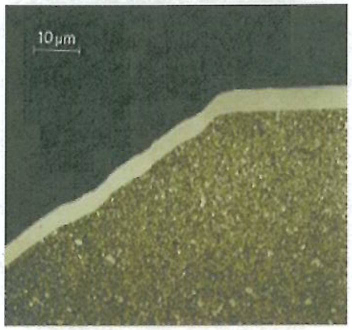
Industrial Applications of PVD Coating Technology Today

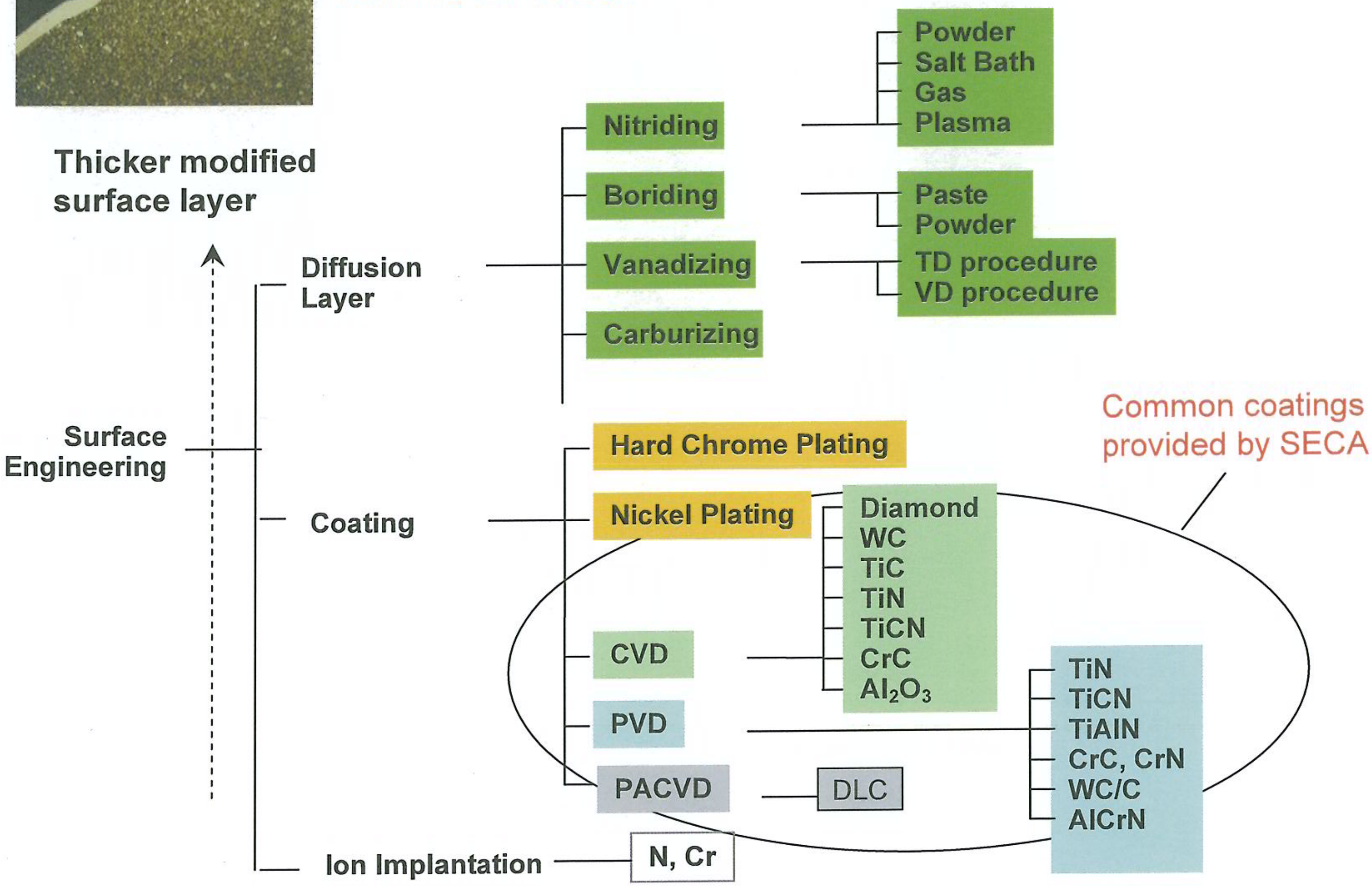
An introduction to coating services provided by SECA member companies

Outline of content

- Surface engineering technologies in general, relative comparisons
- Examples of coated tools and components used in major industrial segments
  - Cutting tools
  - Metalforming stamping, punching tools
  - Plastic injection molding
  - Automotive sliding engine components
  - Decorative applications
- PVD basics
  - Physics of vapor deposition
  - Tool surface requirements for good coating adhesion
  - Some limitations
- How do you acquire PVD technology for your product?
- Some statistical data on coated tools and components, including SECA information

Surface engineering principle: A hard skin protects metals against all forms of wear





Comparison of surface hardening treatments in metalforming

Work material	Surface Treatment	Layer Hardness, HV 1000 2000 3000	Layer Thickness, µm	Process Temperature, °C
Carbon steels, alloy steels, stainless steels	Nitriding, Carburizing		125 - 1500	800 - 1100
	Gas (Ion) nitriding		75 - 750	350 - 570
Tool steels	Hard chrome plating		25 - 250	40 - 70
	Thermal Diffusion carbide coating		5 -10	1000 - 1050
Tool steels, high speed steels, cemented carbide	Chemical Vapor Deposition (CVD)		5 - 15	900 - 1050
	Physical Vapor Deposition (PVD)		2 - 10	250 - 500

25 µm = 0.001 inch

Hard coatings at the cutting edge of carbide tools: PVD developments predominate the last decade

