

MAXIT®
Wear Protection –
In a good shape
for every discipline.

MAXIT® PVD Coating Process

Fast turn-round time, reduced use of consumables and low maintenance are all important requirements for any modern production system.

Thin-film technology has firmly established itself as an effective method for reducing abrasive wear, surface pickup, galling, friction, and both chemical and thermal attack. These coatings help to reduce tooling costs, increase machining speeds and improve product surface quality. Furthermore, machine availability and productivity are also increased.

Today plasma supported vacuum coating processes and in particular PVD (Physical Vapour Deposition) are primarily used for industrial coatings.

At METAPLAS IONON, two important PVD processes are used to produce thin films: The universal PVD technique of cathodic arc evaporation (PVD ARC process) or the sputtering of cathode (PVD sputter process). The PVD process involves converting the mainly metallic base material from the solid to ionised vapour state by thermal (electron beam, arc process) or kinetic (sputtering) energy.

The whole coating process takes place in an evacuated vacuum chamber at 10^{-2} to 10^{-4} mbar. Additional layer-forming components are added in the form of controlled amounts of reactive gases such as nitrogen or hydrocarbons. These gases supplement the metallic source materials so that the required PVD hard coatings are formed.

The PVD process enables the deposition of hard materials in a temperature range from below 200°C up to 650°C. Therefore, any material that can withstand being subjected to a temperature of 180°C can be coated by PVD. In addition a number of plastics after electroplating can be coated. Previously hardened steels can be coated without distortion or loss in hardness. While offering these technical benefits the process causes no impact on the environment.



AIMS

MAXIT® PVD coating technology increases productivity.

Protection against abrasive and adhesive wear

Reduction of tool and processing costs

Increased machining speed

Improved machine availability

Improvement in product surface

Decorative, abrasion-proof product enhancement

ADVANTAGES

Well developed PVD technology.

Increase of surface hardness

Prevention of cold welds

Reduction of friction

Reduction of surface reactions

APPLICATIONS

The MAXIT® PVD coating technique is used throughout diverse branches of industry.

