Vacuum Metallizing Plastic Parts

Vacuum coating is fast becoming the method of choice for depositing bright, shiny, metallic films on plastic substrates . . .

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Vacuum coating methods that use evaporation or high-rate cathode sputtering processes are the best-known means of metallizing plastic components. Physical vapor deposition (PVD) methods are characterized by the large variety of processes they include.

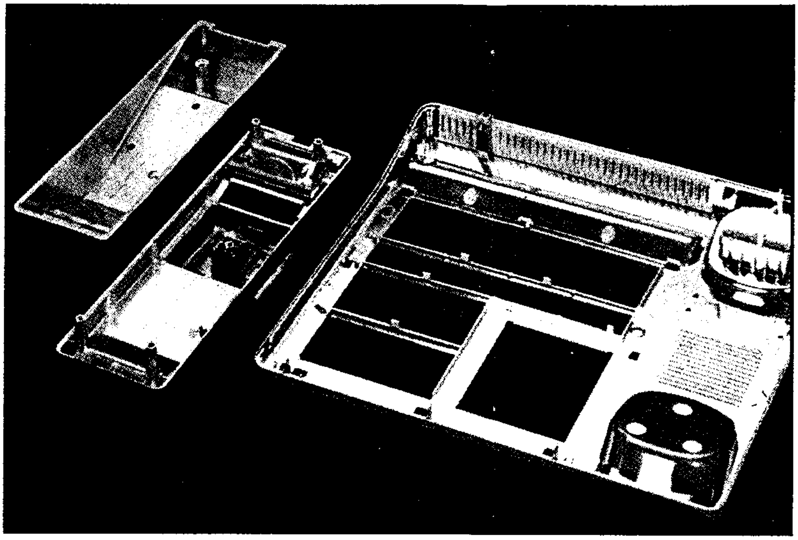
Examples of the flexibility of PVD include the following:

- Deposited film thickness ranges from a few atomic layers to 10 microns.
- Coated surface area ranges from less than one sq mm to as much as several sq meters.
- Both planar and formed components, as well as web materials, can be coated.
- Substrates can be plastic, paper, glass, ceramic, metal or composite materials.
- Multilayer coatings, consisting of stacked films of varying materials, can be deposited in a single coating system.
- PVD coating methods are environmentally friendly.

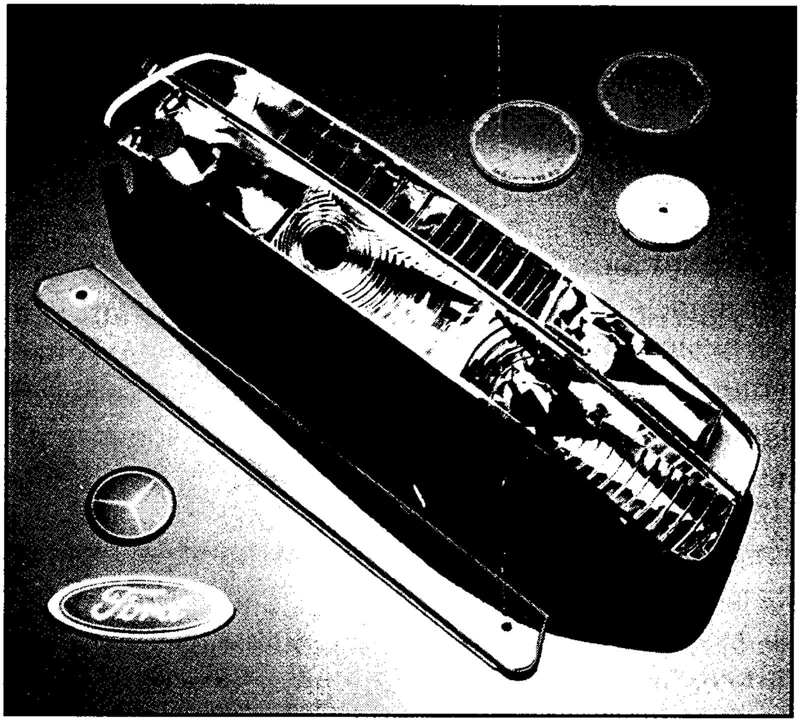
Substrate temperatures, deposition rates and residual gas pressures are simple to regulate. Because of this, deposited film parameters, such as film microstructures, mass densities, hardnesses, electrical conductivity and optical properties, are accurately controlled.