1970 CVD TiC

1975 CVD TiC / TiCN / TiN

CVD TiC / Al_2O_3 / TiN

1980 CVD TiC / TiCN / Al_2O_3 / TiN...

MTCVD TiCN

1985 PVD TiN

PVD TiCN

1990 PVD TiAlN

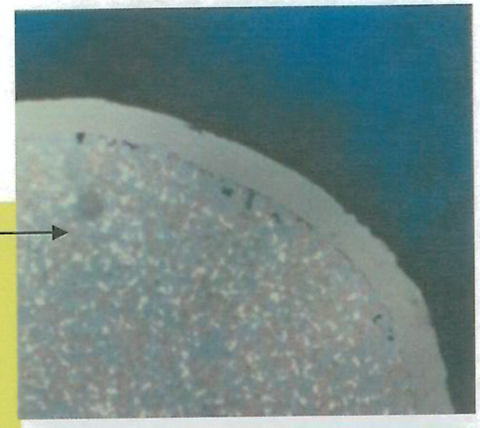
CVD Diamond

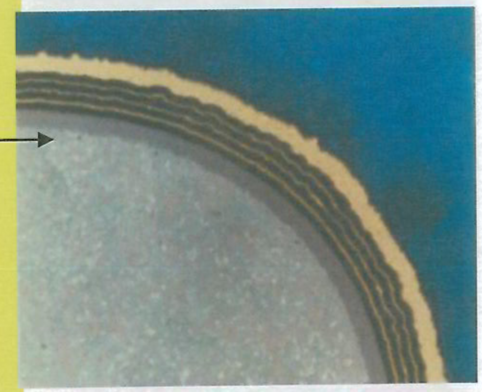
1995 PVD TiN / TiAlN / TiN / TiAlN...

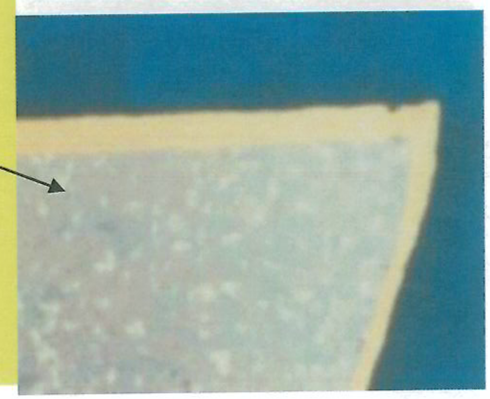
PVD TiB_2

PVD TiN / TiCN /..MoS_2, TiAlN / WC-C

2000 PVD TiAlN multi-, nano-layers, AlCrN







CVD vs. PVD coated tools

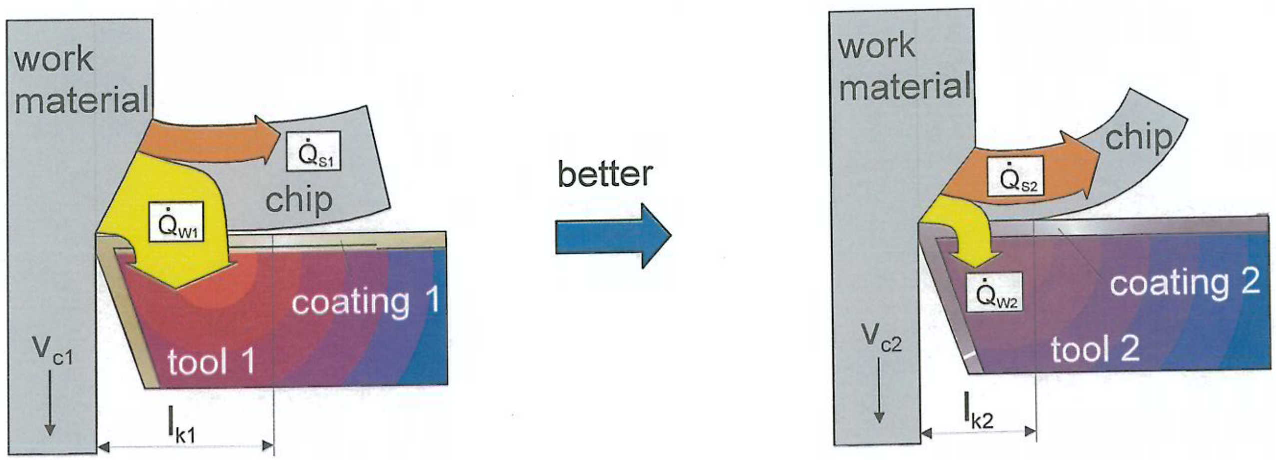
PVD has certain advantages cf. CVD

- PVD applies to HSS and carbide, CVD only to carbide tools
- low T_{dep} preserves carbide edge toughness
- compressive residual stress σ_R inhibits crack propagation
- applied to sharp cutting edges
- finer grains (smoother), higher microhardness
- non-equil. compositions impossible with CVD
- environmentally cleaner process

PVD has certain limitations cf. CVD

- adhesion to substrate <u>sometimes</u> marginal, relative to diffusion bonding in CVD
- thickness limited due to residual stress – typical 4 µm PVD cf. 12 µm CVD coatings
- multilayer coatings more common in CVD, including alumina (not yet economic by PVD).

