Thin Film Coating Technologies – Surface Solutions for Plastic Processing

Coatings in the 2µm to 10µm range (0.00008” to 0.0004”)

November 11, 2015 Society of Plastics Industries
Pomona, California

Agenda

1	Types of coatings used on/in plastic molds and tooling
2	Purposes for coatings on/in plastic molding
3	Application Injection Molding
4	Application Extrusion Processing
5	Application Under the Surface / Base Hardness
6	Dual Solutions, Applications Requiring Multiple Effects
7	Q&A

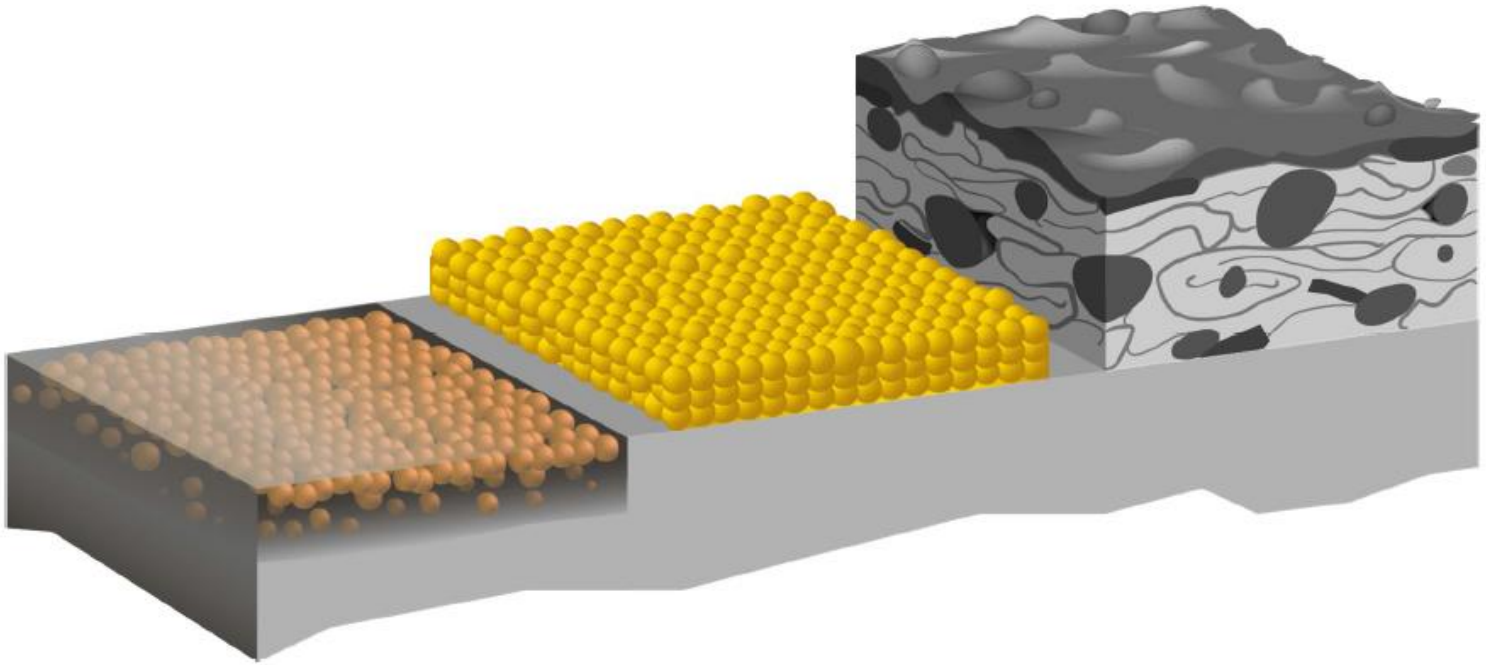
Types of Surface Treatments

Surface treatments

NITRIDING
- Plasma Nitriding

THIN FILM COATING
- PVD
- PECVD (PACVD)

THICKER LAYER COATING
- Thermal Spray
- Laser Cladding/ PTA



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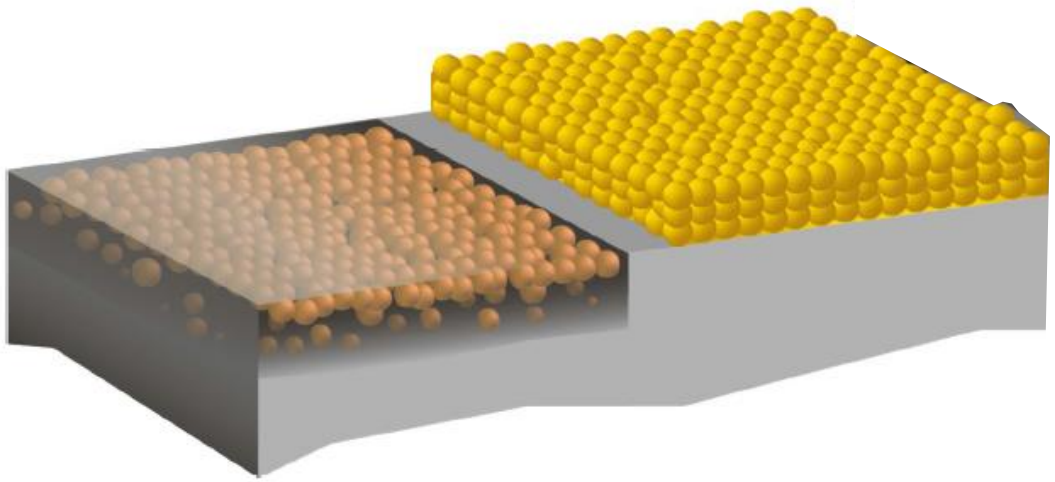


Specific Issues Facing the Plastic Molder

Mold Wear

- Many families of plastics contain fillers that are highly abrasive
- Base tool materials can be dictated by wear issues
- Use of lubricants not always possible due to contamination

Mold Release

- The type plastic molded, the cooling time needed to release the molded part without deformation dictate the productivity
- Contamination issues in the Food & Medical industries may prevent the use of release agents
- Ease of release can have a direct bearing on the bottom line

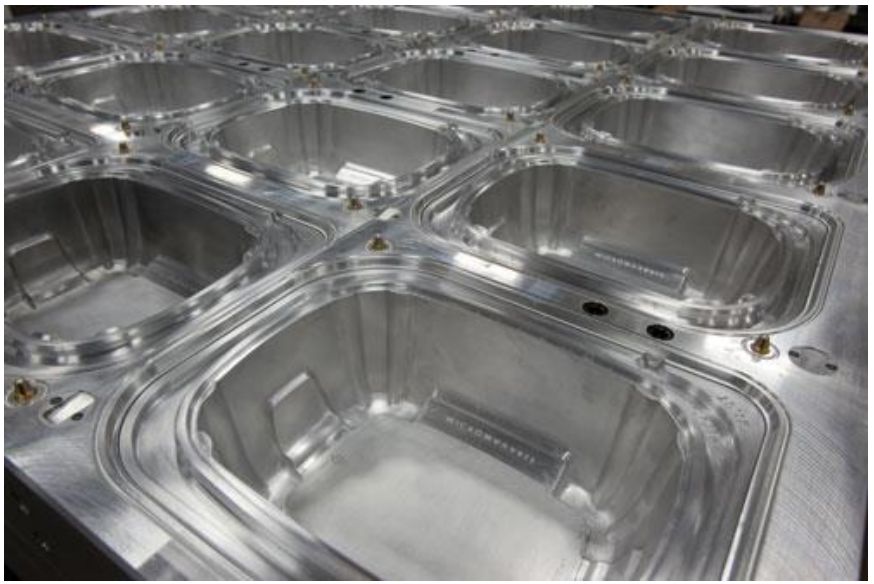
Corrosion Resistance

- Several plastic mold materials generate corrosive by-products
- Base tool choice of materials and working life will be affected by corrosion issues

Use of Alloys and Exotic Substrate Materials in the Fabrication of Molds/Tools

Mold construction are incorporating more heat sinking and dissipative materials such as:

a. **Beriliyum Copper Alloys**
b. **Aluminums Alloys**
c. **Ceramic inserts, etc.**



These highly thermal conductive materials help in mold process achievements, but can become prematurely worn due to their softness in molding today's resin materials.

Coatings can prolong tool life thru wear & abrasion resistance

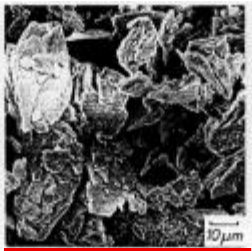
Part Ejection and De-molding Challenges

Complex mold / tool geometries or plastic resin types causing issues of Sticking

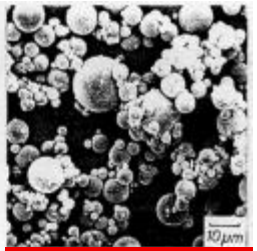
Coatings can be a means of effectively reducing the surface tension in tool cavities creating a more permanent solution over temporary sprays

Hard or abrasive filler materials used in plastics Include items such as:

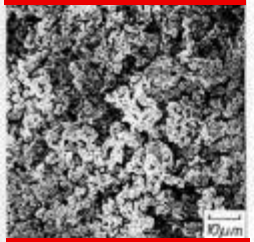
Quartz powder



Talcum

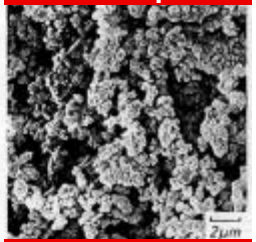


Glass marbles Ø 0-20 µm



Chalk

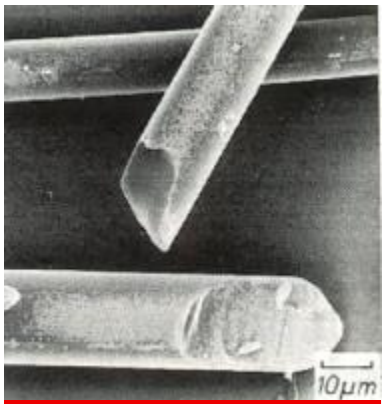
Titanium dioxide



Chromium oxide

Hardness

- Glass ~600 HV
- Quartz 1200 HV
- TiO2 1200 HV
- Cr2O3 2300 HV



Glass fiber

Glass fibers in plastics processing

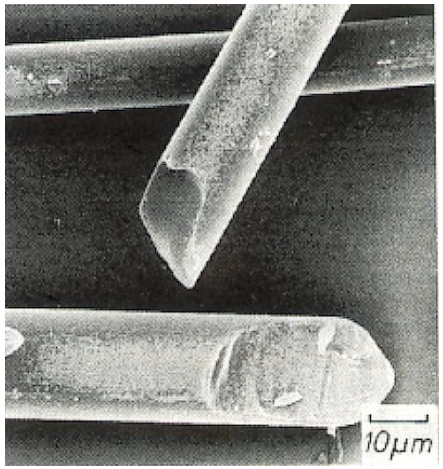
- Hardness: 1200 HV
- Sharp jagged edges
- Abrasive wear by micro cutting

