Coatings for friction coefficient reduction in combination with corrosion and wear protection

DIAGLIDE®

THE FLEXIBLE COATING FOR SLIDING SURFACES

Low friction coefficients **for heavily loaded tribological systems** guarantee long-lasting solutions with **DIA**GLIDE®

THE MOST IMPORTANT PLUS POINTS:

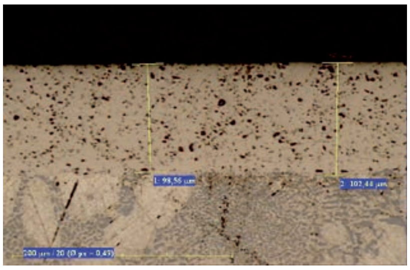
+ The all-rounder for tribological systems
+ Reduces friction and wear
+ Can be used on all components
+ High lubricant film affinity
+ and much more

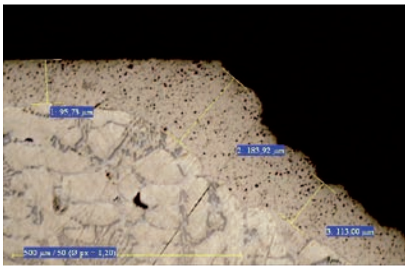
SOLUTION EXAMPLES

THERE IS ALWAYS A PERFECT SOLUTION

The requirements are different for each component. Our **DIA**GLIDE® coating process is flexible and has an adjustable degree of hardness. We adapt to your needs. Please feel free to get in touch.

*Further information and a film about how **DIA**GLIDE® works can be found here or at www.cct-plating.com/diaglide*





__DIA__GLIDE® Coatings can be applied to any component with contour accuracy.

Rotor shaft

AT A GLANCE

TYPE:
Composite or dispersion coating based on nickel and nickel-phosphorus on metal substrate.

PROPERTIES:
> Wear-resistant friction pairing of metallic components
> Adjustable hardness of the nickel-phosphorus layer (approx. 550 HV0.1 to approx. 950 HV0.1).
> High corrosion resistance with nickel and with nickel-phosphorus
> Good contour accuracy or very uniform coating thickness with electroless nickel
> High layer thicknesses when using electroplated nickel

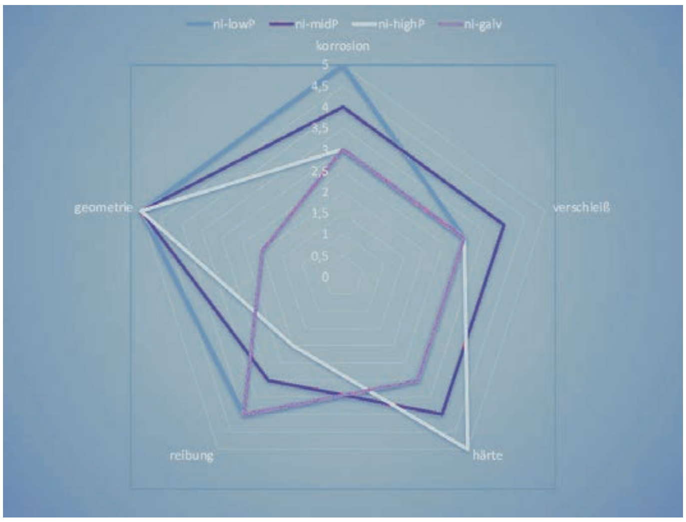
USE:
Tribological pairings in functional systems with high friction and corrosion loads with and without temperature stress, e.g. hydraulic systems, pressure cylinders, engine and gearbox components, cylinder tracks.

COATING CHARACTERISTICS:
Nickel or nickel-phosphorus layer from approx. 5 µm to approx.
800 µm with dispersion materials (SiC, B4C) nano-dispersions (< 1 µm) up to dispersions > 100 µm
Coefficient of friction µ = <0.3 depending on post-processing (finishing)

SUBSTRATE CHARACTERISTICS:
Electro-platable base material with adapted, defined roughness

