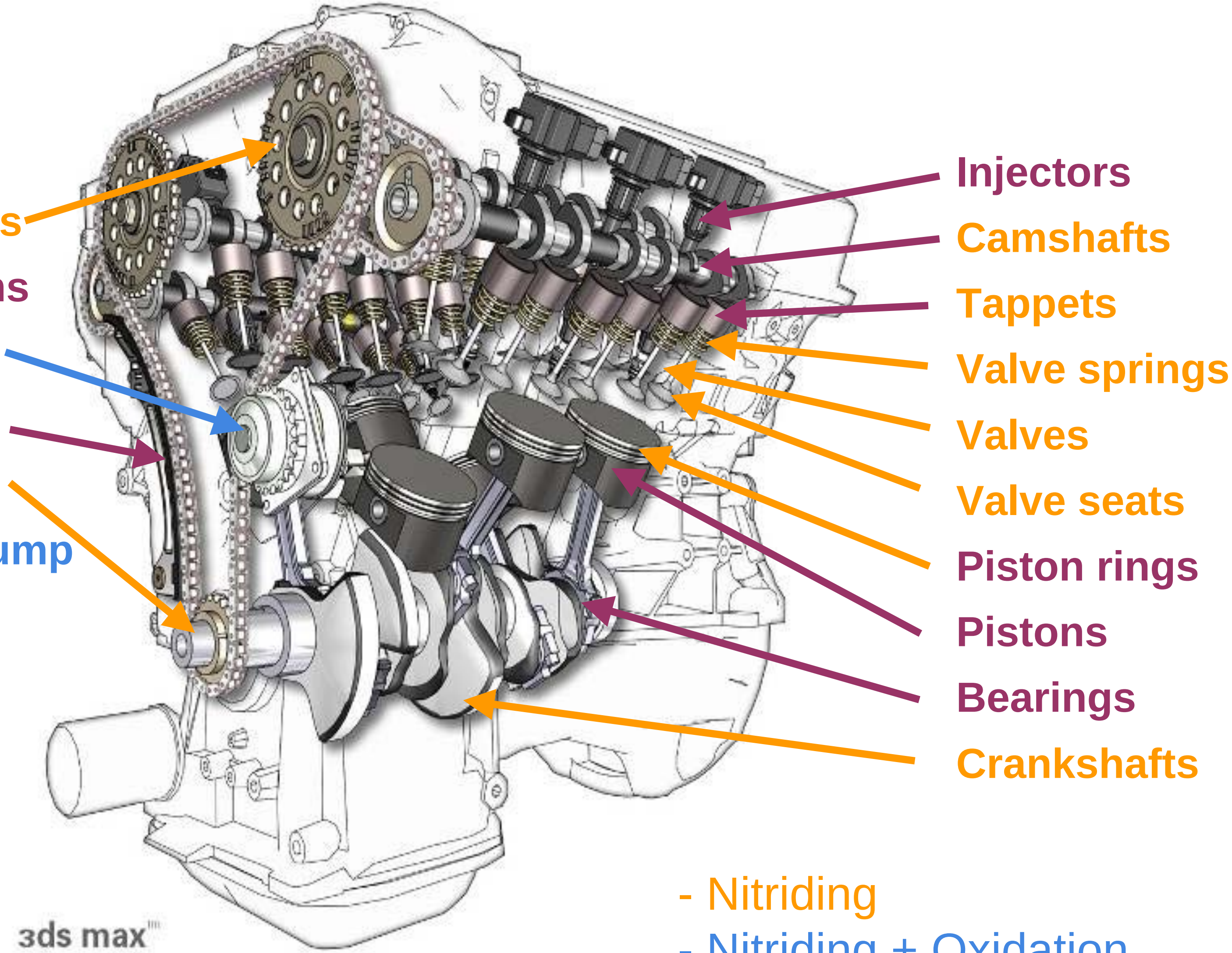
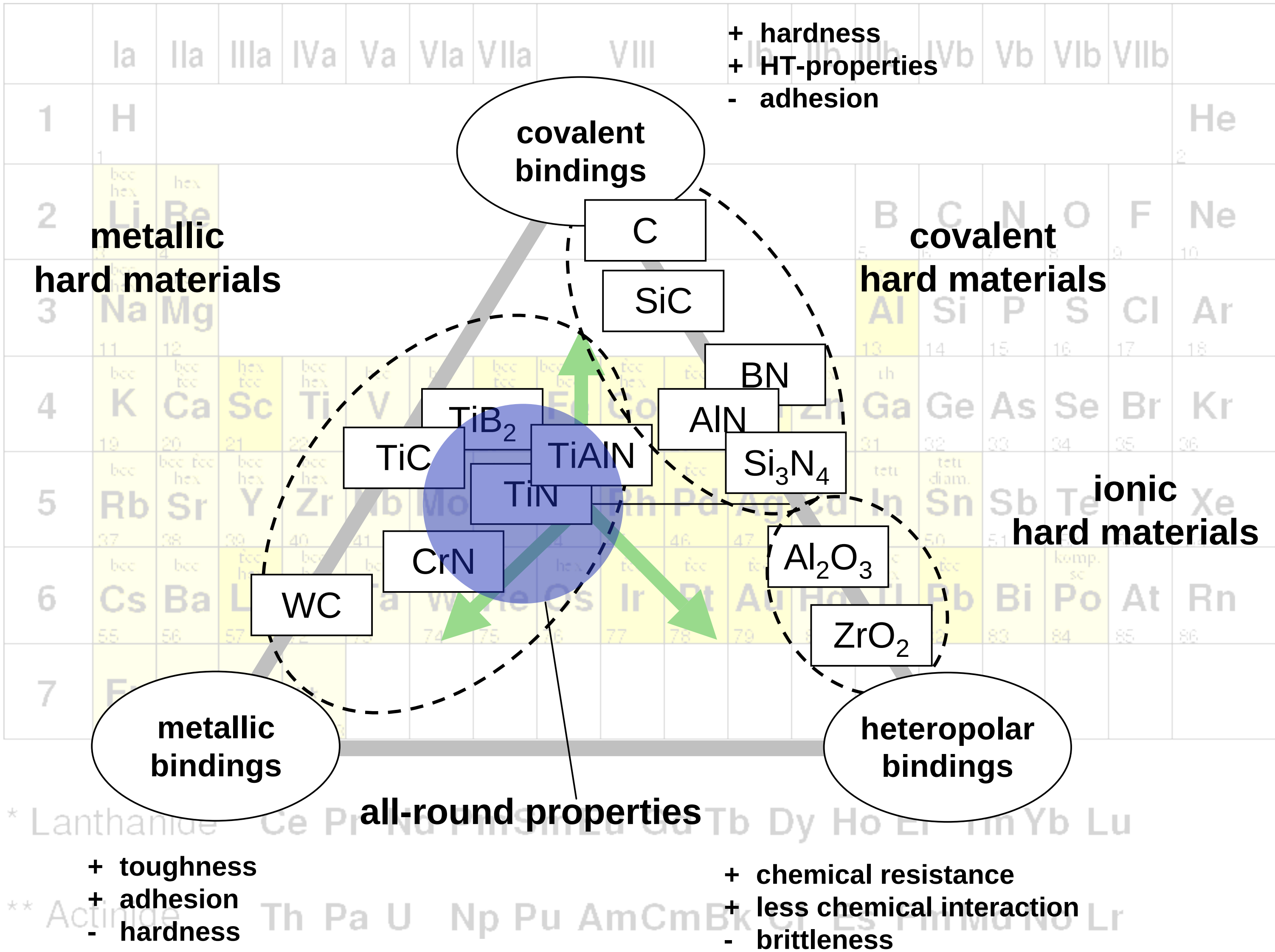
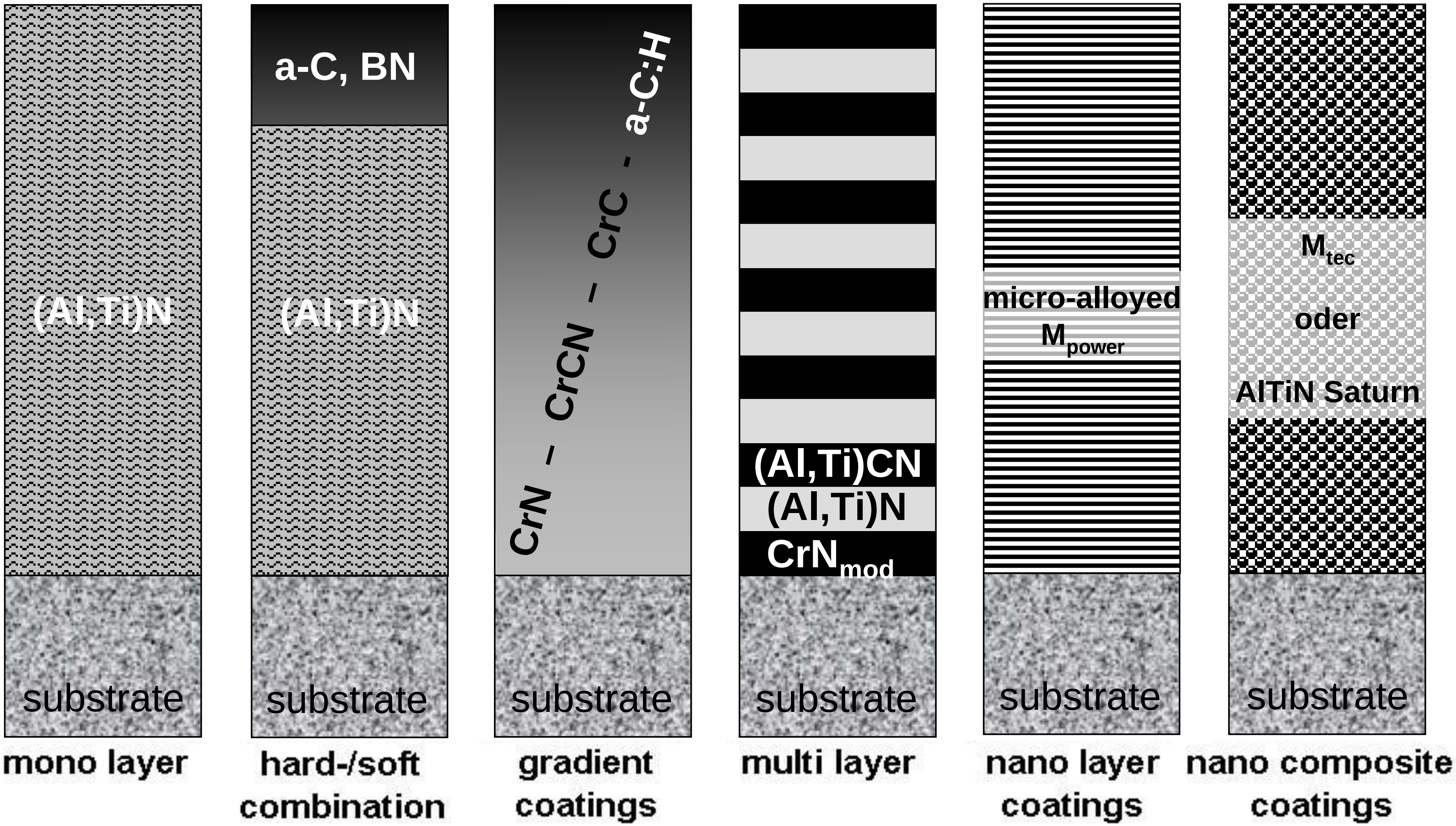


