"Advances in PVD and CVD Tool Coatings for Abrasion & Corrosion Resistance Combined with Toughness and Good Release Properties"

Donald Corbett
Sales Product Manager, Plastics
Oerlikon Balzers, USA
Don.corbett@oerlikon.com | 716-225-9124
Increased productivity demands long term reliability of tool surfaces and mechanical components, with surface protection & longevity.
Initiatives to lessen the weight of vehicles leads to more reinforcements in plastic parts contributing to more wear on mold surfaces.

Greater emphasis on luxury designs require higher quality tool surfaces and more sophisticated rubber and plastics compounds.
North America automotive plastics market volume by product, 2012 - 2022 (Million Tons)
Why Coatings......because stuff happens!

**Deposits**
As a result of micro cracking and **chemical adhesion**

**Abrasive wear**
Due to hard particles like: Glass fibres, calcium carbonate, Titanium dioxide

**Catalytic decomposition**
(separation of Cl and F) causes **corrosion**

- **PVD & DLC**
- **PVD & Diffusion**
- **DLC (PVD & Diffusion)**
Abrasive filler materials / particles in plastics

- Quartz powder
- Talc
- 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 fibers in plastics processing**

- Hardness: Up to 1200 HV
- Sharp jagged edges
- Abrasive wear by micro cutting
Markedly improved tool and component performance with thin-film coatings. Today’s coatings are just a few thousandths of a millimeter thick, but harder than steel. These low-friction, thin-film coatings are extremely wear-resistant as well as chemically inert. The optimum coating is determined both by the intended usage conditions and economic considerations. The chemical composition and properties of coatings can also be tailored specifically to the customer’s needs.
Coatings (Not Platings)

**Platings**
- Health hazardous materials
- Thick build-ups can interfere with design
- Low performance with many plastics

**Coatings**
- Tailored Chemistries for Plastics/Rubbers
- Clean, Safe for the environment
- Thin Nature is Part & Design Friendly
- Easily applied and removed as desired
Attributes for Today’s Coatings for Plastic Tooling

• Very Hard, exceeding 80 Rc
• Extremely conformable to the existing surface topography
• Very Dense, sealing against corrosives and moisture
• Lubricious, aiding in part ejection & release
• Reduces frictional drag between sliding/moving parts
• Compatible with many steels, alloys & ceramics
• Very thin, ranging in thickness of 0.00008” to 0.0003”
Advantages

- Excellent demoldability
- Outstanding wear protection
- High corrosion resistance
- Very smooth tool surface

Application

- Injection molding tools for packaging liquids, food and cosmetics
- Injection molding tools for medical applications
- High-gloss injection molding tools for automotive and packaging industries

Application example

Thread cores and ejector sleeves

Problem until now: Low wear protection; corrosion protection of CuBe cores; polishing required

The solution: CVD (Carbon Coating)

- No visible wear even after 1 year
- No subsequent polishing required
Applications

Door Window/Trim Seal manufacturing of flexible TPU
- High abrasion and scratch resistance
- Increases tool lifetime by up to 6 million metres of produced film
- Reduction of sticking
- Higher productivity and manufacturing reliability
  ... with Chromium Coatings

Rotating cores for manufacturing PET sealing caps
- Service life of up to 10 million parts
- No repolishing required
- Additional corrosion protection for CuBe cooling cores
  with Carbon-based, CVD coatings

Ejectors and sliding systems
- Grease-less ejection systems
- Less servicing required for tools
- Trouble-free production with Carbon-based, CVD coatings
CVD Coating Advantages – Diamond Like Carbon Coatings

Before: Coating with grease
- Poor wear protection (galling)
- Coating adhesion problems due to oxidation of CuBe-based material
- May need post polishing to make coating work
- Black particle contamination may occur during initial start up
- Grease “weeping” onto molded parts causing contamination issues

Now: Carbon-Based DLC Coating
- After more than a year and over 9 Mio. shots – still no visible wear!!
- No loss of coating due to oxidation protection
- No post polishing necessary
- No break in period – no black particle contamination
Chemistries for PVD and CVD Coatings and How They’re Applied Are Important

