Lecture 10:
Scale-up and Design:
Industrial Systems and Practices
Outline

• Coating Systems for Cutting and Forming Tools
• Automotive Parts Coating Systems
  – Examples of Coated Automotive Components
• Glass Coating Systems
• Si wafer Coating systems (Electronic)
• Thermal Barrier Coating Systems
• Hard Disc Coating Systems
• 3 Axis Sample Holders
Cutting and Forming Tool Coaters
Main Characteristics:
• Systems may combine both magnetron and arc-PVD
• Electronic ignition of arc, rectangular cathodes for thickness uniformity
• Shutters between cathode and products
• Temperature measurement on product during process
• Choice of etching methods for best adhesion or smoothness
Cemecon
CC800 fully automated coating unit

CC800/9, CC800/9XL
metals, alloys, hard coatings ...

CC800/9-RF
CC800/9-BP
oxides, metals, alloys, hard coatings ...

Sputter ion plating system
Von Ardenne

Von Ardenne **ALPHA 900T** Hard Coating Plants for Tools

**Application**
- Coating of tools with wear-reducing hard-layer systems

**Technology**
- Physical Vapor Deposition (PVD) by means of cathodic arc evaporation in reactive process mode
- Deposition of single layers and multi-layer systems is possible
Both the UDP450 and UDP650 are versatile R&D systems. The UDP650 is also a very useful small production system.
For large scale production, it is possible to increase the chamber height, without changing the deposition conditions. Increasing the chamber diameter does change the deposition conditions but excellent coatings are obtained in systems up to diameter 1.5m diameter.

The largest system supplied to date had chamber dimensions: Ø1200mm x 1600mm (magnetrons: 1200mm x 175mm).

Chamber height: 900mm
Chamber diameter: 900mm
Six Magnetron Deposition System

In order to increase the deposition rate, the number of magnetrons can be increased from 4 to 6 (and still in closed field arrangement). The photo below shows a 6 magnetron system with dimensions: Ø850mm x 850mm.
Teer Coatings, Ltd.

6 magnetron system
Chamber height : 1400mm
Chamber diameter : 900mm
Automotive Parts Coating Systems
Hauzer

Flexicoat 1200
Hauzer
Cathode configuration for MeDLC
Examples of Coated Automotive Components
Tribological Applications

Applications of DLC and Me-DLC

Automotive components
- Camshafts, crankshafts, pistons, piston rings, tappets/shims, gears, bearings, valves, plungers (diesel injection)
- Increasing wear resistance
- Decreasing friction
- Targets:
  - Reduce energy consumption
  - Improved fuel efficiency
  - Reduction of the CO₂-emission
  - Power amplification (Car Racing)
  - Better acceleration
## Piston Area

<table>
<thead>
<tr>
<th>Piston Ring</th>
<th>Piston Pins</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Piston Ring Image]</td>
<td>![Piston Pin Image]</td>
</tr>
</tbody>
</table>

### Top piston rings

<table>
<thead>
<tr>
<th>Coating</th>
<th>CrN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness</td>
<td>30 µm</td>
</tr>
<tr>
<td>Coating on</td>
<td>outside</td>
</tr>
</tbody>
</table>

| Benefit | Wear |

### Piston pin

<table>
<thead>
<tr>
<th>Coating</th>
<th>DLC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness</td>
<td>1 – 5 µm</td>
</tr>
<tr>
<td>Coating on</td>
<td>cylindrical sides</td>
</tr>
</tbody>
</table>

| Benefit | Wear, friction, performance |

Source: Hauzer Techno Coating
# Powertrain

<table>
<thead>
<tr>
<th><strong>Plunger</strong></th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th><strong>Gears</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coating:</strong></td>
</tr>
<tr>
<td><strong>Coating thickness</strong></td>
</tr>
<tr>
<td><strong>Coating area</strong></td>
</tr>
<tr>
<td><strong>Benefit</strong></td>
</tr>
</tbody>
</table>

Source: Hauzer Techno Coating
Fuel Injection Systems

Part: Diesel fuel injector and plunger
Coating: Me-DLC, CrN
Coating thickness 1 – 6 µm
Benefit Wear resistant

Source: Hauzer Techno Coating
# Cam Shaft Area

<table>
<thead>
<tr>
<th>Tappets</th>
<th>Rocker Arm</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Tappets Image" /></td>
<td><img src="image2.png" alt="Rocker Arm Image" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Tappet Coating</strong></th>
<th><strong>Rocker arm + hydraulic element Coating</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>CrN</td>
<td>DLC</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Thickness Coating on</strong></th>
<th><strong>Thickness</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>2 – 6 µm</td>
<td>1 – 5 µm</td>
</tr>
<tr>
<td>Top side</td>
<td>Head hydraulic element</td>
</tr>
<tr>
<td></td>
<td>Rockerarm (racing)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Benefit</strong></th>
<th><strong>Benefit</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Wear + friction</td>
<td>Wear</td>
</tr>
</tbody>
</table>

Source: Hauzer Techno Coating
Gliding Bearing

Some examples:

- Pure metal alloy for crankshaft gliding bearings
  - New generation of turbo diesel engines has high momentum
  - Abrasive wear
  - Adhesive wear
  - Material AlSnSi alloy with Ni diffusion barrier
Direct-Injection System (1,9 l TDI-Motor)

**Technical Data**
- Engine power: 96 KW (130 PS)
- Injection pressure: 2050 bar
- Pressure power: 14,000 N

**Advantages**
- Increased efficiency (lower friction)
- Increased engine torque
- Reduce energy consumption
- Reduction of the CO₂-emission

