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Physical Vapour Deposition (PVD) Coating: the coatings, the process, industries and applications, and costs

BY DAVID WAYNE

Although the term PVD (physical vapour deposition) isn't a household name, products coated using the PVD process are found in most households and in the automotive, sporting goods, medical device, and tooling industries. Go into a home goods big box store and look at faucets, door hardware, lighting fixtures—products offering a "lifetime finish" are often PVD-coated. This finish is ubiquitous in industries globally.

What is PVD coating?

PVD coatings enhance metal, plastic, and ceramic parts, but PVD is not paint, powder coating or electroplating. PVD is a metallurgical coating process that applies at least one metal on a part's surface via a vacuum deposition process. The process creates a very thin "film" on parts (from less than a micron to five microns for specialty coatings). Commonly used metals include:

- Zirconium (Zr)
- Titanium (Ti)
- Chromium (Cr)

Often, the metal is deposited as a nitride, carbide, or oxide, meaning the metal is combined with nitrogen, carbon, or oxygen to form a metal ceramic compound with increased durability and/or a desirable colour. These elements are added to the process in trace amounts as a gas.

Why use PVD coatings?

As manufacturers know, it's difficult to find materials with all the properties your product requires. The base material may not be hard or durable enough or be an undesirable colour. PVD coatings can improve the durability, appearance, or functional properties of many products. And it can be divided into two basic (and often overlapping) categories.

Colour PVD coatings for durable/decorative applications

PVD coatings can improve both the appearance and durability of your product. These finishes are scratch- and wear-resistant, improve corrosion resistance, and are so thin—less than one micron—they are suitable for high-tolerance parts. Products that benefit from durable coatings in many colours include jewelry, door hardware, plumbing fixtures, sporting goods, consumer electronics, and automotive trim. These coatings include metallic colours such as copper, stainless steel, gold, nickel, brass, and chrome. Specialty colours such as grey, blue, or black include semi-transparent optical layers that can refract light to darken or change the product's colour.

Performance coatings

Performance coatings add hardness, toughness, corrosion protection, wear resistance, and lubricity to cutting tools, injection moulds, metal forming tools, engine components, surgical instruments and implants, and sporting goods. These performance coatings are only microns thick and are suitable for even the highest tolerance parts. They're designed to make your product last longer, operate more efficiently due to lower friction, withstand high temperatures, and resist corrosion. And they can also offer both decorative and performance characteristics when a product must meet functional as well as aesthetic specifications.

The Process

PVD coating machines use several processes to apply finishes. The processes take place in a vacuum chamber where the coating is evaporated and condenses onto the surface of the part, atom by atom or ion by ion.

The vacuum chamber removes unwanted molecules from the deposition environment (i.e.: water and oxygen) for increased control over the reactions that take place, by using a series of pumps to remove the air and water vapour from the chamber and continuously pump to the desired vacuum throughout the process.

The Material

The vacuum chamber contains a solid coating material, commonly referred to as the source or the "target." Depending on the machine, the target may be shaped as a plate, a disk, or a cylinder. Parts to be coated are loaded into to the vacuum chamber, and once the chamber has been pumped down to a high vacuum setting, energy applied to the target evaporates it. As the evaporated material travels to the substrates, the material reacts with gases in the chamber and condenses on part surfaces, covering them with the coating.

All coating processes use a non-reactive (inert) gas such as argon to generate a high energy plasma that helps drive the deposition process. To alter the metal coating material for a specific purpose such as increased durability or colour, reactive gases such as nitrogen (N2), oxygen (O2), methane (CH4), or acetylene (C2H2) are added to the process. These gases react with the source material to create coatings. For example, the popular bright gold coating used on cutting tools is made of titanium nitride (TiN), in which a titanium target metal combines with nitrogen gas in the chamber before condensing on the part.

And for an energy source, the PVD process typically uses sputtering or cathodic arc.

The Cost

A common misperception is that PVD coating adds substantial

cost to a manufactured part. Although having a small volume of parts coated by a coating service vendor can be expensive, coating cost per part can drop drastically when you purchase PVD equipment and bring the process in-house.

High-capacity PVD batch coating systems are capable of quickly coating both small and large volumes of parts. Depending on the part dimensions, a larger coating system can coat many hundreds of parts in one batch. The costs of operating a PVD coating system include the coating source material, electricity, common gases (such as nitrogen and argon), and periodic maintenance. In many applications, the source material may last for months before the need for replacement. The coating source material is usually the highest cost consumable. For decorative colour PVD applications on consumer products, this means coating costs can often be measured in cents, not dollars. Low per-part coating costs, increased efficiency, and better-quality control are key factors in making the decision to bring PVD coating in-house. ■

David Wayne is Vapor Technologies, Inc.'s (VaporTech) director of sales & marketing. VaporTech is a North American manufacturer of PVD and DLC coating systems installed in facilities in Canada and globally.

For more information, please visit vaportech.com or email kperson@vaportech.com

Diamond-like carbon (DLC)

Diamond-like carbon coatings are hugely popular for their performance and aesthetics. DLC combines low friction and high hardness for applications requiring easy release or low sliding wear like engine components, medical devices, dies, and molds. The DLC process creates a rich, neutral, dark grey to near-black colour that enhances product appearance and value in many commonly used products. Technically, the application process isn't true PVD (the coatings are created with a chemical vapour deposition process that uses carbon containing gases rather than a solid source material), but the same machines can often coat with DLC as well as PVD.

PVD hex-chrome alternative

Traditional chrome plating involves exposing parts to chromium baths that contain chromium trioxide (hexavalent chromium or "hex-chrome" for short) and sulfuric acid. Unfortunately, hexavalent chromium and concentrated acids are toxic, and therefore highly regulated to protect worker safety and the environment. These regulations require manufacturers to maintain extensive safety controls, and in many countries require extensive permitting to expand operations.

To avoid environmental impact, improve worker safety, the PVD process can provide a simple, reliable coating alternative that is by its nature beautiful, durable, and safe.
PVD can deposit a durable decorative, pure chromium coating. The addition of elements such as nitrogen can also produce even more durable chrome alternatives such as chromium nitride (CrN) that greatly improve performance in high-wear applications and add colours unachievable with chrome plating.

VaporTech has conducted experiments testing our chromium PVD coating against chrome electroplating. Our findings:

- Colour is virtually identical.
- Equivalent hardness to chrome (1,000 Vickers) with options to further improve surface hardness (up to 2,200 Vickers).
- Equivalent or better abrasion resistance.
- Custom coatings can be designed to meet specific hardness, durability, and corrosion resistance specifications.
- More than a 30 per cent improvement in wear resistance possible with a harder chromium nitride base layer.