Wear mechanism

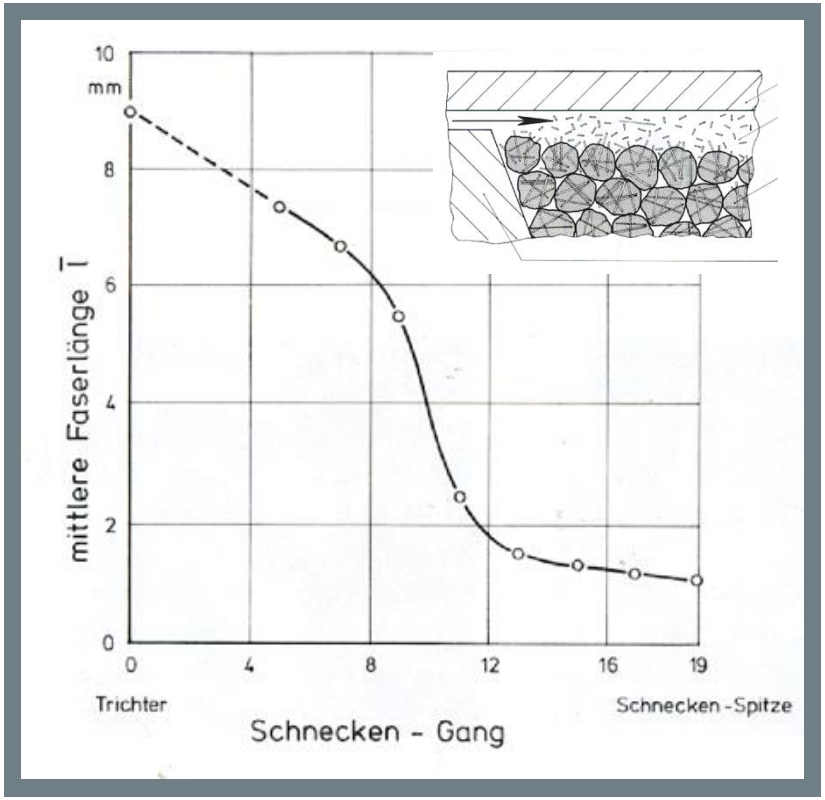
Glass fibers in plastics processing

Often used for increasing stiffness has sharp jagged edges

→ **Causing abrasive wear by micro cutting**



Hardness: 1200 HV



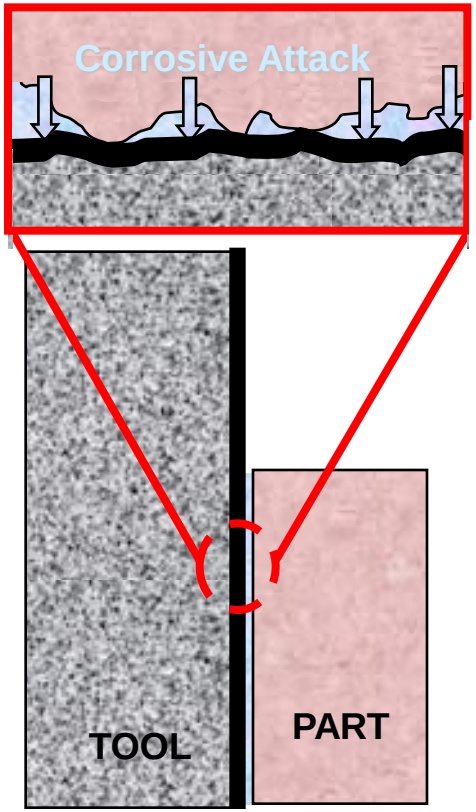
Effective Corrosion Retardation

“Thin Film” Carbon based coating

After 192 hours

TiN

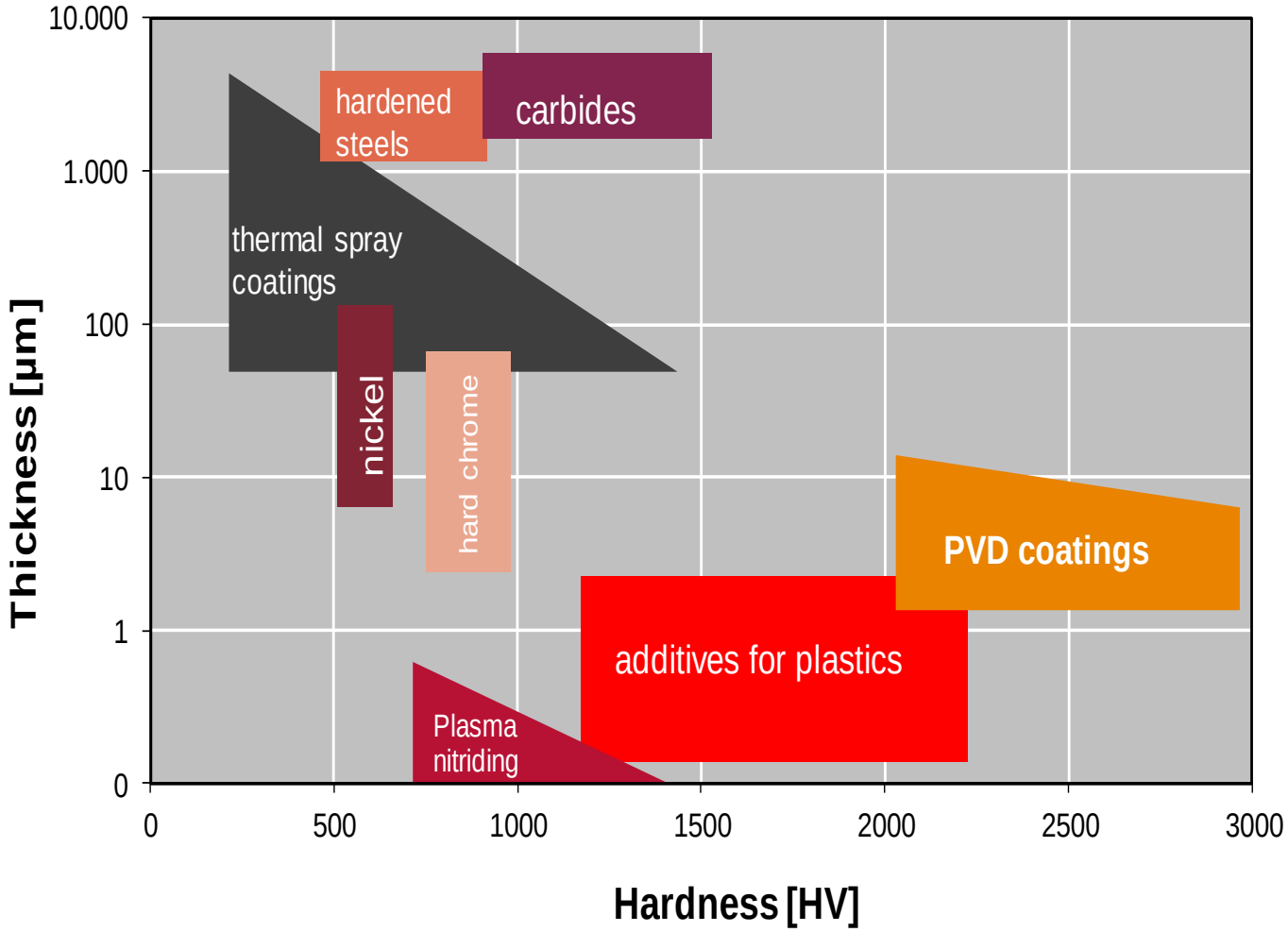
ASTM B 117-97 Salt Spray Test



The high density and amorphous structure of Diamond-Like Coatings inhibit the corrosive by-products from penetrating into the tool.

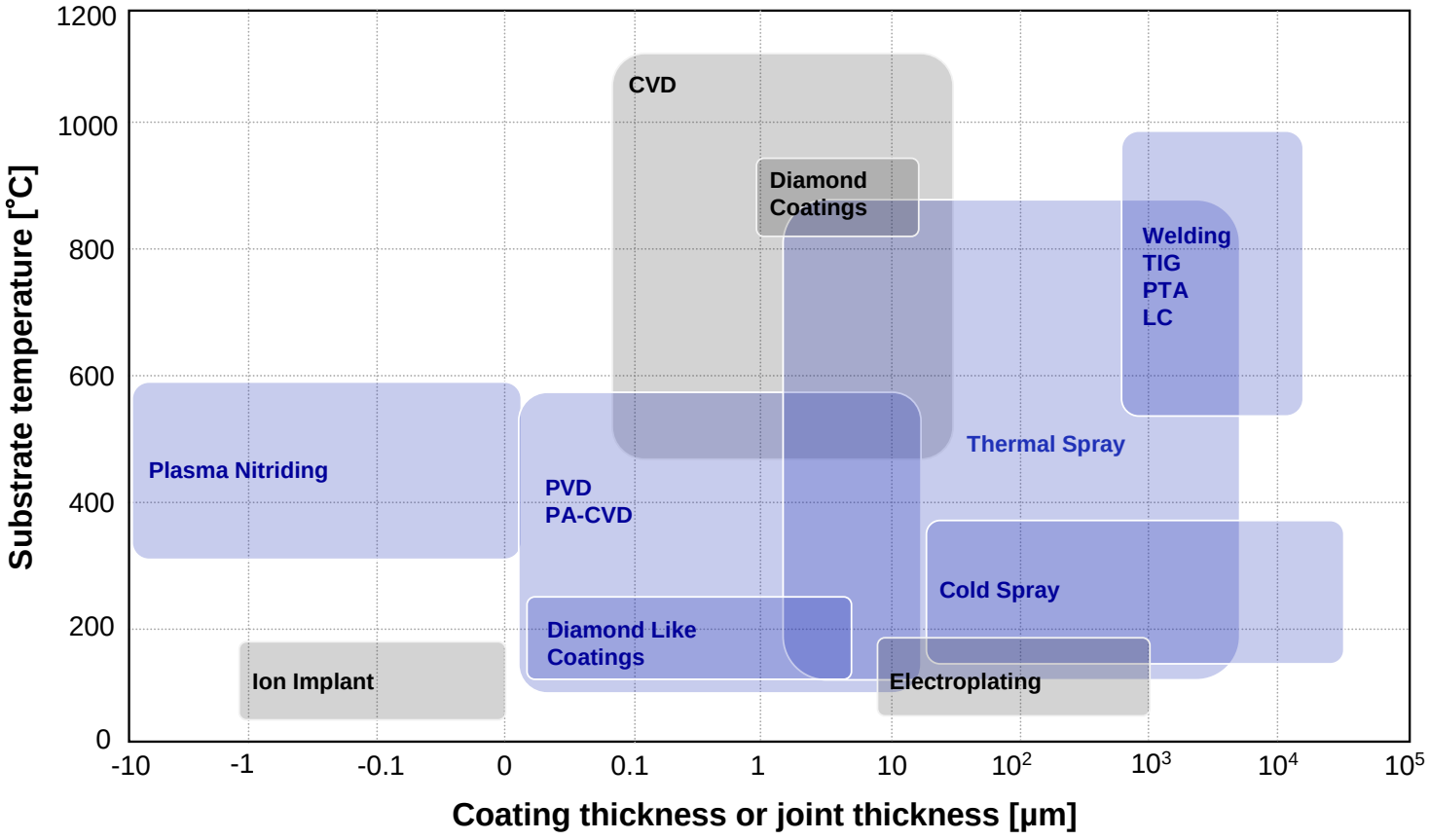
With So Many Coating Types Available, How Do You Know What's Best for the application ?