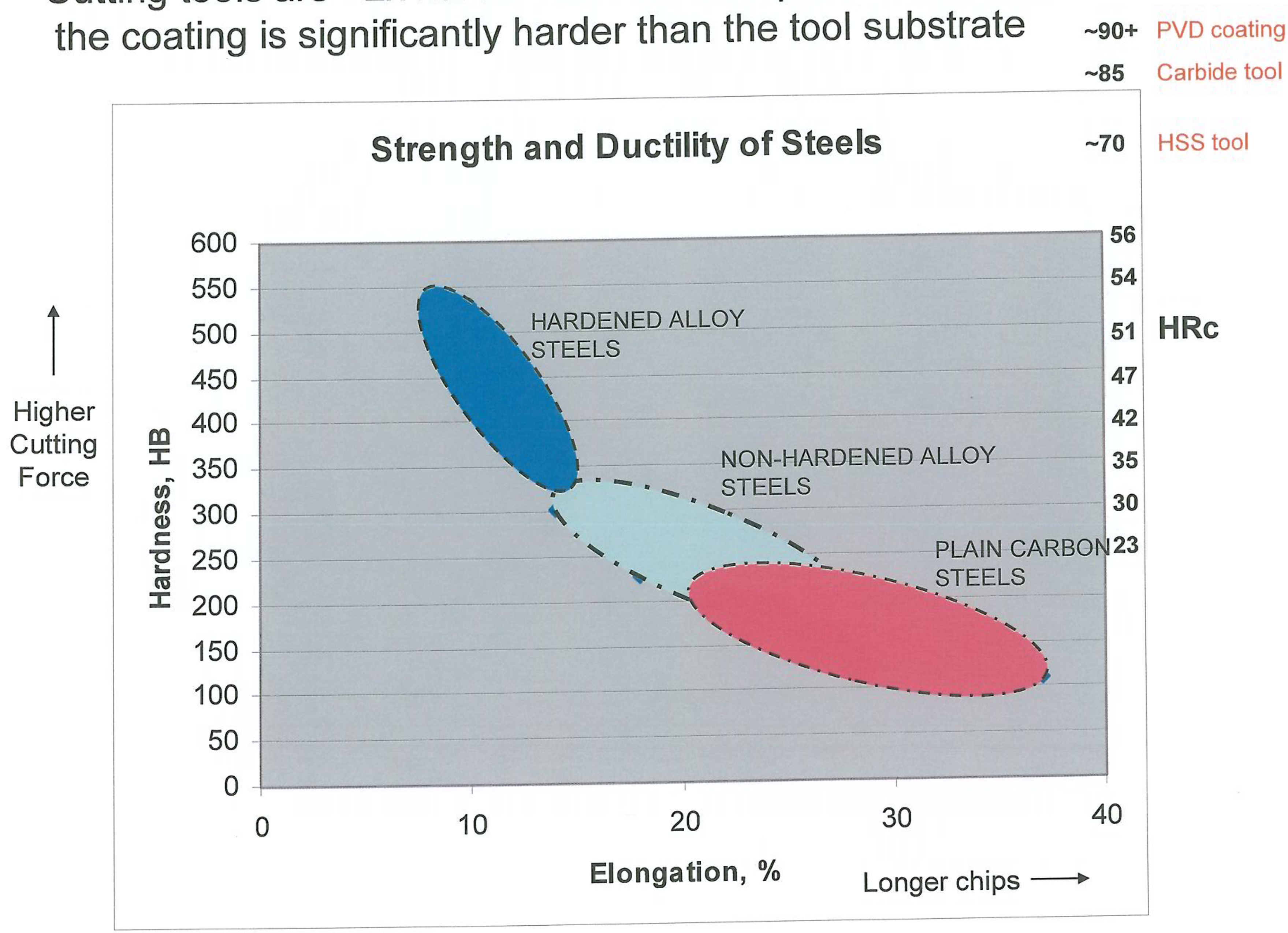
In metal cutting coating properties alter the heat generation and heat transfer between chip and tool



Variables affecting heat generation:

- Work material – fracture energy, strain-hardening coefficient, thermal conductivity
- Friction coefficient at tool/chip contact surfaces, contact length dictated by cutting edge geometry
- Coating thermal conductivity
- Metal cutting parameters (speed, feed, depth of cut)

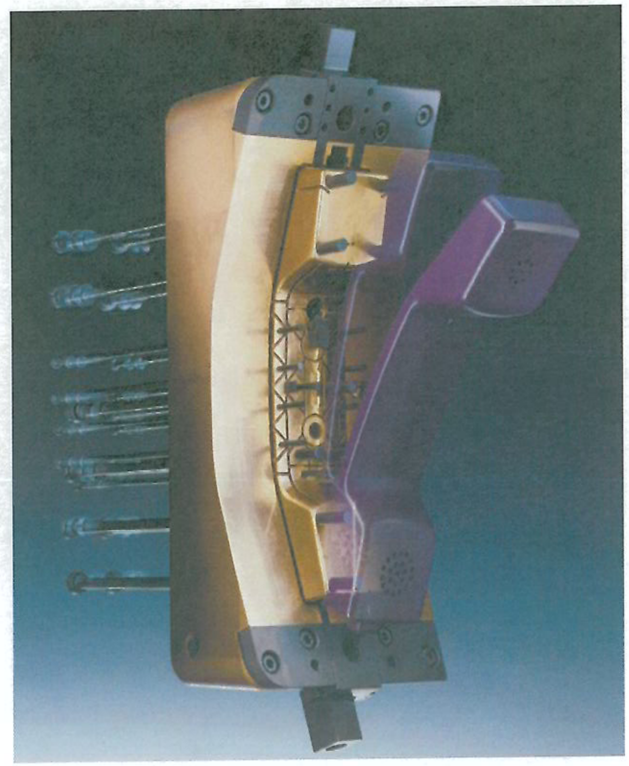
Cutting tools are ~2x harder than the workpiece materials; the coating is significantly harder than the tool substrate