- Nitriding
- Nitriding + Oxidation
- PVD

excellence in coating architecture and design



Schematic illustration of various possibilities to design advanced high performance coatings



Driving High Technology
PVD ARC Technology

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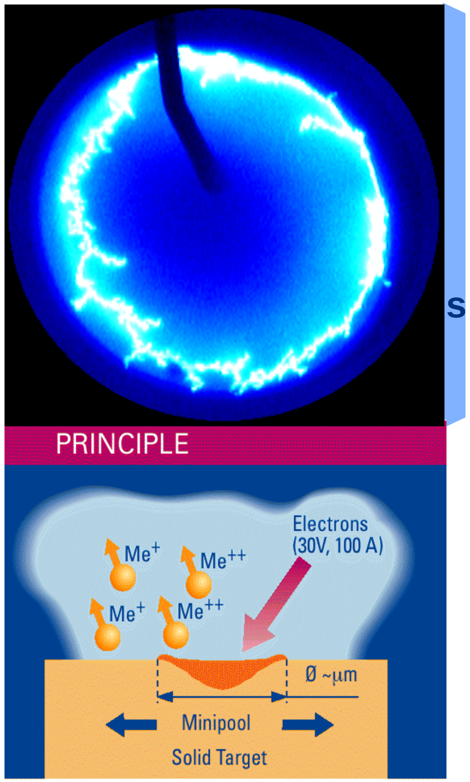

How does it work?
low friction and anti sticking coatings MAXIT®W-C:H

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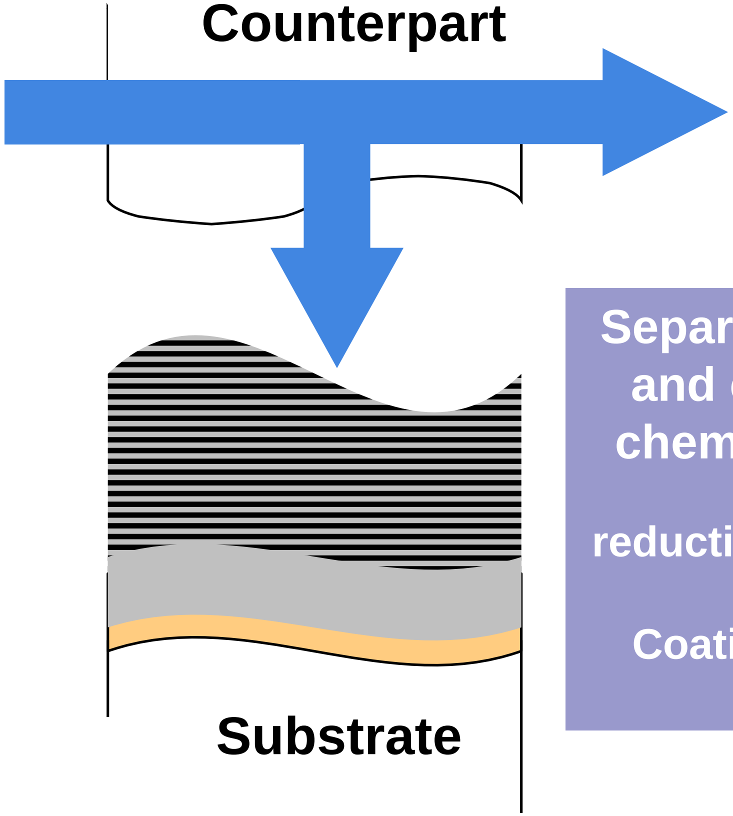
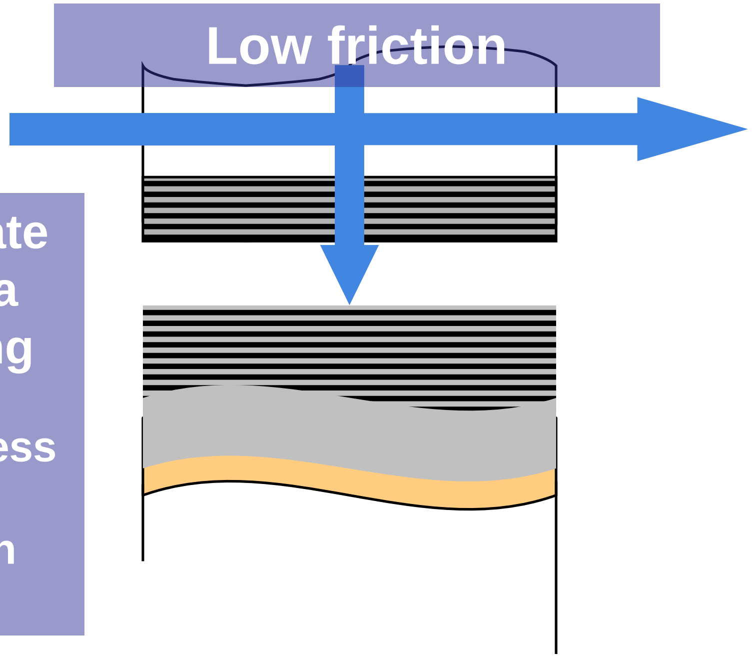
Working principle



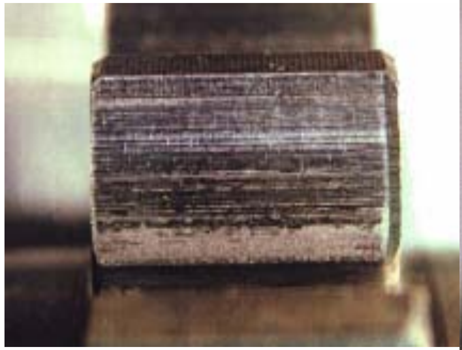
Separation of substrate and counterpart by a chemical inert coating

reduction of the roughness

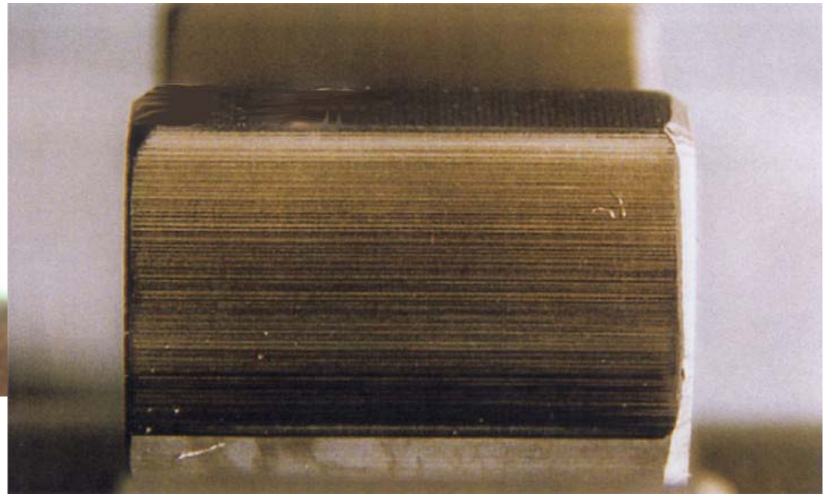
Coating transformation



Application W-C:H - Coating of gears



uncoated
1500 N/mm²
1.35 x 10⁶ cycles
20% grey spots



gear MAXIT® W-C:H coated
counter-gear uncoated
1900 N/mm²
5.4 x 10⁷ cycles

W-C:H coated gears give an efficient protection against grey spotting and also pitting. ⇨ weight reduction

