ELKOTRON

CORUN

PLASMA VACUUM DEPOSITION
PVD TECHNOLOGY

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PLASMA VACUUM DEPOSITION PVD-TECHNOLOGY

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	TiN	TiCN(ML)	CrN	CrCN	ALTITRON	CORTITRON	TITRON	TIALTRON
Coating Material	Titanium nitride	Titanium carbo-nitrid	Chromium nitride	Chromium carbo nitride	Aluminum titanium carbo-nitride	Aluminum titanium-nitride	Titanium aluminum nitride	Titanium aluminum carbo-nitride
	TiN	**TiCN(ML)**	**CrN**	**CrCN**	**AlTiCN**	**AlTiN**	**TiAlN(ML)**	**TiAlCN(ML)**
Microhardness $HV_{0,05}$	2300±200	3500±500	2000±200	2300±200	3000±300	3300±300	3500±500	3500±500
Friction Coefficient Against Steel (Dry)	0,6	0,2	0,3-0,4	0,2-0,3	0,2	0,7	0,7	0,2
Coating thickness [1)] [µm]	2 - 4	2 - 4	2 - 6	2 - 6	2 - 4	1 - 3	2 - 4	2 - 4
Thermal Threshold	500°C	400°C	600°C	600°C	800°C	800°C	800°C	800°C
Colour of the Coating	Gold	Light gray	Silver gray	Silver gray	Old rose	Dark gray	Dark gray	Dark rose
Key Characteristics	Good coating for general usage	High hardness and wear resistance, increased toughness	Low stress / good adhesion and good corrosion resistance	Low stress / good adhesion and good corrosion resistance	High hardness and elasticity, high oxidation resistance, low friction	High hardness, high oxidation resistance and low coefficient of thermal conductivity	High hardness, high oxidation resistance, low friction	Low friction, high oxidation resistance
Primary Applications	• Machining / cutting of iron based materials • Metal forming (forging, rolling ...) • Plastic molding	• Machining of difficult-to-machine steel alloys • High performance cutting where moderate temperatures are generated in cutting edge areas • Excellent for metal forming (forging, rolling ...), eg. stainless steel	• Machining of copper and other non-ferrous materials • Metal forming (forging, rolling ...) • Plastic molding • Coatings for Al and Mg moulds	• Machining of copper and other non-ferrous materials • Metal forming (forging, rolling ...) • Plastic molding (improved release from form) • Coatings for Al and Mg moulds	• Machining of very tough Cr and Ni steel • Copy milling and heavy cutting • Special for interrupted cutting • Lubricated, semi-dry and dry machining • Roughing with special adopted ALTITRON coating 6-7µm	• Machining of thermal treated tempered steel • High performance cutting (lubricated, semi-dry and dry) • Cutting of improved materials where the other coatings achieve the limit of thermic and mechanical loads • For use on carbide end mills	• Coating of wide range of hard metal, cermet and HSS • Machining of cast iron • Machining at high speed (semi-dry and dry). • Very suitable for boring of steel up to 45HRc	• Coating of wide range of hard metal, cermet and HSS • Cutting (dry,semi-dry and lubricated) of all types of steel. • Excellent for boring of steel • Tools for drawing, stamping, pressing, forging, for machining of high and low alloy steel

1) Depending on size of tool, for micro tools - smaller than 2µm

PVD COATING PROCESS

General of the coating

Deposition of hard layers on the surface of a metal part was performed with the aim of improving its properties. Thickness and properties of deposited layer (or multiple layers) can be different, depending on the applied requirements and procedures. The most common requirements that are set in the application of certain metal objects are: wear resistance, corrosion protection, resistance to high working temperature, high stability of properties in the application, low coefficient of friction and reduction of machined material adhesion to the work piece. Depending on the material of metal part and conditions of its exploitation, the process of coating is elected, and because of expressive advantages related to the other, usually in the application are:

CVD - chemical deposition of elements from the steam phase

At this procedure, hard layer occurs by gas reaction on the surface of objects that are coated at relatively high temperatures (about 1000 ^{0}C). Movement of particles in the working chamber is not directed to form a smooth layer without taking the necessary measures (eg, movement of pieces). By this method, elements of a very complex shape can be coated (area outside the zone of sight). Secondary products arise during chemical reaction, that need to be removed from the chamber and are very harmful to the environment. Hard metal parts are usually coated by this procedure. If this process is applied to steel parts, then they must be subsequently thermally processed.