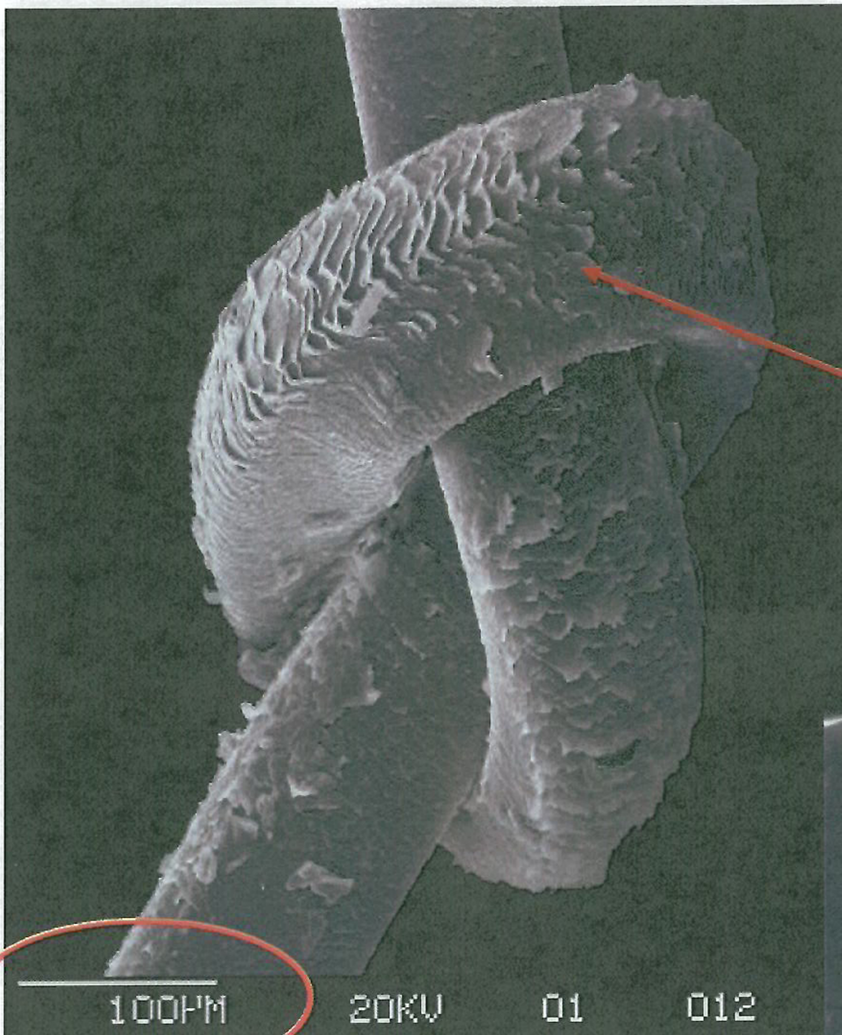
Coatings benefit tools and components

Metal cutting

Punching/Stamping



Plastic forming molds

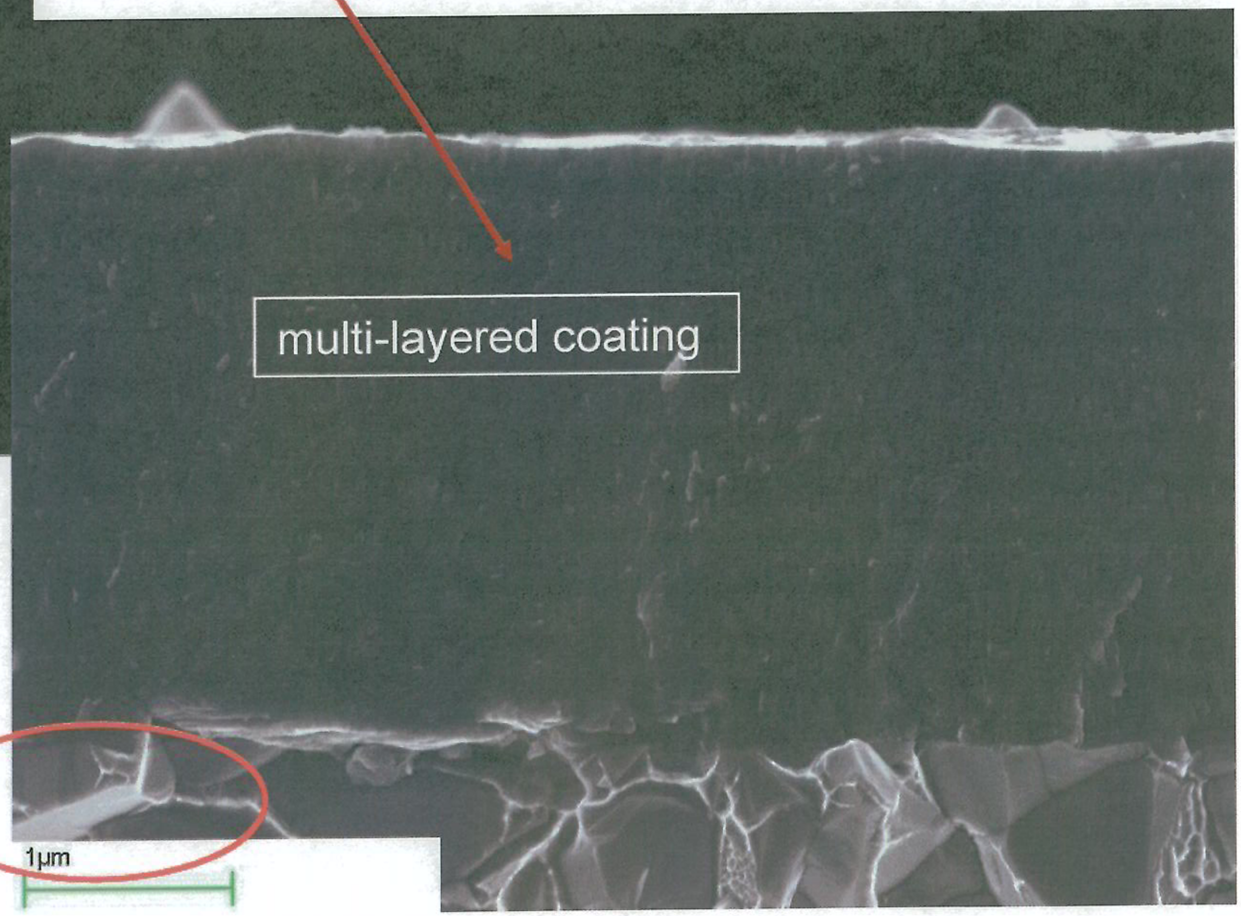


PVD coatings are thin!