Application – clutch actuator pistons

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low friction coating W-C:H for noise and vibration free clutch operation
extremely thin walled app. 0.5 mm

- for components with high tribological stress
- gear, bearing and hydraulic components

deposition temperature:	150 – 250 °C
color:	grey-black
coating morphology:	multi-layer
thickness:	1 - 5 µm
hardness HK0.05:	1000 - 1300
friction against 100Cr6:	0.15 - 0.30 dry running

Coating design
from bond layer to function

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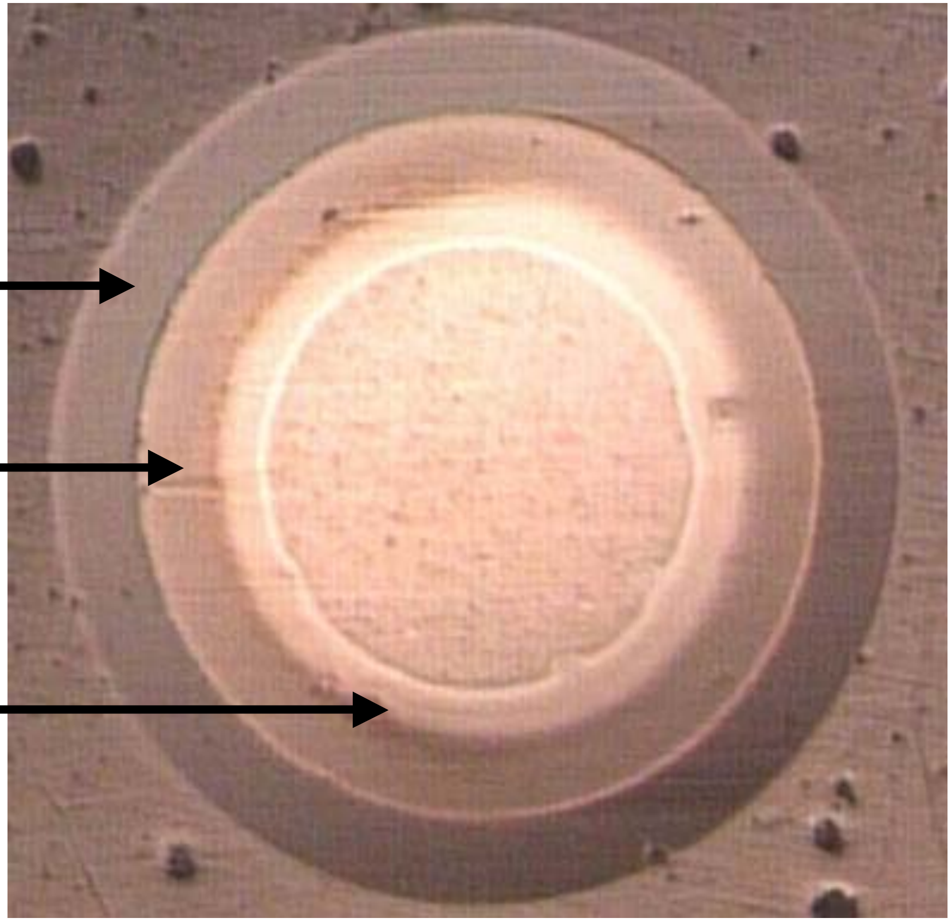
Tailored coatings

function layer a-C:H

W-C:H

bond system Cr - CrN



Application Tappet on Nitrided Camshaft

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advantages:

- improving fuel efficiency
- improving engine power (+3-4%)
- improving dry-running properties
- minimum oil lubrication in field test

⇨ reduction of weight and size of engine

	W:C-H-mod
Thickness	3.0 ± 0.5 µm
Hardness	1750 ± 150 HV
Friction coeff. µ	0.15
Elastic modulus	200 GPa

Diesel injection pistons (heavy oil)

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advantages:

improving fuel efficiency

less maintenance

improving dry-running properties

cavitation resistance by trampoline effect (elasticity of coating)

properties	coatings			
	TiN	**Hardchrome**	**Me-C:H**	**MAXIT® W-C:H_{mod}**
hardness [HV]	ca. 2500	800 - 1100	ca. 1200	ca. 1750
Dry friction coeff. μ	0,65 ± 0,05	0,6 - 0,65	0,20 ± 0,05	0,15 ± 0,05
Abrasion resistance	++	+	++	+ +
Cavitation resistance	++	– / +	+ +	+ ++
Running-in behavior	–	– / +	++	+++

Combination treatment of nitriding and PVD
Support for hard PVD layer – no eggshell effect

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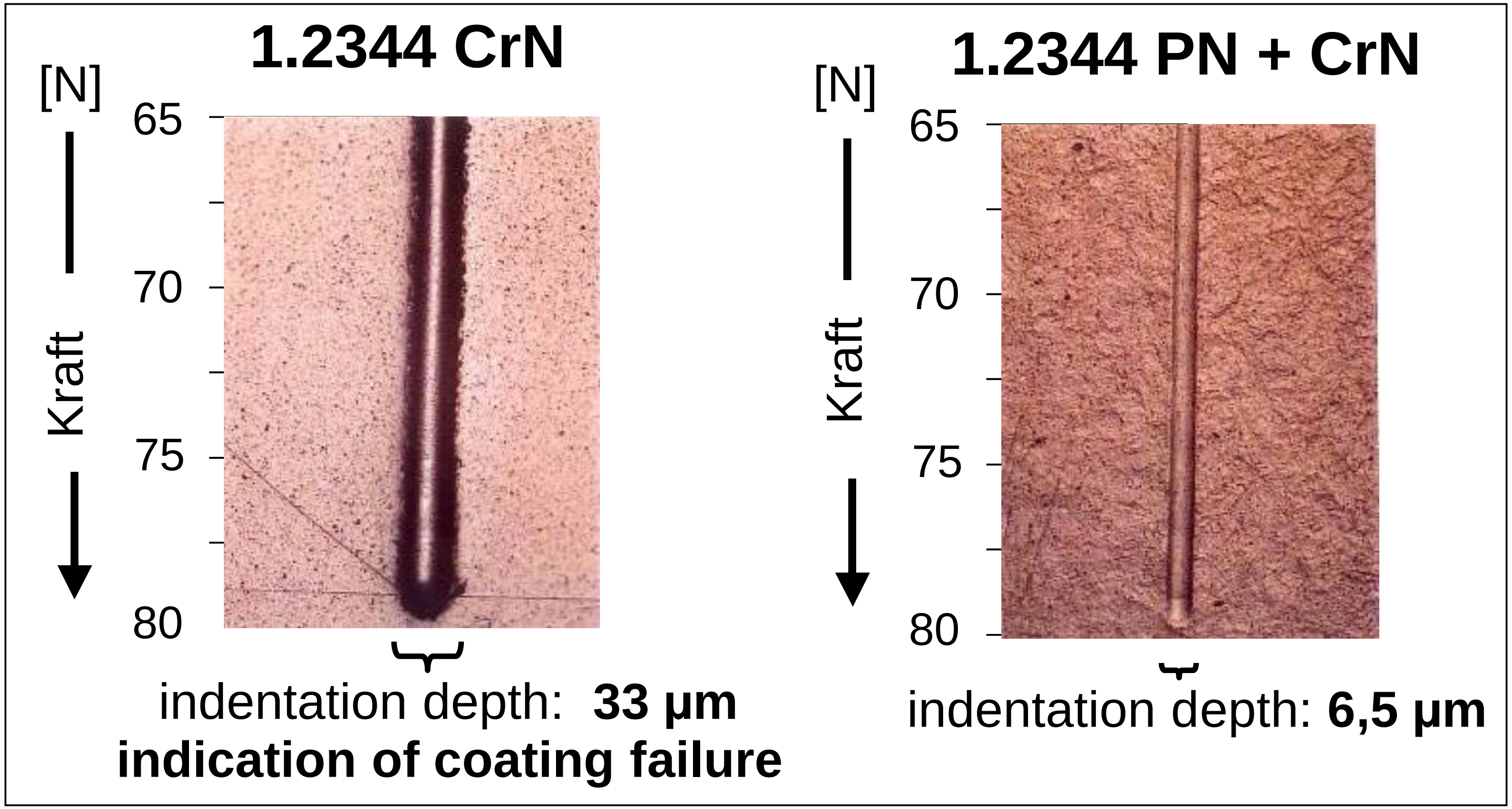

High scratch resistance at the surface also for “soft” materials (smaller 40 HRC) caused by nitriding and coating

Influence of polishing on surface roughness divided or integrated combination process

