Off to New Shores!

DLC and Oxynitrides Also as Upgrades

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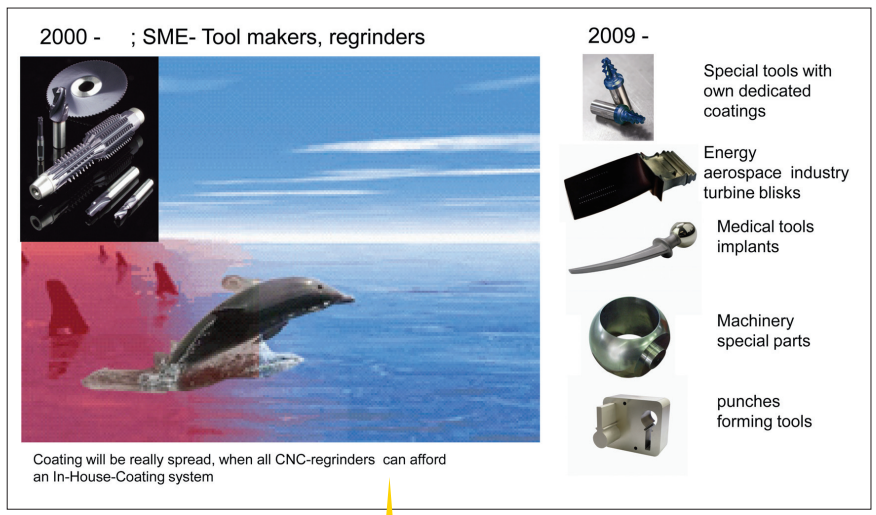


Image 1: Off to New Shores for Tool Makers and Regrinders to "Blue Ocean".

Abstract

"Sooner or later, something fundamental in your business world will change." [1.1]

In booming times the owners of the SMEs (small and medium size companies, e.g. grinders and tool makers) try to create enough production capacities, to be able to deliver their products in time.

In the recession the companies do not need capacity increasing. Innovative technologies, however, can lead to a higher product quality and/or to branch out into new markets. They may help to prevent or even end the crisis.

"When you take the catastrophe out of a crisis it can be quite productive". [1.2]

The In-House-Coating (IHC) is surly one of the most promising business models to realize this with the help of compact and flexible PVD units.

– The change to the own coating away from the job coating makes the production more stable, more qualitative, more innovative and independent.
– The change to new markets, to the "Blue Ocean" from the over crowed "Red Ocean" increases the profit and accelerates the payback of new investments (*image 1*).

On the way to the "Blue Ocean" the grinders should leave the secured harbour of the cutting tools, but "the ships are not build for the harbour" [1.3].

The units of the In-House-Coating should be able to deposit any coatings from simple TiN through Nanocomposites and oxides up to DLC. Since 2003 PLATIT's mainly SME customers have worked worldwide with the π coating systems with their rotating cathodes. This article describes the newest developments for this product family like:

– Oxide and oxynitride coatings as well as
– DLC coatings,
preferably produced as
– TripleCoatings® in combination with Nanocomposite coatings.

1. What is important for the coating users?

"All tool manufacturers can master cutting materials and tool geometries. The competitiveness will be decided by the used coatings." [1.4].

Standard coating offered by job coaters all over the world will not help companies stay ahead of the competition. In order to be successful they need exclusive dedicated (tailor made) coatings adapted to the specific application. This exclusivity is only possible if you make your own coatings in your In-House-Coating centre. All major requirements of coating users [3] bear witness to the validity of this statement (*image 2*).

