Photonics
At Work

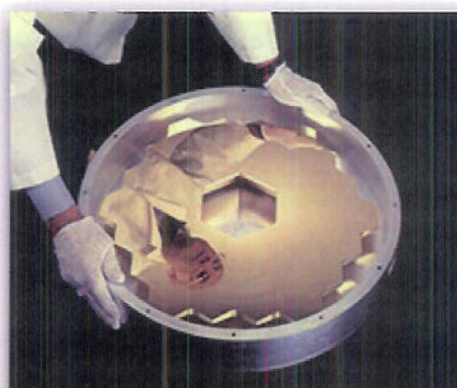
Gold Rules the World of Infrared
Photonics Spectra
by Herbert Kaplan, Contributing Editor

From astronomical telescopes to industrial lasers to scanners at the grocery store, the proper optical coating can mean the difference between telling a distant galaxy from an unformed nebula or peas from carrots. In each case, choosing the proper coating and deposition method will greatly affect the overall system performance.

Gold is the preferred coating material in the infrared because of its high reflectivity and resistance to oxidation, while silver coatings are reflective across extremely broad bands.

Two approaches

There are two approaches to applying high-quality gold coatings: electrochemical deposition and physical evaporation. A telescope mirror constructed for the Keck Observatory in Hilo, Hawaii represents a typical mirror construction using the electrochemical plating process. The mirror began with blanks produced by Brush Wellman Inc.; Speedring Manufacturing machined the blanks and plated them with electro-less nickel to promote adhesion between the blank and the gold coating. Lawrence Livermore National Laboratory diamond-turned the nickel-plated blanks, and Epner Technology Inc. applied the final electrochemical gold plating.



Many steps make up an electrochemical gold-coating process. Epner Technology, a Greenpoint, N.Y., company that specializes in electrochemical deposition, uses as many as 15 separate tanks to make a single part. Typically, the first tank chemically deoxidizes and activates the surface of the nickel-coated part so that the gold will adhere better. Finally, Epner immerses the part in a 200-gallon tank of a proprietary electrolyte with platinum anodes, where the gold is electrochemically deposited over the nickel. According to Epner standards, the reflectance of the finished part is 97 percent at 700 nm and ~99.5 percent at 2 m m, where it remains flat to well beyond 10.6 m m.

Electrochemical plating offers a second benefit: hardness. "Pure," 24-karat gold is rather soft (about 75 Knoop). However, the manipulation of many variables during the electrochemical process, such as the chemistry of the bath and the application of electric current, results in harder surfaces, according to company President David Epner. Epner's process creates gold surfaces with a hardness of more than 200 Knoop, which makes them easier to clean without requiring additional protective coatings.

Although electrochemical coatings offer robust surfaces, physical evaporation techniques can yield very high reflectance at narrow bandwidths. Optical Coating Laboratory Inc. in Santa Rosa, Calif., a supplier of multilayer coatings for mirrors and interference spectral filters, uses physical evaporation to make large mirror surfaces with 98.5 percent reflectivity at IR wavelengths and dielectric gold coatings that reflect more than 99.9 percent.

Many layers and thicknesses

To create a dielectric coating, manufacturers use several layers with various thicknesses and alternating refractive indices. The result is a coating with very high reflectance at a specific wavelength. At wavelengths outside these narrow regions, however, the reflectance is well below that of bare gold.

Interestingly, part of physical evaporation's weakness lies in its strength. Because it does not need a nickel plate in between the blank and the gold, manufacturers can make coatings with very high reflectance. However, gold is very soft, requiring manufacturers to add another coating to protect against scratches.

The hardness of electrochemical gold coatings has attracted the attention of Bob Nehrbas of Lincoln Laser Co. in Phoenix, Ariz. Nehrbas, who puts gold coatings on polygon mirrors for low-cost supermarket scanners, hopes to switch from physical evaporation to electrochemical coatings–if he and Epner can find a cost-effective means.

The high reflectivity of both methods offers benefits to laser designers because it adds to the lifetime of a part by limiting thermal absorption. As the power of infrared industrial lasers emitting at 10.6m m increases from 3 to 10 kW, the nonabsorptive surfaces become a critical issue. Here, even a marginal improvement in reflectivity of less than 1 percent can make a big difference in a laser system's design, according to Eric Ulph, director of optical fabrication at Laser Power Optics in San Diego.

Although vapor deposition optimizes reflectivity at a narrow band, Ulph said electrochemical deposition provides uniform reflectivity over a far broader spectral range and is easier to clean and maintain. On several of his high-power laser mirrors, he uses "Laser Gold, a spectacularly specular" electrochemically deposited gold coating produced by Epner Technology.

Another application is the use of gold coatings with well-known characteristics to help define the performance of other coatings, such as silver. One problem in measuring reflectance in the infrared is that reflectance quotients from the National Institute of Standards and Technology do not cover the infrared beyond 2.5 mm.

Developing standards

Optical Data Associates of Tucson, Ariz., needed to develop reflectance standards from 0.3 to 30 mm for critical protected silver coatings. Optical Data's Michael Jacobson said the company sent diamond-turned nickel-on-aluminum substrate samples to Epner for electrochemical gold plating.

"We measured [reflectance] factors on the returned samples in our laboratory and had them confirmed and certified by several independent laboratories. These standards allowed us, and our subcontractors, to confirm that our sets of sputtered, protected silver coatings met the project goals of $R = 99.2 \pm 0.1$ percent," Jacobson said.

Gold coatings have found their way into all types of applications including laser cavities and advanced astronomy, and the market is still growing. According to Epner, gold coatings will become more widely used as they become more affordable. He sees increasing use in precision components such as radiation shields on the new infrared focal plane arrays, where the smallest unwanted incident energy can affect output uniformity seriously.

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