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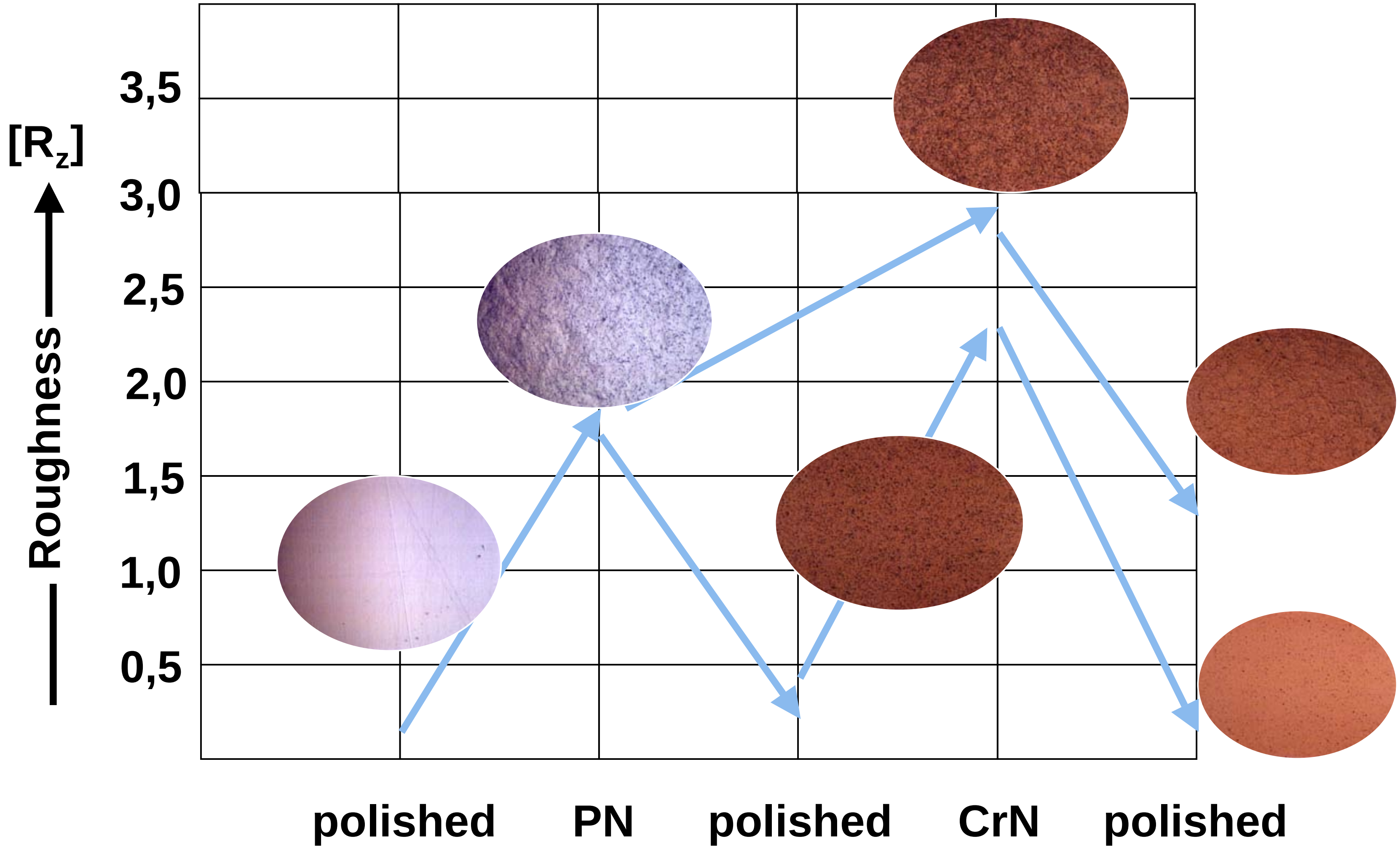

metal forming – combi treatment

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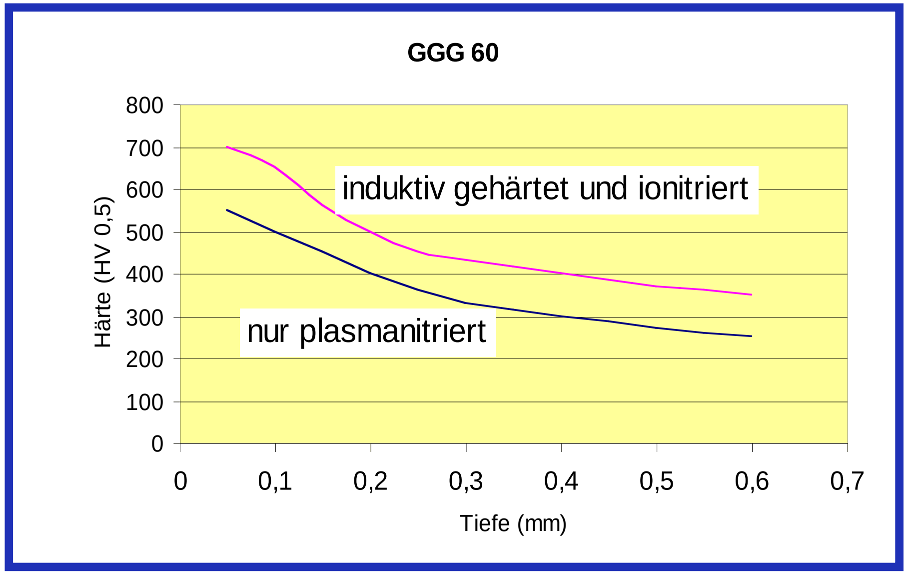
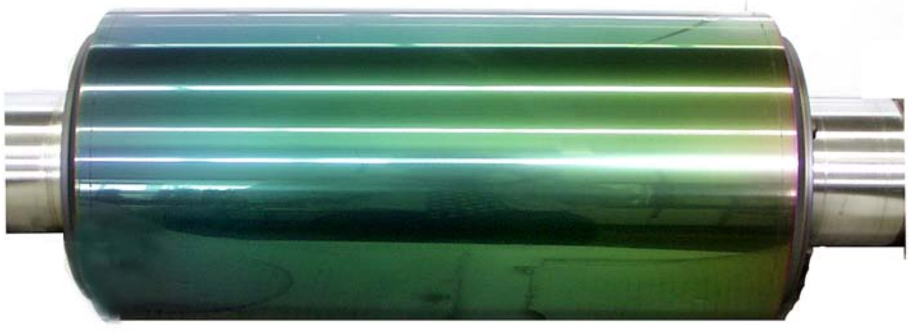


- 3-4 times longer lifetime
- rework possible
- combi treatment PN + PVD



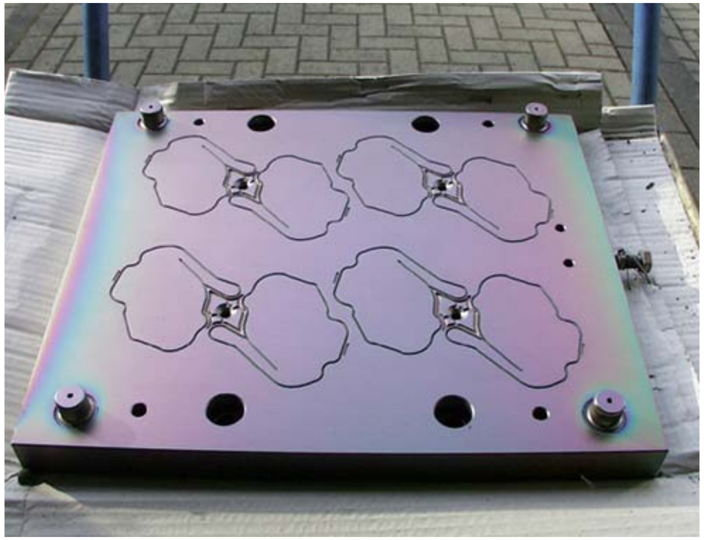
Calender roll Ø 180 x 850 mm
CrN-mod. coated

Threads

- deposits
- adhesion

Polish + CrN-mod coating

➔ Prevention of deposits
➔ Reduced adhesion



Die plate / CrN-mod. coated

Where can PVD coatings boost the performance?

- Wear protection by high hardness
- Reduction of penetration by f.e. glass fibers using combination processes of nitriding plus PVD
- Reduction of deposits by chemical unreactive coatings
- Reduction of sticking tendency by non-reactive coatings
- Reduction of friction by low friction coatings on f.e. ejector pins
- Endurable surface quality

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The innovative APA evaporator technology

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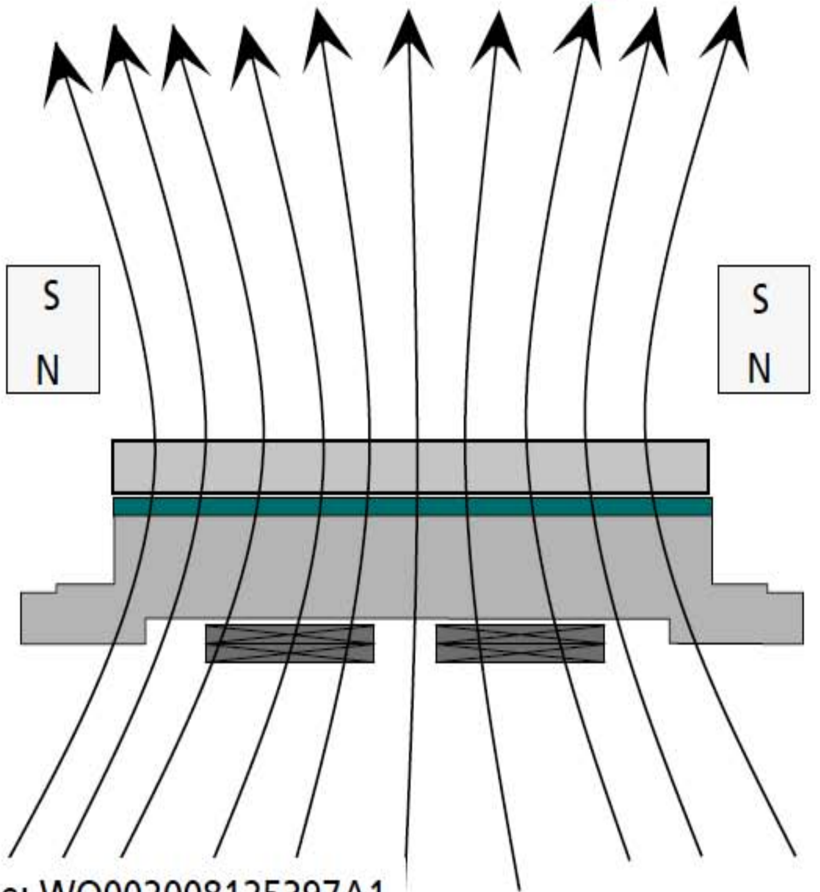
Arc cathode with extended magnetic field



