Understanding How to Extend Tool Life with Coatings: An Overview

2013 PMPA National Technical Conference
April 15, 2013 - Columbus, Ohio
• Process Technology- Manufacturers and Techniques
  – CVD
  – PVD
  – CVD Diamond
• Coating Selection by Application
• Critical Factors Relating to Performance
• Designing a Coated Tool
• On the Horizon
CVD vs: PVD Technologies

Chemical Vapor Deposition (CVD)
- Inserts, Dies and Punches. Heat treating Req’d post coating on Tool Steels

Plasma Assisted Chemical Vapor Deposition (PACVD)

Physical Vapor Deposition (PVD)
- Shaft tools, Inserts, molds - Tool Steel and carbide. Moderate Temp Application

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CVD
HT – CVD
MT – CVD
MO – CVD
PA – CVD
LP – CVD
MW – CVD

PVD Methods
Sputtering
Arc
Evaporation
ABS
Thermionic
HiPIMS
IBAD
EB-PVD
LAPVD
UBM
HIP

CVD Process

PVD Process

Transport space
Source
Substrate

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PVD Equipment Manufacturers

Balzers

Platit

Sulzer Metaplas

PVT

CemeCon

Kyutaro

Taro

Nachi

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Lafer
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• AlSi- and TiAl-Alloys
• MMC-materials
• mineral filled plastics etc.

CVD Diamond 6-8µ
Co-concentration ≤ 6%*

• graphite
• carbide green compact
• ceramic green compact

CVD Diamond 8-10µ
Co-concentration ≤ 12%*

• fiber glass reinforced plastics
• carbon fiber reinforced plastics
• composite- and sandwich-materials such as Al-Ti- or Ti-CFK composite materials etc.

CVD Diamond 12µ
Co-concentration ≤ 12%*

• CVD Diamond Multilayer
Co-concentration ≤ 12%*

*Nano Crystalline
Crystalline
Multilayer
Cutting Tool Coating Production

Dedicated production processes to meet the different geometries, surface conditions, and application of the tools.

Product and Application specific production plans
Machining Properties of Various Steels Matched to Coating Chemistry

- Increased coating heat resistance

Mold Steels
Hardened AlTiN
AlCrN
Increased coating

Elongation, %

Hencky strain,
%

600
550
500
450
400
350
300
250
200
150
100
50
0
0
10
20
30
40
50
150
200
250
300
350
400
450
500
550
600

GOLD STEELS
HARDENED ALLOY STEELS
TiAlSiN
Ni-based SUPERALLOYS
TITANIUM ALLOYS
ALLOY STEELS
STAINLESS STEELS
LOW CARBON STEELS
GREY CAST IRONS
DUCTILE IRONS
SHORT CHIPS
LONG CHIPS

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Coating Selection Based on Cutting Conditions

Coating Thermal Stability

Cutting Condition
- High-Hot: Dry
- Low-Cool: Wet

Coating Property
- Hard-Brittle: AITiAlSiN
- Tough: TiAlN, TiCN, TiN

Cutting Method
- High Speed – Small Chips
- High Feed – Large Chips

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Goal: Match the Coating to the Tool Design and Application

Product Performance determines Productivity

Adapted the coating to the optimum configuration.
History of the Coating Industry

One Fits All

TiN

1980’s

List of Coatings

TiN
TiCN
CrN
TiAlN
AlTiN
Al₂O₃
...

1990’s

Design Dedicated Coatings

Today

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Design of Optimized Coatings

Coating = cleaning + pre-treatment + coating material + coating thickness + tolerance

Design a coating in four steps:
1. Definition of the objective
2. Definition of coating specification
3. Production of test tools, evaluation and, if necessary, optimization
4. Final specification
Modifying the edge preparation & surface quality to match the application and cutting conditions is a standard process for some manufacturers.
• Definition of Objective
  – Material to be machined
    • Properties, Chemistry, etc
  – Cutting Conditions
    • Wet or Dry
    • Speeds and feeds req’d.
  – Tool Geometry Required
    • Type, cutting edge condition, material, etc.
  – Likely Failure Mechanism
    • Notching, Micro Cracks, Adhesive transfer of work piece, abrasion, etc.
  – Finish required

• Definition of Coating Spec.
  – Select a coating chemistry compatible with the work piece
  – Dry or high speed requires a thermally stable coating. (ie: AlTiN either Hard or Tough)
  – Insert, Round Tool, sharp edge for finish, Carbide, HHS, etc.
  – Empirical process from experience. This factor combined with edge preparations will determine coating thickness required.
When machining alloys of Al, Cu or Ti there are many similarities.

- Finish is Critical
- Minimum Lubrication is preferred
- Highest metal removal is desirable
- Sharp Cutting edges are required.
- Effective chip ejection is req’d.
- Failure mechanism for soft alloys is usually adhesive transfer. BUE
- Failure for Ti Alloys is abrasive wear.

Coating Specification- High cutting speeds in these materials will generate more heat, accelerating either adhesive transfer or abrasive wear. From history we know 3µ coatings will dull the cutting edge. The preferred choice has been uncoated carbide tooling. Titanium Di-Boride coatings have two critical properties, anti wetting and high hardness to address failure mechanisms. AlTiCrN is encouraging for Ti Alloys.

- Pretreat the tool for best surface finish
- Apply the coating at 1.5-2µ
- Post treat the tool for best coated finish
The coating industry currently is focused on three key developments:
- Improve Adhesion
- Improve Structure
- Reduce Stress

Productivity improves if we can make the coating stick better.
Industry Focus Modern Technology

HPPMS - High Pulsed Power Magnetron Sputtering
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Coating Thickness [µm]

- Adhesion < Shear force
- Adhesion > Shear force

conventional coating

$\sigma = -4 \text{ GPa}$
$\sigma = -2 \text{ GPa}$
$\sigma = -1 \text{ GPa}$

residual stress
Conclusions

Questions that are always asked!!

- **Is one PVD coating technique or coating better than others?**
  - No! The key is in the consistent application of the process monitoring thickness, adhesion, structure and finish.

- **Is there a difference between coated tools received from the toolmaker and coating applied in the aftermarket?**
  - There can be. Most OEM’s are designing tools with geometry and edge prep to optimize coating integration. Most C/S companies select a generic process to apply to many different tool types.
Conclusions

- It is unlikely that there will be any significant advances in coating chemistry in the near future.
- It is equally unlikely that a magic coating will be introduced for all applications.
- Tool manufacturers are developing application specific product lines optimizing the choice of coating to the application and the tool geometry.

- The development of new coating process technology like HPPMS and improved etching will be slowly integrated over the next years by all PVD equipment designers.
- Improving adhesion of the PVD coating offers the best bang as it relates to productivity improvement.
- Virtually all current coating designs will benefit from this type of development.
What's the End User's Role?

- The end user has the most significant information that can help the tool maker and coating supplier (sometimes one in the same), to improve the performance and productivity of a machining operation.

Determining the Failure Mode.
- The US distribution method for cutting tools can place as many as four levels between the end user and the designer. As you go forward the role for the end users with the highest return is to provide your observations when a tool or coating fails. This can be a critical step in adapting a coating or tool to optimize a machining operation.
Thank You

For a virtual tour of a PVD coating facility use the search words “coating center” at www.youtube.com