Tool and die making

Metal forming

Plastics and rubber processing

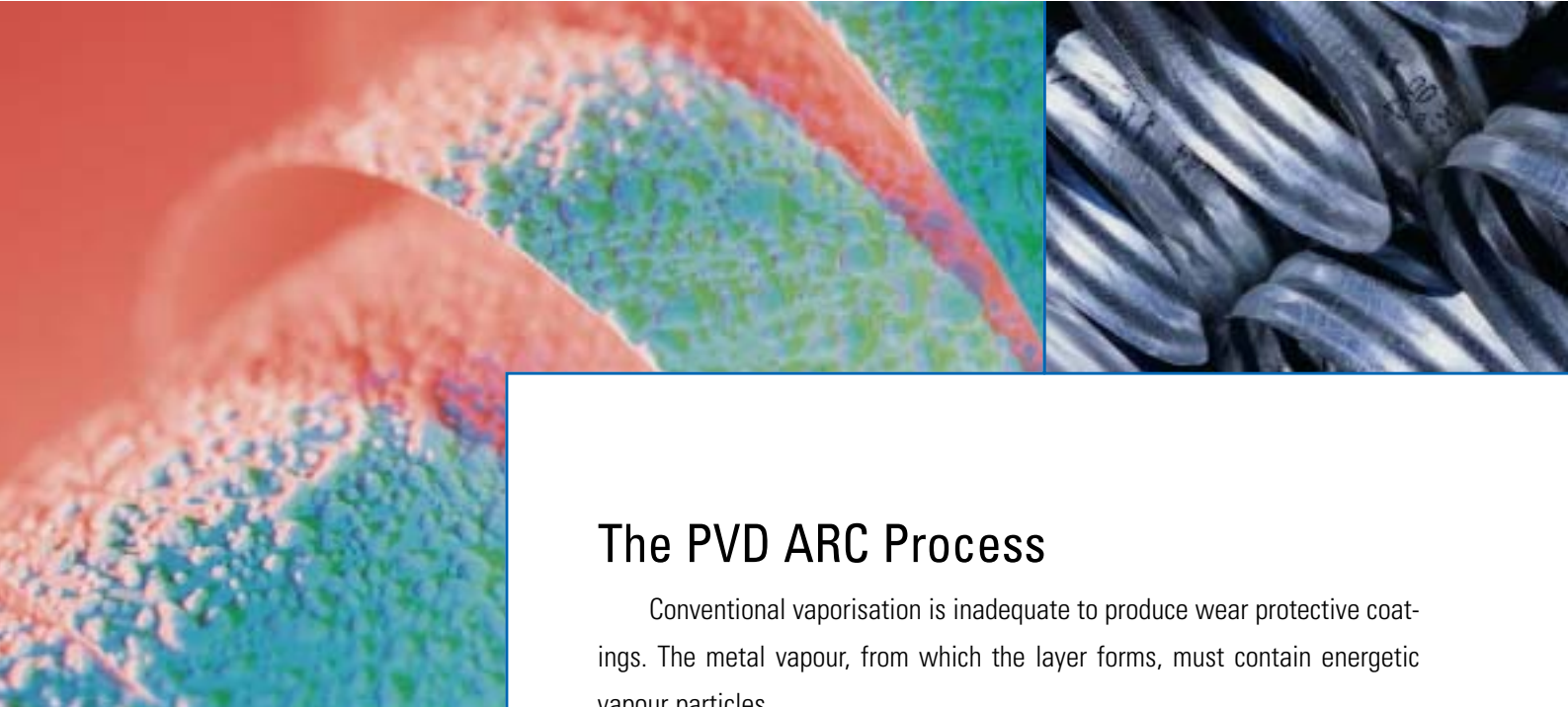
Machine and engine components

Printing and paper technology

Medical and textile technology

Decorative applications

Special applications



The PVD ARC Process

Conventional vaporisation is inadequate to produce wear protective coatings. The metal vapour, from which the layer forms, must contain energetic vapour particles.

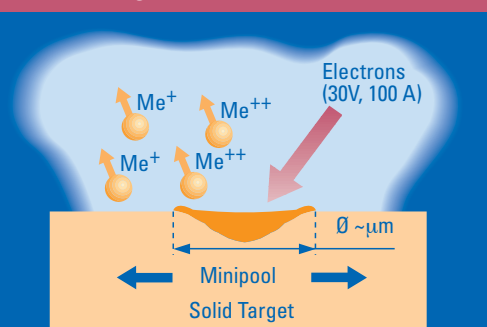
“Energetic” means highly charged particles having a high velocity. This condition is achieved by positively charging the metal particles (ionising) and then accelerating the ions with an electric potential through an electric field between the chamber and the substrate to be coated. This “attractive” negative potential, which is applied to the workpieces to be coated and which accelerates the ions is called the BIAS voltage. An example of such a process is the widely used cathodic arc evaporation, also called the PVD ARC process.

To explain: normal arcs which move through gases between a negatively polarised cathode and a positively polarised anode with low voltages (in the order of 30 V) and high currents (in the order of 100 A) are generally known as flashes. However, in a vacuum, such an arc changes its form at the cathode while retaining the electrical data: the arc no longer attacks the whole cathode but instead affects discrete minute areas with diameters measured in microns. These cathode spots exist for fractions of a second (5-40 ns) and then superseded by one or more, new cathode spots in the immediate vicinity. It is possible to see the trace of the arc race across the cathode at very high velocity.

The whole electrical power of the arc concentrates in the microscopically small crater of the cathode spot. This causes the solid cathode material to be instantaneously vaporised, the vapour particles are ionised several times and are rapidly accelerated in the heated ion cloud – known as the plasma. In this way, the metal is simultaneously vaporised, ionised and accelerated within microscopically small areas. This acceleration of the ions during the PVD ARC process is of particular importance: the energy content of the emitted vapour cloud is over 100 times higher than in the thermal evaporation process.

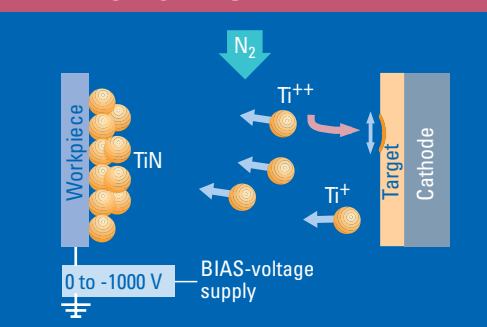
This clearly shows that the PVD ARC process achieves very good coating results even at low BIAS voltage. This is shown by coatings which are deposited at temperatures $< 200^{\circ}\text{C}$ being distinguished by the fact that they have a