Hardness/ thickness comparison



Landscape of Various Coating Processes

There are a number of different coating processes for different purposes

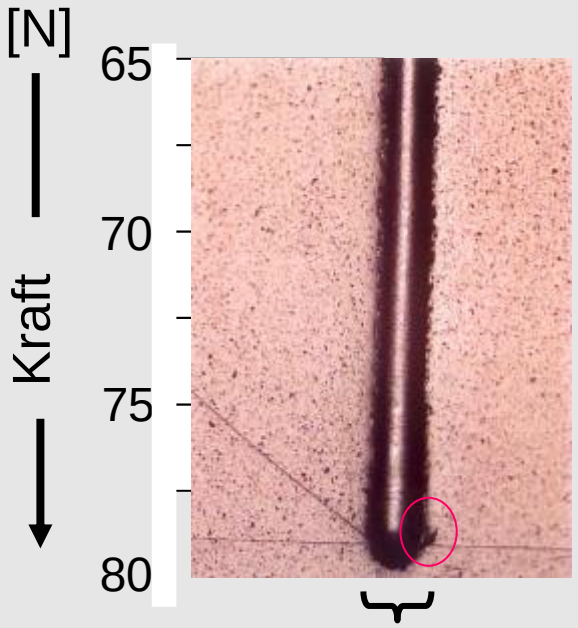


Graph for illustration purposes only, not scientifically exhaustive

CVD:	Chemical Vapor Deposition	PVD:	Physical Vapor Deposition
Friction:	Carbon Friction Layers	PTA:	Plasma Transferred Arc
LC:	Laser Cladding	TIG:	Tungsten Inert Gas
PACVD:	Plasma Assisted CVD		

Scratch test compared on 1.2343 (H11)

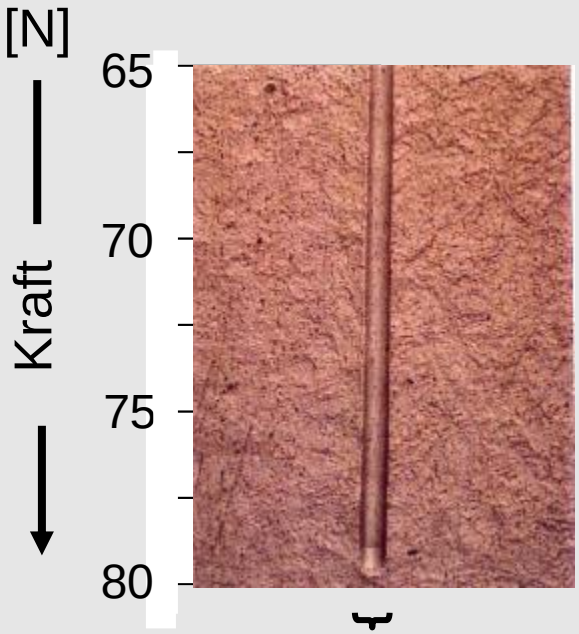
® D on 1.2343



depth of penetration : **33 µm**

Appropriation of coating breakdown

® D Duplex on 1.2343



depth of penetration : **6,5 µm**

Coating Solutions and Properties Chart

Common topicals used on plastic tooling

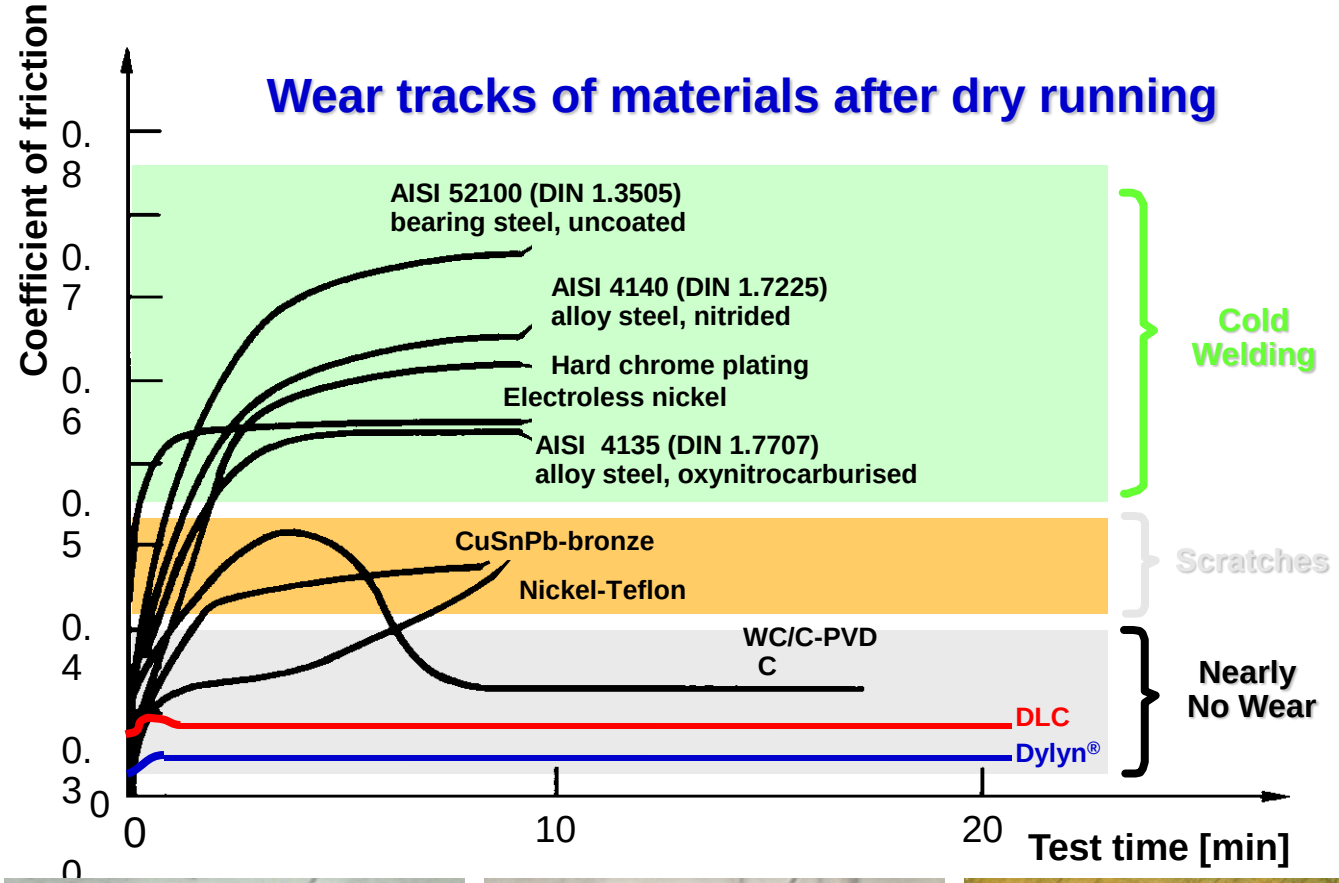
	Properties of DLC Coatings				Properties of PVD Coatings					Defusion Coating	Properties of Other Surface Treatments		
COATING MATERIAL	Balinit C	P.DYLYN® /DLC A	P.DYLYN® 180	P.DYLYN® S	P.TiN	P.CrN	P.CrNmulti	P.CrNmod	P.CrNmod APA	Primeform	*Chrome	*Nickel Teflon	*B_4C
NAME	W-C:H	Ti + C:H:Si:O + a-C:H	a-C:H:Si:O	a-C:H:Si:O	TiN	CrN	CrN (Multilayer)	CrN (Multilayer with top layer)	CrN (Multilayer with top layer)	N + Y	Electroplated CHROME	Electrolysis Nickel Teflon® composite	Diamond Black
Microhardness (GPa)	10 - 15	25	18	10	25	23	25	25	25	11 - 16	8 - 12	4 - 8	35
Rockwell C	68 - 74	85	78	68	85	83	85	85	85	69 - 75	64 - 70	40 - 60	95
Coefficient of Friction Against Steel (Dry)	0.15	0.1	0.05	0.04	0.4	0.35	0.35	0.3	0.3	0.4 - 0.5	0.2 - 0.4	0.1 - 0.3	0.35 - 0.4
Coating Thickness (µm)	1 - 3	1 - 4	1 - 4	1 - 4	1 - 4	1 - 7	2 - 7	2 - 7	2 - 7	10 - 50 defusion zone	Up to 50	5 - 50	1 - 4
Max. Working Temperature	660 °F 350 °C	570 °F 300 °C	750 °F 400 °C	750 °F 400 °C	1000 °F 600 °C	1150 °F 650 °C	1300 °F 700 °C	1300 °F 700 °C	1300 °F 700 °C	750 °F 400 °C	600 °F 325 °C	750 °F 400 °C	1800 °F 980 °C
Coating Temperature	390°F 200°C	390°F 200°C	390°F 200°C	390°F 200°C	390 / 750 °F 200 / 400 °C	390 / 750 °F 200 / 400 °C	390 / 750 °F 200 / 400 °C	390 / 750 °F 200 / 400 °C	480 / 750 °F 250 / 400 °C	715 °F 380 °C	120 - 175 °F 50 - 80 °C	120 - 175 °F 50 - 80 °C	500 - 950 °F 260 - 500 °C
Wear Factor (x 10^{-8} mm^3/Nm)	40 ++	1 - 5 ++++	5 - 10 +++	10 - 20 ++	250 ++	++	+++	+++	+++	++++	+	+	++
Surface Energy (mN/m)		40 - 50	20 - 40	18 - 30	40 - 42	30 - 40						20 - 30	
Coating Method	PVD	PACVD	PACVD	PACVD	PVD	PVD	PVD	PVD	PVD	PN	Galvanic Plating	Electrolysis Plating	PVD