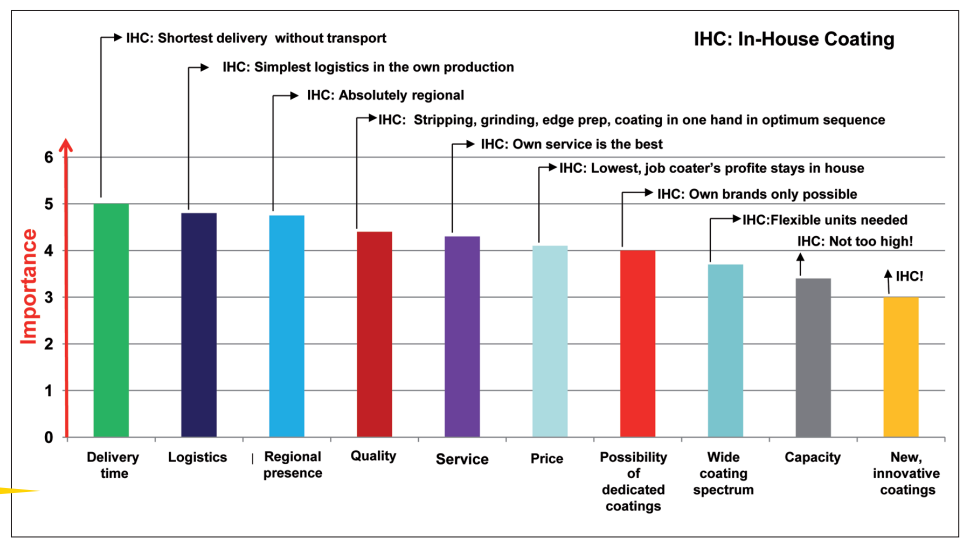


Image 2: What is Important for Coating Users?

Bild 3: LARC®-Cathodes and -Shutters.

The wide variety of applications has led to an increasing number of coatings. Today there are no less than 80 different types in existence with all kinds of chemical compositions. There are even more than 250 considering all the different stochiometries [11].

2. What is flexible coating?

Flexible coating systems will only be integrated into proprietary production processes when:

– Turnkey coating systems [5] are available. They should provide:
  • pre- and after-treatment of cutting edges and surfaces [6], [7]
  • stripping
  • cleaning and
  • quality control systems.
– the system can be operated even without high qualified personnel
– the system reaches cost-efficiency within two years
– the system enables the deposition of
  • conventional as well as high performance coatings
  • dedicated coatings for specific applications.

2.1 Innovative coating units

Innovation distinguishes between a leader and a follower. Innovation is when the customer opens his valet" [1.5].

The cores of the π technology are the rotating cathodes ([5], [8], [9]) with double shutters (***image 3a***):

– Before coating the targets are being cleaned by means of the Virtual Shutter® preventing contamination of substrates (tools):
  • The Tube Shutter® is closed to prevent the tools from being contaminated by previous processes.
  • the ARC ignites toward the back; the Virtual Shutter® is activated.
– Deposition (coating) begins with clean targets
  • the Virtual Shutter® is deactivated,
  • the Tube Shutters® are open,
  • the ARC ignites toward the tools.

This double shutter technique gives a very good adhesion (without prolonged etching) as well as smooth, droplet-arm surfaces.

2.2 Wide coating spectrum

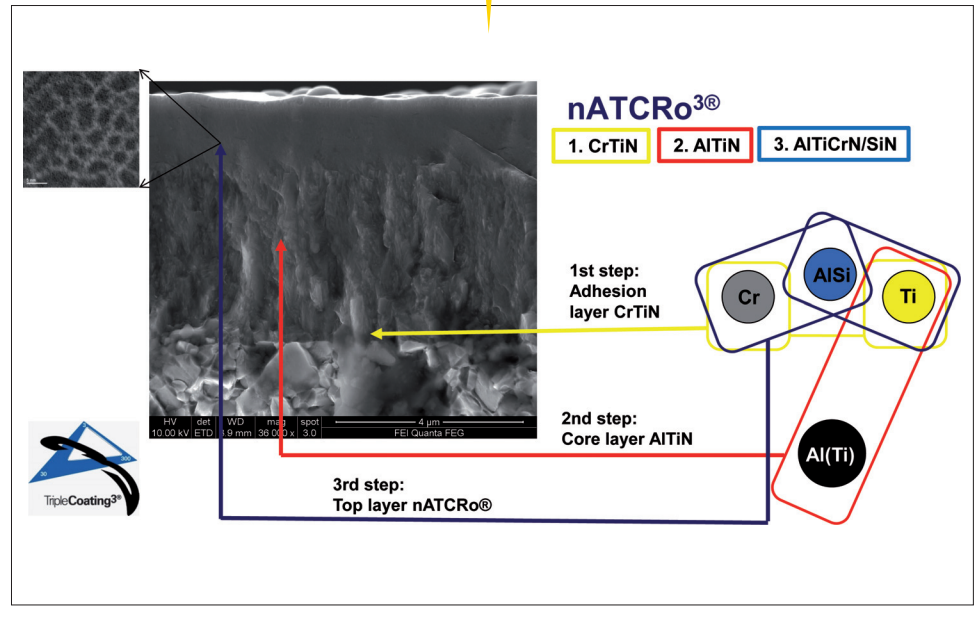
The smooth change-over from one production setup to the next enables the manufacturing of a wide variety of coatings as well as short processing times.