PRINCIPLE

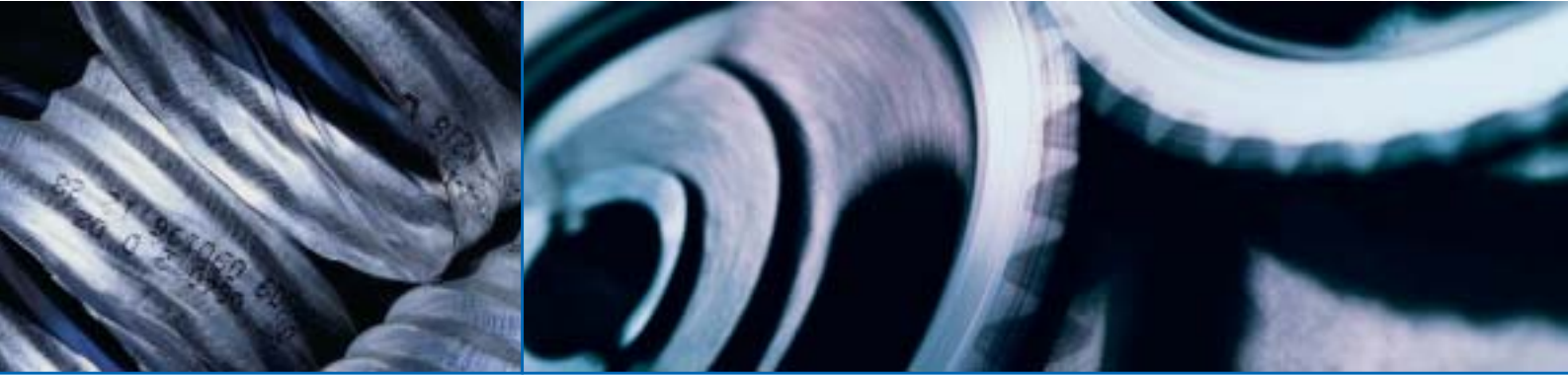


The metal is vaporised, ionised and accelerated in one step by the arc.

BIAS VOLTAGE



A reactive gas is added to the metal ions and ionised. All ions are accelerated towards the workpiece by the BIAS voltage.



very high adhesion characteristics. This means that a range of steels (cold worked steels) can be coated using the PVD ARC process without lowering their hardness produced in earlier heat treatments. Additional reactive gas is added to the process during the deposition of the hard coating. This gas is immediately decomposed and exited within the plasma, and together with the ionised metal ions forms the very hard thin films on the workpiece surface. However, in order to obtain excellent film adhesion, the workpiece must undergo a plasma cleaning process before coating, in addition to the aqueous chemical cleaning carried out before the workpieces are loaded into the PVD system. The PVD ARC process is characterised by its simple and reliable technology. The whole process is user friendly and automated. It enables a wide range of different coatings to be produced in the same coating system without difficulty.

PRINCIPLE PROCESS

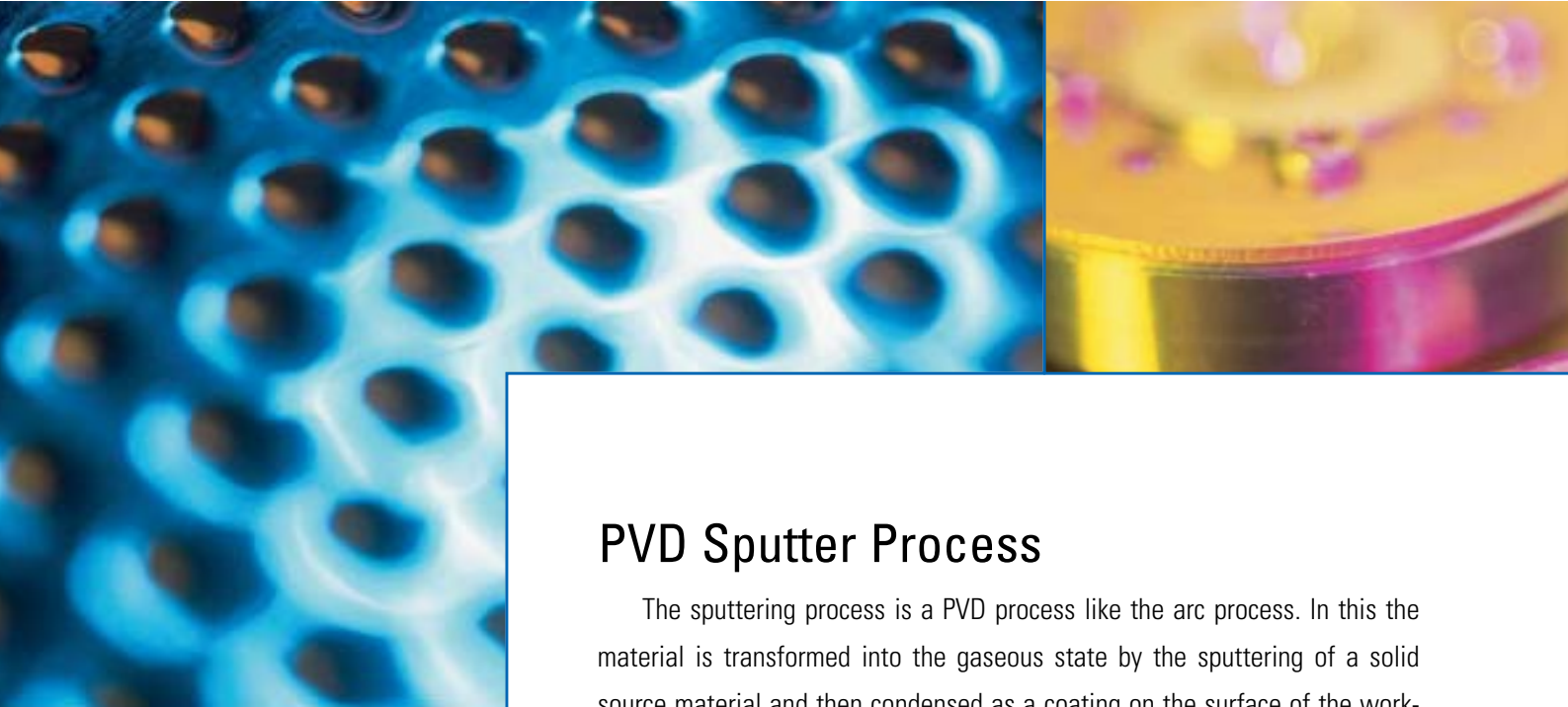
Computer controlled phases.