PVD - physical deposition of elements from the steam phase

Layers of pure metal (aluminum, chromium, titanium, etc.) can be created by this process, layers of compounds (carbide of titanium, tantal, molybdenum, etc.) on the surface of metal parts. Parts must be electro conductive and unmagnetized. The first of all, material to be deposited has to be put on to the steam phase by evaporation in a vacuum. Then the particles of evaporated material are directed by electric field to the negatively charged surface of the working objects. The procedure is performed at relatively low temperatures of 200 to 500 ^{0}C, and the thickness of deposited layer is several microns. In order to enable layer thickness to be equal, parts must be globally rotated in chamber work space, and parts that have areas outside the zone of sight can not be high quality coated (maximum depth of the coating of the hole is up to diameter of the hole). Low temperature of process enables the deposition of layers onthe finished parts and requires no additional heat or finishing (grinding, polishing). This equipment is very expensive because it requires sophisticated reactor and vacuum system to create the conditions for transportation and generating of steam species. But it is environmentally acceptable, because of the low process temperatures and non-separationg of harmful ingredients.

Which coating is better?

Since there are different characteristics that separate the two technologies, there are applications where only one coating is suitable. These two coatings are not competition to each other. However, there are applications where both are overlapped, and both could be of benefit. This would, of course, both coatings led to become a competitor to one another in terms of implementation, but selection of the best coating for a particular application is usually reduced to two main criteria:

1. Connection strength .

Because of the process of temperature diffusion, CVD coating has much higher bonding strength than the PVD and therefore is more suitable for application in areas that suffer great stress, such as pressing or cutting of stainless steel and very thick tin. It is also suitable for use in rough machining by cutting combined with high-speed cutting.

2. The requested precision .

Accuracy is a strong feature of PVD coatings (due to deposition at lower temperature) and is best when you need to maintain tight tolerances of steel that are heat processed. PVD coated cutting tools can achieve higher cutting speeds during finishing by cutting, especially for cutting of stainless steel or light alloys (Ti, Al).

If none of these criteria isn't taken into account, then on the basis of experience, application is determined on the basis on application under similar conditions and thus determine what is the best for user. Costs allways play an important role, but since the coatings affect the costs and savings, this potential difference is ignored if you get a tool for work that is absolutely the best.

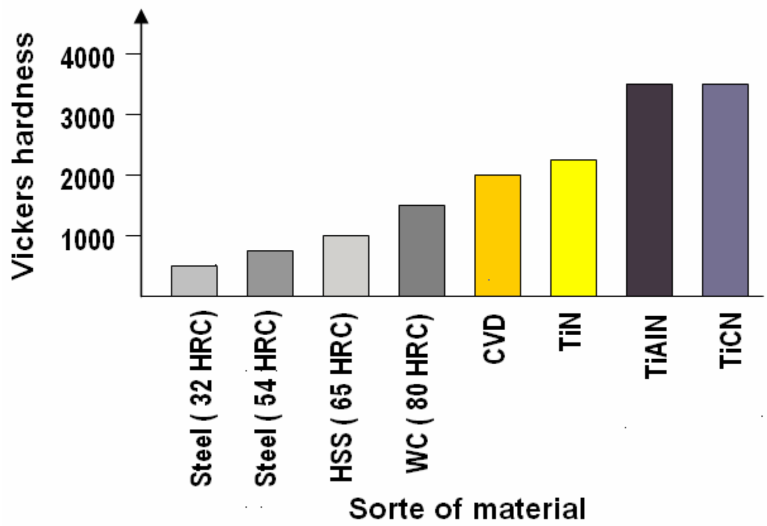


Table 1: Comparison of material surface hardness with and without coating.