2.2.1 Conventional coatings

Thanks to its cathodes sitting right next to each other the LARC (Lateral Rotating Cathodes) technology enables the use of cost effective non alloyed targets as well as the deposition of a great number of coatings with the same cathodes. Composition and stochiometry can be further defined through the use of software. Thus the cathode configuration (Cr-Al-Ti) shown in ***image 3b*** e.g. allows for the production of practically all popular PVD coatings from the market;

– TiN, TiCN, TiCN-MP, Ti2N, Super-TiN;
– TiAlN (50/50%), AlTiN (60/40, 67/33%);
– TiAlCN (75/25, 80/20%)
– CrN, CrTiN, AlCrN (70/30, 80/20%)
– TiAlCrN = All-in-One
– all coatings also with DLC top coating.

Image 4: TripleCoatings® ; Combination of Conventional and Nanocomposite Coatings.



2.2.2 Nanocomposite coatings

For the deposition of Nanocomposite coatings the Al cathode (***image 3b***) is replaced with an AlSi cathode. The spinodal segregation [10] needed for this process is achieved thanks to the closeness of the Ti-AlSi and/or Cr-AlSi cathodes.

The nanocrystalline TiAlN or AlCrN grains are embedded in the amorphous SiN matrix thus enabling the build-up of Nanocomposite structure and coatings [8], [9]:

– nACo®: TiAlN/SiN
– nACRo®: CrAlN/SiN
– nATCRo®: AlTiCrN/SiN

The SiN matrix encases the grains, impedes their growth and this structure makes the increasing of the hardness possible [10].

2.2.3 TripleCoatings®

TripleCoatings [5], [9], [11] consist of conventional and Nanocomposite coatings. .

– nACo3®: TiN + AlTiN + nACo®
– nACRo3®: CrN + AlTiCrN + nACRo®
– nATCRo3®: CrTiN + AlTiN + nATCRo®.

They are deposited in three phases (***image 4***):

– The best adhesion is achieved by using titanium and/or chrome without using of alloyed targets. Thanks to the similar Young's moduli the adhesive layer allows a smooth transition between substrate and coating.
– Because of its low internal stress the middle layer provides a robust core with a good resistance to wear as well as superior hardness. The central ca thode (CERC®: Central Rotating Cathode [5]) ensures a high deposition rate it means high productivity.
– The Nanocomposite top layer shows an extremely high hardness and an excellent thermal isolation (silicon!) as well as a high resistance against abrasive wear.

Due to their different structures the TripleCoatings® lend themselves for all kinds of applications as shown under ([4], [5], [14]) (***image 5***).

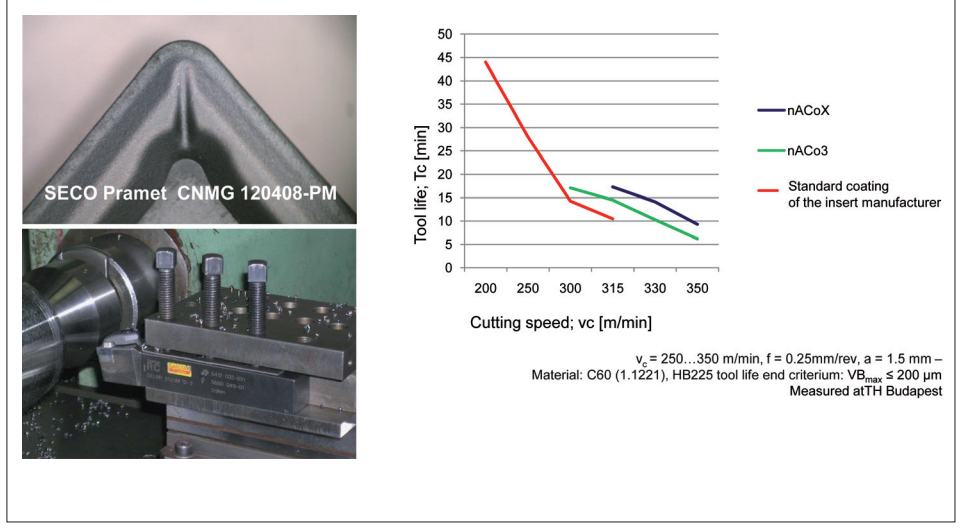


Image 5: TripleCoatings® and Oxynitride-Coatings at Dry Turning with High Cutting Speeds.