Evacuation	ca. 20– 30 mins
Heat up	ca. 30– 60 mins
Plasma cleaning	ca. 20– 60 mins
Reactive coating	ca. 60–120 mins
Cooling	ca. 10– 60 mins

FEATURES OF THE PVD ARC PROCESS

Versatile, simple and robust, these features characterise the PVD ARC process.

Simple and robust technique
High deposition rates
High degree of flexibility for many coating materials
Simple handling
High ionisation density
Coatings with high hardness and dense structure
Chemically stable and inert coatings
Coatings with low thermal conductivity
Very good coating adhesion even at low temperatures



PVD Sputter Process

The sputtering process is a PVD process like the arc process. In this the material is transformed into the gaseous state by the sputtering of a solid source material and then condensed as a coating on the surface of the workpiece to be coated. The most common sputtering process for industrial applications is the so called magnetron sputtering process.

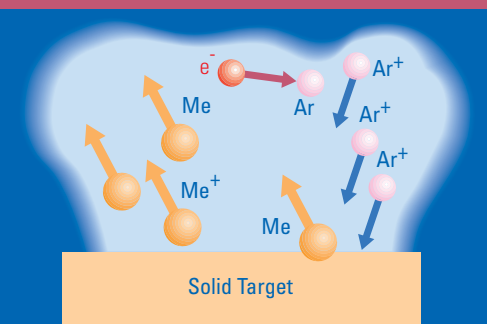
The magnetron sputtering also takes place in a high-vacuum environment. A plasma is formed in an argon atmosphere at pressures of 10^{-2} to 10^{-3} mbar. The inert gas argon serves as the sputter gas. A voltage of several hundred volts is applied to the source material – the target, causing argon ions to be accelerated from the plasma to the target. When reaching the target, atoms of this target are released by momentum transfer and the target material is sputtered. The magnetron sputtering gets its name from a permanent magnetic field which is placed behind the target and which focuses the argon plasma close to the target and therefore enables high sputtering rates.

Due to their kinetic energy, the sputtered atoms reach the workpiece and there they condense as a coating. Unlike the arc process, only a very small proportion of the material transformed into the gaseous state is ionised during magnetron sputtering. Nevertheless, the process of layer growth is assisted by applying an auxiliary voltage on the workpiece to be coated – the substrate. Argon ions are accelerated towards the workpiece through this substrate voltage (BIAS voltage) and influence the structure and adhesion of the layer.

The source material used in magnetron sputtering is often metallic, for example a pure metal or metal alloy. However, hard coatings often consist of oxides, nitrides or carbides for example compounds of the respective source material with oxygen or carbon. The additional components required for the formation of the hard coating are deposited in the layer via the addition of a reactive gas during the coating process. Common reactive gases are oxygen (O_2), acetylene (C_2H_2) and methane (CH_4).

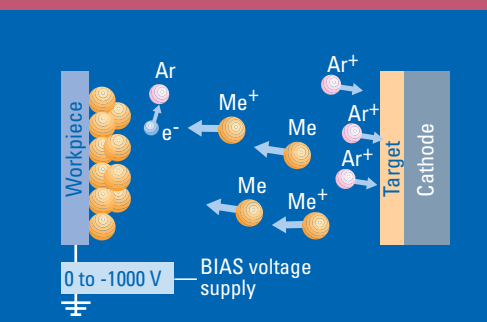
The coatings produced using magnetron sputtering combine good surface adhesion with a very smooth surface. Unlike the arc process, magnetron sputtering also enables the use of source materials, which are thermally very sen-

PRINCIPLE

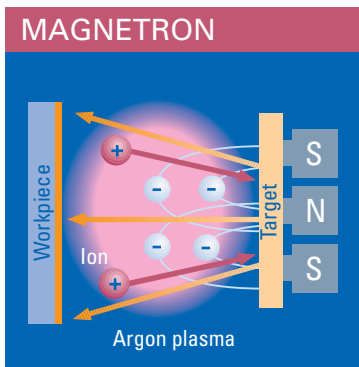
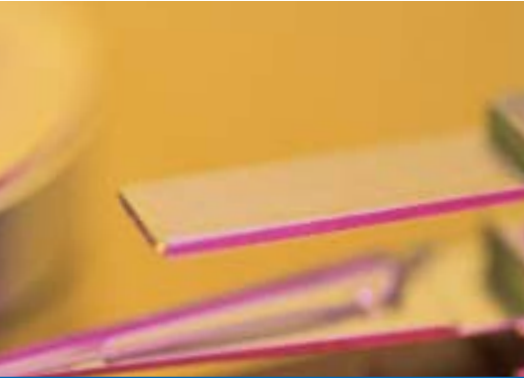


The metal atoms are emitted from the target and partially ionised by the argon ions.