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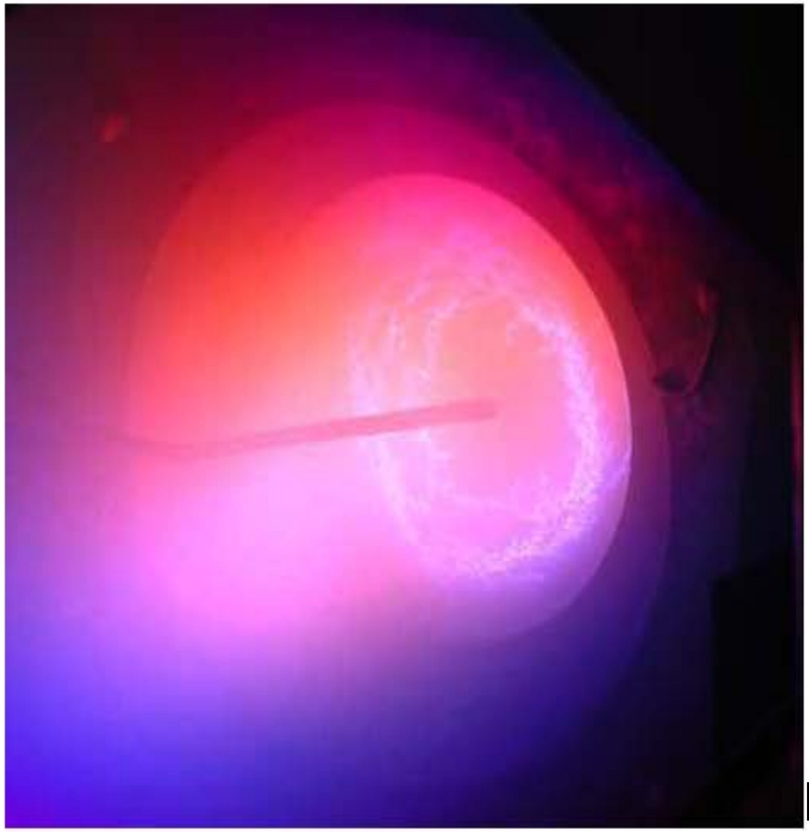

APA cathode (Sulzer Metaplas GmbH)

Driving High Technology
Sophisticated coating designs

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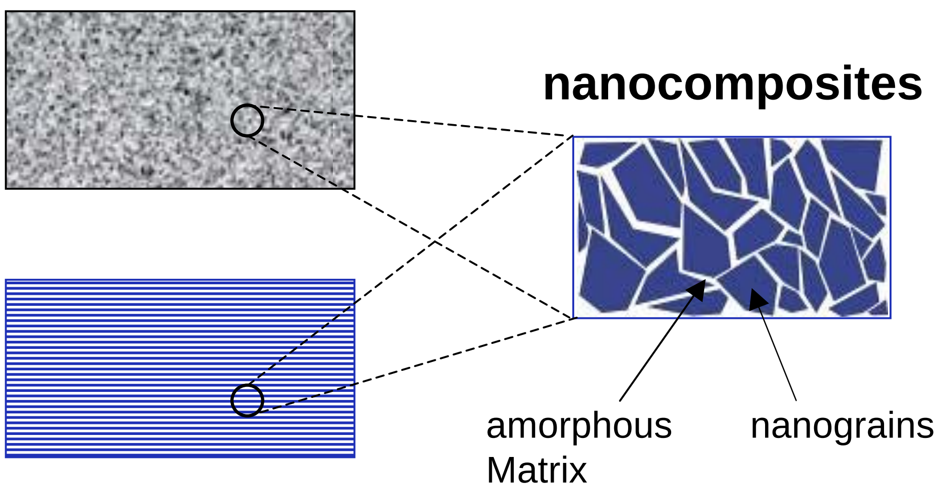
Demands on coatings for modern precision tools

- Hot hardness combined with sufficient toughness
- Thermal shock resistance
- Oxidation resistance
- Minimum chemical/physical interaction with work piece material to reduce sticking and tribooxidation

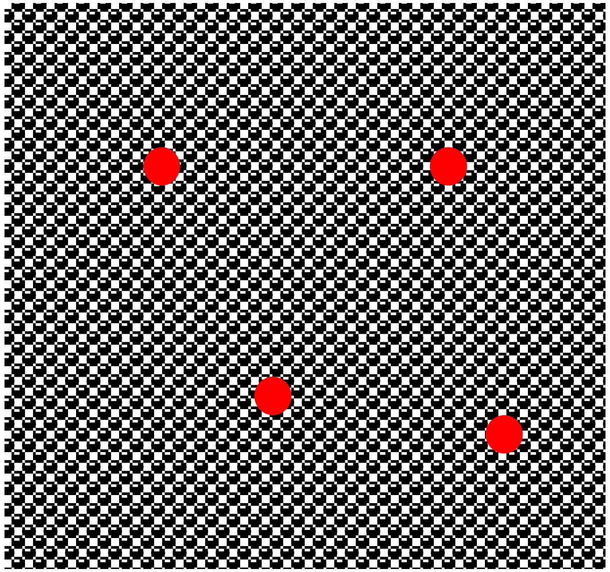
Possible combination:

Nanocrystalline morphology
→ optimum hardness - toughness

Nanostructured multilayers
→ increase of fracture toughness



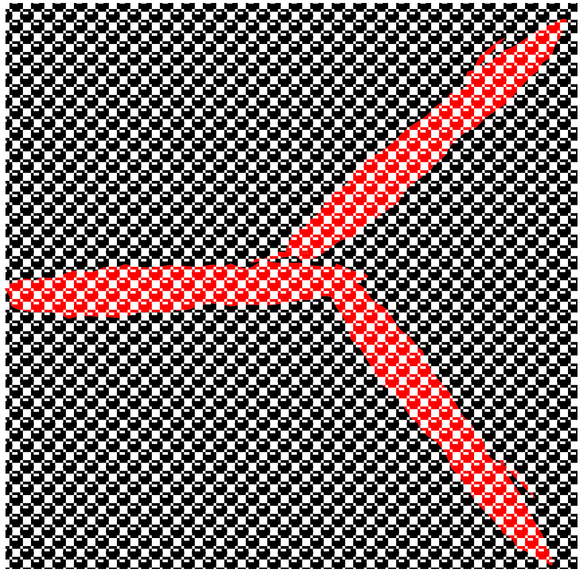
Nano-composite states: alloying - phases



doped coatings

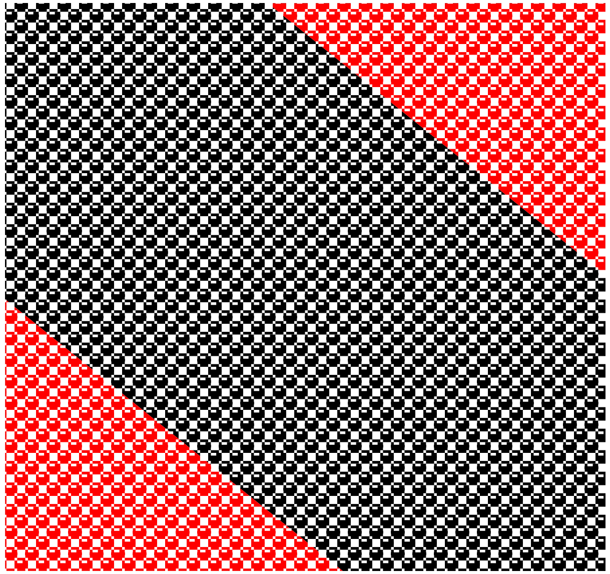
CrN plus some atoms e.g. Si

"micro alloyed"



grain boundary segregation

e.g. AlTiNC/C



two or more phases

hcp AlN + fcc AlTiN
hcp $(CrTi)_2N$ + fcc TiCrN
starting at 17 at% Cr

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Micro alloyed coatings: How does it work?