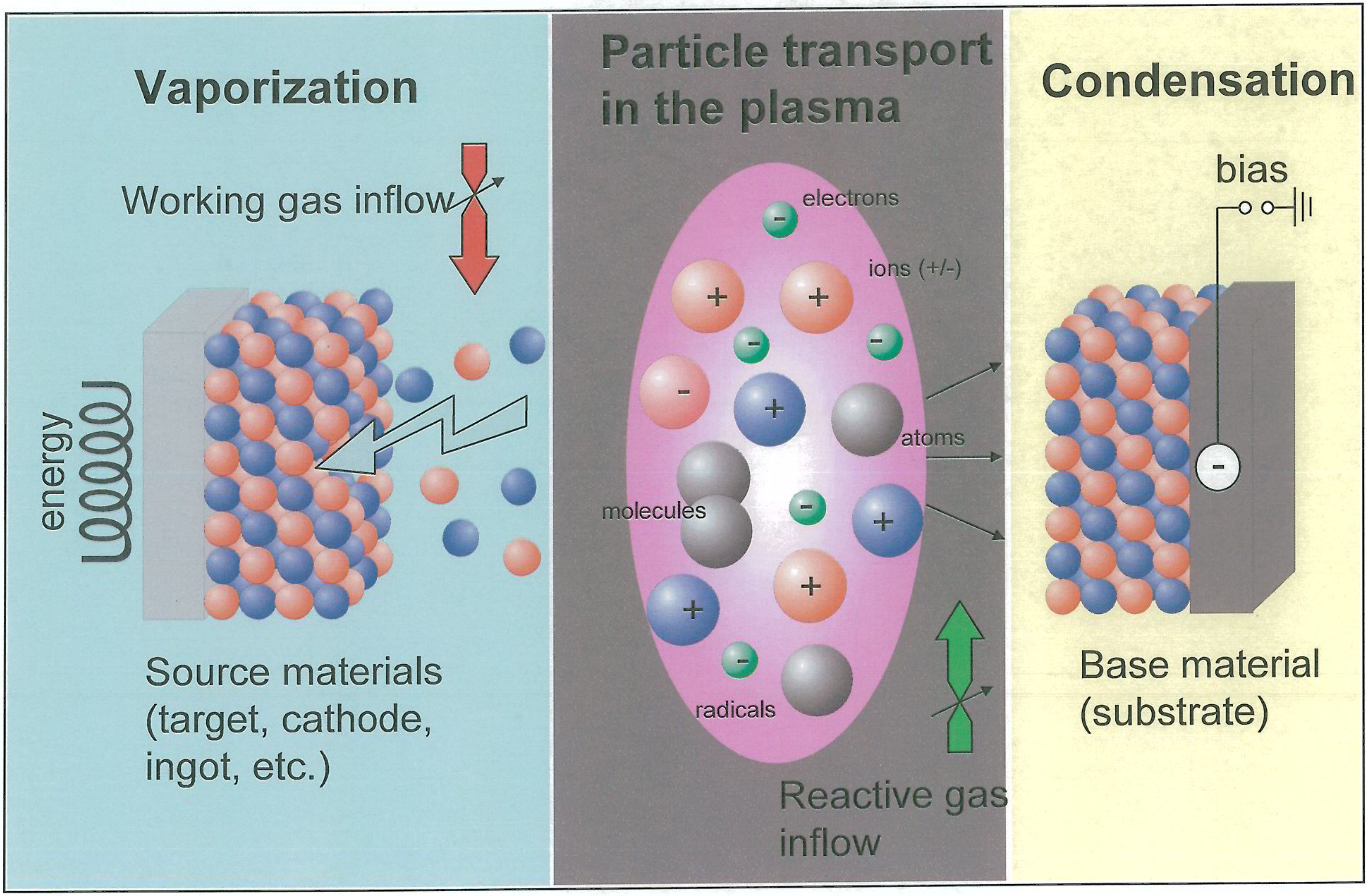
$$1\ \mu m = \frac{1}{1000}\ mm$$

Human hair: 50 – 100 µm

PVD layers: 1 – 10 µm



The three phases of coating formation

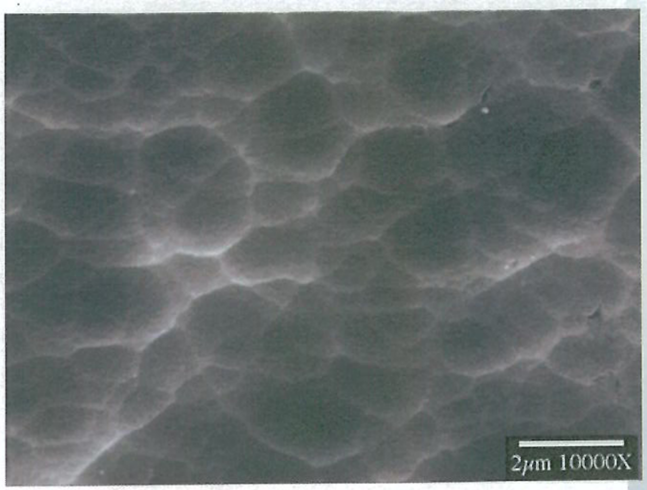


Typical features of PVD coating technology

The Process

- High vacuum, plasma-activated coating deposition
- Coating temperature between 450 and 1030 °F
- Line of sight process (areas can be masked)
- Requires clean, contaminant free surfaces

The Result



- Micro/nano-grained, hard, lubricant coating
- Residual compressive stress
- No edge effects – with proper edge prep
- Polished surfaces can be coated
- No heat treatment necessary after coating
- Limited coatability of holes and slots

Critical factors for coated cutting/forming tool performance

- Good tool design, e.g., cutting edge micro-geometry
- Suitable tool substrate material selection
- Proper heat treatment (HSS) / carbide grade choice
- Correct surface preparation
- Appropriate coating for the application
- Selection of a quality coating process
- Optimize the machining/forming parameters
- Machine trial with coated tool on the job

Importance of surface preparation: factors that affect coating adhesion

- Contamination-free surfaces: grease, oxide layers, polishing residues must be removed; no Zn, Cd and low temp. braze metals
- No overheating during surface grinding: avoid deep grind marks and high surface roughness
- Edge prep is important: sharp edge should be de-burred, correctly honed
- EDM'ed surfaces must be post- treated to remove white layer
- No surface cobalt depletion on carbide substrates
- No cobalt capping on carbide substrates