Beyond molded plastic parts for the automotive industry and household utensils, other major coating application areas are plastic and paper web materials in the packaging industry, thin-film data-storage media, glass and plastic architectural and automotive glazing, and optical components such as laser mirrors, "cold" mirrors, thermal radiation shields and broadband optical filters, reflectors and semiconductor devices.

Typical vacuum coatings are thin and coatings closely follow substrate contours, replicating even the finest features. Metallic films deposited on



EMI SHIELDINGS on computer and telephone housing produced by vacuum metallizing.



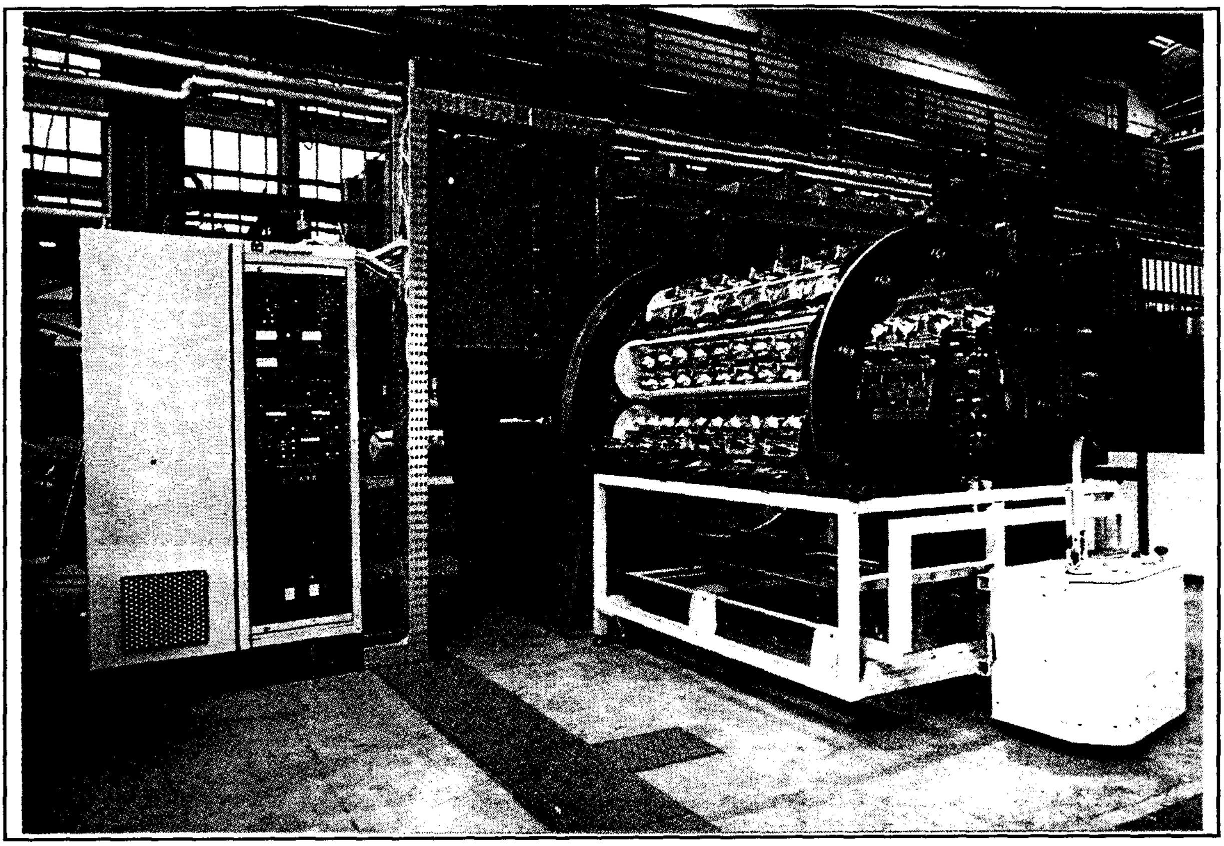
METALLIZED AUTOMOTIVE accessory items meet demands for high reflectivity.