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- **a significant amount of 0.1 – 3 at% of an additional element**
- **The element is incorporated into the crystal leading to higher stability, higher oxidation resistance, etc.**
- **The element is accumulated at the grain boundaries leading to an amorphisation and thus forcing the formation of a nano-composite.**
- **Influencing the nucleation towards smaller grain sizes and thus forming nano-crystalline structures, e.g. nano-columns**

MAC: M_{power} (TiSiXN)

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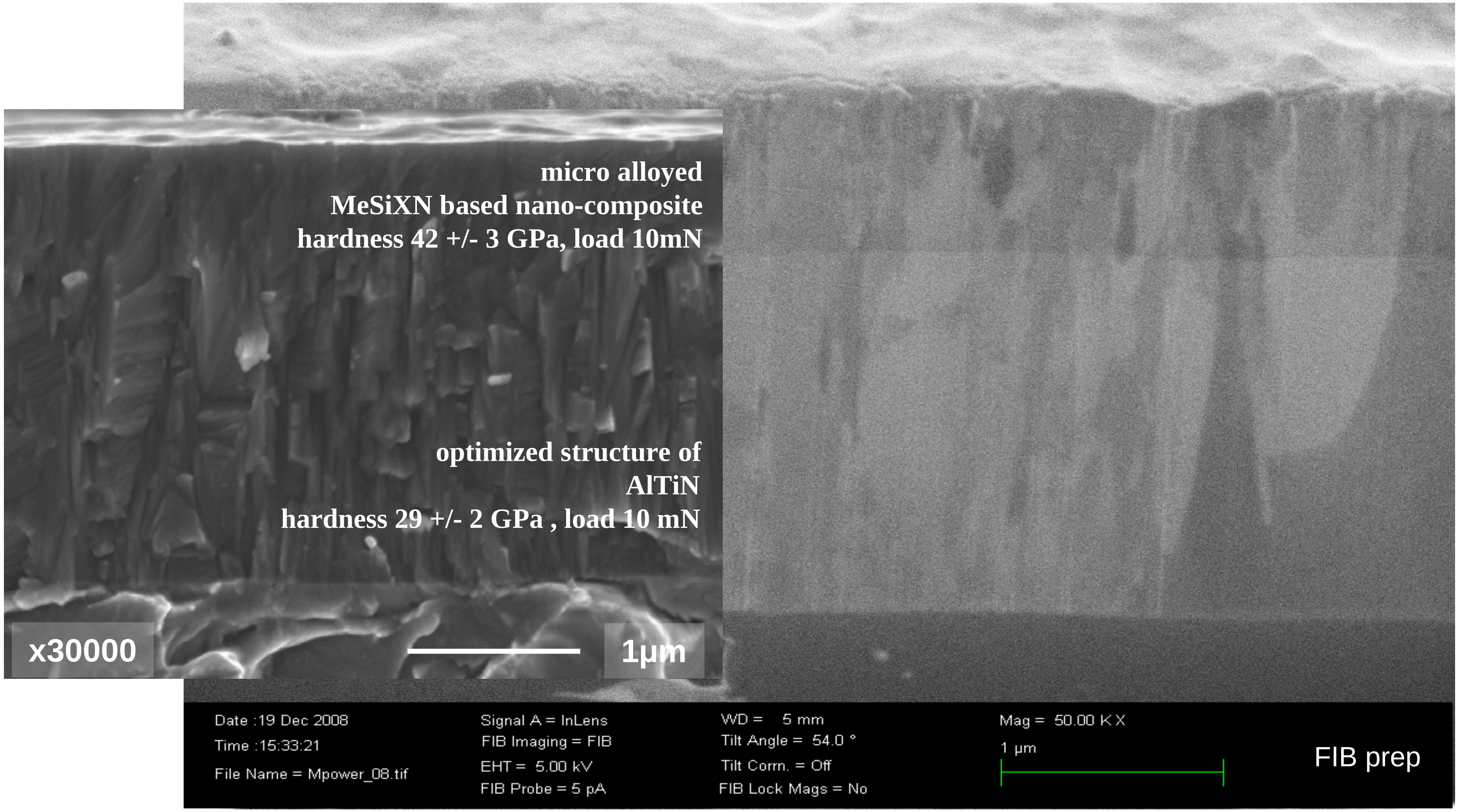
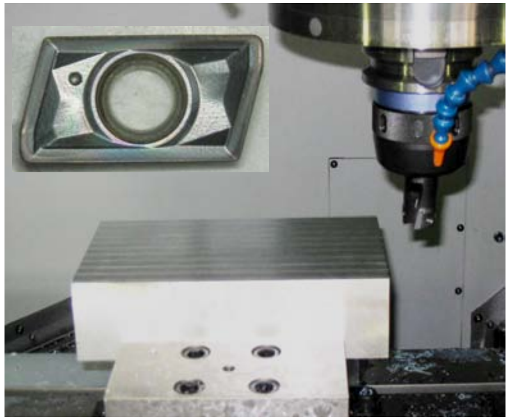
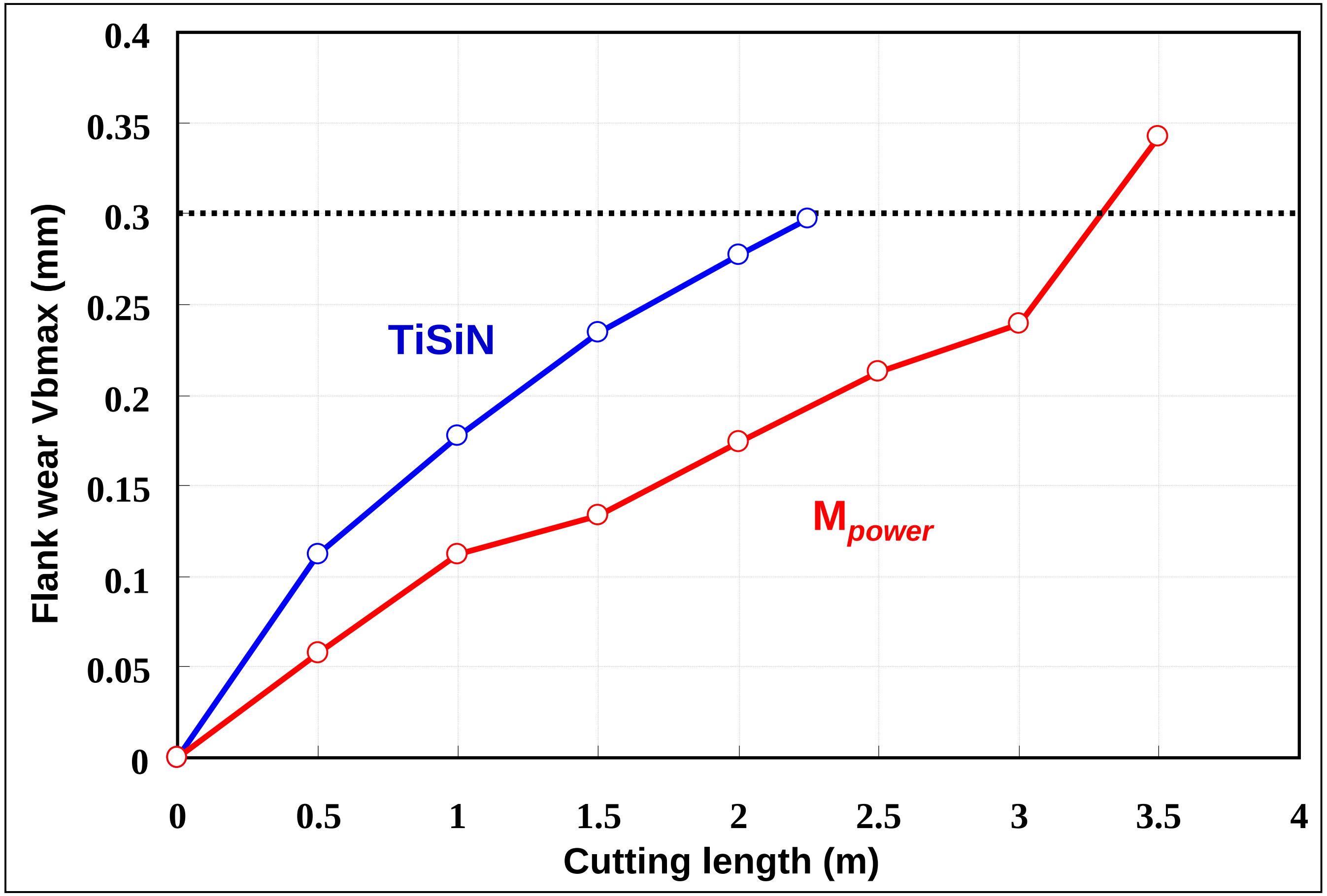
M_{power} from the METAPLAS machining Series



Dry rough milling of X210Cr12, 200 HB annealed
v_c = 150 m/min, f = 0.15 mm/tooth, $a_p \times a_e$ = 3 x 10mm





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Multilayer structure design: tailored M$_{power}$