BIAS VOLTAGE



All ions are accelerated towards the substrate by the BIAS voltage.



Magnetron sputtering gets its name from the magnetic field placed behind the target.

sitive, such as molybdenum disulphide, MoS_2 . This is used to produce coatings, which are used as lubricant layers. Materials with poor electrical conductivity can also be sputtered.

Magnetron sputtering is widely used in the manufacture of carbon based low-friction hard coatings (non-metallic a-C:H and metal containing Me-C:H coatings).

PRINCIPLE PROCESS	
Computer controlled phases.	

Evacuation	ca. 20– 30 mins
Heat up	ca. 30– 60 mins
Plasma cleaning	ca. 20– 60 mins
Reactive coating	ca. 120–240 mins
Cooling	ca. 10– 60 mins

FEATURES OF THE SPUTTER PROCESS	
The magnetron sputtering produces many different types of coatings.	

Coatings with very smooth surfaces
Coatings with a very low coefficient of friction
Coatings with high hardness
Use of thermally sensitive coating materials
High degree of flexibility for many coating materials
Chemically stable and inert coatings
Use of coating materials with low electrical conductivity



Materials and Pre-treatment

Most materials that can withstand being subjected to a temperature of 180°C can be coated using PVD. Therefore, tools and components made of hardened tool steel or cemented carbide are commonly coated. However, aluminium materials, non-ferrous heavy metals and electroplated plastics (e.g. ABS+Cu/Ni/Cr) can also be coated.

The rule of thumb is that the micro-roughness of the surface should not be greater than the selected coating thickness. Otherwise, a closed coating cannot be guaranteed. The functional areas which are usually coated are finish-grinded or polished. For example, a roughness value of $R_z < 2 \mu\text{m}$ must be achieved for cutting tools. It is often advisable to polish the functional area of metal forming tools up to surface qualities of $R_z < 0.5 \mu\text{m}$. Substrates with polished metallic surfaces must be cleaned of all physical contaminants such as dust, grinding and polishing agents, fingerprints, oils and waxes before the coating begins.

In the case of nitrided or eroded parts, the surfaces must first be mechanically treated by abrasive-blasting or polishing. As long as agents containing silicon are not used then there are no problems in using corrosion protection oils for transport.

The cleaning of the components is carried out in appropriate cleaning systems, modern cleaning systems operate CFC free using an aqueous and/or acid basis. Thorough alkaline and/or acid cleaning/degreasing is commonly supplemented by ultrasonic cleaning.

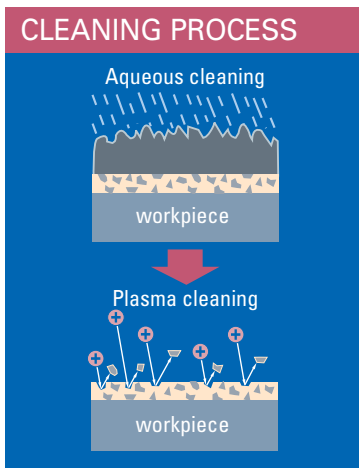
Although cleaning workpieces with ultrasonic requires costly system technology, it achieves the best cleaning effect, especially in areas that are not easily accessible such as undercuts or holes. After cleaning an extensive pure water rinsing and stain free warm air-drying of the tools follows. Thorough drying of the components is very important as certain materials can corrode very quickly. In rare cases, stain free drying is carried out using vacuum drying.

Depending on the size of the workpieces and the number of workpieces to be cleaned, determines whether small manually operated injection-clean-

COATABLE MATERIALS

Steel / stainless steel
HSS steel
Nitride steels
Cemented carbide
Titanium
Aluminium
Metal with chemical nickel
Electroplated brass
Electroplated die casting
Pre-electroplated plastics

A large number of materials can be coated using the PVD process.



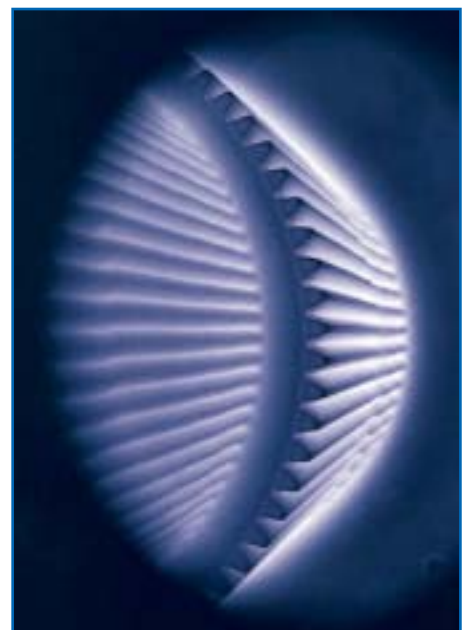
Aqueous cleaning and plasma cleaning must be carried out before the actual coating in order to achieve excellent coating adhesion.

ing systems or ultrasonic systems can be used, or if large automatic throughput systems will be necessary. The parts are ready for loading into the PVD coating plant following the aqueous cleaning. Here, plasma cleaning is carried out prior to the actual coating. This is achieved with the inert gas argon being positively electrically charged (ionised) and then accelerated by an attraction voltage. This negatively polarised attraction voltage (BIAS voltage) is applied to the workpiece to be coated.