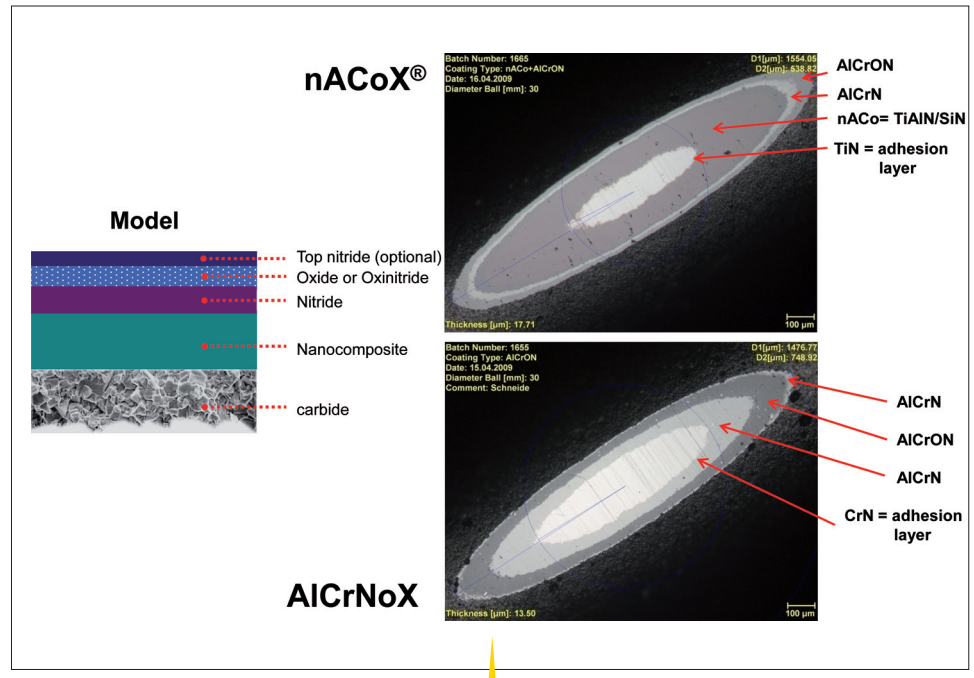


Image 6: Structures of Oxide- and Oxynitride-Coatings from PLATIT.

2.2.4 Oxide and oxynitride coatings

"Creativity is the combination of ideas"[1.5].

A successful PVD deposition and/or application of oxide and oxynitride is only possible in conjunction with other coatings. Otherwise, the end result lacks the desired adhesion, cohesion, and hardness. When combined with conventional nitrides and especially Nanocomposite coatings the range of applications is pretty wide.

Oxide and oxynitride coatings serve to separate tool/component and workpiece and achieve a low affinity between the two, especially in dry cutting processes (***image 5***) where high temperatures are reached [12]. They offer the following advantages:

– High resistance against:
  • adhesive wear
  • abrasive wear
  • oxidation, oxygen diffusion (the layer already is as an oxide)
– Chemical and thermal isolation and chemical indifference
– Reduced friction
  • Even at temperatures of more than 1000°C
– Fewer built-up edges and less material inter diffusion in the tribo contact zone.