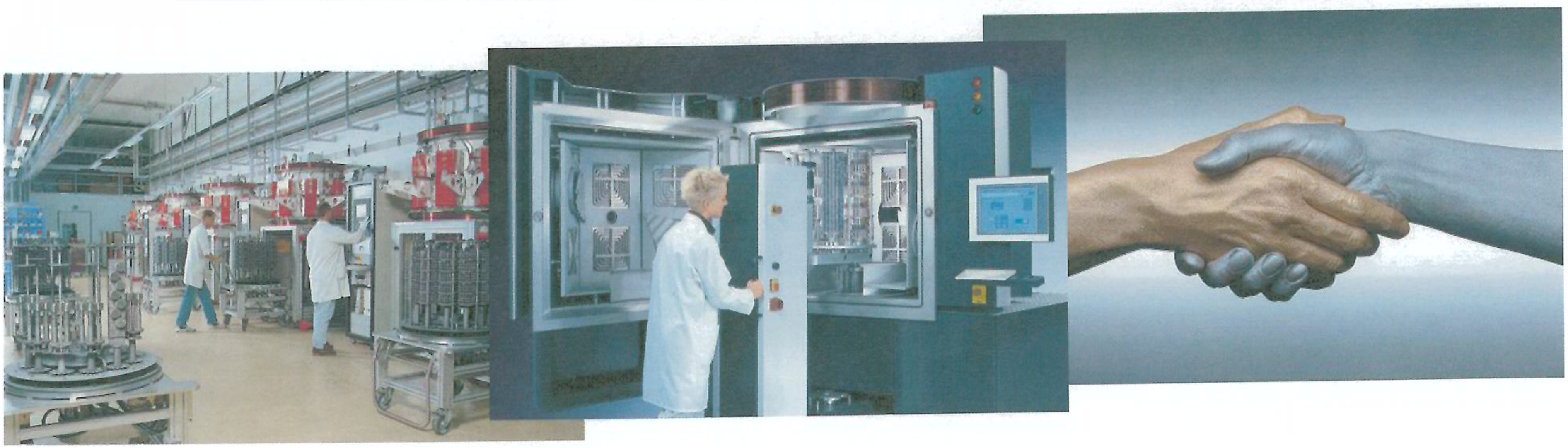
PVD technology acquisition options

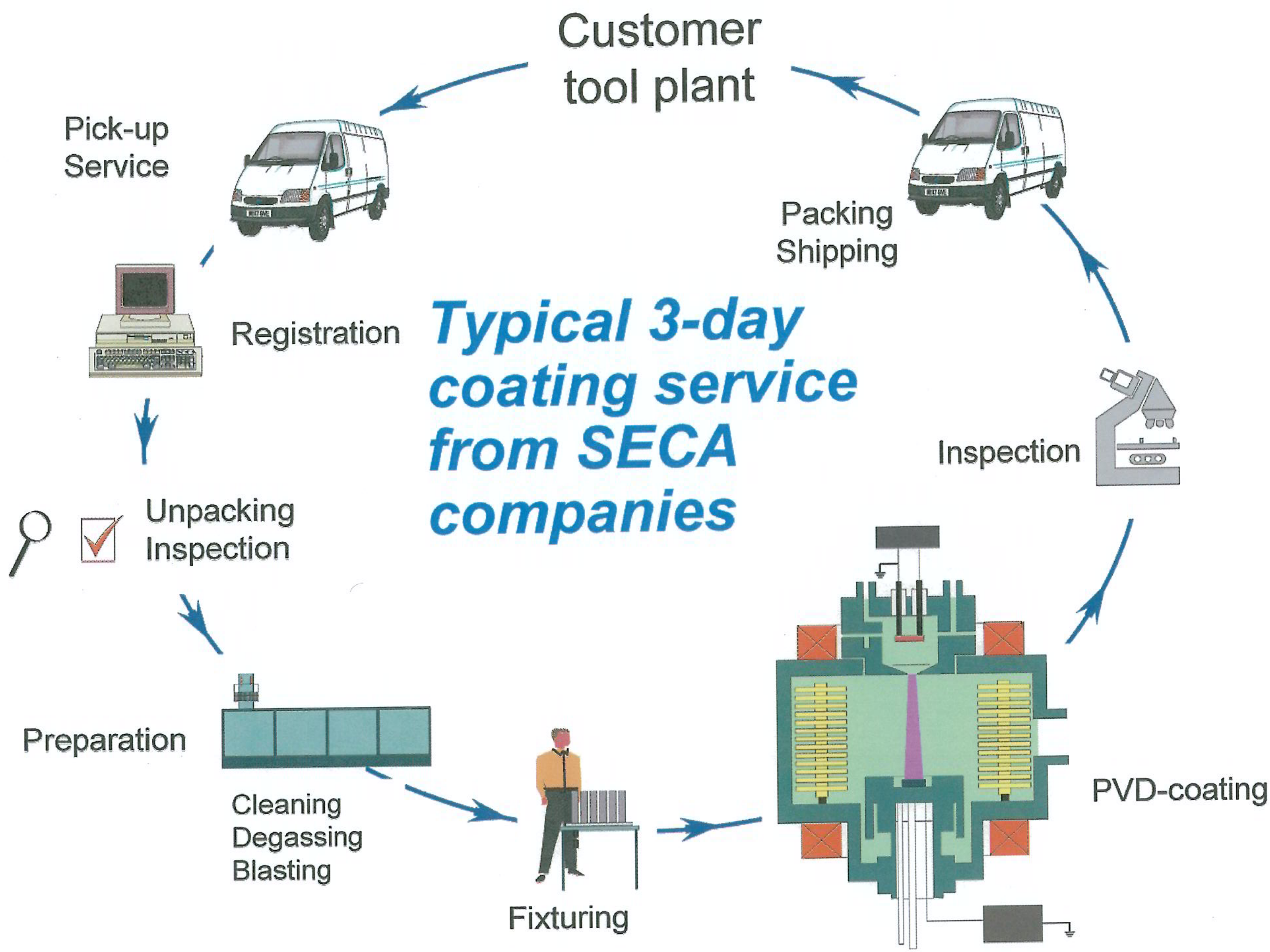
Tool company, major end user

1. Toll coating service with one or several toll coaters

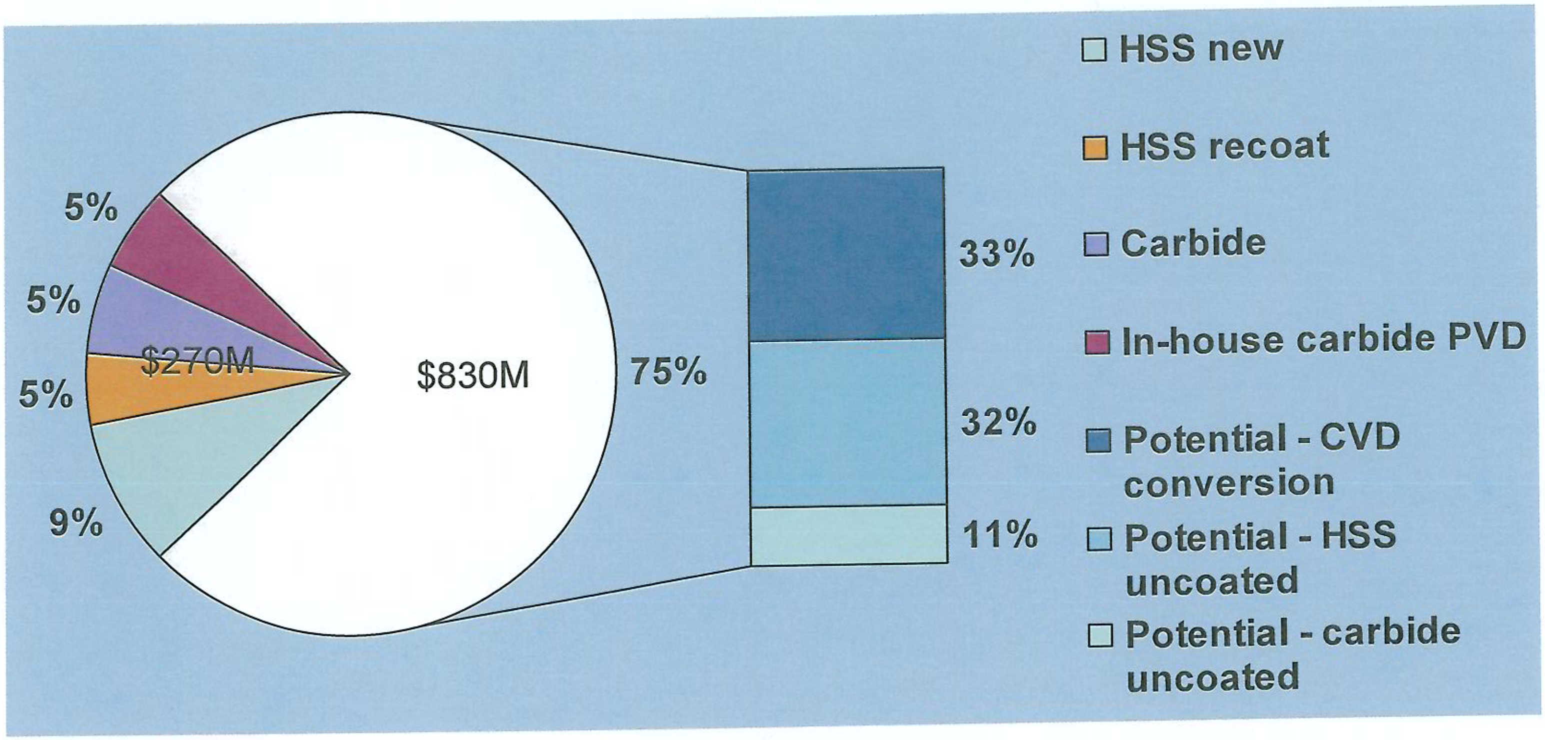
2. Investment in coating plant

3. Partnership on in-house coating plant



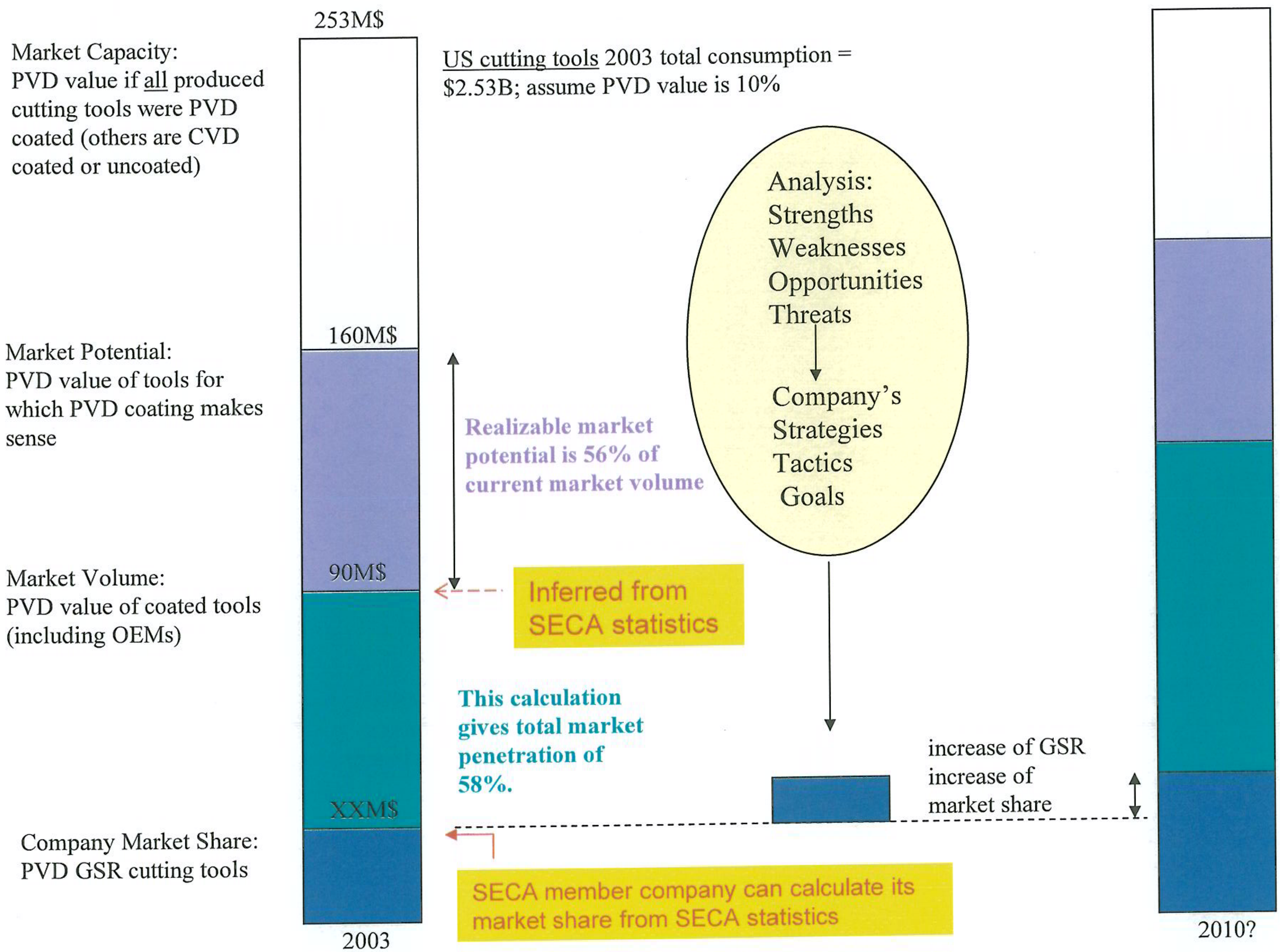

Customer
tool plant
Pick-up
Service
Packing
Shipping
Registration
Typical 3-day
coating service
from SECA
companies
Inspection
Unpacking
Inspection
Preparation
Cleaning
Degassing
Blasting
Fixturing
PVD-coating

Estimates of realized and potential PVD coating global market for cutting tools