ADVANTAGES OF USING FRICTION-REDUCING COATINGS **DIAGLIDE®**

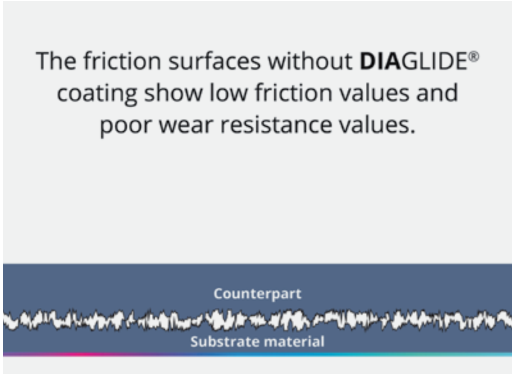
+ The all-rounder for tribological systems
+ Reduces friction and wear
+ Can be used on all components
+ High lubricant film affinity
+ Optimum sliding behaviour
+ Wear-resistant friction pairing
+ Durable corrosion protection
+ Adjustable hardness (400 - 1,100 HV)
+ Increase of the safety factor
+ Cost reduction of individual components
+ Easy handling

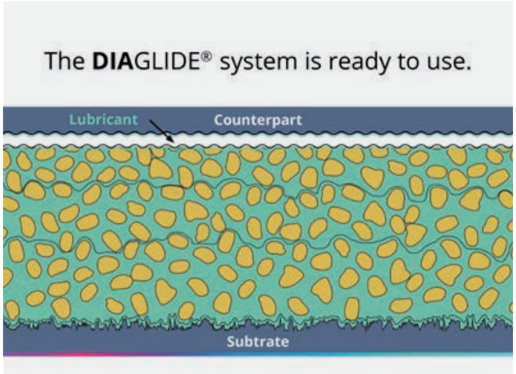


Overview of all advantages in the network diagram

The composite and dispersion coatings based on nickel, nickel-phosphorus and chromium are characterised by the fact that they have several important properties, or rather that the **properties can be adapted to the requirements of the application depending on the composition and/or heat treatment.** This can be illustrated by means of a network diagram for qualitative evaluation, on the basis of which the user can select the required properties.

APPLICATION





Schematic representation of a wear-resistant DIAGLIDE® system consisting of dispersion layer and counterpart of friction pairing.

In numerous applications, it is necessary to move metallic components on top of each other without them being subject to noticeable wear during use. Depending on the area of application, such component or material contact can take place with or without additional lubricant.

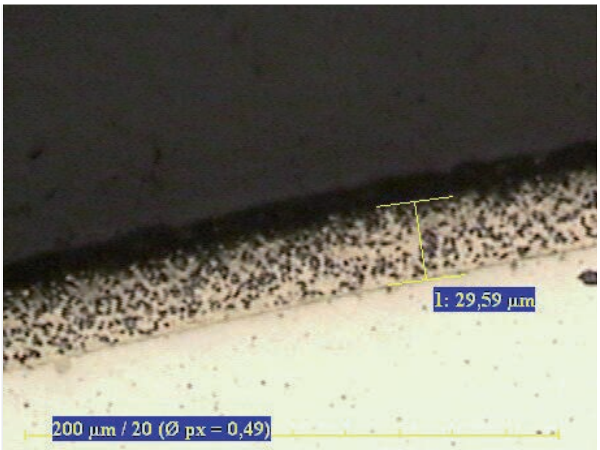
Typical examples of components are rotors and plungers for oil production, drive components for combustion engines, gearboxes or compressors, hydraulic cylinders or hydraulic components, pumps, pressure cylinders or components in textile machines. In most cases, the requirements go beyond a high wear resistance paired with low friction, in that, in particular, a high corrosion resistance of the surface is also needed. In addition, applied **DIA**GLIDE® coating systems must have exceptionally good adhesion to the base material and, in the case of cost-intensive components, allow damaged or worn surfaces to be repaired.

Wear-resistant coatings with a high degree of widespread use are mainly those based on chromium and nickel or nickel alloys, which are used for **DIA**GLIDE® coatings. Both materials have a high to very high basic hardness. Hard materials withstand the mechanical stresses caused by pressure and/or friction. This avoids the break-out and break-off of coating fragments If, on the other hand, such break-outs and break-offs occur and get caught between moving components, they act as abrasive particles and increase the damage to the surface due to wear. Another possibility for reducing wear is the incorporation of friction-reducing solid lubricants – so-called dispersion layers. Proven solid lubricants include, for example, PTFE (polytetrafluoroethylene - Teflon), hexagonal boron nitride, but also graphite and MoS_2. As a matrix material for embedding solid lubricants, electroplated and electroless nickel as well as nickel-phosphorus alloys offer ideal conditions for producing surfaces with different properties tailored to the respective application. The hardness of the layers can be adjusted in a range between about 450 HV and about 1,100 HV. The corrosion resistance of the coatings varies depending on the selected phosphorus content.