<u>Fields of PVD coatings application</u>

For ease of applicability and characteristics that give the surface of the object, PVD coating is used in:
- metal processing industry to increase the consistency of tools (cutting tool, a tool for stamping, drawing, deformation in the hot and cold condition, etc.).
- Industry of consumer goods as corrosion protection and in decorative purposes
- in electricity
- in the production of medical equipment, etc.

<u>Application of PVD coating in metalworking industry</u>

Need for PVD hard coating in the tool and dies industry is growing due to its technical progress and constant demands for savings. Its pronounced advantages are:
- Increased wear resistance of the tools and dies (surface hardness of 2300 to 3500 HV)
- Increased corrosion resistance of the tools and dies (up to 900 ^{0}C)
- Increased smoothness and improved appearance
- Lower coefficient of friction
- Reduced adhesion of the material on the tool
- Increased stability of tools
- Increased cutting speed and charge rate
- Less maintenance and downtime
- Savings regarding the new tools and dies

The most suitable for applying the coating is HSS steel, but stainless steels for operation in hot condition and some steel work in the cold state can be coated, whose dismissal the minimum temperature is 520 º C. Coating of brazed parts is possible if the solder is resistant to vacuum and temperature (must not contain cadmium and zinc, soldering temperature must be higher than 600 º C). Process temperature should be below material discharge temperature, to avoid changes in its basis (structure, hardness). Before coating, it is necessary to perform certain operations on the object, as it is shown in the picture.

Roughing » *Normalization of the material* » *Semi-finishing* » *Thermo-treatment* » *Finishing* » *Polishing* » ***PVD coating***

It is important to prepare the surface properly, since the coating adhesion strength depends on the mechanical connection between steel and coating. It is proposed for PVD coating to become the most effective, roughness of steel surfaces must be less than the thickness of coating (for example, the cutting tool less than 4µm, and forming tools less than 2 µm). Tools for forming and injection of plastic must be highly polished. Surfaces must be free of rust, oil, hardening salts, grinding marks, deposits and without polishing means. The *pieces must be subjected to multi-ultrasonic degreasing in alkaline bathroom, cascade rinsing and final drying without stains.*

PVD coating on cutting tools

Application method of PVD coatings for cutting tools in metal cutting industry is one of the main themes in the industrial application of coating modern technologies in the last 30 years. The first material for the PVD coating, which has had commercial application for coating of cutting tools was TiN, in the early 1980s, and since the 1990s, the most cutting tools were individually coated with TiN, in cases when sharp cutting edges were required (eg. Cutting of threads, grooving, end milling or turning, etc..), and the cutting tools with high demands for tough and resistant cutting edge (eg. drilling). At hard metal cutting tools (milling cutters and drills) PVD technology is a standard coating technology. TiAlN PVD coating is currently the most widely distributed PVD coating for cutting tools, but the other coatings, such as TiCN and CrN offer a great solution in the exploitation of tools.

Use of PVD coatings on cutting tools made savings in several ways:

1 - tools work faster

By proper combination of speed and cutting procedures, PVD coated tools can work faster reducing cycle, process time and enabling production of multiple components in a short period of time.

2 - Reduced wear and need for replacement

When cutting of metal, cutting tools wear differently depending on the material of work pieces. PVD coatings are resistant to all forms of wear and increase the stability of cutting tools and reduce the costs of changes of the tools.

3 - Reduced need for cooling liquid

Fluids for cooling of cutting tools cost the company up to 15% of their total production costs. Cutting under the high speed and dry process involves very high temperatures at cutting edge. PVD coating, such as TiAlN have incredible stability on temperatures, hardness in the hot condition and resistance to oxidation. PVD coating allows, therefore, work in dry conditions or with very limited amounts of cooling liquid.

