Kalcor University

PVD and Vacuum Metallization

The Look of Bright Metal

Call it Bling! Customers love the bright, shiny, metallic look of chrome. From bathroom faucets to car bumpers bright metal finishes are everywhere.

Traditionally these parts were Chrome plated. Chrome plating is a technique of electroplating where a thin layer of chromium is electrically deposited onto a metal or plastic object's outer surface. Typically, a cleaned part is placed into a large chrome plating vat, where it is allowed to warm to solution temperature and then, using application of electrical current the part is electroplated.

THE DEMISE OF CHROME PLATING

But, from a health standpoint, hexavalent chromium is the most toxic form of chromium. In the US it is now heavily regulated by the Environmental Protection Agency (EPA). The EPA lists it as a hazardous air pollutant because it is a human carcinogen, a "priority pollutant" under the Clean Water Act, and a "hazardous constituent" under the Resource Conservation and Recovery Act. Due to the low efficiency and high solution viscosity a mist of water and hexavalent chromium is released from the bath, which is toxic. So dangerous is hex chrome that the US automakers have prohibited its use on car parts.

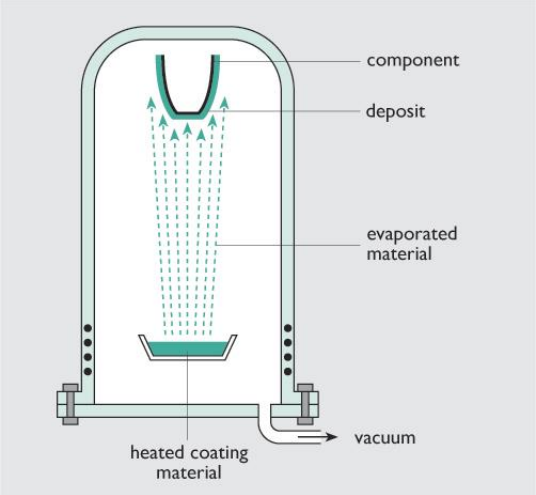
Several alternatives to the highly toxic process of Chrome plating have emerged, such as chrome-looking paints and the use of trivalent chrome; neither of which provides comparable appearance to Chrome plating. But for many decorative purposes, a process known as **Physical Vapor Deposition**, or **PVD** also frequently referred to as **Vacuum Metalizing**, is now quite common and can achieve a the look of Chrome plating. PVD or metallization even offer alternative appearances such as antique brass, polished stainless, brushed nickel, or tinted chrome (such as the stylish "black chrome") appearance.

WHAT IS PVD OR VACUUM METALIZATION?

The process of applying a thin film metallic coating by means of PVD is to place the part into a sealed vacuum chamber, and apply electric current and voltage or bombardment of inert gas to ionize a target material (which can be a pure metal or an alloy). Once the target material is ionized into a vapor form it is the deposited on the part surface. There are several three popular types of PVD coating: Vacuum Evaporation and Sputtering, and Arc Vapor Deposition (or cathodic arc).

VACUUM DEPOSITION

Vacuum evaporation, also known as vacuum deposition, is a process where the target material intended for coating is heated to very high temperatures and vaporized. The vaporized metal is drawn to the part surfaces because of an electrical potential difference. A common term for the trajectory for this type of deposition is "line of sight" and so the process is most useful for simple geometries.



By running this process within a vacuum, contamination by other gases is greatly reduced. Normal vacuum levels in a PVD chamber typically range from 10^{-5} to 10^{-9} Torr (millimeters of mercury). With little contamination, the deposition rate can be much faster than other methods such as sputtering. Thermal evaporation is normally done using resistive coils or a high energy electron beam. The substrates are often located at a greater distance from the target source to reduce radiant heat transfer. Vacuum deposition is used to form optical coatings, decorative coatings, permeation barrier films on flexible packaging materials, electronically conducting films, wear resistant coatings, and corrosion protective coatings.

SPUTTER DEPOSITION

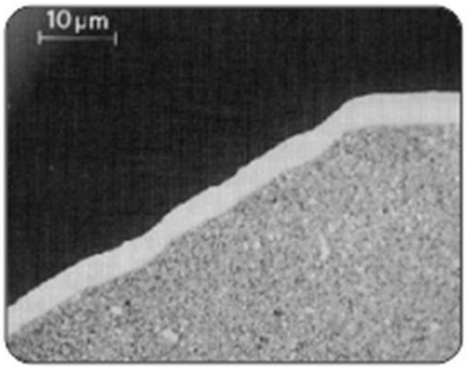
Sputtering is a metal deposition process where the target material is not vaporized using heat, but its metal atoms are physically dislodged from the target by the collision of a bombarding particle. The distance from the target to the part in a sputtering chamber is much shorter than in vacuum deposition. Sputtering is also done under much higher vacuum. The sputtering source itself can be made of elements, alloys, mixtures, or compounds. This form of metal deposition is commonly used in semiconductor manufacturing, on architectural glass, reflective coatings, compact discs (CDs), and decorative coatings.