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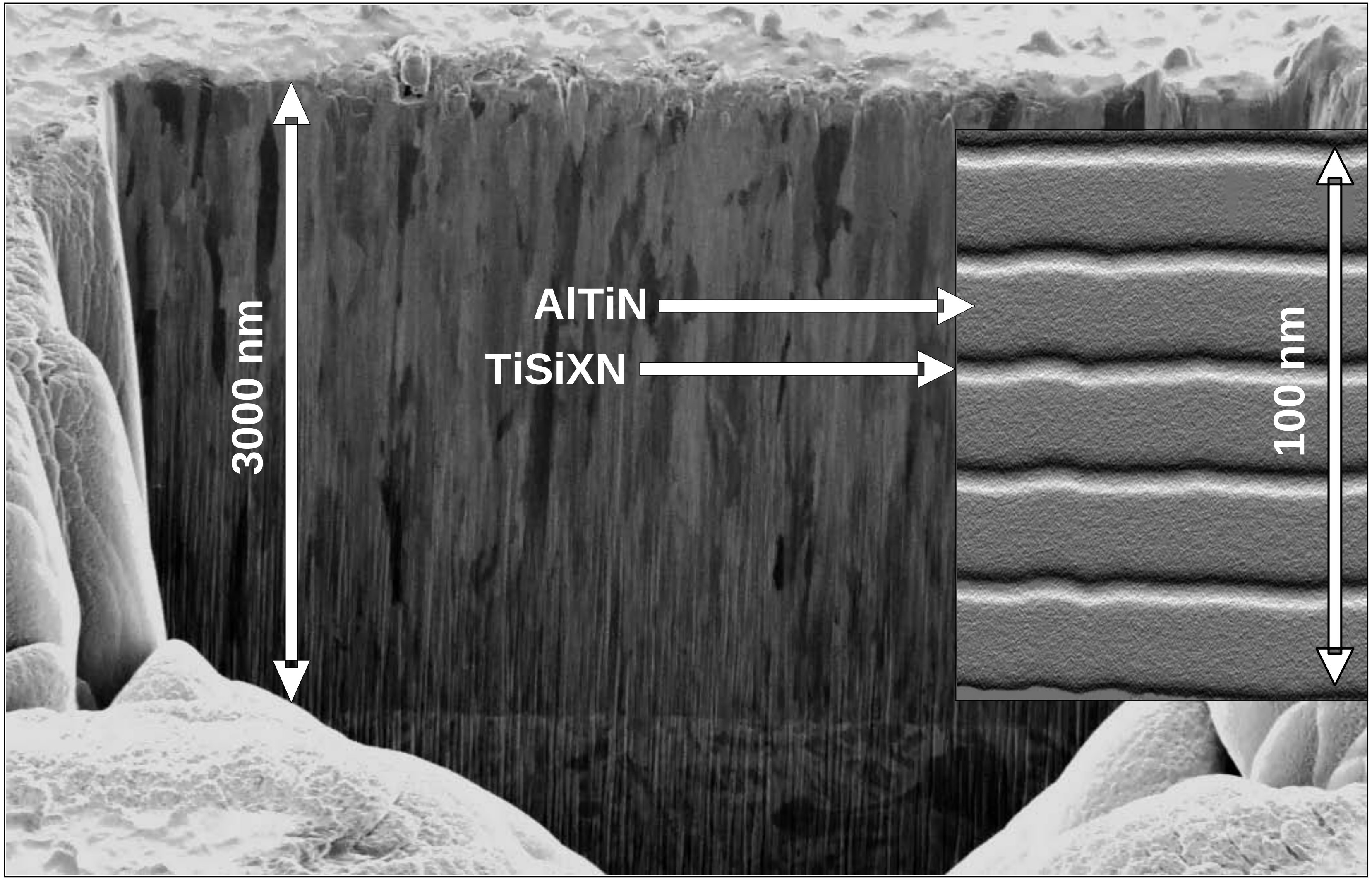

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Cutting test M*powerNano*

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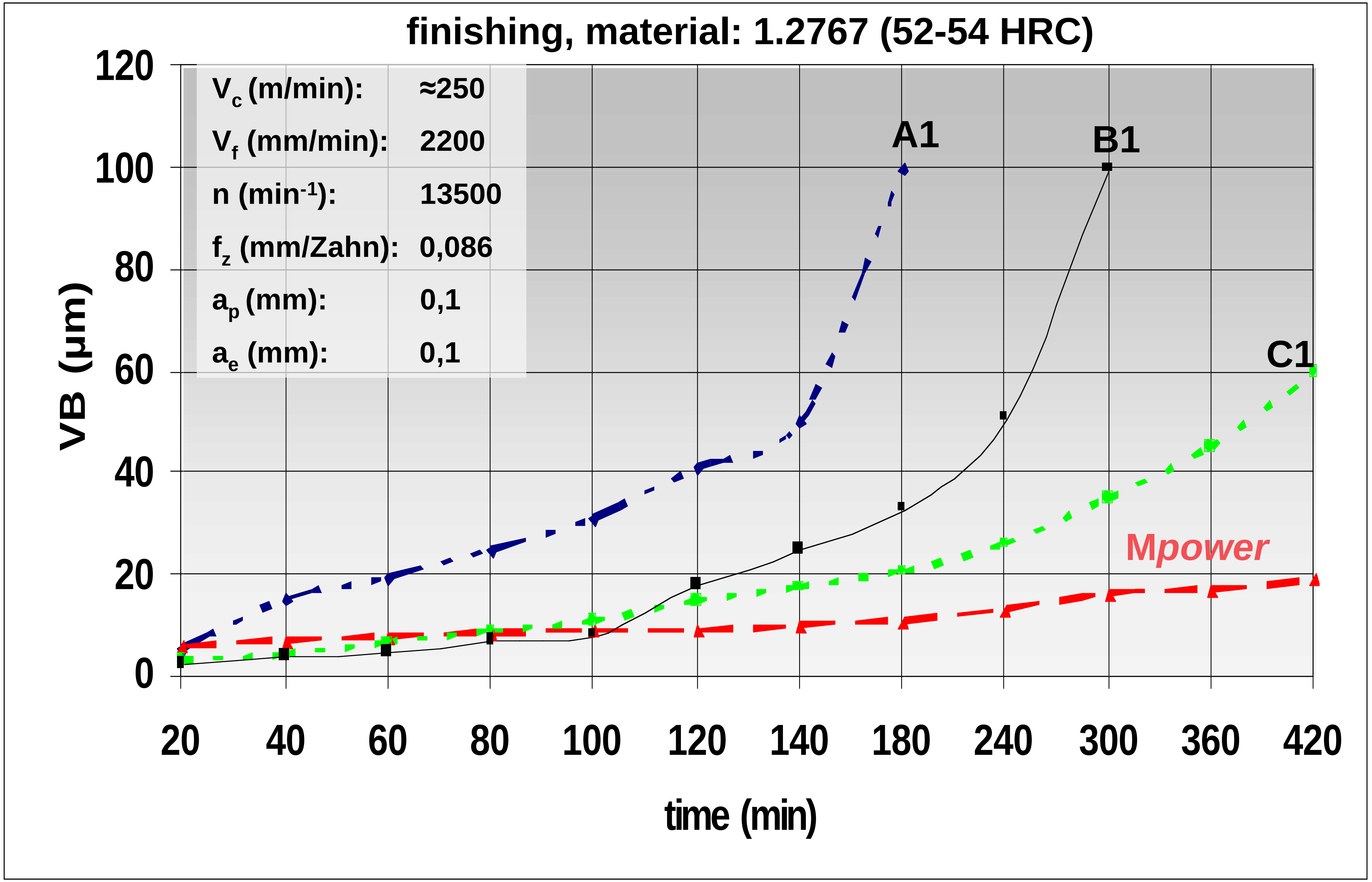

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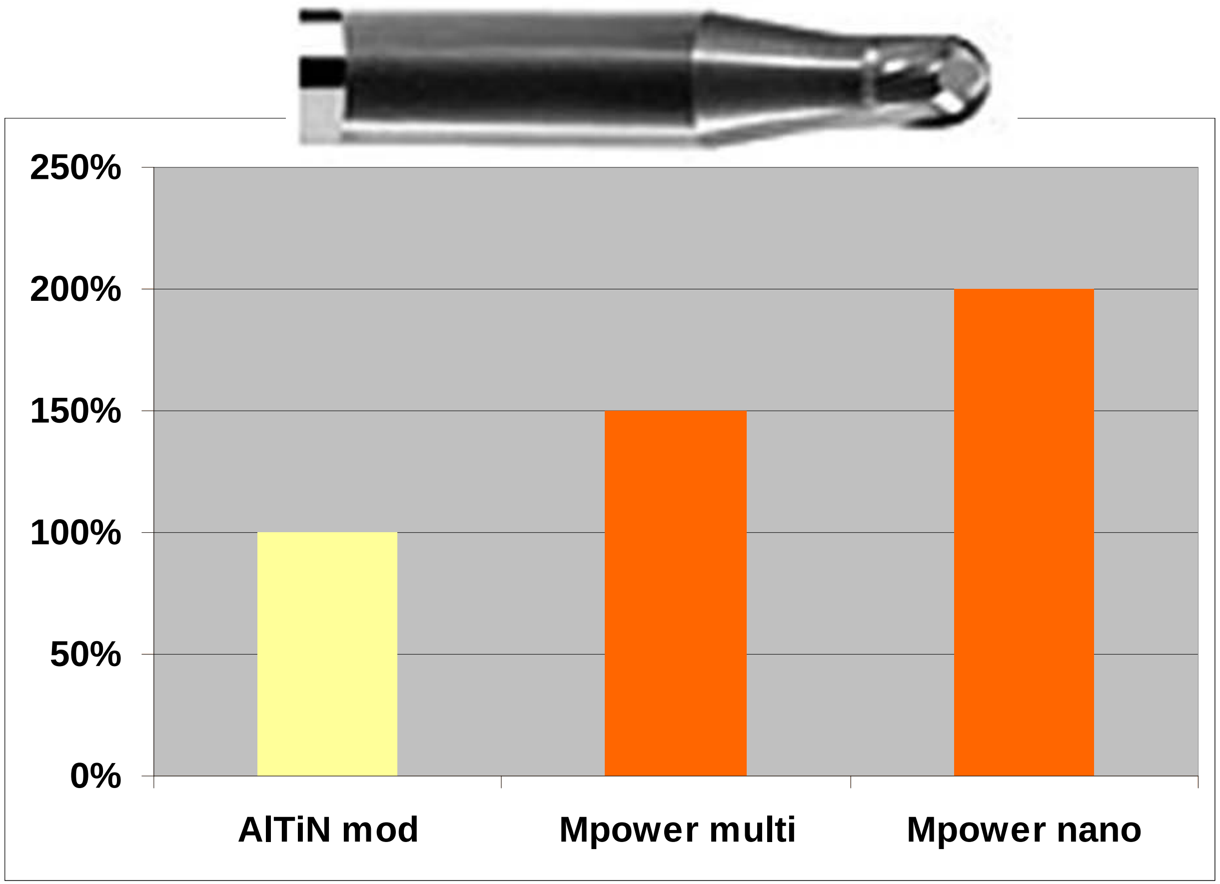
Hard milling, smoothing, Material 1.2379 60-62 HRC



dry, v_c = 115m/min, f_z = 0,05mm, a_p = 0,1, a_e = 0,2

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MAC: F_{fusion}

pressing force : [illegible],000 ton.