- Physical Vapor Deposition (PVD) process
- PVD coatings can be made using 3 primary evaporation methods;
  - Arc
  - Sputter
  - Ion Evaporation (Molten Pool)
- PVD coatings are made by evaporating one or more metals to produce charged metal ions and introducing one or more ionized gases that are both attracted to an oppositely charge part where they meet and form the coating.
- PVD coatings have high hardness, high oxidation resistance & a reduced chemical reactivity.
- Properties are changed by using different metal / gas combinations to meet specific customer needs. (e.g. TiN, CrN, TiCN, AlCrN, TiAlN, etc.)
PVD Magnetron Sputter Technology
<table>
<thead>
<tr>
<th>Resin Type</th>
<th>DLC</th>
<th>AlCrN</th>
<th>TiAlN</th>
<th>CrN</th>
<th>CrNO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>PE, PP, PB</td>
<td>+++</td>
<td>++</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PS, SB, SAN, ABS, ASA</td>
<td>++</td>
<td>++</td>
<td>+++</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ABS</td>
<td>++</td>
<td>++</td>
<td>+++</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PVC</td>
<td>+++</td>
<td>++</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PTFE, PVDF</td>
<td>++</td>
<td>++</td>
<td>+</td>
<td></td>
<td>+++</td>
</tr>
<tr>
<td>POM</td>
<td>+++</td>
<td>++</td>
<td>+++</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PA</td>
<td>+++</td>
<td>++</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PC, PBT(B), PET(P)</td>
<td>+++</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PEEK, PPS, PSU, PES, PPE, PPO</td>
<td>++</td>
<td></td>
<td></td>
<td></td>
<td>+++</td>
</tr>
<tr>
<td>PI</td>
<td>++</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CA, CP, CAP</td>
<td>++</td>
<td></td>
<td></td>
<td></td>
<td>++</td>
</tr>
<tr>
<td>PMMA</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
<td></td>
<td>+++</td>
</tr>
<tr>
<td>TPU</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
<td></td>
<td>+++</td>
</tr>
<tr>
<td>PA</td>
<td>+++</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PF</td>
<td>++</td>
<td>+++</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EP</td>
<td>++</td>
<td>+++</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UP</td>
<td>++</td>
<td>+</td>
<td>+++</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PUR</td>
<td>++</td>
<td>+</td>
<td>+++</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MF, UF, MP</td>
<td>+++</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PUR +</td>
<td></td>
<td>++</td>
<td>+++</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EPDM, Si</td>
<td></td>
<td>++</td>
<td>+++</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TPE, FPM</td>
<td></td>
<td>++</td>
<td>+++</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

+ = maybe suited
++ = well suited
+++ = very well suited
# One Size Doesn’t Fit All – Coatings Tailored for Applications

<table>
<thead>
<tr>
<th>Name</th>
<th>Titanium Nitride</th>
<th>Titanium Carbo-Nitride</th>
<th>Chromium Nitride</th>
<th>a:CH</th>
<th>a:CHSiO</th>
<th>TIAISIXN</th>
<th>AITiN</th>
<th>AlCrXN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microhardness (GPa)</td>
<td>25</td>
<td>28</td>
<td>23</td>
<td>25</td>
<td>25</td>
<td>36</td>
<td>34</td>
<td>33</td>
</tr>
<tr>
<td>Rockwell C</td>
<td>85</td>
<td>88</td>
<td>83</td>
<td>85</td>
<td>85</td>
<td>96</td>
<td>94</td>
<td>91</td>
</tr>
<tr>
<td>Coefficient of Friction Against Steel (Dry)</td>
<td>0.4</td>
<td>0.3</td>
<td>0.35</td>
<td>0.15</td>
<td>0.05</td>
<td>0.45</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Coating Thickness (μm)</td>
<td>1 - 4</td>
<td>1 - 7</td>
<td>1 - 7</td>
<td>2 - 4</td>
<td>2 - 4</td>
<td>2 - 4</td>
<td>2 - 4</td>
<td>2 - 4</td>
</tr>
<tr>
<td>Max. Working Temperature</td>
<td>1000 °F</td>
<td>600 °C</td>
<td>930 °F</td>
<td>500 °C</td>
<td>1150 °F</td>
<td>650 °C</td>
<td>750 °F</td>
<td>400 °C</td>
</tr>
<tr>
<td>Coating Temperature</td>
<td>500 - 950 °F</td>
<td>500 - 950 °F</td>
<td>500 - 950 °F</td>
<td>220 °C</td>
<td>220 °C</td>
<td>500 - 950 °F</td>
<td>500 - 950 °F</td>
<td>500 - 950 °F</td>
</tr>
<tr>
<td>Wear Factor (x 10^-8 mm^3/Nm)</td>
<td>250</td>
<td>60</td>
<td>++</td>
<td>+++</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>Surface Energy (mN/m)</td>
<td>40 - 42</td>
<td>42 - 46</td>
<td>30 - 40</td>
<td>20 - 40</td>
<td>20 - 30</td>
<td>30 - 40</td>
<td>42 - 46</td>
<td>30 - 40</td>
</tr>
<tr>
<td>Coating Method</td>
<td>PVD</td>
<td>PVD</td>
<td>PVD</td>
<td>CVD</td>
<td>CVD</td>
<td>PVD</td>
<td>PVD</td>
<td>PVD</td>
</tr>
</tbody>
</table>
Chromium Nitride Advanced with Chromium Oxide Skin