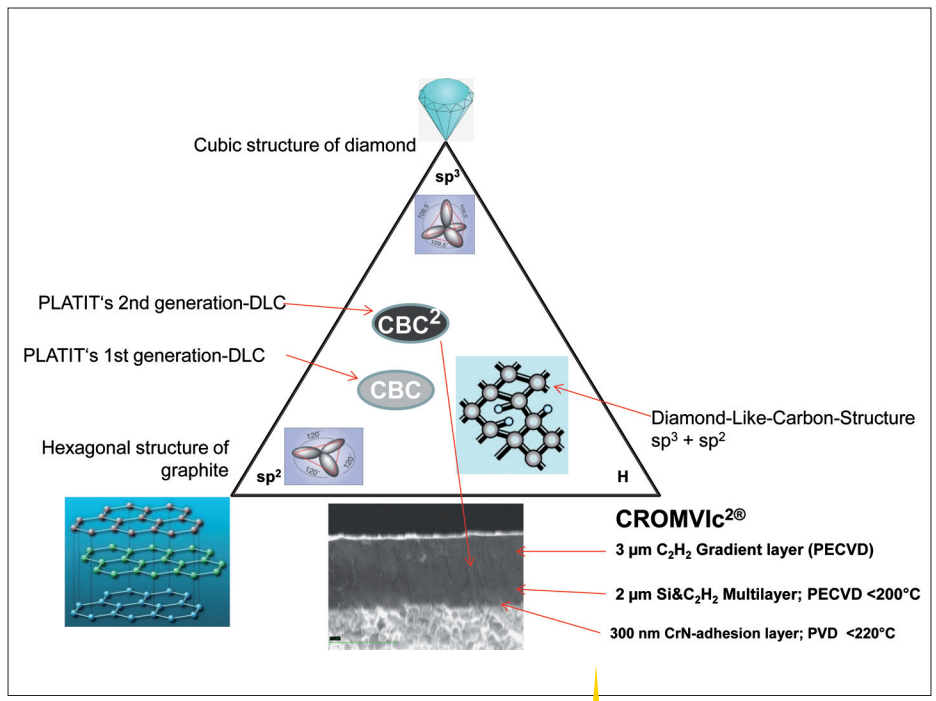


Image 7: Structures of DLC-Coatings from PLATIT.

As a metal nitride basis is needed to prevent cracking and plastic deformation the coatings are (like with CVD) being built into a multi-layer structure (*image 6*).

Our current oxide coatings are based on an evolution of the TripleCoatings® principle:

- AlCrNoX : CrN + AlCrN + AlCrON (optional + AlCrN)
- nACoX®: TiN + nACo + AlCrN + AlCrON (optional + AlCrN)

ARC processes with oxygenic gaseous mixtures are particularly stable thanks to the rotating LARC® cathodes:

- No increase in ARC voltage during the process.
- Possibility of using high ionic currents and therefore high deposition rates.
- Possibility of using DC BIAS amplifiers with low O_2 contents where charges can be avoided by means of an MF pulsed BIAS (up to 350 kHz).
- The preferred nitrogen/oxygen rate is: N/O: 50/50% - 80/20%.

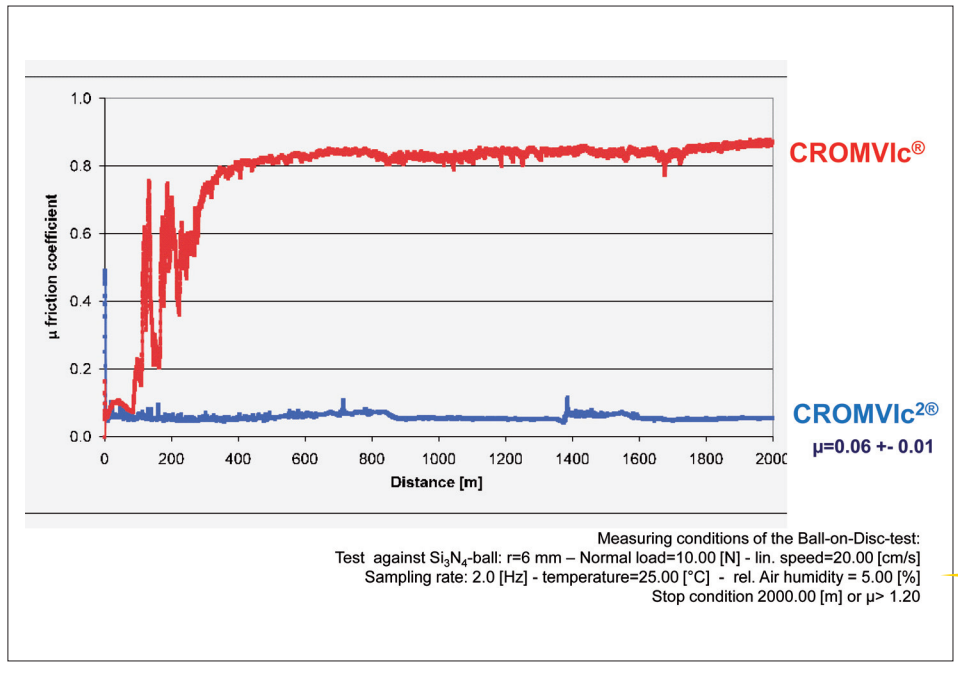


Image 8: Comparison of Friction Behavior of PLATIT-DLC-Coatings.

- Typical coating thickness at turntable: 7 - 18 µm
- Typical overall hardness: 30 GPa
- Typical Young's modulus: ~400 GPa.