ARC VAPOR DEPOSITION

Cathodic arc deposition or Arc-PVD is a physical vapor deposition technique in which an electric arc is used to vaporize material from a cathode target. The vaporized material then condenses on a substrate, forming a thin film. The technique can be used to deposit metallic, ceramic, and composite films. The arc evaporation process begins with the striking of a high current, low voltage arc on the surface of a cathode (known as the target) that gives rise to a small (usually a few micrometers wide), highly energetic emitting area known as a cathode spot. The localized temperature at the cathode spot is extremely high (around 15000 °C), which results in a high velocity (10 km/sec) jet of vaporized cathode material, leaving a crater behind on the cathode surface.

BATCH SIZE AND DEPOSITION TIME

Since the vacuum metallization process happens under a high vacuum, it is inherently a batch process. Parts are loaded in the chamber, a vacuum is drawn, the evaporation or sputtering process initiated, and then after sufficient time to build the required film, the chamber is pressurized, opened, and the parts removed. Chambers can be as small or large as needed for the production requirements; but large chambers require much more time to evacuate and achieve the required vacuum. Deposition times in large chambers can run into hours, making the PVD process the pacing step in many decorative processes. Some innovation has taken place, and today there are systems available where only a few small parts are in the chamber at a time. This permits a vacuum to be drawn much more quickly, and the metallization of small parts using such a system can be in-line, synchronous with other operations such as molding, or coating.



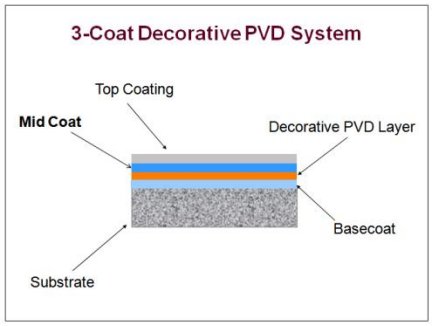
WHAT DOES PVD HAVE TO DO WITH SPRAY COATINGS?

In theory, a plastic part can be metalized without the use of any coating at all – but that's theory. In reality coatings perform several important roles:

1. First, spray-applied coatings provide a **surface primer** that fills many nearly invisible voids and imperfections on the part surface. Molded plastics, cast metals and other machining operations result in a surface, that if metalized would be too irregular to provide the mirror-like appearance of bright metal. Surfaces that may be perfectly adequate for traditional paint finishing are usually unacceptable for the high demands of metallization. The surface primer coat provides the smooth, uniform surface required for metallization.

2. Metallization is a time consuming and costly process. Target materials are expensive, and the energy required to create a high vacuum, and to vaporize the metal is expensive. Generally, the applicator seeks to deposit the thinnest metal film required to get the bright metal appearance – often a nearly microscopically thin film. This thin film is not very durable. So a **protective top coat** is ordinarily applied to guard the thin metal film from scratches and wear.

While the top coat serves a functional, protective purpose, it can also provide an aesthetic function. **Cosmetic top coats** can be formulated to be water-clear, transparent to the underlying metal film, or they can modify its appearance. By tinting the top coated a wide range of shaded metallic looks can be achieved. These are the popular blue- and black- chrome finishes on many automotive parts.



An even wider range of attractive finishes can be attained if a third coat, or a **cosmetic mid coat** is applied between the metal deposition layer and the top coat. This "mid coat" can be formulated to work with the metal to provide pearlescent metallic appearance, or a rich palette of other fashionable colors from "candy" metallic to rich, highly-chromatic finishes.

3. The top coating can add other functionality to the part beyond protection of the film or aesthetics. For example, additives in the top coating can provide features such as **fingerprint resistance**. This is a benefit since oils from the skin can spoil the mirror like finish desired with PVD coatings. These oleo-phobic coatings look like any ordinary top coat but resist the deposition of oils on the skin.

APPLICATIONS for PVD

Physical vapor deposition in combination with smooth primers and decorative top and mid coat systems are a popular choice for highly cosmetic applications to metal, plastic and other substrates.

In cosmetic packaging for example, tinted clear coats over bright metals are used for closures. In the automotive industry, interior parts from the center console, electronics, handles and other parts are often metalized. But PVD is finding its way into a wide range of other applications from small appliances, to hand tools, and from bathroom and door hardware to lighting components. The advances in high speed, in-line PVD, the development of new

target materials that produce stainless, antique brass, and nickel chrome textures, along with advanced coatings for scratch resistant primers, beautiful mid- and top-coats continue to offer designers new freedom of choice and to open new doors to novel applications of vacuum metallization and PVD.