Note a Combi Treatment of P.IONIT® + *x* (where "x" stands for any PVD or DLC coating) can be done

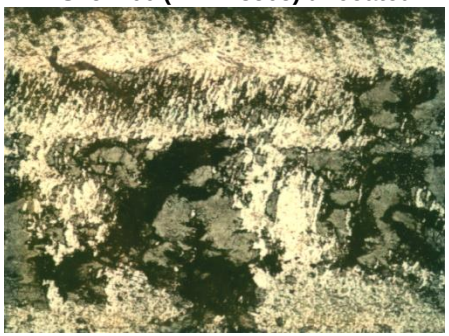
Dry Running Properties of Materials

oerlikon metco

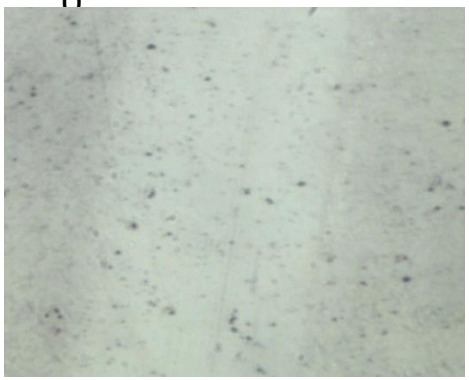
Wear tracks of materials after dry running



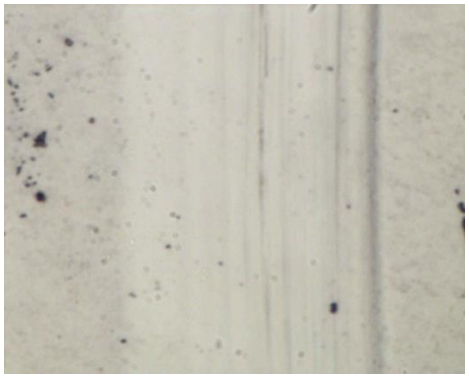
AISI 52100 (DIN 1.3505) uncoated



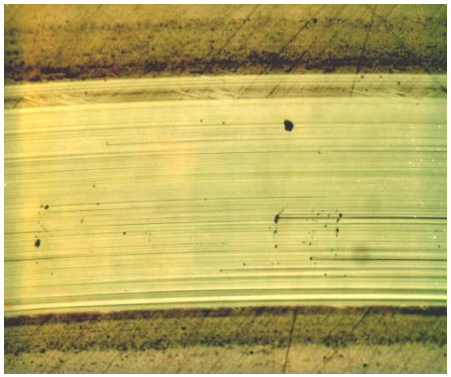
AISI 4140 (DIN 1.7225) nitrided



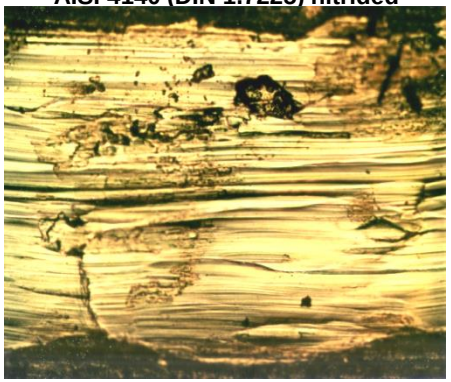
Dylyn®



DLC

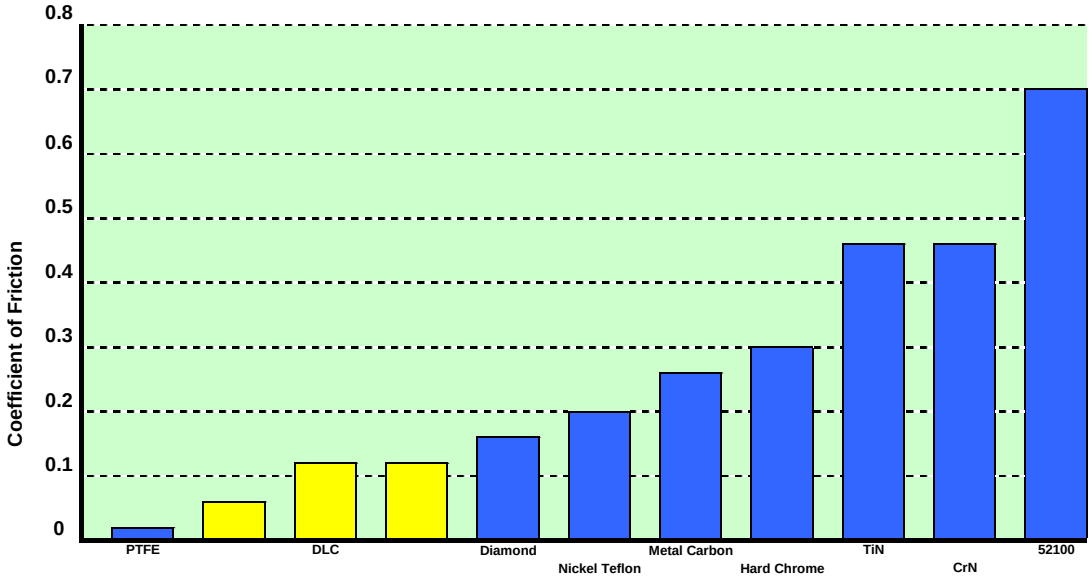


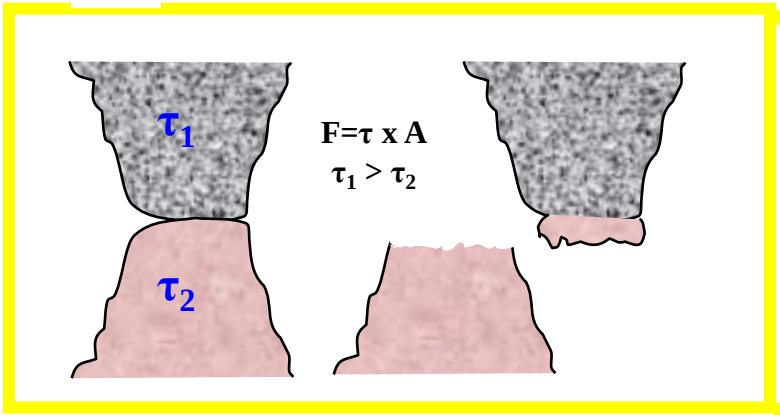
AISI 52100 + ® C (WC/C)

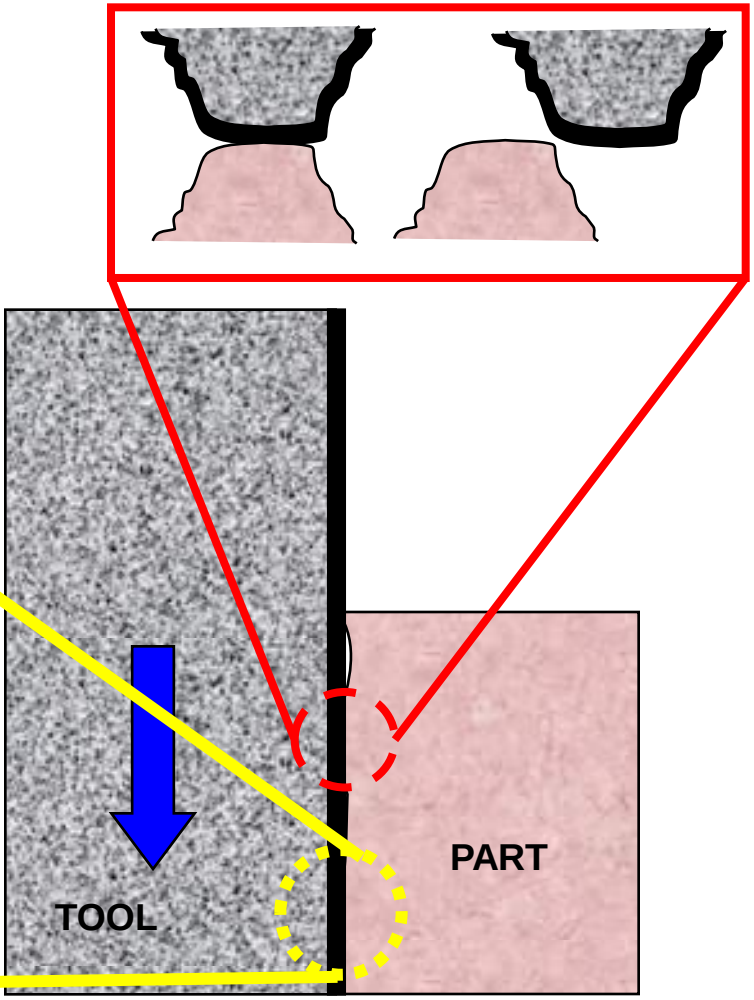


Cu Sn Pb - bronze

Coatings Reduce Friction / Material Pickup







RESISTANCE TO ADHESION:

The chemically inert characteristics of diamond-like coatings dramatically reduce possibility of cold welding and material pickup on the surface of the tool

Coefficient of Friction, Surface Tensions of Materials, Sticking and Why Surfaces Matters

What's Holding You Back?