4 – Re-sharpening and re-coating of cutting tools

Companies that make coating, offer services and removing of the coating, re-sharpening and re-coating of cutting tools. Cutting tools coated in that way have the same characteristics as well as the newly-coated tools.

Application of PVD coating to decorative purposes

PVD coatings are resistant to abrasion and are applied evenly over the surface. Usage of the object which is coated by this procedures, does not change the surface or color. These features and a wide selection of colors and textures, along with the fact that it is very environmentally acceptable process, have led to wide application of this process in the decorative purposes. It is possible to reduce the temperature of the process so that materials, such as brass and aluminum can be coated, too.

Fields of application:

- *Sanitary devices and equipment*
- *Equipment for architecture*
- *Nautical equipment*
- *Household appliances*
- *External and internal parts for cars*
- *Electrical*
- *Manual Cutting Tool*
- *eyeglasses, clocks, jewelry*
- *Equipment for weapons*

APPENDICES:

1. *Table 1: Types of PVD coating from Corun offer*
2. *Table 2: Recommendations for the selection of PVD coating - plastic processing*
3. *Table 3: Recommendations for the selection of PVD coating - cutting, forming, separating and machine elements*

ELKOTRON TiN

Titanium Nitride (TiN) Coating

Titanium nitride is coating that is often used due to its well balanced coating properties. It is the most used in cutting and forming of metal and decorative purposes because of its characteristic yellow color. Application of TiN coating on cutting tools extends the life of the tools, because it reduces the coefficient of friction on the surface. It helps the flow of chips, preventing deposits of material on the cutting tool edge, reduces the cutting force and heating of cutting tool. High chemical stability makes TiN suitable for use in food industry and medicine.

Application of TiN

- ***Machining***
  Machining of iron based material. It is often used for the tools for making of gears, drilling tools with low and medium cutting parameters
- ***Application in medicine***
  Coating of implants, prostheses and surgical tools.
- ***Decorative coating***
  Sanitary equipment, home appliances, clocks, weapons
- ***Equipment in the food industry***
  knives, mills, mixers
- ***Forming***
  Coating of tools for forming of metal and tools for plastic injection.

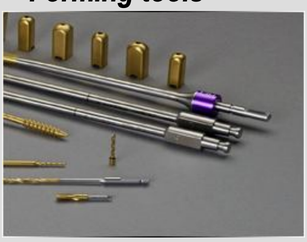
Coating properties

- High surface hardness
- Good adhesion to the substrate
- Good chemical stability
- Increased toughness
- Ecologically suitable for use
- Low heat conductivity

Hardness	2300±200 HV
Max. threshold temperature	500 ^{0}C
Friction coefficient against steel	0,6
Coating thickness	2 – 4 μm
Color	Gold

Forming tools

Cutting tools



Medical instruments

Decorative coating

ELKOTRON TiCN

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Titanium Carbo-Nitride (TiCN) Coating

TiCN is specially designed with a complex multi-layer structure, which gives it higher hardness and lower coefficient of friction than TiCN. Besides high hardness, TiCN has a high toughness and resistance to abrasion at high temperatures. These features are desirable for many applications, eg. interrupted cutting, when changed temperatures occur at the cutting edge during operation. It has successful application on milling cutters, reamers, drill bits and cemented carbide inserts. In operations of forming, TiCN reduces wear and problems that result from sticking of material on the tool.

Application of TiCN

• ***Machining***

Milling, turning, drilling and cutting of high and low alloy steel. Suitable for machining of hard to machine alloy steel and stainless steel.

• ***Forming***

Suitable for coating the tools for drawing, stamping, punching and pressing. Excellent in application in a wide range of forming of steel and non-iron alloys in cold state.