2.2.5 DLC coatings (Diamond-Like-Carbon)

Diamond-Like Coating (DLC) is a metastable form of amorphous carbon with a high percentage of cubic sp^3 elements (*image 7*).

The metal-doped first generation of PLATIT DLC coatings (CBC; a-C:H:Me) is deposited in a pure PVD process. In order to achieve good adhesion it is being manufactured in a batch in combination with hard coatings. Hence their names:

- CROMVIc® = CrN+CBC
- cVIc®= TiCN+CBC
- nACVIc®: nACRo+CBC usw.

CBC coatings improve the running-in characteristics of chip removal and forming tools and play an important role in the treatment of soft and adhesive materials which cause built-up edges.

The metal-free second generation of PLATIT DLC coatings (CBC^2: a-C:H:Si) is deposited in a combined PVC/PECVD process [5]. Here specific siliceous gases help improve the following characteristics:

- chemical stability
- optical transparency
- extremely good adhesion (DLC coatings) (L_{c1}> 55 N, L_{c2} > 75 N, L_{c3}> 100 N)
- high mechanical hardness (> 25 GPa)
- smooth surfaces (Sa < 0.03 µm)
- low friction coefficient (µ<0.1 for good durability without break-through; *image 8*).

Image 9: Different Applications for PLATIT-DLC-Coatings.

Today, DL C coatings are mainly used in component mass production to protect against wear and tear through less friction. This is, however, not a field of business PLATIT will participate in. As opposed to standard equipments the new machines (π111+DLC, π300+DLC, PL1001+DLC, ***image 10***) feature the following additional characteristics [5]:

- Virtual Shutter® in combination with Tube Shutters®
- 350 kHz BIAS amplifier
- Pulsed ARC amplifier (optional)
- Additional gas tanks and pipes with mass flow controller
- Specific heaters with dust filter
- Optional upgrades at operator plant

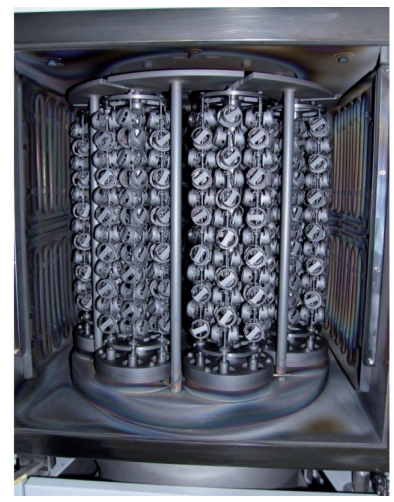
The CBC² coatings deposited with these equipments are ideal for high-quality tools and components as well as the requirements of high tech installations (***image 9***):

- die, stamp and forming tools,
- thread moulding
- medical instruments and implants
- heavy-duty components in motor sports like valve rods, lever grips, etc.
- general engineering components like turbine blades, sewing-machine spindles, etc.

The CBC² coatings are manufactured with at least one thin adhesive PVD layer, but also in combination with complete PVD coatings in one batch. The most important types of structures and fields of applications are:

- cViC²®: TiCN + CBC²; die and forming tools, medical instruments and implants
- CROMVIc²®: CrN +CBC²; components with low coating temperatures
- CROMTIVIc²®: CrTiN + CBC²; components with corrosion protection, tools for aluminium chip removal
- nACVIc²®: nACRo® + CBC²; chip removal and forming tools for specific materials (Inconel, titanium alloys, etc.)

Image 10: PLATIT's Coating Units for Deposition of Oxynitride- and DLC-Coatings.



More than 1000 parts of sewing maschines
In one batch of the π300+DLC
for coating with CROMTIVIc²®
Source: KPTU, Seoul, South Korea

– Fi-VIc²®: nACo® + CBC²; heavy-duty components (e.g. valve rods)

3. Summary

From a high-quality coating plant manufacturer SMEs expect not only regular technical support, but also a continuous product development e.g. for specific applications [13]. This is the only way companies can stay ahead of the competition.

This article describes the current developments of the π family of coating machines from PLATIT. The existing equipment can be upgraded on-site by means of hardware and software in order to produce oxide, oxynitride and/or a new generation of DLC coatings.

These upgrades enable:

– The production of coatings for cutting tools in new fields of applications and
– the break into new markets fields [14].

"Sustainable success can only be achieved by developing new and innovative markets and offering the customer a differentiated and relevant value system." [1.6], [15], [16]

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