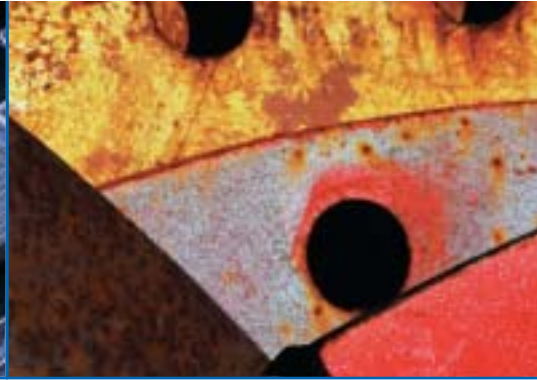
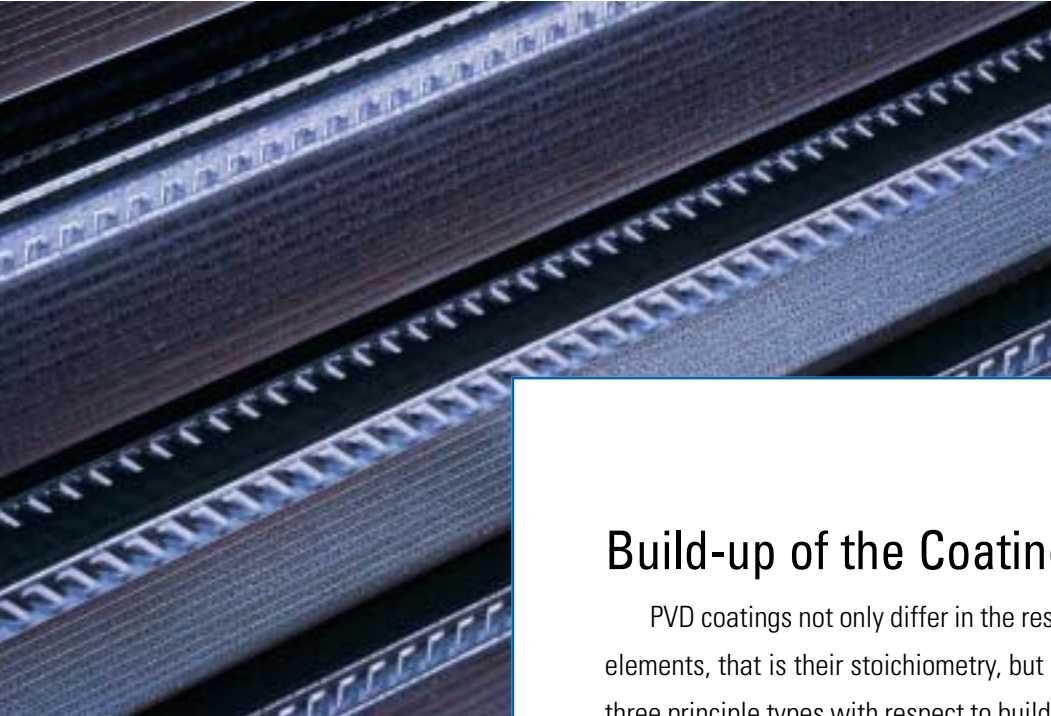
Due to the high kinetic energy of the particles, caused by the rapid acceleration, the ions impact and strip the upper layer of contaminants off of the workpiece to be coated. This combination of aqueous cleaning and plasma cleaning guarantees the clean surface which is necessary for excellent adhesion and best quality of the coating.



The aqueous cleaning is carried out, e.g. in fully automated cleaning systems.



The plasma cleaning process removes the final oxide and contaminant residues.



Build-up of the Coating

PVD coatings not only differ in the respective composition of the different elements, that is their stoichiometry, but also in the layer build-up. There are three principle types with respect to build-up: single layer coating, multi-layer coating and gradient coating.

The simplest build-up is that of single layer coating. In this form, the composition of the coating is constant throughout. In a multi-layer coating there are a sequence of defined individual layers. Each individual layer is constant throughout, however these individual layers differ amongst themselves. The thickness of the individual layers can vary from the nanometer range to the micrometer range. A multi-layer coating that is several micrometers thick may consist of two or very many individual layers.

The third important type used for special coating build-up is the gradient layer coating. In this form, the ratio of the individual layer components varies over the thickness of the coating.