Coating properties

• High hardness
• Good adhesion to the substrate
• Good wear resistance at high temperatures
• Increased toughness
• Low coefficient of friction
• High heat conductivity

Hardness	3500±500 HV
Max. threshold temperature	400 ^{0}C
Friction coefficient against steel	0,2
Coating thickness	2 – 4 μm
Color	Light gray

Cutting tools and other application

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ELKOTRON CrN

Chromium Nitride (CrN) Coating

CrN coatings are the best choice when resistance to wear due to friction is required as well as corrosion and oxidation resistance and good slipping when insufficient lubrication exists. The hardness of CrN coating is about 2x higher than the frequently applied “hard" chromium coating. High hardness and low toughness that involve thicker coating (up to 40µm in the car industry) have a very good adhesion to substrate.

Application of CrN

- ***Components in the car industry***
  Coating of the parts with slipping contact surfaces, exposed to atmospheric influence, oxidation and corrosion
- **Components in process industry**
  Coating of components in hydraulics, pneumatics...
- ***Equipment in food industry***
  Coating of knives, mills, separators
- ***Equipment for weapon***
  Coating of gun barrel, shuters...

Coating of weapon

Coating properties

- High hardness and adhesion
- Very good chemical stability
- Low coefficient of friction against steel
- High temperature stability in the air
- Small stresses in layer structure
- Thickker coating is possible

Hardness	2000±200 HV
Max. threshold temperature	600 ^{0}C
Friction coefficient against steel	0,3-0,4
Coating thickness	2 – 6 µm
Color	Silver gray

Parts for process industry

Blades

Components for medical and pharmaceutical industry

ELKOTRON CrCN

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Chromium Carbo Nitride (CrCN) coating

CrCN coatings are the best choice when you require wear resistance due to friction, resistance to corrosion and oxidation as well as slipping at insufficient lubrication. CrCN layer has a higher surface hardness and lower coefficient of friction than CrN coating. It is very suitable for application on injection tools, because of the easy elimination of mould from the tool.

Application of CrCN

• ***Machining***

Tools for milling, turning, drilling and parting at machining of non-iron metals, particularly Ti and Cu alloys.

•***Forming***

Tools for drawing, stamping, punching, pressing and forging at machining of non-iron metals. In particular it is used for forming of Ti and Cu alloy as well as cast aluminum and magnesium.

• ***Plastic processing***

Tools exposed to corrosive and abrasive wear, eg. under the influence of aggressive and hard materials for the casting, can be strengthened with CrN layer.

Coating properties

- High hardness and adhesion
- Very good chemical stability
- Low coefficient of friction against steel
- High temperature stability on the air
- Small stresses in layer structure
- thicker coating layer is possible

Hardness	2300±200 HV
Max. threshold temperature	600 ^{0}C
Friction coefficient against steel	0,2-0,3
Coating thickness	2 – 6 μm
Color	Silver gray

Tools for injection of plastic

Tools and components for forming

Cutting tools

ALTITRON

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Alminium Titanium Carbo Nitride (AlTiCN) coating

AlTiCN (ALTITRON) with its multi-layered structures, is a basic choice for cutting of tools for machining of stainless steel and nickel-based alloys. It is most used for coating of tools for interrupted cutting under dry, semi-dry conditions or machining with cooling.

Application of AlTiCN

- ***Machining***

Because of its qualitative characteristics, such as low coefficient of friction and resistance to high temperatures, ALTITRON found the widest usage in cutting and milling of metals using minimal amounts of coolant and llubricant.

The appearance of machined surface of thread with uncoated (right) and ALTITRON (left) coating

Coating properties

- Low friction coefficient
- High resistance to high temperatures
- High wear resistance

Hardness	3000±300 HV
Max. threshold temperature	800 C°
Friction coefficient of against steel	0.2
Coating thickness	2-4 μm
Color	Dark rose

Application examples of ALTITRON coating

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CORTITRON

Alminium Titanium Nitride (AlTiN) coating

AlTiN (CORTITRON) is hard coating, specially developed for heavy, dry machining and high speed machining. It is very suitable for hard machining conditions where other coatings reach its limits of mechanical and thermal loads.

