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Reflecting Coatings by PVD

Reflecting coatings reflect the incident radiation, and what is not reflected is absorbed. If there is spectral reflectance, the surface is a mirror. If there is scattering, the surface is a diffuse reflector, such as a white paint. For deposited metal films, the difference is generally the surface finish—a smooth surface is necessary to make a good mirror. PVD mirror coatings on a smooth glass surface were one of the earliest uses of PVD coatings, and Strong coated the 100-in. Palomar telescope mirror with aluminum in 1935. Reflecting coatings are used to reflect the incident radiation to a desired location, or to keep a surface cool. Optically smooth glass surfaces can be formed by flowing, or by grinding and polishing. The technologies for forming smooth glass surfaces has been available for a long time. Machined, optically smooth metal surfaces are now available by diamond-point turning.

Figure 1 shows the optical spectrum of solar radiation (AM0), the solar spectrum after it has passed through two standard air masses (AM2) and the optical sensitivity of the human eye, which ranges from 4,500 Å to 7,000 Å. The diagram also shows the radiant energy from black-body surfaces at various temperatures. Most of the incident solar radiation is out of the range of human vision (61 percent AM2), either in the long wavelength (>7,000 Å), or the short wavelength (<4,500 Å) ultraviolet region (8 percent AM2). Artificial lights, such as tungsten filament lamps, emit a higher percentage of their radiation in the infrared than the solar, although halogen lamps and the new sulfur lamps more nearly approach the solar spectrum.

Figure 2 shows the reflectivity of metal surfaces. Aluminum (Al) and silver (Ag) are the most common reflector materials, and gold (Au) is a good reflector in the infrared. A highly-reflective white paint is shown for comparison. A good metallic electrical conductor will completely reflect all of the incident radiation possible if it is about 1,000 Å thick. A thinner film will let some of the radiation pass through to the underlying material. A “half-silvered” or “beam-splitting” mirror, for example, has less than a fully reflecting film and lets some of the radiation through to the glass substrate. Metallization of a glass mirror can be done on the “back surface” or the “front surface.” If the metallization is on the back surface, there is some distortion and some radiation is lost in passing through the glass to and from the metallization. A front surface mirror, therefore, is a more efficient reflector. If the metallization is on the back surface, it can be protected with protective paint and silver, deposited by a PVD technique. A wet chemical technique (chemical silvering) is often used.

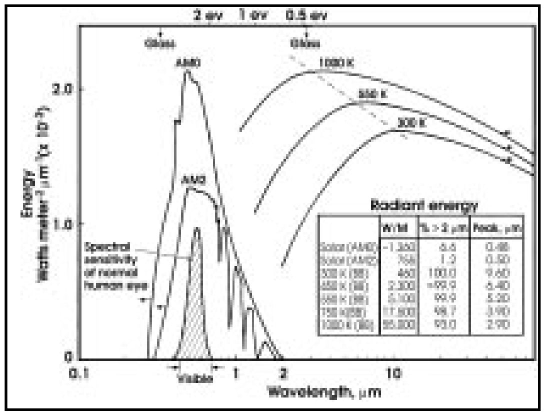

Fig. 1—Optical spectrum of solar radiation.

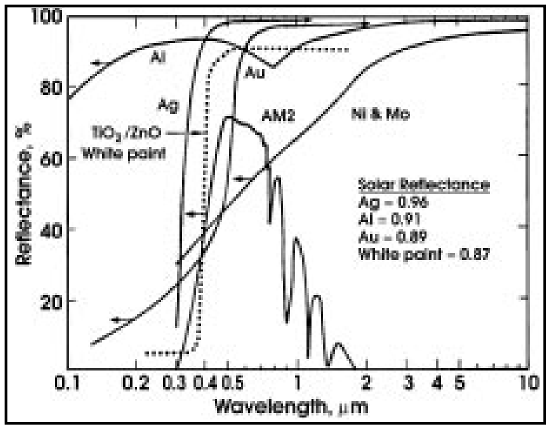

Fig. 2—Reflectivity of metal surfaces.

If the metallization is on the front surface without a topcoat, however, it is exposed to corrosion and aluminum is the preferred material. Aluminum reflectors are often given a topcoat to provide abrasion resistance and enhance corrosion protection (*P&SF*, November 1993).

Overcoatings

Mirror surfaces can be overcoated with other transparent coatings (optical stacks) to further define the flux of radiation that is reflected. The radiation is adsorbed by using optical interference effects. An optical stack of films consists of alternate layers of film material of specific thickness having high and low indices of refraction. For example, by designing the optical stack so that the infrared is not reflected (*i.e.*, adsorbed), a “heat mirror” can be made that minimizes the reflected heat from the light source. Such reflectors are used in light sources for hospital operating rooms and movie studios.

The optical properties of a multilayer optical stack can be designed to give specific properties, such as the reflected or transmitted “band width,” and the “cut-off” frequency for the edge of the frequency band. In fabricating the optical stack, the reflectance properties of the surface are monitored by a spectrophotometer during the deposition and compared to the design criteria. The deposition is automatically controlled by the spectrophotometer readings.

Most reflecting coatings and optical stack film materials are deposited by vacuum evaporation. Early transparent optical materials used to form optical stacks by evaporation were SiO_2 and MgF_2. More recently the ion beam assisted deposition (IBAD) process, which uses concurrent bombardment during deposition (*P&SF*, March 1994), is being used because it can deposit more dense materials for the optical stack, and therefore, increase its ability to provide corrosion to the underlying reflective surface. The use of ion beams of reactive gases, such as oxygen, also allows the deposition of a wide variety of transparent materials (*e.g.*, ZrO_2 and TiO_2) having various indices of refraction to produce optical stacks.

Polymer Coatings

A reflective surface can be overcoated with transparent or semi-transparent polymer coatings that have color and/or texture. These are often used for decorative coatings. A zinc die-cast lamp base, for example, which has a rough surface, is flow-coated with a polymer basecoat to give a smooth surface, metallized with aluminum to give a reflective surface, and then topcoated with a colored lacquer to five a reflective, colored decorative finish to the lamp base. A molded polymer bottle cap can be coated with aluminum and a lacquer topcoat to give a decorative coating. Metallized molded polymers are used as reflectors, such as the auto headlight reflectors used with halogen light sources.

Electrochromic Coatings

Mirrors can also be overcoated with an electrically-active optical stack, which can be made to be transparent or absorbing to varying degrees, by application of an electric field. These optical stacks are called "electrochromic" coatings. Electrochromic coatings are composed of an ionic conductor (solid electrolyte) layer, such as hydrated SiO_2, and an electrochromic material, such as tungsten oxide, sandwiched between transparent electrical conductor films, such as indium-tin-oxide (ITO). When a voltage is applied across the sandwich, ions from the electrolyte enter the electrochromic material, changing its transmittance. When the potential is reversed, the ions leave the electrochromic materials, thereby, restoring the transmission. Such electrochromic mirrors are available as anti-dazzling rearview mirrors for automotive use. o

Bibliography

F. Meyer "*In situ* Deposition Monitoring" *J Vac Sci Technol* A7(3) 1432 (1989).