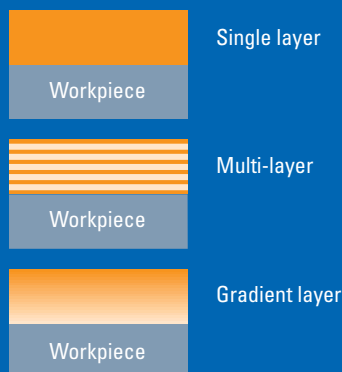
These three basic forms of coating build-up do not always exist in a pure form but can be combined, for example, a multi-layer coating with another composition can be applied to a single layer coating in order to achieve a certain overall function for the coating.

Apart from the actual properties of different types of coatings, this variety with respect to the coating build-up also explains the wide range of possible applications for PVD coatings. The layer can be specifically modelled to meet the requirements of a particular problem.

Considering the overall complex function of the workpiece and coating, it becomes clear that not only the coating build-up and the coating composition but also the basic material have their own part to play in determining the final performance properties. The actual substrate has the task of providing the strength in the workpiece to counter, for example, fatigue failure.

The task of the bond strength between the coating and the workpiece, the coating adhesion, is taken over at the boundary between the workpiece and the coating. The hardness of the bulk of the coating counters abrasion. The coating comes into contact with other media at its surface – here only a

TYPE OF COATING BUILD-UP



Different types of coating build-up allow the optimum adjustment for the respective application.

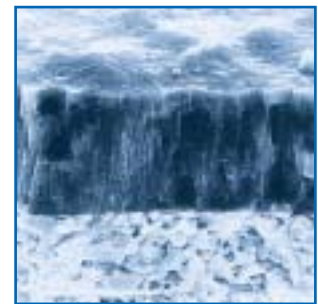


FUNCTIONAL ZONES OF PVD COATING		
Adhesion	Chemism	0.3–10 nm
Abrasion	Hardness	1–10 μm
	Compound strength	~nm
Fatigue	Workpiece strength	

The PVD coating and the workpiece form a composite with several zones, each of them has its own task.

very thin area of a few nanometers is active. This area primarily determines the chemical behaviour of the coating for example with respect to the adhesion of other media to the workpiece.

The coatings themselves are extremely resistant to corrosion, that is they have high electrochemical potential. However, they are characterised by columnar growth. Therefore, electrolytes can penetrate along the grain boundaries or in micropores. PVD coatings alone can therefore not automatically offer corrosion protection. Therefore, combination coatings can be selected for this task in which, for example, first chemical nickel and then a hard coating is applied. Further possibilities for coating build-ups lie in the combination of different coating technologies. For example, it is possible to first provide a workpiece with an electrochemical coating and to subsequently apply a PVD coating. An example of this is the PVD coating on electroplated plastics or electroplated brass components.



COMBINATION OF COATING TECHNOLOGIES

The combination of PVD coating processes with other surface treatment techniques can enhance the performance of the component.

PVD hard coating	PVD hard coating	PVD hard coating
Electrochemical coating	Electrochemical coating	
Plastics	Metal	Nitride steel



Standard types of coatings

The coatings offered by METAPLAS IONON include a wide range of standard coatings such as TiN, AlTiN or even W-C:H coatings. In addition, METAPLAS IONON also offers a range of special coatings such as multi-layer coatings for special applications to match the customer's requirements.

TiN coatings

Prominent properties are the high hardness and inert chemism. The main areas of use are found in machining and in plastics processing. The inert chemism of the golden colour TiN coatings is particularly exploited in plastics processing.



CrN coatings

Coatings with CrN have proven to be particularly useful in metal forming, plastics processing and non-ferrous heavy metal processing.

The particular characteristics of CrN are its high residual ductility and its low tendency to cold weld. CrN coatings are metallic grey in colour and can hardly be differentiated optically from other common tool steels.



TiCN coatings

TiCN coatings offer additional improved resistance against abrasive wear due to their high degree of hardness. This red-brown type of coating is mainly applied on cutting tools (drills, end mills, hob cutters), on blanking dies and punches as well as on forming tools for aluminium working.





AlTiN coatings

The AlTiN coatings stand out for their very high hardness and oxidation resistance. Therefore they are applied on drills, shell end mills and hob cutters made of HSS or cemented carbide for the machining of hard and tough materials, for high speed or dry cutting. The responding anthracite appearance is also used for decorative coatings.



ZrN coatings

The properties of ZrN coatings are comparable with those of TiN coatings. Recently they have been increasingly used in machining of aluminium casting on shell end mills or drills. Due to their white-gold appearance, ZrN coatings are frequently used as decorative coatings.



W-C:H coatings

This type of coating was specially developed for tribological highly-loaded components. W-C:H coatings have very good wear resistance and very low coefficients of friction. They are therefore especially good for finishing running surfaces in tribological systems, for example in gear wheels or on hydraulic components. Investigations have shown that it is often sufficient to only coat one friction partner with W-C:H.



Decorative coatings

The aim is to provide a combination of wear protection, easy maintenance and decorative improvements. Apart from the hard coatings already mentioned, brilliant multi-coloured layers can be created by producing highly developed multi-layer structures. By using appropriate types of coatings, graded colour transitions can also be produced in multi-coloured coatings in rainbow colours.