rough surfaces will have a dull appearance, but the same films deposited on smooth surfaces have a bright, highly reflective appearance.

Aluminum is used often in vacuum metallizing because of its silvery brilliance and high adherence. Even gold tones are attained by coating aluminum films with yellowish lacquer overlays.

With most metallic coating materials, coating deposition requires only a few minutes once required vacuum levels are reached. In these processes, vapor-phase atoms condense on the relatively cold exposed surface of pre-formed or molded parts. Parts heating is so slight that even highly temperature-sensitive materials maintain their shapes. Deposition time and evaporation temperatures regulate film thickness. Opaque films are typically less than 0.1 micron thick.

Horizontal coating systems make best use of processing chamber volumes. Since plastics outgas in vacuum coating, systems are usually equipped with additional cold traps that sub-



SUBSTRATE CARRIER loaded with metallized headlight reflectors

stantially reduce pump-down times. All modern coating systems have automatically controlled vacuum pumps and valves and automated evacuation cycles. State-of-the-art coating systems are also equipped with programmable logic controllers for operating process control systems.

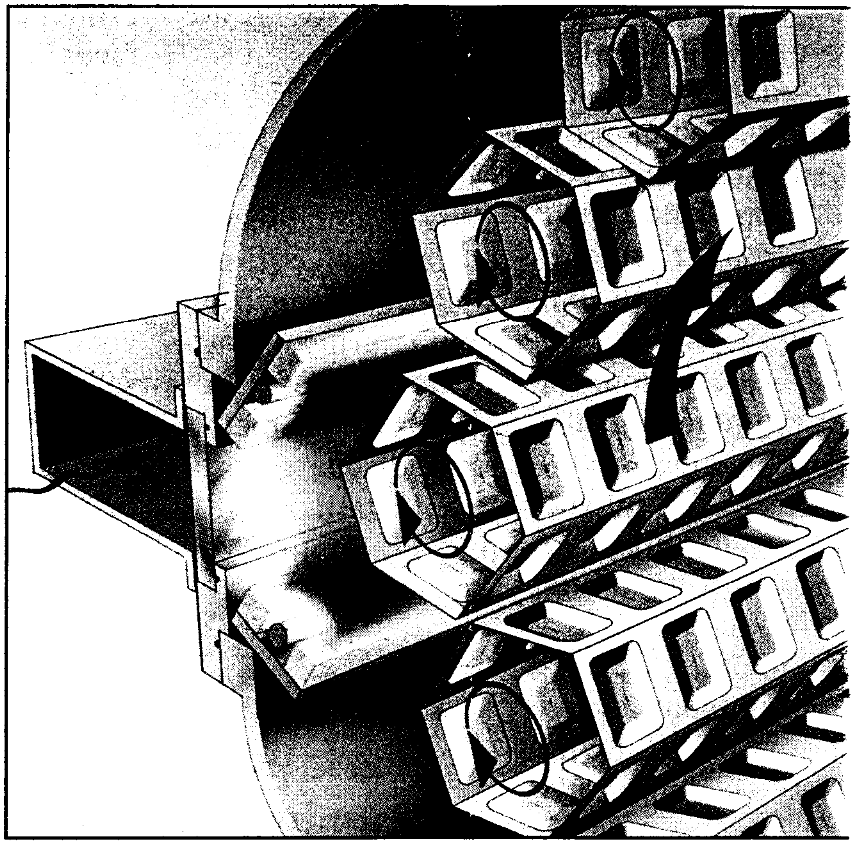
During vacuum metallizing, molded plastic parts usually undergo planetary motions above coating sources so that a uniform coating is applied. In horizontal coating systems this is achieved using the appropriate substrate carrier drive system. Evaporation sources are aligned on the substrate carrier's major axis of rotation. Rotation of substrates about a single axis is usually sufficient when coating planar parts.