APPLICATION EXAMPLE HYDRAULICS

In hydraulic systems, especially in cylinders for power transmission, the components used are subject to high loads due to friction because of the small permissible gap width, e.g. between cylinders and pistons. For this purpose, the friction contact surfaces are designed to be very smooth (minimum roughness). In order for the lubricants used to have the best possible effect, good adhesion of the oil film must also be ensured. Here, galvanically applied nickel dispersion layers with silicon carbide (SiC) as an embedded component prove to be a good option. Usual characteristic values for the layer are:

Layer thickness:	20 µm - 800 µm
Proportion of SiC:	3 wt.% - 8 wt.%
Grain size:	0,5 µm - 3 µm
Layer hardness:	550 HV0.1 - 650 HV0.1



Alternatively, a nickel-phosphorus alloy, also galvanically deposited, can be used instead of the pure nickel layer for these requirements:

Layer thickness:	10 µm - 200 µm
Proportion of SiC:	approx. 5 wt.% / 20 - 25 vol %
Grain size:	1 µm - 3 Nano / µm
Phosphorus content of the coating:	2 % - 12 %
Layer hardness:	400 - 1.100 HV0.1 (with/ without heat treatment)

*The electrolessly deposited **DIA**GLIDE® nickel-phosphorus layer with built-in hexagonal boron nitride (hBN) for stresses caused by sliding wear and corrosive media.*

***DIA**GLIDE® is used, for example, in motorbikes and racing.*

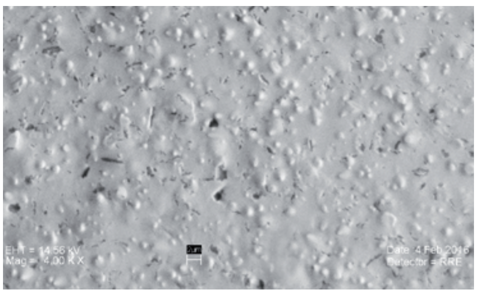
CHARACTERISTIC VALUES FOR WEAR/CORROSION PROTECTION THROUGH **DIA**GLIDE® COATINGS

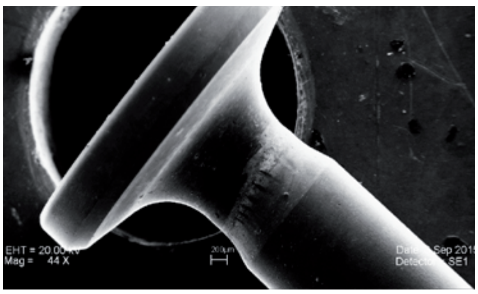
Metal workpieces are given improved properties with regard to wear and corrosion by the application of **DIA**GLIDE® coatings. Depending on the application, different variants from the group of composite and dispersion coatings are available.

Variants by electroless deposition	Variants by electrolytic deposition
Nickel + nickel-phosphorus dispersion	Nickel + nickel dispersion
-	Nickel + chromium (chromium electrolytic)
Nickel-phosphorus + nickel-phosphorus dispersion	Nickel + nickel-phosphorus dispersion
Nickel + chromium	Nickel-phosphorus + nickel-phosphorus dispersion
Nickel-phosphorus + chromium	-

The alloy variant nickel-phosphorus can be deposited both electrolessly/external current-free (> **high contour accuracy,** > **low deposition speed) and electrolytically (** > **low contour accuracy,** > **high deposition speed). Electrolessly deposited nickel is preferred for layer thicknesses below 30 µm (0.03 mm) due to the low deposition speed. Electrolytically deposited nickel is suitable for layers up to several millimetres thick.** For dispersion coatings based on nickel, the following variants are available:

Characteristic	Electrolessly deposited	Electroplated
Deposition rate	0,17 µm/min - 0,35 µm/min	3 µm/min - 10 µm/min
Material	Nickel-phosphorus alloy with 2 % to 12 % phosphorus	Nickel + nickel-phosphorus with 2 % to 12 % phosphorus
Layer thicknesses	up to 30 µm (in exceptional cases up to 100 µm)	50 µm - 200 µm (up to 1000 µm on request)
Dispersion material	Diamond, silicon carbide (SiC), Hex. Boron nitride (hBN), boron carbide (B_4C), PTFE; nanoparticles (< 1 µm)	Diamond, silicon carbide (SiC), Hex. Boron nitride (hBN), boron carbide (B_4C)
Particle sizes	1-3 Nano / µm (for special applications up to 50 µm)	1-3 Nano / µm
Contour accuracy	High	Medium-high