Application of CORTITRON

- ***Machining***

Cutting of metal under harder operating conditions (higher cutting speed, without lubrication).

Coating properties

- High oxidation resistance (800°C)
- High hardness at high temperatures
- High chemical resistance
- Low coefficient of thermal conductivity

Hardness	3300±300 HV
Max. threshold temperature	800 ^{0}C
Friction coefficient against steel	0,7
Coating thickness	1 – 3 µm
Color	Dark gray

Application examples of CORTITRON coating

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TITRON

Titanium Alminium Nitride (TiAlN) Coating

TiAlN (TITRON) coating give higher resistance to temperature than TiN, as well as higher hardness at higher temperatures. Coating on the tool forms thin layer of clay (Al_2O_3) or Aluminium oxide of ceramics. During operation and wear, the layer is continually renewed. To enable this process tha tool has to work in hot conditions.

Application of TITRON

- ***Machining***

  Specially developed for drilling operations under extreme conditions (bad cooling or without cooling). Excellent results can be achieved in milling, grooving and metal sheets forming. Re-sharpening and re-coating is possible and it is recommended.

Coating properties

- High hardness (harder than TiN,TiCN, 3x harder than CrN)
- Extremly high hardnes in hot state
- Good adhesion to the substrate
- High toughness

Hardness	3500±500 HV
Max. threshold temperature	800 ^{0}C
Friction coefficient against steel	0,7
Coating thickness	2 – 4 µm
Color	Dark gray

Application of TITRON coating

Cutting parameters		
Cutting data	v_c [m/min]	85.0
	f [mm/U]	0.14
	Materijal	1.2311
	Hardness $[N/mm^2]$	1000
	Diameter [mm]	6.8
	Adoption Ø [mm]	8.0
	Drilling depth[mm]	23 (~3.5 x Ø)
	Cycle time [s]	3.0
Setting of the machine	n_c $[min^{-1}]$	3979
	v_c [mm/min]	557

Example of cutting data for hard metal drills ø8 with TITRON

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Titanium Alminium Carbo-Nitride (TiAlCN) Coating

TIALTRON

TiAlCN (TIALTRON) is a new generation of multilayer coatings. It has very low friction coefficient. Excellent for application in machining of all kind of steel with and without cooling or lubrication.

Application of TIALTRON

•Machining

Cutting tools for machining of low and high alloy steel at high speeds.

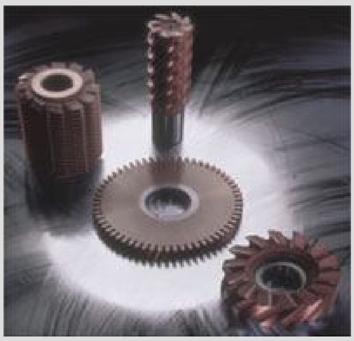
•Forming

Pressing and drawing of low and high alloy steel and other types of forming where friction coefficient is important.

Coating properties

- Low coefficient of friction
- High oxidation resistance
- High surface hardness

Hardness	3500±500 HV
Max. threshold temperature	800 ^{0}C
Friction coefficient against steel	0,2
Coating thickness	2 – 4 µm
Color	Dark rose



Application of TIALTRON coating

Table 3: Recommendations for the selection of PVD coating
Coating of tools for plastic processing depending on the type of plastic that is prossesed

ELASTOMERS	Mark	TiN	TiCN	CrN	AlTiN
Kautschuk	NBR, Si, EPDM	☺		☺ ☺	
Polyurethane	PUR			☺	
Fluorierte Elastomere	TPE			☺ ☺	

DUROPLASTS	Mark	TiN	TiCN	CrN	AlTiN
Polyurethane	PUR			☺	
Epoxydharze	EP	☺	☺	☺ ☺ ☺	
Phenolharze	PF	☺	☺	☺ ☺ ☺	
Aminoplaste	MF, UF, MP	☺ ☺		☺ ☺ ☺	
Ungesattigte Polyester	UP	☺ ☺		☺	