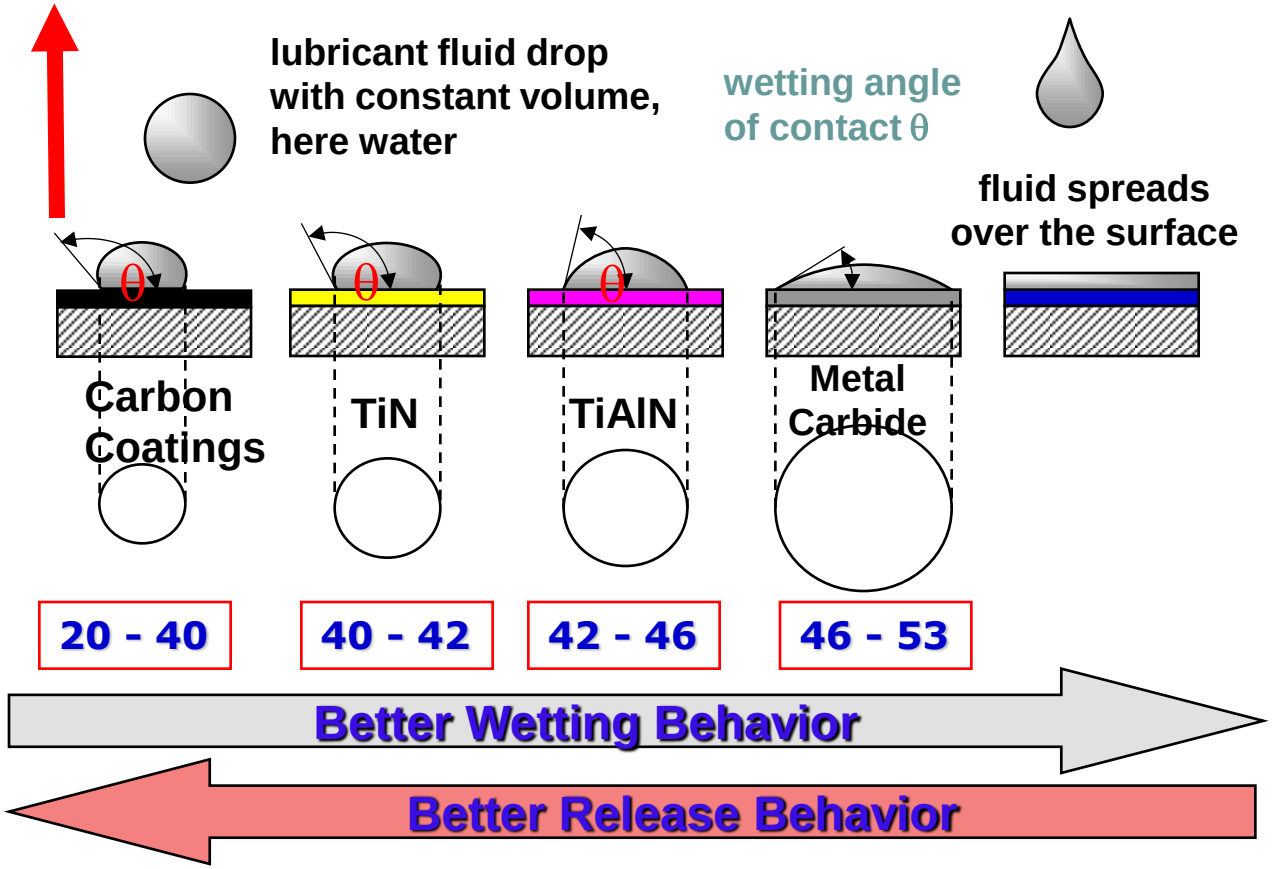
Sticking, Stiction and Dragging Force

Definition - Frictional force is the force exerted on a surface when an object moves across it - or makes an effort to move across it.

- **Sticking can occur in a mold as a result of**;
  - Undercuts or negative geometries
  - Vacuum, due to poor or little venting
  - Resin materials are tacky or low durometers
  - High concentration of fillers within the resin materials

Surface Energy & Wetting Behavior of Different Coatings

Close-up of a series of liquid droplets on a carbon-based coated sample



- Surface energy is a measure of the affinity of a substance to stick to the material.
- The lower the value, the less likely a material will weld or stick to a surface.
- PFTE has a surface energy of 18 mN/m

Surface Energy (mN/m)

Applications

Reduced Friction In Sliding/Functional Parts

Coatings that reduce the need for lubrication in food, beverage and medical tooling

- Rotating Cores
- Mold Locks
- Ejector Pins
- Stripper Plates
- Horn Pins
- Gate Inserts
- Guide Pins
- Slides
- Tapers

Reducing risk for contaminating molded parts with heavy grease

Injection molding - Ejector sleeves

Product: Closures for food packaging

Before: competitive coating with grease

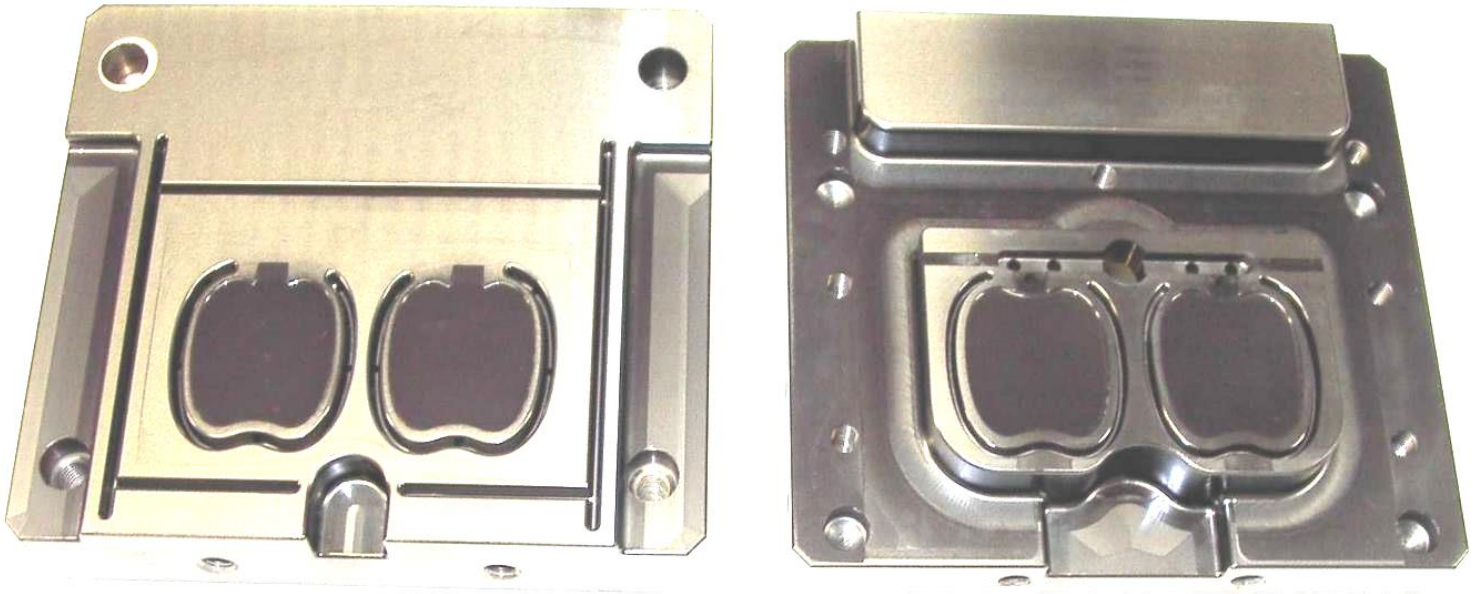
- Lifetime not satisfactory
- Black visible abrasion on produced closures

NOW: Carbon based coating without grease

- Last documented wear control after 4 million shots without visible wear
- No break-in period needed so no black stained parts produced

Injection Molding - Mold Inserts for Sight Glass Mobile Phones

Product: **Sight glasses for mobile phones**



Before: **Uncoated**

- Build-up of residues
- Removing residue produces scratches
- Corrosion
- Carbide erosion

NOW: **DLC Coating Solution**

- All 4 demands solved with ***ONE*** coating!
- No change of transparency of the product
- No post-polish necessary because coating has no change of roughness

Applications: Parts for injection molding machine coated with Chromium Nitride Coating, reduces sticking & wear tendencies

Wear in plastics processing

catalytic decomposition
(separation of Cl and F)

abrasive wear
by hard particles
(glass fibers; $CaCO_3$; TiO_2)

deposits as a result of micro cracking and **chemical adhesion**

corrosion

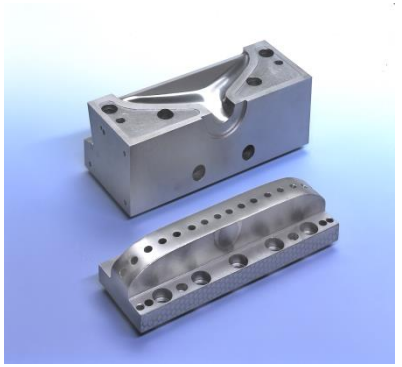
Advantages of Chromium for: Mandrels, Screws & Dies

Reduced sticking of plastic material which

- avoids little burners that show in the foil
- better cleaning during maintenance
- longer intervals between cleaning
- better flow of material with higher throughput
- Screws: quicker purging times in case of color changes

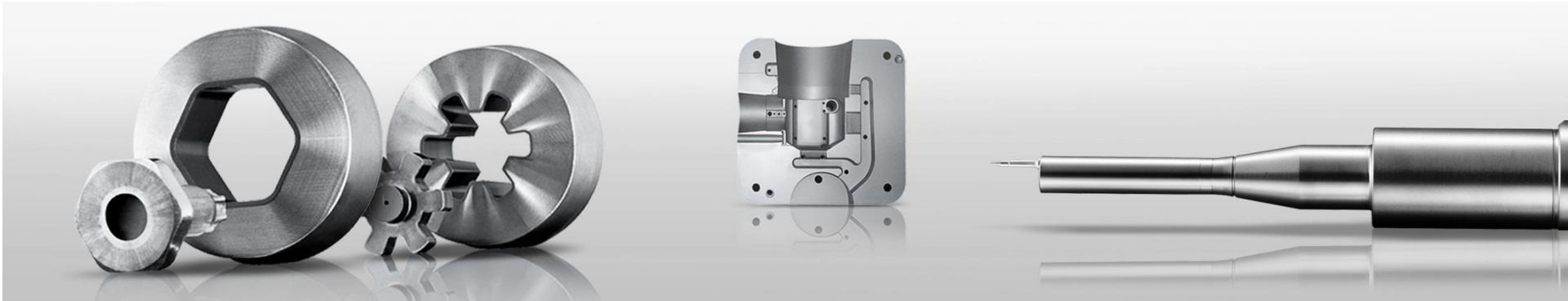
Coating hardness which brings

- Wear protection against the cleaning
- Preservation of the polished surface / gloss
- Much slower degeneration of the surface quality in compression to hard chrome
- Screws: Wear protection against abrasive material



> Excellent Performance as DUPLEX Coating

Make your products shine with Special Nitride™ Processes that provide wear on HIGHLY POLISHED / AESTHETIC SURFACES



Special Nitride™

The new Special Nitride™ service is a plasma supported treatment system, where a diffusion layer with a surface hardness gradient is produced.

With the Special Nitride™ treatment, wear and corrosion protective properties of the base material are improved.

After Special Nitride™ processing, the surface characteristic allows an improved polish compared to an untreated condition.