Top view of a nickel layer with SiC coating

PREREQUISITES FOR WEAR/CORROSION PROTECTION BY **DIA**GLIDE® COATINGS

The property of reducing the friction coefficient is linked to certain design prerequisites, or rather, certain designs influence the properties of the protective coatings:

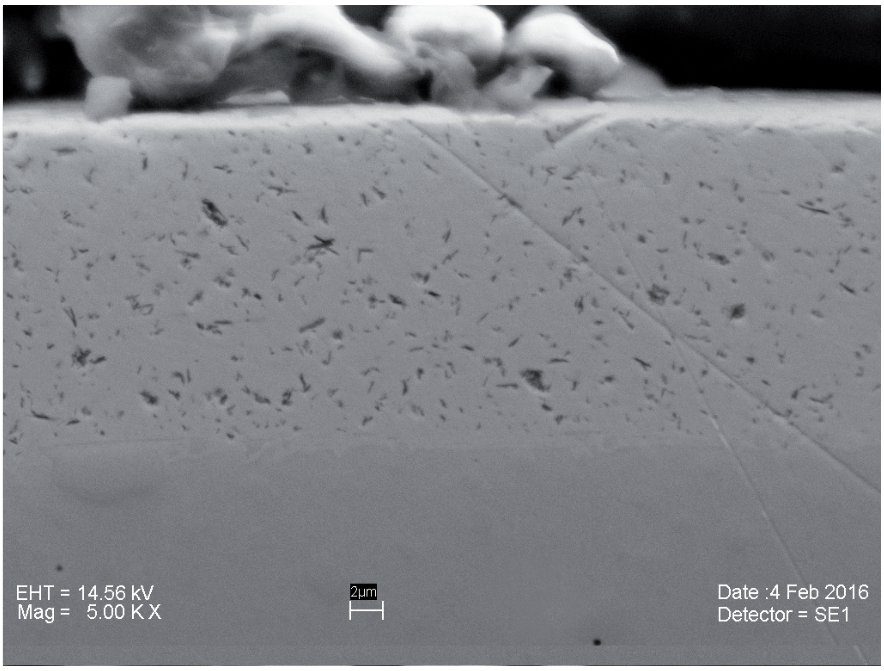
> Design of contact surfaces – wear when surfaces rub against each other is greatly influenced by the type and size of the actual (microscopic) contact surfaces. The roughness of the contact surfaces as well as the orientation of processing structures such as turning or grinding grooves play a role here. The smoother a surface, the larger the actual contact surfaces and the lower the actual surface pressure at the contact surfaces. The severity of wear tends to increase with an increase in the surface roughness of one or both friction partners.

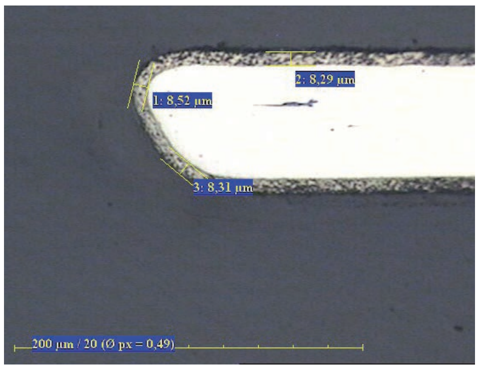
> Hardness of the surface of the contact surfaces – a higher surface hardness improves the resistance to shearing or breaking off of material from the component surfaces of the friction partners. The risk of shearing or chipping is lower if the surfaces of the friction partners are made of the same material.

> Mechanical properties of the substrate – Coatings with high hardness, such as chromium, require a substrate with sufficiently high strength to avoid cracking or breaking; alloy steels, for example, are ideally suited.

> Coating of the contact surfaces with foreign substances – the friction properties of two tribological surfaces are changed by the presence of foreign substances (oil, grease, dirt). Oil and grease usually have a positive influence on the friction properties, dirt a negative influence. However, oils and greases as well as any degradation products that may arise can impair the corrosion resistance. If dispersion coatings are used, it must be checked as to what extent foreign substances impair the effect of the deposited particles.

> Design – electroless nickel coatings (primarily nickel) are characterised by a high degree of contour accuracy and do not require mechanical finishing to achieve surfaces with a high degree of accuracy of fit. With electroplated coatings, edge build-up must be expected, which becomes more pronounced with increasing coating thickness. In individual cases, the possibilities for mechanical finishing must be checked before applying a coating.





Cross-section through the electroplated nickel dispersion layer ***DIA****GLIDE® with embedded nanoparticles (left) and an electroless nickel-phosphorus layer with embedded silicon carbide (SiC) and very good, contour-true layer distribution (top).*