TERMOPLASTS	Mark	TiN	TiCN	CrN	AlTiN
Polyolefine	PE, PP, PB	☺		☺ ☺	
Styrol Polymerisate	PS, SB, SAN, ABS, ASA	☺ ☺ ☺		☺ ☺	
Chlorhaltige Polymerisate	PVC			☺ ☺	
Fluorhaltige Polymerisate	PTFE, PVDF			☺ ☺	
Acetalharze	POM	☺ ☺		☺ ☺	
Polyamide	PA	☺ ☺ ☺		☺ ☺ ☺	☺ ☺
Lineare polyester	PC, PBT(B), PET(P)	☺ ☺ ☺		☺ ☺ ☺	
Polyarylenethene	PPS, PSU, PES, PPE, PPO	☺	☺ ☺	☺ ☺ ☺	☺ ☺ ☺
Polyimide	PI	☺ ☺ ☺			
Celluloseester	CA, CP, CAP	☺ ☺ ☺			
Polyacrylate	PMMA	☺ ☺ ☺			

Legend:
☺ *Conditional suitable*
☺ ☺ *Suitable*
☺ ☺ ☺ *Very suitable*

Table 4: Recommendations for the selection of PVD coating
Coating of tools for cutting and separation, depending on the type of the machined material

CUTTING	TiN	TiCN	CrN	CrCN	AlTiN	TiAlN	TiAlCN
Steels of normal hardness Conventional cutting parameters	☺ ☺	☺ ☺ ☺					☺ ☺ ☺
Steels of increased hardness Increased cutting parameters		☺ ☺			☺ ☺ ☺	☺ ☺ ☺	☺ ☺
Heavy and high speed cutting (HSC)		☺			☺ ☺ ☺	☺ ☺ ☺	☺ ☺
Gray cast iron, steel cast, Hard alloys, Ti and Ni alloys	☺	☺ ☺			☺ ☺ ☺	☺ ☺ ☺	☺ ☺
Alloys of Al and non-ferous metal	☺ ☺		☺ ☺ ☺	☺ ☺ ☺	☺ ☺	☺ ☺	
Cutting without SHP					☺ ☺ ☺	☺ ☺ ☺	☺ ☺

FORMING AND SEPARATION	TiN	TiCN	CrN	CrCN	AlTiN	TiAlN	TiAlCN
Steel sheet of normal to medium strength	☺ ☺	☺ ☺ ☺					☺ ☺ ☺
Steel sheet of increased strength, stainless steel sheet	☺	☺ ☺		☺			☺ ☺ ☺
Alloys of Al and non-ferous metal	☺		☺ ☺ ☺	☺ ☺ ☺	☺		☺ ☺
Forming in area of high load		☺					☺ ☺
Forming of galvanized sheet in area of high load		☺	☺ ☺	☺ ☺			☺ ☺ ☺
Moulding under preasure			☺ ☺ ☺	☺ ☺ ☺	☺		

MECHANICAL ELEMENTS	TiN	TiCN	CrN	CrCN	AlTiN	TiAlN	TiAlCN
Mainly adhesive wear	☺	☺ ☺ ☺	☺ ☺ ☺	☺ ☺			☺ ☺
Mainly abrasive and erosive wear	☺	☺ ☺		☺ ☺	☺ ☺ ☺		☺ ☺ ☺
Tribochemical (eg, diffusion, Tribooxidation)	☺		☺ ☺ ☺		☺ ☺ ☺		☺ ☺
Wear due to thermo stroke	☺ ☺				☺ ☺ ☺		☺ ☺ ☺
Different use with special request for distortion		☺ ☺		☺ ☺ ☺			☺ ☺ ☺
Movable parts, reduced friction		☺ ☺	☺ ☺ ☺	☺ ☺ ☺			☺ ☺

