# Decorative Finishing Using PVD

## A pilot production program was formed to test a new way of applying a decorative finish with a polished-brass look...

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Building hardware manufacturers formed a pilot production program to test the applicability of physical vapor deposition (PVD) for their parts. Several of these hardware manufacturers had previously tested the technology and found more reasons not to use the process than reasons to use it.

Arc plasma physical vapor deposition (PVD/ARC) is a vacuum plating technique where metal vapor in highly ionized plasma is generated by use of electric arcs. Reactive deposition of titanium nitride (TiN) and titanium carbide (TiC) are presently the most common applications.

The most extensive research and widely implemented application of arc deposited plating is as a wear-resistant finish on cutting and forming tools. TiN coatings also have a rich color that closely simulates brass or real gold. With the combination of abrasion resistance, corrosion resistance and attractive color, TiN plated surfaces open up many new applications in consumer oriented products.

The objectives of the pilot program were 1) To provide an excellent finish and lifetime warranty for consumers, and 2) To eliminate some of the toxic chemicals from the plating process. Because of the improvements in PVD, the cost of production is estimated to be lower than that of electroplating. Physical vapor deposition technology has helped high-tech industries because, unlike conventional plating methods, the deposited material is a metal or alloy. No toxic chemicals are involved in the process.

However, some of the major problems associated with the PVD process are the restricted size and shape of the components and slow production rates. Improvements in the technology, using cathodic arc plasma (CAP) technology, provided a high deposition and ionization rate as well as low-temperature operation.

In the pilot program, the supplier provided coated square panel plates for manufacturers to test. The manufacturers carried out their own tests on these panels. When the results were positive, the manufacturers sent the supplier a small quantity of components for further testing.

Manufacturers were cautious before purchasing any PVD equipment, even after sample testing, components testing and plant visits. However, their confidence was eventually won.

**Technology.** CAP is a branch of physical vapor deposition technology used for decorative coating.

Various metallurgical thin films combat wear, chemical corrosion, and protect against high temperatures and the environment. CAP deposits compounds such as nitrides, oxides, carbides and mixtures. Some of the coatings most frequently used are TiN (titanium nitride), TiC (titanium carbide), ZrN (zirconium nitride), CrN (chromium nitride), their mixtures, and sometimes, with multi-layers.

In the CAP deposition process, part of the cathode is evaporated by the action of vacuum arcs. The basic components consist of a vacuum chamber, cathode assemblies, arc power supply systems, bias power supply, control panels, water-cooling system, compressed-air supply system, and a vacuum pumping system.

A typical system has eight cathodes. This system includes a vacuum chamber, cathode assemblies and vacuum pumping system. The chamber's interior dimensions are 40 by 60 inches. This system has eight cathodes in order to achieve optimum uniformity of coating.

**Coating chamber.** The coating chamber is made of stainless steel with a double wall for water cooling. A front door for loading and unloading also provides access for cleaning and maintenance. Two view ports are mounted on the front door for visual inspection. A shutter behind the view port keeps the glass window clean during operation. Cathodes are mounted on either side of the chamber wall. The back of the coating chamber is connected to the pumping system. The fixturing system, including a planetary rotation system for racks, is mounted on the top.

**Pumping system.** The pumping system consists of two mechanical pumps, one base pump, two diffusion pumps and a series of pipes and valves that connect the pumps together with the coating chamber.

Pumping is done in three stages. First, the mechanical pumps pump the chamber to low vacuum (rough pumping). Second, the base pump then will pump to chamber to medium vacuum. The base pump adds efficiency and pumping speed. Finally, the diffusion pumps will pump the chamber to high vacuum. The mechanical pumps also serve as a backup pump for the base and diffusion pump, which is the high-vacuum pump.

**Fixturing system.** The planetary rotation system supports six fixturing posts and is driven by a variablespeed motor. The planetary system provides two degrees of motion for each of the fixturing posts, self-spinning as well as circling around the chamber. Consequently, uniform coating is achieved.

The automatic pressure controller maintains a constant gas pressure in the chamber during deposition. Two gas channels are allowed for argon and nitrogen. A thermocouple thermal gage is used for low-vacuum measurement, and an ion gage is used for high vacuum measurement. Both readings are shown on the controller display.

**Bias power controller.** A bias power supply provides electrical potential bias between the cathodes and the substrates. As a result, the charged particles emitted from the cathodes will gain acceleration from the electric field and deposit onto the substrate with high kinetic energy. This kinetic energy turns into bonding power, which ensures good adhesion.

Local area arcing due to out-gassing on the substrate surface during deposition may damage the quality of the coating. The bias power controller has an arc suppression circuit to minimize local area arcing.

**An arc-power-circuit-supply controller** for the cathodes has eight sets of controllers, one for each cathode. Three parameters are displayed and can be adjusted: the current of the cathode, arc restarted with automatic restart circuit, and water cooling for cathodes. The voltage between the anode and cathode is about 20v depending on the anode-cathode configuration. To sustain the arcing, the minimum current is about 40 amps and 60 amps for titanium and zirconium, respectively. Low current is preferred for fine-grain-size deposit. The drawback of low current is that the arc spots traveling on the surface of the target are not stable and extinguish easily. This arc can be restarted automatically.

Maintaining high-quality coating consistently requires a reasonable control of the coating room environment. Humidity, temperature and particulate levels within the coating facility affect the cleanliness of the parts to be coated. Specification of the cleaning equipment, materials and procedures for preparing the parts for finishing is critical to ensure quality.

Table I outlines the coating performance specifications as required by the Builders Hardware Manufacturers Association, Inc. in ANSI/BHMA A 156.5-1992, intended for organic coatings. Also listed in Table I is the required performance of vacuum deposited coatings.

To test the performance of the CAP systems, numerous runs were used to test the uniformity of the coating characteristics within each part and from part to part as well as throughout the chamber and from run to run. These tests were performed on small, medium, and large parts.

The team members of the pilot program were able to coat products that passed all the tests within the time frame set by the manufacturers.

Some disagreement on cleaning procedure in the early stage of the program caused some coating failure. However, once the correct cleaning procedure was used, coatings applied using PVD equipment exceeded the specifications with TiN test (see Table I).

To avoid future misunderstanding with customers regarding the cleaning process, a substrate pretreatment system was designed specifically for PVD deposition.

Thin TiN coatings are producing dramatic increases in tool life and productivity in numerous industrial applications. The flexibility of the process, its capability to deposit metals at high rates, and the qualities of the finish, make PVD/ARC an attractive low-cost, high-quality surface finish for decorative hardware. **PF**

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(See hard copy for Table I)

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## TABLE I—Required Performance of PVD Coatings

**BHMA Test (Ref ANSI/BHMA A156.18-1993 Test Procedures)**

| Procedure | Required | Required with TiN Test | |
|---|---|---|---|
| Salt Spray | 96 Hrs | 1000 Hrs | ASTM B 117-90 |
| Humidity | 240 Hrs | 1000 Hrs | ASTM D 3359-78 |
| Pencil Hardness (gouge) | 4H | 6H | BHMA A156.18 |
| Perspiration | 4 Cycles | 4 Cycles | BHMA A156.18 |
| UV Resistance (proposed) | 144 Hrs | 500 Hrs | ASTM G 53-91 |
| Tabor Abrasion (proposed) | 500 Cycles | 1000 Cycles | ASM D 4060 |
| MEK | | 100 | ASTM D 4752 |
| Scratch Resistance | | 4H | ASTM D 3363 |
| Color | | CIE lab | |