Properties of PVD coatings

Apart from the different possibilities for designing the build-up of the coating, the properties of the PVD coating are also determined by the properties of the individual PVD layers.

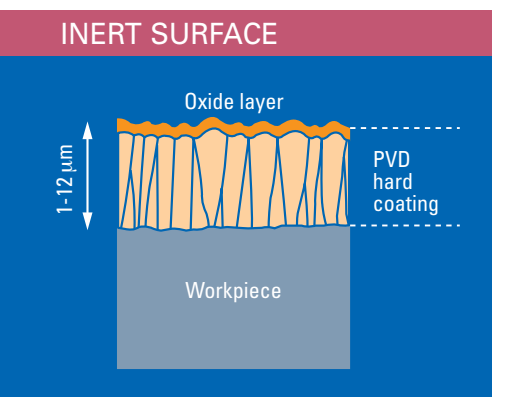
In general, the hard coatings produced industrially today are characterised by their layer hardness, high oxidation resistance, low coefficients of friction and their inert chemical behaviour.

Common to all hard coatings is the formation of a natural ceramic oxide layer on the direct surface with a layer thickness in the order of several times ten nanometers. This results in an inert chemism of the hard coatings. The unwanted tribooxidation of the tool during the cutting process can be considerable decreased by means of using a PVD coating.

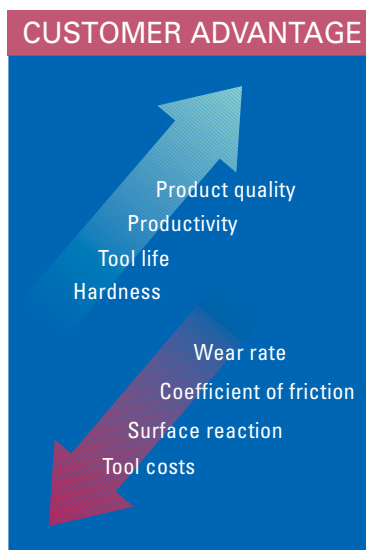
Hard coatings are extraordinarily chemically resistant and inert. Hard coatings display a tendency to low adhesion or welding to other materials. Cutting edges and working areas remain free of built-up edges and cold welds. Due to the achieved surface quality of the product the step of postprocessing can often be reduced or saved.

The high hardness, which results from the highly covalent bonding proportion of the atoms of the layer, counters abrasion. For tools within machining the high hardness reduces significantly free area and crater wear. Very good adhesion and the quasi-elastic behaviour of the thin film prevent flaking and cracks on the cutting edges and functional areas even at highest stresses or high cutting forces. The reduced friction between the hard coatings and steel or other materials reduces the cutting and forming forces and the heat produced during processing.

Compared to a steel substrate the coatings have a lower thermal expansion. In the cooled state they are therefore subjected to compressive stress, which counters the spread of surface cracks. If the coating takes up a point or linear loading, the base material must pro-



The natural ceramic oxide layer of PVD hard coatings ensures an inert and protective surface.



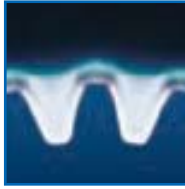
PVD coatings allow operational properties to be optimised.

vide sufficient support (hardness), otherwise the coating can break into the too soft base material.

Due to the mentioned properties the application of PVD coatings achieve considerable customer advantages such as decreasing tool costs or increasing productivity.

This method cannot be used for the deposition of adhesive coatings on ceramic. In addition, it should also be noted that shading effects can occur in holes and undercuts. The inside coating of holes to a depth which exceeds the diameter of the hole is not possible.

SELECTED COATING PROPERTIES						
Coating material	TiN	TiCN	CrN	ZrN	AlTiN	W-C:H
Hardness HK (1N)	2500 ±400	2900 ±400	2300 ±300	2400 ±400	3000 ±400	900 to 1400
Temperature resistance °C	550 ±50	450 ±50	650 ±50	600 ±50	800 ±50	350 ±50
Electr. resistance $\mu\Omega$ cm	60 ±20	8 ±20	640	30 ±10	4000– 7000	– –
Thermal conductivity (Ws ^{0.5})/m ² K	8800 ±1000	8100 ±1400	8100 ±2600		7000 ±400	7600 ±1000
Coefficient of friction (100Cr6)	0.65– 0.70	0.40– 0.50	0.50– 0.60	0.50– 0.60	0.55– 0.65	0.15– 0.30
Layer thickness (µm)	2–4	2–4	3–8	2–4	2–4	1–5
Colour	gold-yellow	red-brown/ grey	silver	light gold	anthracite	anthracite/ blue-grey
Ductility	good	satisfactory	very good	good	satisfactory	–



IONIT®

Plasma nitriding technology and equipments, leading in technology, quality and profitability.



IONIT OX®

Equipments and service for environmentally-friendly corrosion protection with patented nitriding processes.



MAXIT®

PVD technologies and equipments for hard coating, low friction coating, decorative applications and more.

METAPLAS IONON

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