Layer structure

Applications
- PVC extrusion (abrasion, adhesion, sticking, corrosion)
- PA injection moulding (polyamide) (abrasion, sticking, corrosion)
- PE/PP extrusion & injection molding (sticking layer, sticking, flow rates)
- PMMA/PC injection moulding (adhesion, sticking, flow rates)
- PUR/TPE (sticking, flow rates)

Characteristics
- High hardness
- Low surface energy
- Improved density
- Improved material flow
Diamond Like Carbon Coatings (DLC), are advanced carbon coatings very high tribological demands, requiring anti – galling and abrasive wear resistance.
Surface Energy & Wetting Behavior of Different Coatings

Close-up of a series of liquid droplets on a Diamond Like Carbon coated sample

- Surface energy is a measure of the affinity of a substance to stick to a given surface.
- 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
Corrosion Test

Diamond Like Carbon

After 192 hours

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

ASTM B 117-97 Salt Spray Test
Plasma Nitriding (w/o oxidation)
The innovative and highly efficient treatment for brilliant mold surfaces.

Advantages

- **Wear resistance**: Increase in the surface hardness of up to 1400HV
- **Scratch resistance**: Reduced mold sensitivity to improper handling
- **Very good polishing properties**: Improved surface brilliance
Surface Properties after Plasma Diffusion Processing

- extremely dense surface, the creation of pores is clearly reduced
- danger of orange peel is greatly reduced
- improvement in brilliance of the surface is achieved
- Hard and scratch resistance
Head Lamp Truck PC
Steel 1.2344

After Diffusion Process:
- Improved part quality.
- Lower injection pressure.
- Less residue deposits.
- Mold cleaning is not critical anymore.
- No mirror repolishing is necessary after cleaning.
- Improved scratch resistance
- Good Reparability.
- Stabile production
- All the ejectors and lifters are treated with Diffusion and Carbon coating for grease free production.
- Main improvement less downtime for cleaning the mold surface for residues.
- Before stop each day new 1 time per week is enough.
high-end technical solutions to get the best out of your tools with all kinds of finishes against a variety of resin types

A winning combination for tough applications that may be abrasive and tacky, like mineral filled TPE

Plasma Nitriding, providing a boost to tool’s base hardness

Topical PVD or CVD coatings, to offer slickness and scratch resistance

Tough scratch resistant surfaces w/ lubricious finishes accomplished with only micron thicknesses
In Summary – Today’s Thin Film Coatings Can

- Conformable to existing mold surfaces
- Compatible with most common tool steels and alloys
- Provide wear protection against abrasive filler materials in plastics
- Eliminate need or greatly reduce need for grease
- Improve release of parts from mold surfaces
- Provide a barrier against corrosion
- Reduce polishing efforts
- Keep vents open longer
- Work within existing tolerances, without intruding on dimensions
- Environmentally friendly
- Repairable, strippable