In mass production applications load locks are added to coating systems. These help maintain a constant vacuum in the coating chamber during processing. This also allows for continuous operation of coating sources, increasing both deposited film uniformity, reproducibility and processing rates.

An intense glow discharge operating at a chamber pressure of 0.1 millibar (a bar is a centimeter-gram-second (C.G.S) unit of pressure equal to 750 mm of mercury) frequently precedes coating deposition in order to increase deposited film adhesion. The coating chamber is then pumped down to a pressure of 10^{-4} millibar and substrate carrier rotation is started before coating deposition begins.

In addition to vacuum coating systems, lacquering equipment and drying ovens will also be needed for pretreating and post treating parts. Microwave plasma polymerization processes allow operators to pretreat, deposit metallic films and apply protective overlays in a single processing cycle.

Evaporated materials and evaporation sources. Coating materials ideally suited for use in PVD processes include aluminum, silver, gold, copper and chromium, as well as dielectrics such as TiO_2, MgF_2, SiO and ZnS.



PLASMA POLYMERIZATION SUBSYSTEM installed in a typical batch coater.

Coatable plastics. The major criteria determining the compatibility of plastic with PVD processing methods are as follows: outgassing rates per unit surface area; ability to withstand high temperatures; and homogeneity.

Further factors affecting compatibility are types and amounts of plasticizers, additives and fillers and surface finish. Polystyrene (PS) is most commonly used in vacuum metallizing. It is suitable for use in virtually all applications and is the substrate of choice in the manufacture of toys, badges and push buttons.

Polymethylmethacrylate (PMMA), noted for its high transparency, high resistance to discoloration and ability to withstand adverse environments, is often used for automotive taillights and turn-signal reflectors. In the process a transparent, molded part is metallized over its entire surface and then lacquered in various colors.

Acrylonitrile-butadiene-styrene (ABS) copolymers are able to withstand relatively high thermal loads and are thus often used as substrate materials for lacquered parts. Since these materials also behave well under vacuum conditions, they are becoming more important in vacuum coating technologies.

Polyamides (PA) outgas in vacuums and are seldom used in vacuum coatings processes. Metallized molded parts fabricated of PA and PMMA are used in indoor lighting systems.

Polycarbonates (PC) are receiving much attention from automotive part and safety glass manufacturers. PC substrates are also employed in the manufacture of compact audio and video disks.

Polyethylene (PE) has long been employed in toy manufacturing. Its surface properties preclude use of adhesion-enhancing lacquers under metallic coatings, but glow discharge processing must precede metallizing. PE materials are frequently employed in web coatings operations.

Polypropylene (PP) is meeting with growing interest as a substrate material for metallized automotive parts and bottle caps. This material is now metallized under high vacuum conditions, since a special adhesion-enhancing base coat has recently become available. This base coat must cure for a few minutes in air before vacuum metallizing and applying protective overlays.

Problems often arise in dealing with plastics containing plasticizers. Plasticizers must remain nonvolatile at pressures of 10^{-4} millibar and normal temperatures. Use of release agents may increase defects in metallized parts.

Pretreatments/post treatment processes. Pores and other slight surface defects must be coated with lacquer primer prior to metallizing if final surfaces are to have the appearance of polished metal.