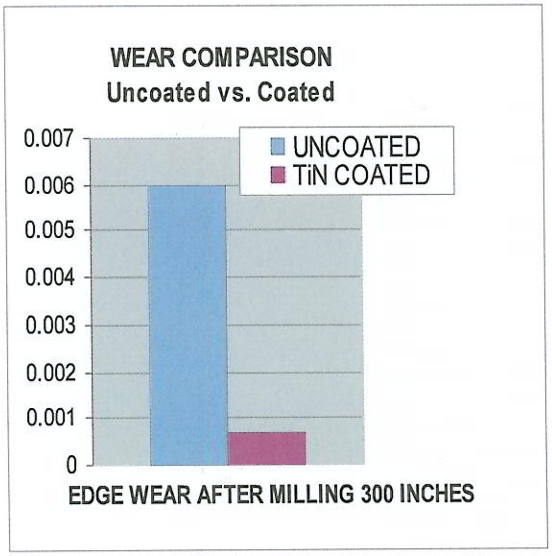
Assume PVD value = 10% of $1.1B tool sales = $1100M; total PVD coated penetration of the global cutting tool market is ~25%, cf. 33% CVD coated, 32% uncoated.

PVD coating USA statistics help SECA members plan their business



A simple and proven application of PVD TiN on cutting tools.

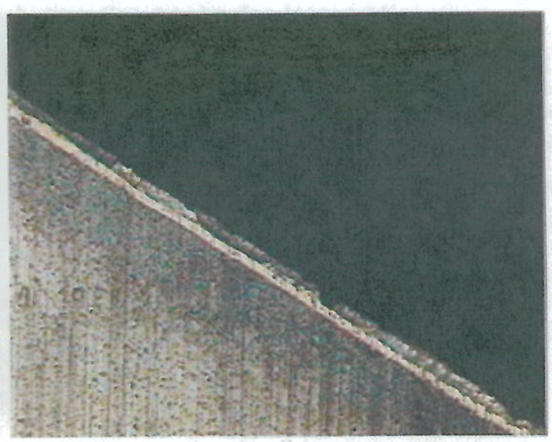
½" diameter 4-flute carbide end mill, milling 4140 steel HRc28.



Tool Type:	1/2" 4-flute Carbide end mill	1/2" 4-flute Carbide end mill
Condition:	UNCOATED	TiN COATED
Material:	4140 Steel DIN 1.7225	4140 Steel DIN 1.7225
Depth of Cut:	.500" 12.7mm	.500" 12.7mm
Width of Cut:	.125" 3.18mm	.125" 3.18mm
Spindle Speed:	1955 RPM 78 m/min.	2933 RPM 117 m/min
Feed Rate:	23.5 IPM 597mm/M	32.5 IPM 825mm/M

100X MAGNIFICATION OF THE CUTTING EDGE

Uncoated wear .006"



TiN Coated wear .0007"

The TiN coated end mill milled the same amount of steel at a speed 50% faster than the uncoated end mill and still had less wear.

Drilling hardened tool steel with an AlTiN coated straight flute carbide drill.

Tool Type:	Straight Flute Carbide drill	Straight Flute Carbide drill
Condition:	UNCOATED	AlTiN COATED
Material:	M-4 @ HRc64	M-4 @ HRc64
Depth of Cut:	.591" 15mm	.591" 15mm
Dia. of Cut:	.2362" 6mm	.2362" 6mm
Spindle Speed:	477 RPM 9 m/min.	477 RPM 9 m/min.
Feed Rate:	1.0 IPM 25.4 mm/M	1.0 IPM 25.4 mm/M