Plastic mold treated with Special Nitride™

Recommended applications

Automobiles:
Examples: bumpers, headlights, and seat shells

Agricultural machinery:
Examples: external parts

Trucks:
Examples: external parts

Furniture:
Example: plastic seats

Household appliances:
Examples: high-gloss fittings and covers

Electrical devices:
Example: covers

Brilliant benefits

Wear resistance

Surface hardness increase to over 1400 HV

Corrosion resistance

Greater protection against aggressive substances and condensate

Scratch resistance

Reduced mould sensitivity to improper handling

Very good polishability

Repolishing possible without repeating the Special Nitride™ treatment

Reduced maintenance costs

Mould repairs possible without stripping and recoating (good weldability)

Consistently high component surface quality

Preservation of mold gloss

Efficient production

Properties of Special Nitride™ treated steel moulds for plastics

Steel grade	1.2738/1.2311/1.2312		1.2343/1.2344	
	P20+Ni/P20/P20+S		H11/H13	
	-/-/-		SKD 6/SKD 61	
	untreated	**Special Nitride™**	untreated	**Special Nitride™**
Polishability	+	++	+	++
Etchability	-	+	+	+
Weldability	+	+	+	+
Surface hardness	--	+	-	++

The Special Nitride™ Process for XL Molds

An example

Problem so far:
Slight corrosion in hard-to-reach places despite TiN / CrN. Scratches caused while cleaning the mould – difficult or impossible to remove. Disadvantages: Multiple stripping and recoating or new hard chrome-plating, elaborate maintenance required.

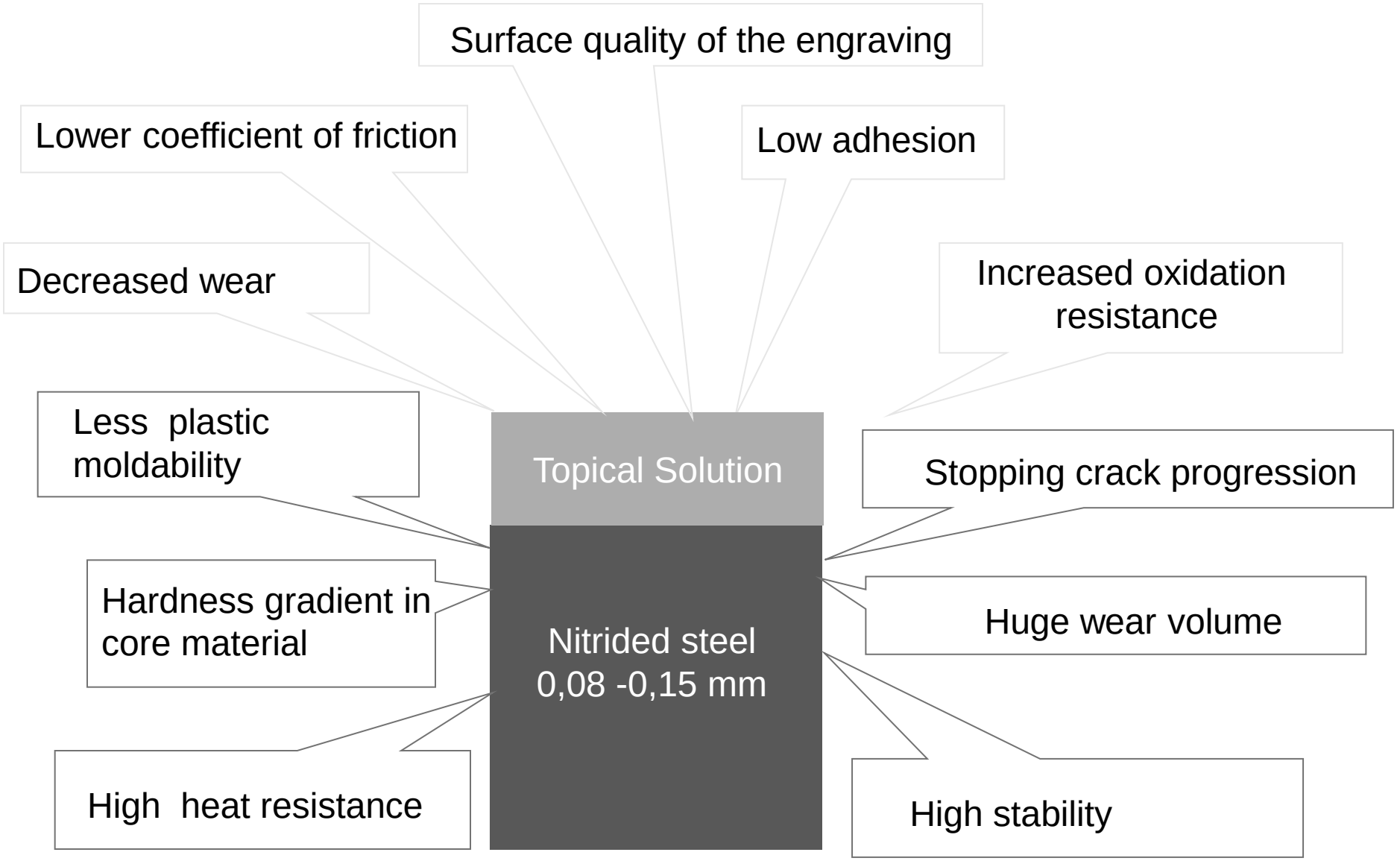
Solution:
Special Nitride™. For noticeably improved demoulding, optimised process reliability, enhanced component quality.

Result:
Improved production efficiency and reliability. Reduced scrap costs. Productivity gain in the magnitude of 60%.

Specifications

Treatable steels	Tool steels with no deformation at temperatures up to 480°C, such as 1.2311, 1.2738, 1.2316, 1.2343, 1.2344, 1.2379, 1.2083 (secondary heat treatment)
Treatable surfaces	Polished surfaces (mirror/brushed) and textured surfaces (shot-peened, etched, eroded)
Post-Treatment	Generally possible
Combination with other Coatings	Chromium nitride, ® Aluminum chromium nitride, Titanium Aluminum nitride, and Carbon based coatings
Tool dimensions	Length max. 9.500 mm Part weight up to weight 25 t

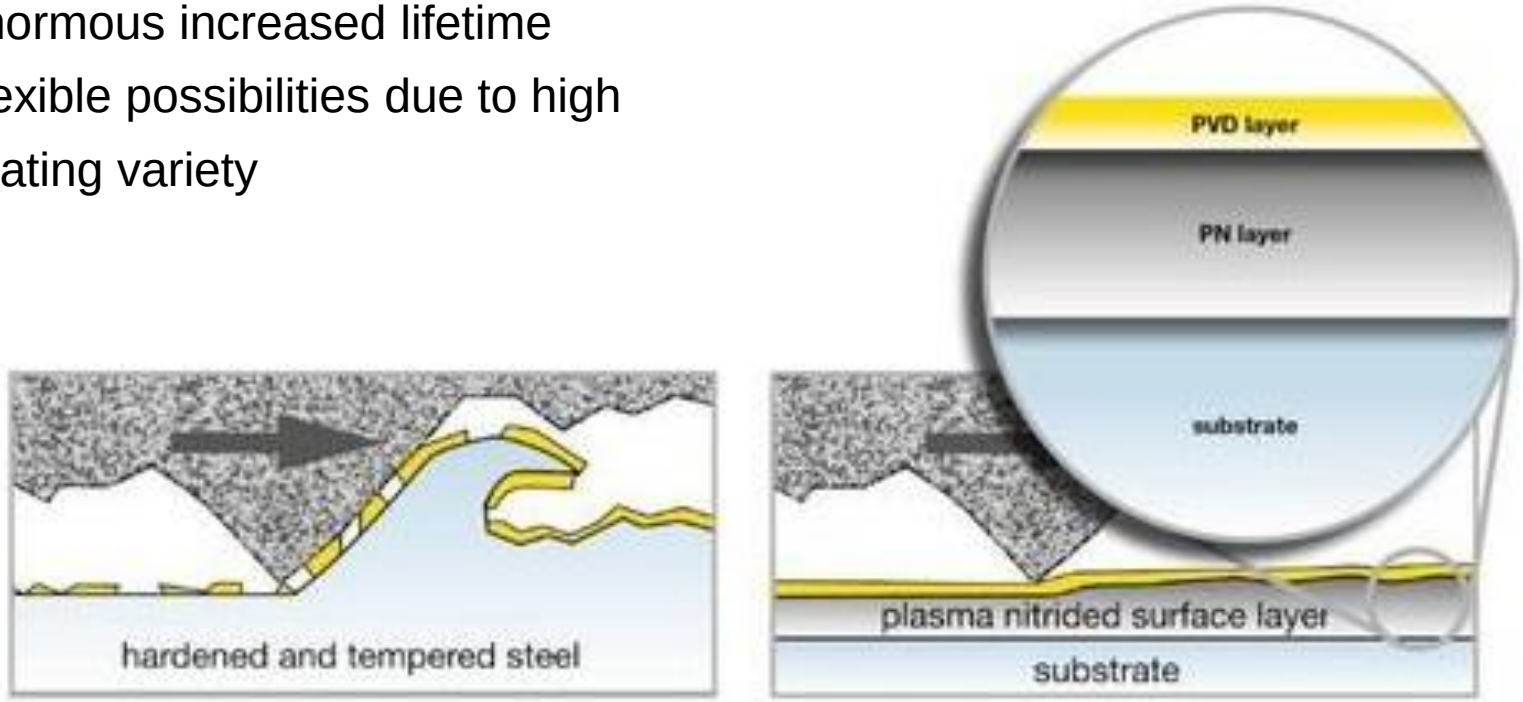
DUPLEX Treatment



Combi treatment PVD + Plasma Nitiriding

Benefits of the combi treatment

- Substitution of expansive steels
- specific optimization of tool and component
- Enormous increased lifetime
- Flexible possibilities due to high coating variety



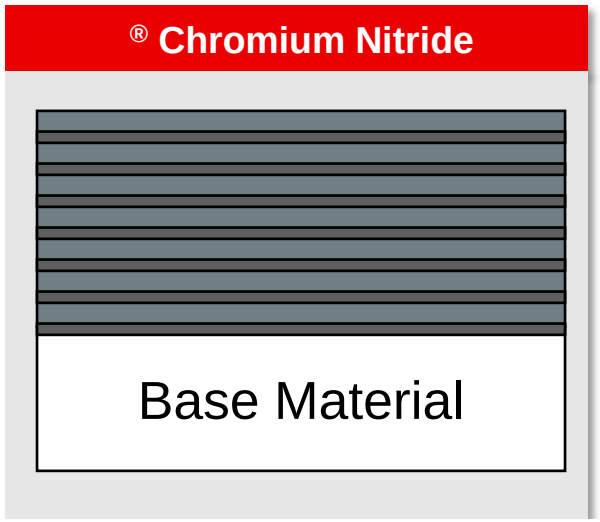
The comparison shows: a plasma nitrided barrier layer offers increased supporting effect for PVD/DLC coating