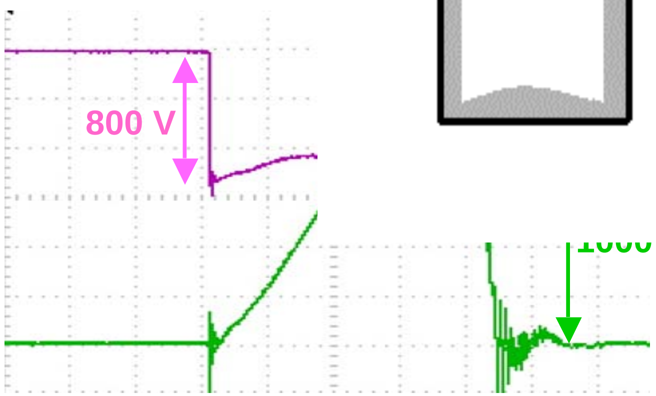
- the tested die is for a part of the most critical area.

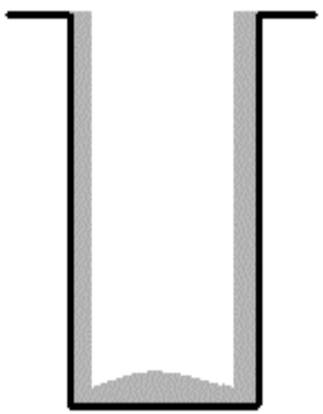
HIPAC results in a highly ionized metal and gas plasma
and ... ss

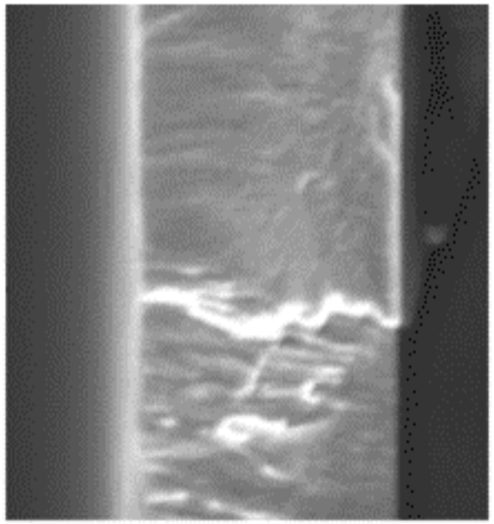
HIPAC coating blind hole L:D 2:1
Standard L:D 1:2

HPPMS

- power is applied to the magnetron in pulses of ... a few tens of µs at
- peak target curren ... i.e. 1 MW
- plasma density ~1
- ionization of the sp ... up to 90 % for Ti a

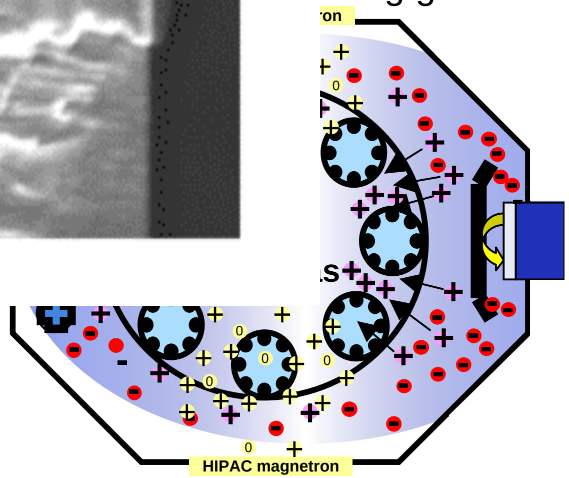




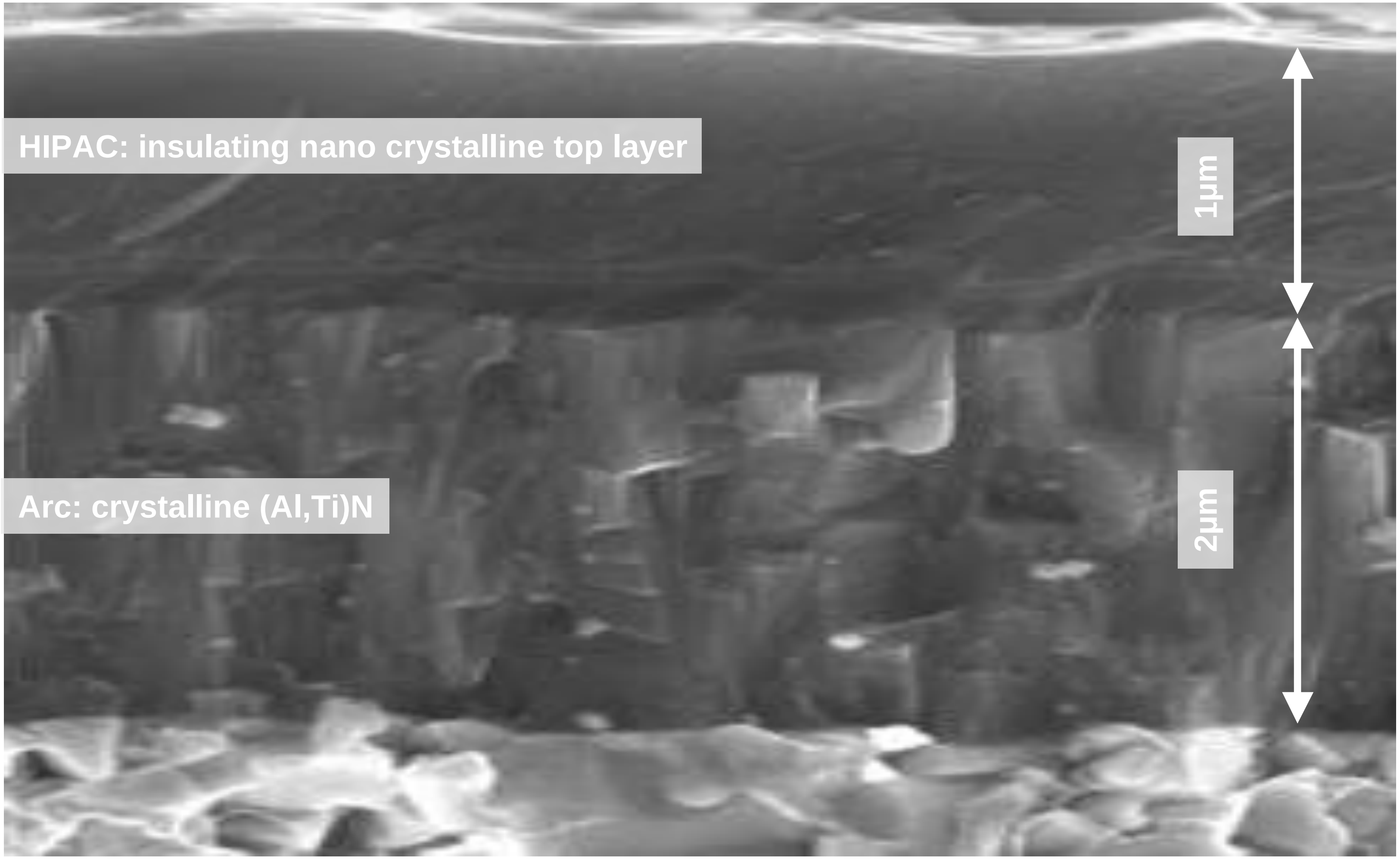


... Glow Discharge)

- magnetically designed arc evaporator ... nctions as an ion source
- ... 0 %
- ... ng of the substrate ... ergy bombardment of ... uring growth



Smooth and dense sputtered insulating top coat



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Conclusions

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- PVD coatings ensure high quality in component production
- New developments open up economic machining of new materials
- Lower coating temperatures allow even direct coating of plastics
- Overcoming line-of-sight coating using HIPAC
- New options for component design using PVD coatings
- DLC coatings represent a group of their own and can be adapted to existing components lowering friction losses and raising lifetime
- Combination of ionitriding and PVD can help substituting expensive materials and protect aftermarket
- Combination treatment can make PVD coatings affordable for mass production


Thank you for your attention !