Source: Volkswagen AG, Wolfsburg

Source: Hauzer Techno Coating
Door Lock

Source: Hauzer Techno Coating
Glass Coating Systems
Von Ardenne GC 60 V Vertical in line sputter Plant for Flat Glass

**Application**
- Deposition of float glass with different multi-layer systems, especially with TCO layers, in a continuous single-pass mode

**Technology**
- Physical Vapor Deposition (PVD) by means of Magnetron sputtering in metallic and reactive process modes at substrate temperatures of max. 300 °C

*Source: Von Ardenne*
**Application**
- Coating of glass substrates with different multi-layer systems, in particular low-Ohm TCO-layers and/or layer systems in continuous single-pass mode

**Technology**
- Physical Vapor Deposition (PVD) based on Magnetron sputtering in metallic and reactive process modes

Von Ardenne **GC 124 VC** Vertical In-line Sputter Coater for Displays

Source: Von Ardenne
**Application**
- Particle-free coating of flat and curved glass substrates with different multilayer systems for various optical applications

**Technology**
- Physical Vapor Deposition (PVD) based on DC and MF-Magnetron sputtering in metallic and reactive process modes, controlled by Plasma Emission Monitor (PEM)
- Substrate pretreatment optionally with glow discharge or ion beam source

Von Ardenne **GC 120 VC** In-line Sputter Coater for Automotive Glass Modular System

Source: Von Ardenne
**Application**
- Production plant for flat glass coating with optical multi-layer systems for low-e and solar control glazing in buildings

**Technology**
- Physical Vapor Deposition (PVD) by means of DC and MF powered Magnetron sputter sources in metallic and reactive process modes

Von Ardenne **GC 321 H** In-line Glass Coater System 600

Source: Von Ardenne
Von Ardenne GC 321 H Inline-Glass Coater System 780 plus

• **Application**
  • Production plant for flat glass coating with optical multi-layer systems for low-e and solar control glazing in buildings

• **Technology**
  • Physical Vapor Deposition (PVD) based on planar and cylindrical sputter sources with metallic or reactive process control in DC or MF-mode, Plasma Emission Monitor (PEM®) controlled

Source: Von Ardenne
Si wafer Coating systems
(Electronic)
Von Ardenne **CS 850 S** Cluster System for 6" Substrates

**Application**
- Development and deposition of multi-layer stacks for GMR-sensors on Si-wafers in vacuum sequence

**Technology**
- Substrate pretreatment by RF-etching and rear-side heating
- Deposition by temperature-controlled reactive and metallic RF and DC-sputtering
- Pressure range within UHV-range

Source: Von Ardenne
Von Ardenne LS 730 S Load-lock System for 4" x 4" Substrates

**Application**
- Deposition of metallic and insulating layer systems on ceramic substrates in vacuum sequence

**Technology**
- Substrate pre-treatment by rear-side heating and RF-sputter etching
- Reactive and non-reactive DC and RF-sputter coating in stationary and multi-pass mode
- Substrate bias operation

Source: Von Ardenne
Thermal Barrier Coating Systems
Von Ardenne TUBA 150 Thermal Barrier Coater

**Application**
- Coating of thermally highly stressed machine parts, e.g. gas turbine blades and vanes (Thermal Barrier Coating)

**Technology**
- Preheating of the parts by radiation heating
- Reactive electron beam evaporation of metal oxides
- Substrate rotation and wobbling during coating is possible

Source: Von Ardenne
Von Ardenne TUBA 800 In-line Turbine Blade Coater

• Application
  • Thermal barrier coating of gas turbine components

• Technology
  • Reactive electron beam evaporation of Y-stabilized ZrO2

Source: Von Ardenne
Von Ardenne TUBA 1000 Turbine Blade Coater

**Application**
- Coating of industrial gas turbine blades with ceramic thermal barrier coating

**Technology**
- Electron beam preheating of the turbine blades
- Electron beam evaporation from three crucibles with ceramic ingots
- Gas cooling (Quenching) of the turbine blades

Source: Von Ardenne
Von Ardenne LS 740 S Sputter System for Large-area Substrates

• **Application**
  - Deposition of metallic and dielectric HTSL-layer systems

• **Technology**
  - Heating-based substrate pretreatment
  - Deposition of layers by DC and asymmetric bipolar pulse sputtering
  - Vertical substrate coating, stationary, oscillating and in multi-pass mode

Source: Von Ardenne
Hard Disc Coating Systems
3 Axis Sample Holders
Diagrammatic Representation of CFUBMSIP System

One axis

Two axis

Three axis
In order to increase productivity it is necessary to use special fixturing to maximise the chamber load.

A 3-axis planetary rotation system suitable for drills is shown.
Cemecon

10 spindle

6 spindle

3 spindle
In-line Coating systems
Von Ardenne **VISS 450** Vertical In-line Sputter System for 450 x 600 (mm) Substrates

**Application**
- Deposition of metallic and insulating layer systems on ceramic substrates in vacuum sequence

**Technology**
- Substrate pretreatment by means of RF-etching
- Deposition by reactive RF and DC-sputtering in single-pass and multiple-pass mode

Source: Von Ardenne
Basic Design of Sputter Roll Coater FOSA 1300D10 (Von Ardenne)

Magnetron Carriages of Sputter Roll Coater FOSA 1300D10 (Von Ardenne)

Source: Von Ardenne
In-line Strip Coaters

Scheme of R&D Strip Coater – SiO2 Coating of Strip Steel (Von Ardenne)

Source: Von Ardenne