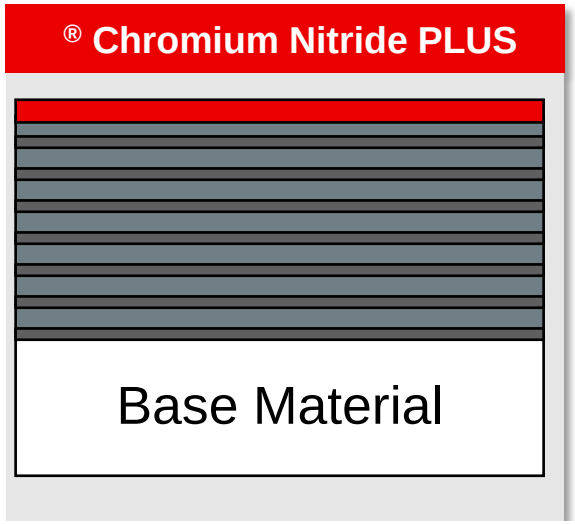
Structure & Properties

Oxide Layer

CrN

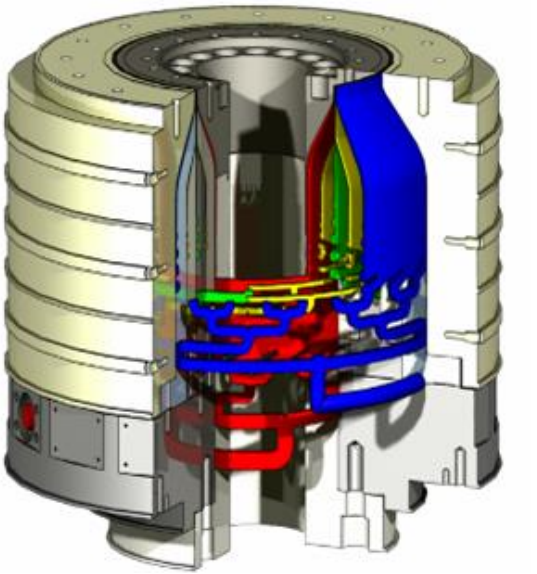
Cr





	BALINIT® CROMA	BALINIT® CROMA PLUS
Micro hardness (HV 0.05)	2,500	2,500
Coefficient of friction (dry against steel)	0.3 – 0.5	0.3 – 0.5
Coating thickness (µm)	4 – 10	4 – 10
Coating material / coating structure	CrN (multi-layer)	CrN+OX (multi-layer with top layer)
Maximum service temperature (°C)	700	700
Coating temperature (°C)	250 – 450	250 – 450
Corrosion protection	++	++
Intrinsic roughness	++	++
Colour	Silver-grey	Rainbow

Main arguments for coating mandrels for foil extrusion



- Reduced sticking of plastic material which
  - avoids little burners that show in the foil
  - better cleaning during maintenance
  - longer intervals between cleaning

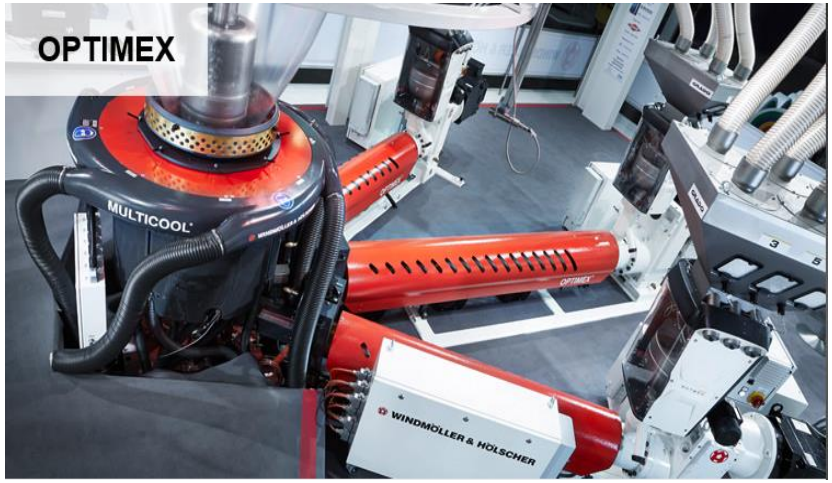
- Better flow of material with higher throughput
- Wear protection against the cleaning
- Preservation of the polished surface / gloss
- Much slower degeneration of the surface quality in compression to hard chrome

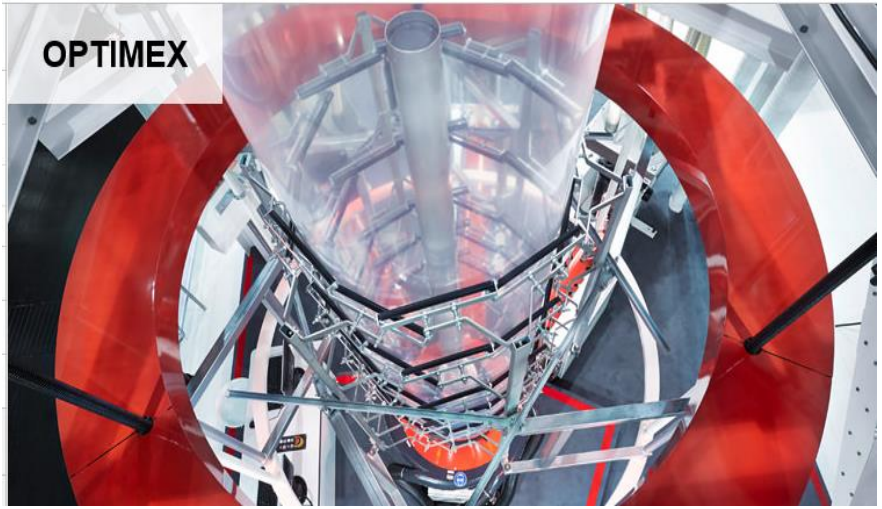
Attention:

Thickness with 6-8 µm PVD coating is generally smaller than the hard chrome therefore, this will require changes in the tolerances of the tool.

Due to the lower thickness the PVD coating has certainly a lower corrosion resistance than the hard chrome for very corrosive plastics.

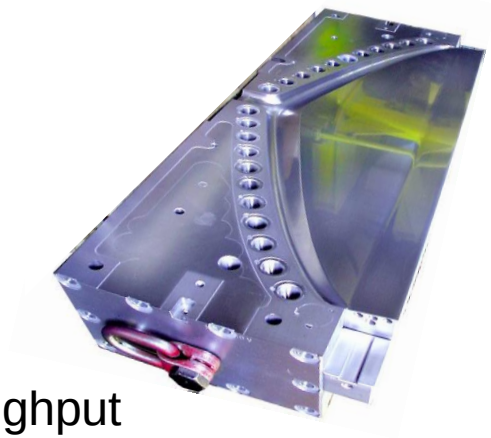
Film Extrusion system





Main arguments for coating dies for sheet and foil extrusion

- Reduced sticking of plastic material which
  - avoids little burners that show in the foil
  - better cleaning during maintenance
  - longer intervals between cleaning



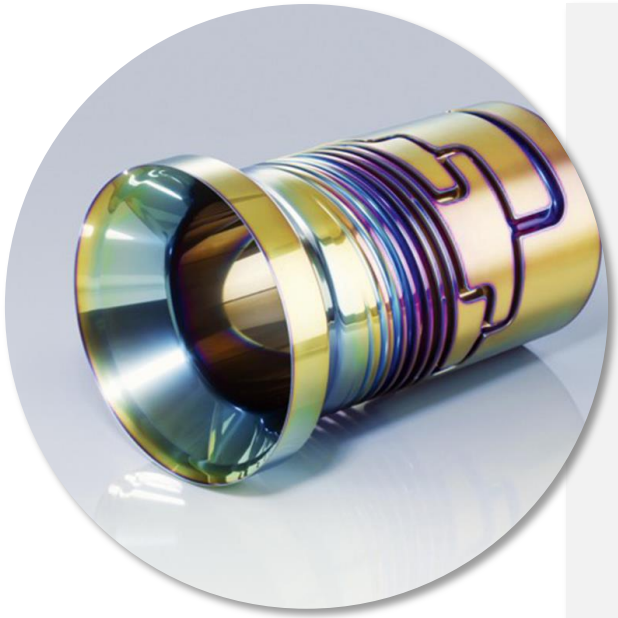
- Better flow of material with eventually higher throughput
- Wear protection against the cleaning
- Preservation of the polished surface / gloss
- Quicker purging times
- Much slower degeneration of the surface quality in comparisson to hard chrome

<u>Attention:</u>

Thickness with 6-8 µm PVD coating is generally smaller than the hard chrome therefore, this might require changes in the tolerances of the tool.

Due to the lower thickness the PVD coating has certainly a lower corrosion resistance than the hard chrome for very corrosive plastics.

Example: Foil Extrusion



Product: HDPE- Foil, 0,045mm, three-layered

Tool: tube die, 9 parts out of 1.2316 (approx 422) (16% Cr), polished

Problems:

- Each 9 to 12 months demounting due to irregularities in the product
- Complex cleaning of the blow head
- 4 to 8 days production stop
- Risk of damage to the hard chromium surface during mounting and cleaning, thus influence on product quality

Solution: ® Chromium Nitride PLUS coated functional surfaces

- Increased cleaning intervals to 36 months
- Clearly easier and faster cleaning
- Scratch protection during mounting and cleaning
- Approx. 1/3 shorter start-up after color/material change
- More simple start-up after production stop
- Increased output approx. 4%

Applications

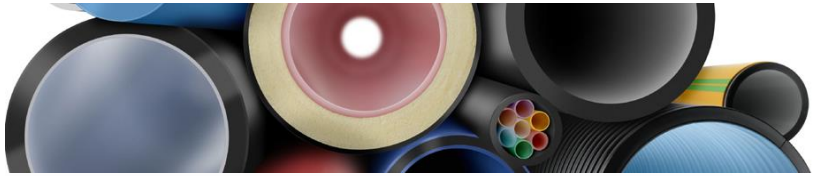
PP pipe extrusion

Without coating

Hard chrome chemically reacts with plastic

- → **Parts becomes matt**
- → **Periodically reworking necessary**
- → **Pore formation or fractures by reworking**

Not scratch resistant



Our solution: ® **Chromium Nitride**

After coating

No more reaction with plastic

- → **Parts do not become matt**
- → **No reworking necessary**

Scratch resistant

® Chromium Nitride: Extrusion Die for Pipes

Dimensions:

Diameter: 1400 mm

Length: 800 mm

Weight: approx. 4000 kg

Application

- Extrusion die for PVDF flexible pipes for Oil, Gas, Chemical or water fluids

Why coating

- Corrosion resistance (due to the “F”) and a better flow of the plastic resign.
- Combination of stainless steel (1.4125: 17% Cr) and the PVD coating makes the success

Examples: Extrusion Screws

Rubber tubes

Problems:

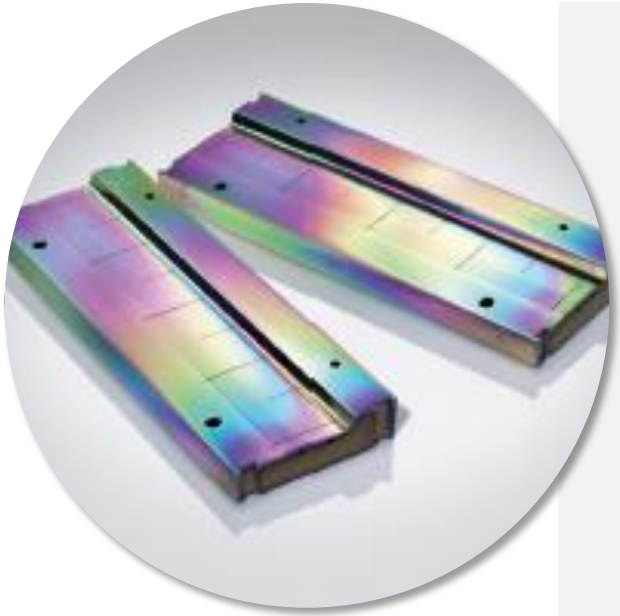
- ƒAbrasive wear caused by particles in the elastomer
- ƒRubbing wear between screw & barrel
- ƒLife time of stellite: 18 months
- ƒWear control: 4x/year

Solution:

® Chromium Nitride coating

- ƒLife time of Chromium Nitride: even after 6 years no wear
- ƒWear control: 1x/year

Example: PVC Profile Extrusion



Calibration units (1.2316; 16% Cr)

Problems:

- Abrasive wear through TiO_2 - pigments
- Adherence through lead-free stabilizer

Solution:

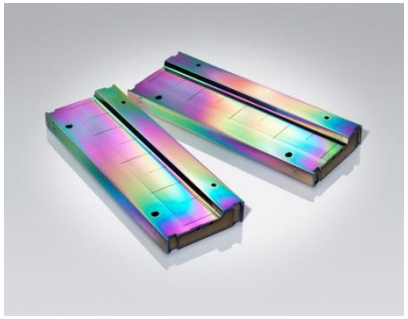
® Chromium Nitride

- Wear protection
- Improved flow properties
- Avoiding slip-stick-effects → high Product quality
- Conservation of the polishing
- Longer service life

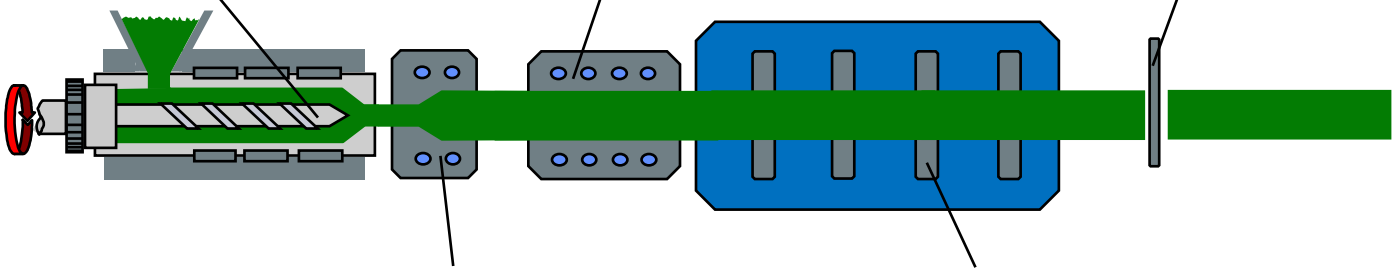
PVC Extrusion Line

Screw
® Chromium Nitride PLUS

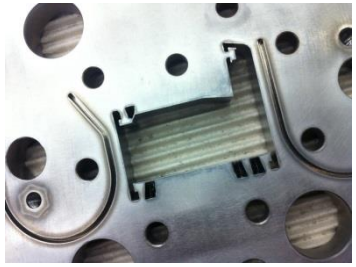
Calibrating Tool
® Chromium Nitride



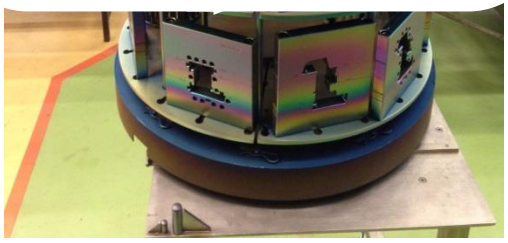
Knife
® B



Extrusion Tool
Special Nitride™



Holding Elements Cooling Tank
Chromium PLUS Nitride

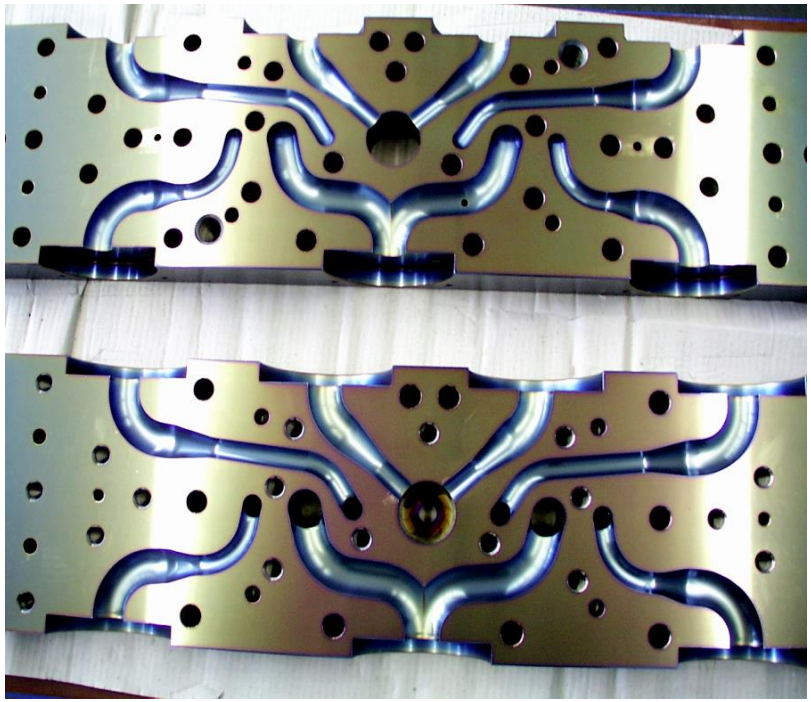


Applications

Distributor plate

Without Oerlikon coating

Deposits



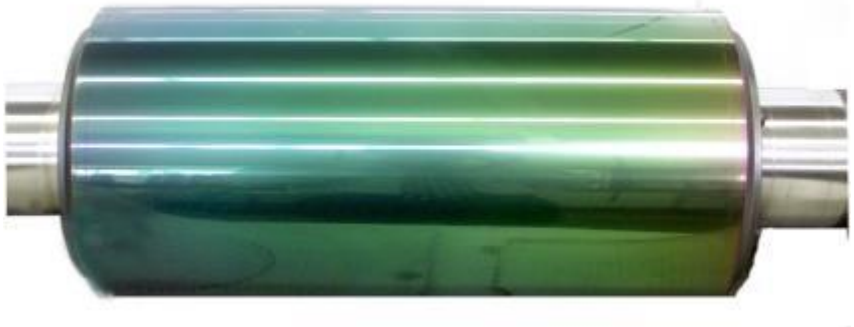
Our solution: ® Chromium Nitride

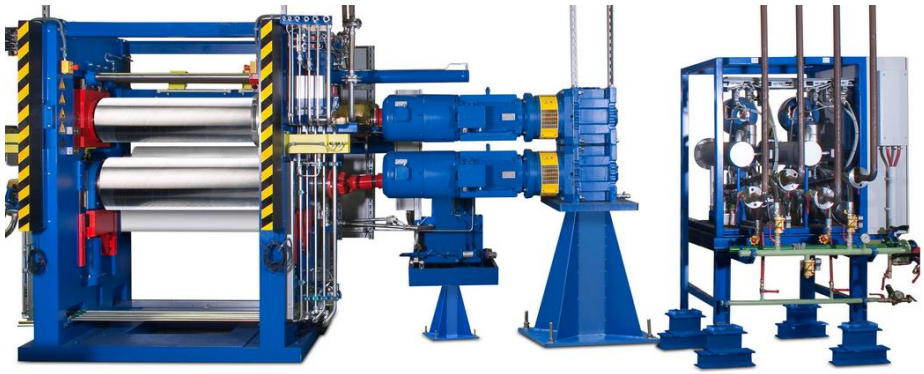
After coating

No deposits

Conservation of the polishing

Examples: Rubber





Calendering roller Ø 180 x 850 mm

- Without Oerlikon coating
  - Deposits
  - Sticking

Our solution: ® Chromium Nitride

After coating

- No deposits
- Reduced sticking

Applications

Elastomer processing / vulcanizing

Without coating

Deposits

Sticking, adhesion

Our solution: **® Chromium Nitride PLUS**

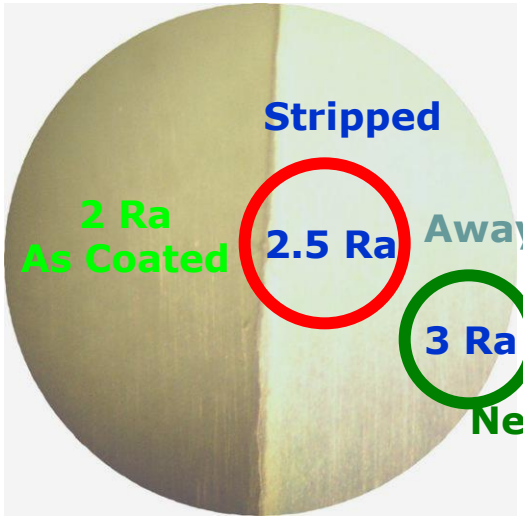
After coating

Reduced deposits

Reduced corrosion

Oerlikon Stripping Process

Stripped Masked Steel Sample



- Oerlikon uses an Reactive Ion Etching process to decoat diamond-like and other carbon based coating types
- Stripped finish on 8620 steel typically changes about 1 to 2 Ra
- This process can be used on titanium, beryllium copper and aluminum parts in addition to steels and ceramics

Note: Chrome plated parts and small geometries may not be advisable to strip.

Recap - What are the benefits offered with “thin-film coatings?

- Increased tool life
- Lower maintenance effort
- Higher operation reliability
- Corrosion inhibitor (not corrosion protection)
- Reduction of sticking
- Savings of release agents
- Protection against cleaning related wear and damage
- Inert surfaces

Don’t Go It Alone!

Let an experienced “Coatings Expert” help guide your plastic tooling success in coatings

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