Legend:
☺ *Conditional suitable*
☺ ☺ *Suitable*
☺ ☺ ☺ *Very suitable*

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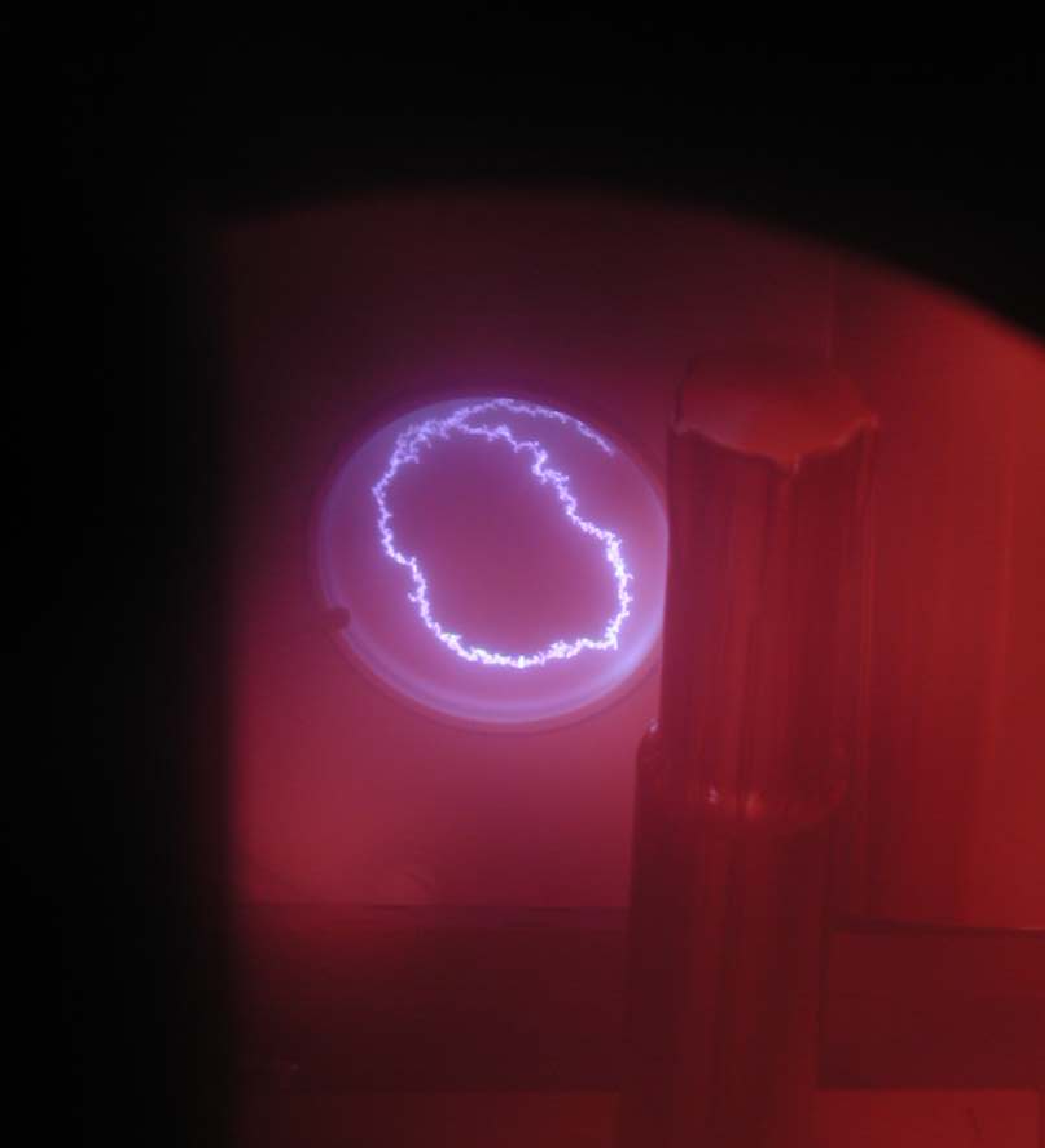

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