Ultrathin metallic films normally require lacquer overlays to protect them against the effects of mechanical wear, corrosion and atmospheric influences. These protective overlays must not adversely affect the metallic films themselves or their underlying primer coats and substrate materials.

Plasma polymerization subsystems installed within vacuum coating systems apply highly chemical-resistant protective overlays that meet automotive specifications for headlight reflectors. Plasma polymerization subsystems can be installed in both batch coaters and in-line vacuum coating systems.

"Ultrathin metallic films normally require lacquer overlays to protect them against the effects of mechanical wear . . ."

In plasma polymerization processes, gas-phase monomers are introduced into the coating system's vacuum chamber. In the chamber they are polymerized in a glow discharge, condensing out on parts as uniform, protective films.

This approach is invariably used when corrosion resistance is imperative and conventional lacquer overlays are not used. Thin films deposited using microwave plasma polymerization processes are highly abrasion and moisture resistant. Film thickness uniformity of ± five pct can be maintained at film deposition rates as high as 10 nanometers per second.

Special Effects and Special Applications.

Second-surface reflectors use transparent plastic substrate materials, such as PS or PMMA. Typical items coated include medallions, advertising signs, taillight and stoplight reflectors. Application of primer coats prior to depositing second-surface reflective coatings is inadvisable. Injection molded dies must be highly polished in order to give molded parts smooth exposed surfaces.

First-Surface Reflectors. Most reflectors are coated on their outer surfaces (first surfaces). First-surface reflectors are used on/in radio tuning dials, costume jewelry, toys, souvenirs and bottle caps. Aluminum is the metal most commonly used. Templates or special masking lacquers, which are easily removed following coating operations, shield sections not to be metallized.

"Other metals can be deposited over one another in a single high-vacuum processing cycle, yielding multilayer coatings."

Multilayer Coatings. Other metals can be deposited over one another in a single high-vacuum processing cycle, yielding multilayer coatings. The processing method involves sequentially evaporating various materials from individual evaporation sources. Use of a single film of gold will yield a golden appearance, but gold is expensive. An opaque silver film is usually deposited over the lacquer primer coat in order to obscure it, allowing gold films to be thinner and simultaneously enhancing their brilliance.

Reflectors, such as road-hazard signs must be coated with silver, since the reflectivity of aluminum films is too low. Copper overlays are usually applied to protect the silver films from atmospheric attack.

Iridescent Effects. High-vacuum coating can be used to deposit iridescent films on plastic. The costume jewelry trade is particularly interested in the "rainbow effects" achieved using a dual-crucible evaporation source to alternately evaporate high (TiO_2ZnS) and low (SiO_2/MgF_2) refractive index materials. Anywhere from three to as many as nine or more films may be needed, depending on the degree of iridescence and the color saturation desired. The first and last films deposited must be high refractive index materials.

Gold tones and other colorations. Gold-tone films and films having other semitransparent colorations, such as metallic-looking greens, reds, blues or yellows are produced by vacuum depositing single films of gold or depositing aluminum and then adding special lacquer overlays.

But it is difficult to maintain highly uniform thicknesses of sprayed-on lacquer overlays. Thickness variations in lacquer overlays result in lighter/darker colorations. Uniform color tones, independent of local film thicknesses, are produced with a final dip in colored lacquer.

Protective coating on plastic optical components. Applying wear-resistant, non-absorbing glass films to diecast parts is a relatively new, highly specialized field. Such coatings have long been applied to optical components, such as plastic lenses.

Uncoated PC lenses exhibit scratches even after they are briefly subjected to scratch testing. Protected with suitable vacuum-deposited coatings, they are able to survive as many as 5,000 test cycles without scratching.

Vacuum coating has grown into a technology having numerous applications. Many more applications will emerge because industrial mass production of these new processing methods will contribute to reductions in final product manufacturing costs. Environmental regulations will become major factors in selecting processing methods that will inevitably result in wider use of vacuum coating technologies, because they generate no air or water pollution. **PF**